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Mapping the way for a new stormwater strategy for the city of Hanko

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KOMULAINEN, VEERA:

Tien kartoittamista Hangon kaupungin uudelle hulevesistrategialle

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TIIVISTELMÄ

Ihmisvaikutus hulevesien syntyyn on merkittävä. Kaupungistumisen lisääntyessä ja tehostuessa rakennettujen vettä läpäisemättömien pintojen määrä kasvaa ja luonnollinen veden kiertokulku estyy. Samaan aikaan ilmastonmuutos aiheuttaa lisää sään ääri-ilmiöitä ja rankkasateita. Hulevettä on aikaisemmin pidetty puhtaana, mutta tutkimukset ovat osoittaneet veden sisältävän erilaisia haitallisia aineita ja epäpuhtauksia. Hulevedellä onkin epäsuotuisia ekologisia, taloudellisia, sosiaalisia ja jopa terveydellisiä vaikutuksia.

Osa kansallisista laeista ja säädöksistä käsittelee hulevesiä ja niiden hallintaa. Tuorein asiaan liittyvä lakimuutos on Laki vesihuoltolain muuttamisesta (681/2014), jonka mukaan huleveden viemäröinti ei enää kuulu vesihuoltoon ja hulevesi tulee käsitellä erikseen jätevesistä.

Hangon kaupungilla ei ole hallintajärjestelmää tai yhteisiä ohjesääntöjä hulevesien ehkäisemisestä ja/tai käsittelemisestä. Kaupungin sekaviemäriverkko on vanha ja huonokuntoinen. Sadevesi johdetaan pääosin sekaviemärin kautta jäteveden puhdistamolle, jossa se muodostaa yli puolet puhdistamolle tulevasta vesimäärästä. Osa vesistä johdetaan myös erillisviemäröinnin kautta suoraan mereen.

Hulevesien hallinnan tarkoitus on vähentää valumavesien negatiivisia vaikutuksia. Sekä laadun että määrän hallitsemiseksi on olemassa erilaisia keinoja, jotka ehkäisevät, vähentävät, tasaavat ja hidastavat vesimäärää. Nämä menettelytavat kuuluvat luonnonmukaisiin hallintamenetelmiin, jotka hyödyntävät luonnossa ilmeneviä puhdistusprosesseja.

Opinnäytetyö on tehty selvittämään nykytilannetta, muutostarvetta sekä vaihtoehtoja Hangon kaupungin hulevesien hallinnan parantamiseksi.

Asiasanat: hulevesi, valumavedet, vihreä infrastruktuuri, luonnonmukainen hulevesien hallinta

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ABSTRACT

Human impact on stormwater formation is significant. As urbanization intensifies, and the amount of built impervious surfaces increases, the natural water cycle is hindered. At the same time, climate is changing bringing more weather extremes and heavy rainfall events. Urban runoff has previously been regarded as clean water, but studies have shown it to contain a variety of harmful substances and impurities. Stormwater has unfavorable ecological, financial, social and even health impacts.

Some national laws and regulations address urban runoff and its management. The most recent law change is that according to the Amended Water Services Act (681/2014) stormwater sewerage is not regarded as part of water services, and it should be handled separately from sewage.

The city of Hanko does not have a stormwater management system or common guidelines for preventing and/or handling urban runoff. The combined sewer system in the city is old and rundown. Precipitation is mainly directed through the combined sewers to the wastewater treatment plant where it forms over 50% of the incoming water. Some of the water is also directed through separate sewers directly into the sea.

The aim of stormwater management is to minimize the negative effects of urban runoff. There are different ways to manage both the quality and the quantity by preventing, reducing, leveling and slowing down the volume of surface runoff. These methods are part of the Best Management Practices (BMPs) of the Low Impact Development (LID) techniques that utilize natural processes.

This study explores the current situation, the need for changes and the options available for improving stormwater management in the city of Hanko.

Key words: stormwater, urban runoff, green infrastructure, Low Impact Development (LID), Best Management Practice (BMP), Integrated Management Practice (IMP)

CONTENTS

ABBREVIATIONS

BMPs - Best Management Practices

EPA - United States Environmental Protection Agency

ELY – Centre for Economic Development, Transport and the Environment

GI - Green Infrastructure

IMPs - Integrated Management Practices

LID - Low Impact Development

SYKE - Finnish Environment Institute

1 INTRODUCTION

1.1 Background

Stormwater is rain and melted snow that flows over land and surfaces instead of percolating into the ground. The relationship between surface and runoff depends greatly on whether the surface is in natural state and pervious or if it is impervious. An impervious surface generates surface runoff, in other words, it is hydrologically active. As the amount of impervious cover increases, so does also the surface runoff while infiltration is noticeably inhibited. (Figure 1). (Natural Resources Conservation Service 1998.)

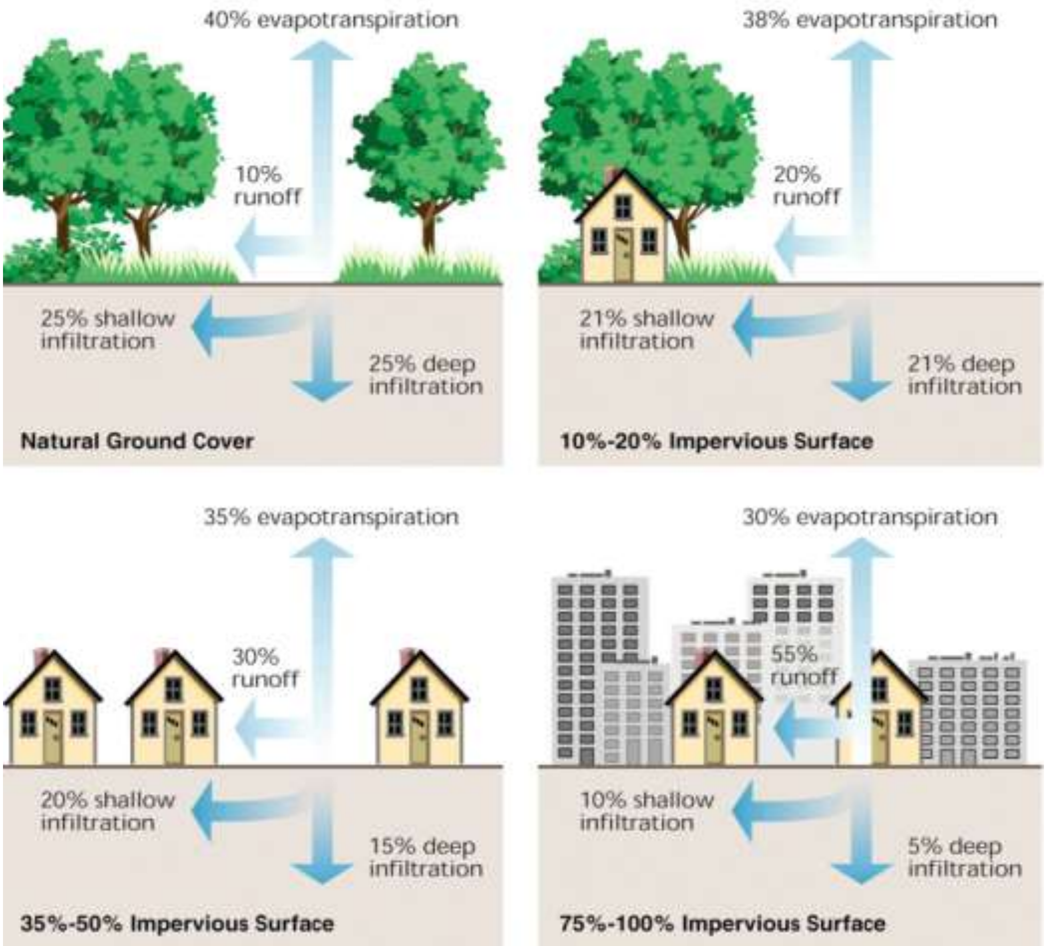

FIGURE 1. Surface runoff increases in relation to impervious surface cover. (Natural Resources Conservation Service 1998)

Human impact on stormwater formation is significant. In urban areas, surfaces are altered and often constructed impervious. These built surfaces, such as roads, sidewalks, parking lots and buildings, are covered by impenetrable materials that seal soil and prevent water absorption. In addition to the built, permanently impervious surfaces also compacted and frozen soils as well as soils with high clay content can be practically impervious. Even saturated soils can be temporarily imperveable. (Barnes, Morgan III & Roberge 2002.)

Intensifying urbanization especially combinated with climate change require new management solutions for stormwater. Problems caused by heavy rainfall events and weather extremes as well as detoriorating water quality and the requirements of the EU Water Directive (2000/60/EC) are some of the important reasons for the increased interest and efforts to better manage urban runoff (Hakola 2012). The city of Hanko is no exception. In addition to the curret challenges caused by stormwater, the city wants to increase the downtown building density, which will add to the need for efficient stormwater management (The city of Hanko 2014). The main presumption in the city is that the urban runoff is directed through piping into the sea (Takala 2013).

1.2 Research question

This is a qualitative study to support the development of stormwater management in the city of Hanko. The scope of the study is limited to a few parts of the city center.

The objective of this study is to explore how the city can improve the management of urban runoff, and what are the different tools and options, Best Management Practices (BMP’s) and Low Impact Development (LID) methods, available. The study focuses on the following questions:

- What alternatives are there for stormwater management besides directing it into the sea?
- What is the current situation and the contributing elements regarding urban runoff in the city of Hanko?
- Where in the city center of Hanko is stormwater flooding most likely to occur and why?
- What are the options to implement new stormwater management ways?

1.3 Materials and methods

The background material for the study was gathered through literature and interviews. Maps, information on soil layers, topography and impervious surfaces were also utilized as well as my own observations to some degree.

2 SURFACE RUNOFF IN URBAN AREAS

Urban areas increase the amount and have a negative effect on the quality of stormwater. The more densely an area is built, the poorer is the quality of surface runoff (Vakkilainen, Kotola & Nurminen 2005). Stormwater contains pollutants from roads, roofs and other surfaces. The impurities are originated from traffic, wearing and de-icing of asphalt, buildings and building sites, the industry as well as the use of fertilizers, pesticides, fire extinguishing and other chemicals. Nutrients, mainly phosphorous and nitrogen, as well as hydrocarbons and heavy metals are among the impurities. Also bacteria, pathogens and harmful or toxic chemicals, trash as well as oxygen-demanding substances are often present. While urbanization increases the surface runoff, it decreases the amount of naturally purifying elements such as ditches, ponds and wetlands. (University of Washington 2011.) For example, in Turku in 2012, both phosphorous and nitrogen levels increased dramatically in the surrounding sea-area due to stormwater runoff and sewage releases caused by flooding in the city (Vauras 2013).

Urban areas are expanding and built more densely than before. The effect on vegetation, groundwater and water balance intensifies and even a small rain can cause a significant surface runoff. The amount of impervious surfaces can even have a negative effect on the local air quality. When rainwater does not infiltrate in the area and evaporating greenery is absent, air becomes drier and air pollutants stay longer in the air. (Närhi 2012.)

Stormwater can cause different kinds of problems. Flooding and infrastructural damage, polluted waters, impaired coastal ecosystems, erosion, damaged streams and wetlands as well as combined sewer overflows are some of the negative effects (SYKE 2013). In addition, the more rainwater is running directly from different surfaces to water systems, the less of it is filtrated through ground to form groundwater. This can cause water shortages. (Geological Survey of Finland 2015.)

Information about urban flooding incidents both in Finland and internationally is more often than before seen on the news. For example, in October 2015, an extreme stormwater catastrophe happened both in Riviera, France (BBC News 2015) and in South Carolina, USA (Yan, H., Sanches, R. 2015).

It is estimated that annual precipitation will most likely increase and heavy rainfall events are becoming more frequent in Finland due to the climate change. The change will be most noticeable in the intensified precipitation, in other words heavy rain events. (Ilmasto-opas 2013.)

2.1 Legislation and other regulations

There are laws and regulations that address stormwater and its management. The most central laws for that in Finland are the Amended Water Services Act (681/2014), the Land Use and Building Act (132/1999), the Environmental Protection Act (527/2014) and the Flood Risk Management Act (620/2010). Other stormwater related laws are the Water Act (587/2011), the Act on Water and Marine Resources Management (1299/2004 and 272/2011) and Highways Act (503/2005).

According to the Amended Water Services Act (681/2014), sewerage of stormwater is not part of the water services. The municipality can, however, decide that the water and sewer services authority takes care of the stormwater sewerage if it can be done economically and properly, and if the customer fees are reasonable and equal. Properties must be connected to the stormwater sewerage unless the property can otherwise properly take care of urban runoff. Stormwater must not be directed to wastewater sewerage, with the exceptions that the sewer is built before 2015, and it is dimensioned adequate also for stormwaters, or, if there is no strormwater sewerage.

The Land Use and Building Act (132/1999) states four general goals for stormwater management. They are:

1) To develop a systematic management of stormwater especially in the zoned area.
2) To infiltrate and detain runoff.
3) To prevent damage caused by stormwater to the environment and properties.
4) To take the climate change into account in the long run and promote other alternatives over directing stormwater to wastewater treatment plants.

According to the Act, the property owner is responsible for the management of stormwater in the property, and the municipality is responsible for organizing stormwater management in the zoned area.

The purpose of Flood Risk Management Act (620/2010) is to minimize flood risks and to prevent negative impacts of floods. According to the Act, attention needs to be paid on the land-use planning and development. The municipality should be aware of and draw up a map of the areas with a flood risk.

The Environmental Protection Act (527/2014) says that the municipality should monitor the state of the environment and develop a plan for managing stormwater flooding risks.

Although not directly mentioning stormwater, the Amendment to the Act on the Maintenance, Clearing and Cleaning of Public Areas (547/2005) has some practical relevance on flooding caused by urban runoff. The Act notes that the property owner is responsible for keeping the sidewalk and gutters in front of the property clean and clear of snow, ice and trash. Residents are not always aware of this (Varjus 2016).

At a local level, city planning has the most important role in stormwater management (Rontu 2014). City planning should pay attention to the natural and altered circumstances of the area. Topography and flow-routing, the absorption ability and rate, the amount of impervious areas and the groundwater level are things to consider. (Kuntaliitto 2012.)

3 STORMWATER MANAGEMENT

The aim of stormwater management is to minimize the negative effects that stormwater has on urban areas and water bodies (Kuntaliitto 2012). Stormwater is traditionally handled through an “end-of-pipe” treatment, which means capturing and distributing the runoff to sewer systems and/or nearby watercourses (Scholz & Grabowiecki 2006). This is also the case in Hanko where stormwater is mainly directed to the combined sewer system (Varjus 2013).

Stormwater can, however, also be managed by other methods, such as preventing, reducing, leveling and slowing down the volume of surface runoff (Nurmi, Heinonen, Jylhänlehto, Kilpinen, Nyberg 2008). These methods manage both quality and quantity of the water by infiltration, filtration, evaporation, evapotranspiration, water absorption and pollutant removal. It can be done by Best Management Practices (BMPs) of Low Impact Development (LID), which are techniques that utilize natural processes. (The City of Edmonton 2011.)

Stormwater contains different pollutants including phosphorus, nitrogen and suspended solids (Vauras 2013). Concentration measurements are not available for Hanko but according to researches from Espoo, Kajaani and Tampere (Table 1), city centers have the highest concentration of phosphorus. Nitrogen concentration levels are the highest in apartment building areas while city centers come second. Industrial and warehouse areas have the highest percentage of suspended solids.

TABLE 1. The amount of total phosphorus, nitrogen and suspended solids in urban runoff within cities based on researches from three Finnish cities (Vakkilainen, Kotola, Nurminen 2005).

	Total phosphorus ($kgP/km^2/a$)	Total nitrogen ($kgN/km^2/a$)	Total suspended solids (1000 $kg/km^2/a$)
Apartment building areas	38	884	21
Single-family housing areas	24	495	10
City centers	142	725	45
Traffic areas	41	300	37
Industrial and warehouse areas	86	290	79

In order to have baseline data with research information regarding different BMP types and their functionality, the city of New Hampshire, USA, was chosen for this work. The climate in New Hampshire does not drastically differ from that in Hanko even if New Hampshire has higher precipitation amounts (Table 2). The values from New Hampshire are therefore given in this work as directional results for different BMP methods (Table 3).

TABLE 2. The average climate in New Hampshire and Hanko during 1981-2010 (US Climate Data 2015 and Pirinen, Simola, Aalto, Kaukoranta, Karlsson, Ruuhela 2012).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
New Hampshire, Concord												
Average high in °C:	-0.7	1.6	6.6	14.1	20.5	25.2	27.9	27.2	22.6	15.8	9.1	2.4
Average low in °C:	-12	-10.1	-5.3	0.4	5.9	11.4	14.3	13.4	8.6	2.1	-2.1	-8.2
Av. precipitation in mm:	69	67	83	87	93	94	95	81	86	103	94	81
Hanko, Tvärminne												
Average high in °C:	-0.6	-1.5	1.3	6.3	12.8	17.4	20.7	19.4	14.5	9.3	4.3	1.3
Average low in °C:	-5.4	-6.6	-4.1	0.4	5.6	10.3	13.9	13.4	9.3	5.0	0.5	-3.2
Av. precipitation in mm:	55	36	39	30	35	45	51	79	55	75	72	62

TABLE 3. The BMP removal efficiencies for total phosphorus, nitrogen and suspended solids in New Hampshire (The New Hampshire Department of Environmental Services 2011).

BMP type	**BMP**	**Tot S**	**Tot N**	**Tot P**	**Runoff Reduction Efficiency**
Infiltration practices	Infiltration Trench	90%	10-55%*	60%	90%
	Infiltration basin	90%	10-60%*	65%	90%
	Dry wells	90%	55%	60%	90%
Filtering practices	Aboveground or Underground Sand Filter	90%	10-60%*	65%	0%
	Aboveground or Underground Sand Filter with underdrain	51%	10%	33%	0%
	Tree box filter	99%	N/A	N/A	15%
	Bioretention system	99%	65%	65%	80%
	Permeable Pavement	90%	10-60%*	65%	75%
	Permeable Pavement with underdrain	90%	10%	45%	45%
Treatment swales	Flow through treatment swale	N/A	N/A	N/A	60%
Vegetated buffers	Vegetated buffers	73%	40%	45%	N/A
Pre-treatment practices	Vegetated filter strip	73%	40%	45%	50%
	Vegetated swale	65%	20%	25%	60%
Stormwater ponds	Wet pond	70%	35%	45%	0%
Stormwater wetlands	Shallow wetland	80%	55%	45%	0%
	Gravel wetland	99%	85%	64%	90%

* The higher value is for methods that are located at least 23 meters from surface water. The removal efficiency reduces when the BMP method is closer to surface water.

N/A means that there is no given value.

Choosing between the different management practices depends on what the aim is and what method is concretely possible to implement for the location in question. Factors to consider regarding each location are the size of available space, human activities and natural characteristics such as soil type, topography and climate conditions. Best results will be achieved through a combination of different management practices. (Lee, Selvakumar, Alvi, Riverson, Zhen, Shoemaker, Lai 2012.)

3.1 Low Impact Development, Integrated Management Practices, Green Infrastructure and Best Management Practices

Low Impact Development (LID) is a stormwater management concept that was first introduced in the early 1990's in Maryland, United States. LID means using land planning and engineering together with nature in order to mimic a site's natural hydrology and manage stormwater as close to its source as possible. (Low Impact Development Center 2011.)

The terms LID, Integrated Management Practices (IMPs) and Green Infrastructure (GI) are all used in stormwater management. Systems and practices are often refered to as LID or IMPs while GI usually means natural areas that provide runoff management using the same processes as LID/IMPs. Green areas provide in addition to flood protection ecosystem services such as cleaner air and water and healthy habitats. LID/IMP techniques aim to preserv, restore and create green spaces. (United States Environmental Protection Agency EPA 2015.)

According to Natural Resources Defense Council (2001), LID has many benefits ranging from being effective and economical to giving added value to the landscape. It is a practical and simple way to reduce runoff and remove pollutants from stormwater. The utilization of natural processes in small-scale methods is often relatively cheap to construct and maintain. The units also have a long life cycle. While LID helps in flood control it also offers multi-functional landscapes, enhances the aesthetic value of a city and even helps with drought impact prevention.

Since urban development always affects the site hydrology, the idea of LID/IMPs is to preserve or imitate the original hydrological conditions with the help of methods that store, infiltrate, evaporate, and detain surface runoff and remove pollutants from it. (Department of Environmental Resources 1999.) In practice, the Best Management Practices (BMPs) of LID include e.g. water retention and detention areas, flood plains, vegetated rooftops and permeable pavements. All of them share the same principle of managing stormwater as close to its source as possible while reducing and detaining surface runoff in small-scale areas or “units” where nature’s abilities are utilized. (EPA 2015.)

It is important to be aware of the natural circumstances for each site where a LID system is planned in order to choose the best functioning management method for that particular place. Methods that are based on absorption are suitable for locations where the soil is porous and water would naturally be absorbed. Water retaining functions should be preferred where the soil is poorly permeable. (Vakkilainen, Kotola, Nurminen 2005.)

3.1.1 Preventing, reducing and slowing down urban runoff

Stormwater is naturally absorbed into soil and further filtrated as groundwater. However, in built areas human actions cripple these natural routes. The soil type or sloping does not have significance in the runoff coefficient anymore when the amount of impervious surfaces exceeds 40%. (Kuntaliitto 2012.)

Due to lack of vegetation, surface runoff is usually even bigger during construction work or in areas that are recently built (Vakkilainen, Kotola, Nurminen 2005). Minimizing impervious areas and favoring vegetated areas is the key to prevent excess surface runoff from being formed (Kuntaliitto 2012). According to Professor Heikki Setälä, a birch can transpire water up to 800 liters per day from its leaves. Vegetation also removes nutrients from stormwater. Setälä states that even a small increase in city greenery helps to mitigate stormwater problems. As an example he mentions a study conducted in the USA according to which a pervious, vegetated area of two percent is enough to prevent stormwater runoff on a parking lot when the water is directed to the pervious areas. (Vauras 2013.) A research done in California (Xiao, McPherson and Shakur 2007) shows, that vegetation coverage has also a noticeable effect on the amount of nutrient concentration levels in the runoff. By delaying and infiltrating part of the precipitation, vegetation helps to decrease the amount of nutrients and other pollutants entering the ground. The study concluded that the only exception was heavy metals, which did not show a significant difference in the concentrations between areas with higher and lower canopy coverage. The conclusion of the study was that not only impervious surfaces but also trees could reduce stormwater runoff.

Vegetation is an important part of many of the different BMP's in helping with rainwater absorption and thus preventing or reducing the stormwater runoff. Plants not only transpire water but also improve soil's permeability and thus its infiltration capacity. Vegetation is most effective at mitigating the effects of urban runoff when grasses, shrubs and trees are used diversely. It is also important that the plants are tolerant, suitable for the area and location and need very little maintenance. (Ilmastonkestävä kaupunki 2015.) There are ongoing studies of how different forms of land uses affect the hydrology in built areas (Vauras 2013). Here is a look at some of the methods already used in different parts of the world.

Stormwater planters are pervious, vegetated areas that are usually built for runoff water between the street and sidewalk (Figure 2) or in parking areas. Water is directed to the planters through a notch or channel made into the curb that helps keeping the water in the planter while it absorbs into the soil. Stormwater planters infiltrate solids and pollutants from the water. (EPA 2012.)

FIGURE 2. Stormwater planters between street and sidewalk (Wilkes East Neighborhoods Association 2015).

Similar kind of permeable, vegetated areas can also be built right next to a building and direct rainwater through rooftop drainage pipes into the soil (Figure 3). These **downspout disconnections** work the same way as stormwater planters absorbing and infiltrating runoff water into the soil. (EPA 2014.)

FIGURE 3. Downspout disconnection into a vegetated area (EPA 2014).

According to the United States Environmental Protection Agency (2013), the runoff volume can be reduced by not having curbs and gutters wherever possible. Instead the sheet flow, meaning uniformly dispersed water across a surface, will increase requiring vegetated bioretention areas where the water can go. However, where curbs are needed to enhance safety by separating pedestrian from vehicular traffic, another option can be implemented. A **curb cut** (Figure 4) is a cut in the curb that allows water to flow off the street into a green area or sandy soil.

FIGURE 4. The amount of curb cuts can be adjusted according to the need. Here is an example from Seattle (Feliciano 2015).

Parking lots form often big, impervious areas. These areas are also especially susceptible for contaminants such as small oil and fuel leaks from cars. Minimizing the impervious area with **rain gardens/bioretention cells** (Figure 5) and **bioswales** can significantly reduce the runoff volume from parking areas where green space is limited. In addition to slowing down stormwater runoff, bioretention cells help also with pollutant removal and groundwater recharge. Technically the cell is a depressed, either under-drained or self-contained area consisting of porous soil such as backfill and a vegetated surface. (EPA 2012.) Plants selected for the bioretention will have to withstand both flooding and drought. It is advantageous to install small, preferably native, plants that grow to adapt to the challenging conditions. The most suitable for filtrating water are plants with deep fibrous roots. (Low Impact Development Center Inc. 2007.) It is important that the water is absorbed through the soil and vegetated surface in order for the cell to provide adequate filtration and infiltration resulting in groundwater recharge and removal of pollutants (EPA 2012).

FIGURE 5. A rain garden situated in the middle of a parking lot (Philadelphia water department 2015).

Another version of a rain gardern is a **rock garden** (Figure 6), a shallow excavation with gravel of the size of approximately 2 to 7 cm in diameter. A grock garden can have some plants but is not covered with vegetation and it does not have a ponding area. Instead it stores rainwater in the void spaces between the stones and water percolates from there into the soil. Rock gardens are durable and low maintenance. Rain and rock gardens as well as bioswles function best in areas where soil has a high permeability. (EPA 2012.)

FIGURE 6. An example of a rock garden with some educational information (EPA 2012).

According to a study by the University of Maryland (Davis, Li & Jones 2007), bioretention cells indicated good performance in particulate/adsorptive pollutant removal. In addition to reducing stormwater runoff, bioretention cells are also effective in oil/grease and heavy metal removal.

Grassed swales (Figure 7) are grass-covered linear areas that can be used to manage stormwater from drainage areas that are less than four hectares in size and do not have slopes higher than five percent. A long depression with an uneven bottom is most effective. These vegetated channels both slow down and treat urban runoff. There are different versions of grassed swales. A grassed channel, a dry swale, and a wet swale have different designs and treatment methods but they are all improvements on the traditional drainage ditch. These swales are especially usable alongside roads and as connecting passages between different LID systems. (EPA 2014.)

FIGURE 7. A grassed swale built between street and sidewalk (Steed 2012).

The use of **permeable pavers** such as paving blocks (Figure 8) instead of asphalt is also a way to reduce surface runoff. Paving blocks are less impervious than asphalt and the voids between the blocks allow water to seep into the soil. The best option is if the voids are vegetated by grass.

Surface permeability is gained by manufacturing the surface with materials that have a coarser particle size than the ones used in asphalt and concrete. (EPA 2013.) A cause of worry in icy winter conditions is whether sand will clog the surface making it more or less impervious. However, according to Houle (2008), permeable pavements actually provide better functionality than impervious pavements even in winter conditions.

FIGURE 8. The structure and form or pervious pavement is planned to direct rainwater through the grass growing in between of the paving (HB-Betoniteollisuus Oy 2013).

Green roofs have increased their popularity during recent years. They have the capability of tying a large proportion of rainwater in the vegetation and the permeable soil that lay on top of the impermeable roof material. This proportion, which can be up to 75 percent of the precipitation on the roof, is filtrated and mostly evaporated back to the atmosphere by the plants. (Kerabit 2014.) Green roofs, like green infrastructure overall, also help to improve the air quality by removing airborne contaminants. They have a sound damping effect especially against air traffic as well as an aesthetic and ecological value. They have also been found to help reduce the use of energy because of good thermal insulation. Green roofs are even said to have lower maintenance costs and longer life cycles than traditional roofs. (EPA 2012.)

Tree box filters are bioretention areas similar to rain gardens but much smaller in size (Figure 9). There are different versions of the system but the principle is the same. A tree box consists of a box or container with soil and a mulch layer, a discharge pipe, a grate that is on top of the mulch layer on the curb level, also called a tree gate, and a shrub or tree that is planted in the box/container. (LID 2014.)

FIGURE 9. A newly built tree box filter (Steed 2012).

The root growth of the vegetation planted in the box should be taken into consideration in order to prevent any possible future damage to the road surface. Approximately 33% of a tree is usually beneath the ground as the tree's root system. As woody tree roots grow and thicken within their limited space, they can cause cracking or heaving of asphalt, pipes and walls. However, if the soil is loose and well aerated below the asphalt or concrete, the largest roots are likely to stay deep instead of pushing their way to the surface. (Forestry Commission 2015.)

When stormwater is slowed down on pervious surfaces, water is given the possibility to infiltrate into the groundwater aquifer. **Infiltration trenches** slow down urban runoff by forming a place to collect water from where it infiltrates to groundwater. These trenches are ditches with lots of rocks and no outlets (Figure 10). Infiltration trenches work best together with other management practices, such as grassed swales, in order to give better quality for the water before it enters groundwater. (EPA 2012.)

FIGURE 10. An infiltration trench located in the median strip (Steed 2012).

A vegetated filter strip is a common concept next to agricultural fields but can also be used in urban areas (Figure 11). The strips slow down the runoff water allowing soil and vegetation to filter nutrients, pollutants, sediment and organic material from the water. Since concentrated flow might disable the filtration process, the best location for a filter strip is a gently sloping area where stormwater flows evenly as sheet flow. Filter strips are effective for treating low-intensity storms and often used as a pretreatment for a number of sequential treatment methods. They are best suitable for areas where soil has poor permeability. (EPA 2012.)

FIGURE 11. A vegetated filter strip located in the middle of a city (3 Rivers Wet Weather 2012).

Rain barrels are suitable for small-scale rainwater harvesting for later reuse in gardens. Diverting downspout water into a covered barrel is an easy and low-cost method to reduce the volume of runoff water and nutrients (Figure 12). A bigger version of the barrels is rainwater cisterns, which can store water in larger volumes and are thus more suitable for bigger buildings such as apartment buildings. (EPA 2014.) The barrels/cisterns should have a sealed yet removable top to keep children and animals safe. A barrel can also be covered with a tightly secured close-knit mesh screening that will prevent mosquitos from breeding in the standing water. (Urban Design Tools, LID 2016.)

FIGURE 12. One rain barrel design and an example of a rain barrel in use (City of Dublin, Ohio, USA 2016).

In urban areas where groundwater level is high and there is not enough room for rainwater retention, water volumes can be buffered in **water squares**. A water square is a storage area for stormwater but has other functions when it is dry and can serve, for example, as a playground or sports field. Rotterdam has implemented a water square in 2013 (Figure 13). (Rotterdam climate initiative 2013). Light rain do not fill up the water square but during heavy rainfall stormwater can be retained in the squares and be then either infiltrated to the soil beneath the pavement or pumped further to channels or other suitable areas (C40 cities 2014).

FIGURE 13. Benthemplein's full-scale water square in Rotterdam (C40 cities 2014).

3.1.2 Directing into the sea

During very heavy rainfall events efficient **stormwater drainage** is needed in order to reduce the risk of urban flooding even if LID methods are also used in the city. The rapid discharge with high volumes of untreated stormwater can, however, have harmful effects on the coastal environment. In addition to erosion also trash, bacteria and pollutants can have a negative effect on the coastal ecosystem and even human health. (Victorian Government Department of Environment and Primary Industries 2013.) By installing a stormwater interceptor large debris can be screened and oil and grease separated and contained from urban runoff before it reaches water system. This applies especially near harbors, streets, parking lots and industrial areas. (Ilmastonkestävä kaupunki 2015.)

3.1.3 Snow disposal

Snow contains all the same pollutants as stormwater. In fact, urban snow can hold even more health hazards since, unlike stormwater, it also soaks up carcinogenic air pollutants such as car exhaust (Nazarenko, Kurien, Nepotchatykh, Rangel-Alvarado and Ariya 2016).

Snow should not be disposed in a place where it enters waterways or groundwater. The best dumping place has an even surface and is located on a permeable soil type. Some vegetation consisting of plants tolerant to salt on or at least surrounding the area is beneficial. Most natural runoff management systems can even be used as storage places for snow. (Vakkilainen et. al 2005.)

Dumping snow is in some cases also mentioned in the environmental permits. The permit can stipulate where the snow ploughed from that particular area is allowed to be stored. For example, the environmental permit (242/2014/1) for Hanko Outer Harbor specifies snow from the dock and harbour areas to be heaped on land so that sand, thrash and oil from melting snow cannot enter the sea or concervation area.

3.1.4 Tools for planning

A **runoff coefficient** gives an estimate for stormwater runoff rate. It is the relation between runoff and precipitation. The value is larger for areas with low infiltration, high runoff and smaller for permeable, vegetated areas. Runoff coefficient is affected by the soil type, permeability, gradient, surface evenness and land use. (Table 4) The coefficient varies during a rain event depending on the duration and heaviness of precipitation. A rule of thumb is that for every 100 m^2 of impervious surface there should be preparedness to retain 1 m^3 of water. (Ilmastonkestävä kaupunki 2015.)

TABLE 4. Some examples of runoff coefficient values (Kuntaliitto 2012, Vakkilainen et. al 2005).

Surface	**Runoff coefficient**
Roofs	0.8 – 1.0
Asphalt, cement	0.7 – 0.9
Pavement with impervious joints	0.7 – 0.8
Pavement with sand filled joints	0.6 – 0.7
Gravel road	0.2 – 0.5

Grass banking	0.4 – 0.6
Meadow, garden, field	0.1 – 0.3
Grass covered yard, park	0.1 – 0.4
Larger park areas	0.05 – 0.1
Swamp	0.05 – 0.15
Mixed forest	0.05 – 0.2
Even gravel field	0 – 0.05
Bedrock terrain	0.3 – 0.5
Forest with bedrock	0.15
Area of apartment buildings, hard surfaces or gravel	0.7 – 0.8
Area of row houses	0.2 – 0.6
Residential district, small plots	0.1 – 0.3
Residential district, big plots	0.05 – 0.25
Sports field, playground	0.1 – 0.2

A more specific calculation of **peak stormwater runoff rate** can be carried out with rational equation Q = C*i*A where Q is runoff (m^3/s), C is runoff coefficient, (dimensionless) i is rainfall intensity (l/s*ha) and A is drainage area (ha) (Kuntaliitto 2012).

A **green factor** tool helps city planning by counting the efficiency of greenery in the area. Different green elements are scored based on perviousness and vegetation. One element can also have more than one score depending on its features. For example, a vegetated area can get a score for both the greenery and its function as a stormwater detention area. Factors such as landscape and maintenance can also be assessed. The different green elements are summed together and divided by the total size of the property in question giving a green factor value. Developing land-use specific target and minimum green factor levels for the city would help with land-use planning. It would also be beneficial to utilize in infill development. The target value has to be taken into consideration in the planning and new impervious building areas need to be compensated with green elements. (Climate-proof city 2014.) A green factor tool has been developed, for example, for the city of Helsinki. It can be found as part of the Climate-Proof City – Tools for Planning (ILKKA) project. (Ilmastonkestävä kaupunki 2015.)

3.1.5 Maintenance and the economical aspect of natural stormwater management

Green infrastructure can save money compared to traditional grey infrastructure. Even though green infrastructure does not completely eliminate the need for sewer services in built areas, it is a sustainable practice to provide infrastructure savings by reducing the need for additional grey infrastructure. Economic and environmental benefits are also achieved by decreased amount of stormwater and better working sewers. With the help of LID, IMPs and GI, basement backups, sewer overflows and flooding on the streets can be mitigated or prevented. Greenery increases property value, saves energy and helps mitigate carbon emissions. It also helps keeping the coastal waters and beaches cleaner as well as increases the aesthetical value of a city. (Milwaukee Metropolitan Sewerage District MMSD 2015.)

Like all stormwater infrastructures, natural systems require regular inspections and maintenance to assure proper function. Maintenance of green infrastructure generally requires more labor and less heavy equipment than that of gray infrastructure. (EPA 2015.) The amount of required maintenance can be minimized through careful planning when establishing LIDs/IMPs. Foundation methods as well as soil and plant selection have a big impact on the functionality and success of the management systems and the need for maintenance. (Kosonen 2014.)

The costs for natural stormwater management practices vary greatly depending on the type of system, size, design, soil conditions and the desired aesthethics. For a rough idea of the price level, The Association of Finnish Local and Regional Authorities (2012) has given a few examples of cost estimates (Table 5). The price is higher when establishing a natural stormwater management system requires deconstruction work such as asphalt removal.

TABLE 5. Examples of cost estimates for different LID/IMP methods. The prices are directional and based on the price level of 2010. (Kuntaliitto 2012, Ilmastonkestävä kaupunki 2015.)

Management system	Costs
Bioretention cell	90-190 €/m^2
Grassed swale	40-250 €/m^2
Green roofs	50-80 €/m^2
Permeable pavers	30-50 €/m^2
Rock gardens and gutters	25-45 €/m^2
Stormwater pond	40-80 €/m^2
Built stormwater reservoir (water square)	320-640 €/m^2

If urban runoff contains debris, water should be directed either through a stormwater interceptor or into a basin with a hard surface bottom before it enters a LID system. It is easier and more cost-effective to remove trash from them compared to a vegetated stormwater infrastructure or the sea. Overall, it is important to remove garbage, sediment, sludge and sand especially in the spring from the stormwater management systems in order to ensur their functionality. (Ilmastonkestävä kaupunki 2015.)

Seasonal changes have an effect on the functionality of natural systems. Especially ground frost reduces water absorption. It also weakens the biological purification process and solids retention. However, with proper design, a natural management system can address seasonal changes with minimal effects to its functionality. A draining system or a layer of gravel or sand placed under, for example, a bioswale help preventing ground frost. When ploughing snow, it is important to be careful not to break the surface of a green infrastructure. (Vakkilainen et. al 2005.) According to Inha

(2010) some drainfileds of gravel were built in Kouvola in the 1980s. These stormwater management areas in the street corners and parks function still today.

There are handbooks for maintenance of LID/IMP/GI. For example, the City of Philadelphia has a comprehensive Green Stormwater Infrastructure Maintenance Manual (2014) that includes useful information even if the conditions in Philadelphia are not identical to the ones in Finland. Some maintenance guidelines from 3 Rivers Wet Weather (2012) are also mentioned in Appendix 2.

4 BACKGROUND INFORMATION OF THE CITY OF HANKO

Hanko is the southernmost town, located on the tip of continental Finland in a peninsula surrounded from three directions by the Baltic Sea. The total area of the town is 632 km^2 of which land 117 km^2 and inland waters only 2 km^2 while the majority of the surface area consists of sea. (Tilastokeskus 2015.) The population of Hanko is 8930 (Väestötietojärjestelmä 2015). The urban population percentage is 96.3% and the number of households 4583 while there are 779 summer cottages. Of all households 63.8% live in row houses or small residential buildings. (Tilastokeskus 2015.) Hanko city center is built densely (Figure 14) and with relatively low buildings. The city is planning to increase the urban density. (FCG Finnish Consulting Group Oy 2012.)

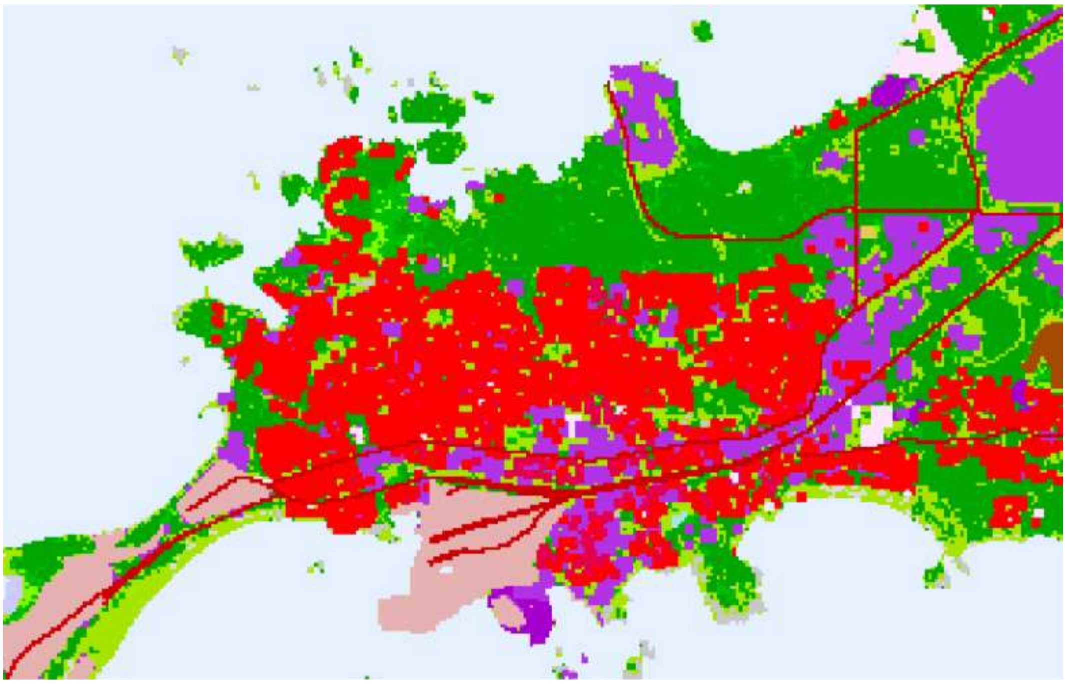

FIGURE 14. CORINE land use and land cover from 2012. The red and purple colors stand for built environment - apartment house and small residential building areas, industrial, traffic and port areas. Green colors show wooded, unbuilt areas. (SYKE 2015.)

There are 16 regions in Hanko that are classified as protected. They include land, sea and shore areas as well as islands. (Töyrylä 2012.) The city center also has three larger parks - Hagapuisto, Kirkkopuisto, and the area of Puistolampi - and some smaller green areas mostly situated near the shoreline. Two of the three parks include a small pond and these two parks are also designated in the local master plan as important breeding and resting sites for specimens of animal species referred to in Annex IV(a) of the Habitats Directive. (FCG Finnish Consulting Group Oy 2012.)

4.1 Location and characteristics

Since Hanko is located on the southernmost tip of mainland Finland, the Baltic Sea has a strong impact on the entire Hanko peninsula. The city area includes seashore for over 100 kilometers and sandy beaches for altogether 30 kilometers. Because of the sea, climate in Hanko is more like that of an island, in other words the temperatures are relatively mild throughout the year. The average day temperature for the whole year is +6˚C, average yearly rainfall is 634 mm and average amount of rainy days is 169 per year. (Pirinen, Simola, Aalto, Kaukoranta, Karlsson, Ruuhela 2012.) The sea around Hanko freezes later than in other parts of Finland (Hangon kaupunki 2015) and nowadays it rarely freezes for any longer period of time. For example, during winter 2014-2015 it did not freeze at all.

Vegetation in Hanko is rich even if dry podzolic forests are dominant. The windy coastal areas have mostly coniferous trees while deciduous trees are more common further inland. (FCG Finnish Consulting Group Oy 2012.) Hanko belongs to vegetation zone 1A, which for the plants is the most favorable zone in Finland (Ilmatieteen laitos 2015).

4.2 Topography and soil formation

Hanko was described in 1892 by K. A. Moberg as a place of relatively large sandy plains with sparse coniferous forest and big swamps. The peninsula is less than 20 meters above seal level (Figure 15) and coastal forces have shaped it as a gently toward the sea sloping moor. (Kielosto, Kukkonen, Stén & Backman 1996.)

Hanko peninsula is dominated by bedrock that for most parts is covered by the first Salpausselkä ridge formation. Salpausselkä is a result of the latest ice age, which ended approximately 10,000 years ago. The ridge was formed of soil carried by the continental glacier and its meltwaters. Due to a sudden cooling of the climate, the melting of the glacier ceased for couple of hundred years before the climate warmed up again and the melting continued. The first Salpausselkä ridge continues from Hanko at least 15 kilometers into the Baltic Sea. (Saarnisto, Rainio & Kutvonen 1994.)

The ridge formation consists mainly of a 1-4 meters thick layer of compact basal till. The coastline is mainly low-lying, close to the sea level, but there are also some cliff formations. Approximately 44% of the land area is covered by gravel and sand while 35% consists of either exposed bedrock or bedrock that is covered with less than one meter of till. 3.5% of Hanko area consists of organic deposits such as peat and gyttja. There are also smaller areas where peat can be found in thin layers in between sand banks. Some areas have clay, but it is mostly covered by coastal sand. Mud can be found in the northern part of the town in low-laying areas in between exposed cliffs. All the different soil layers are quite thin while the thickest ones can be found in the northern part of the area. (Kielosto, Kukkonen, Stén & Backman 1996.)

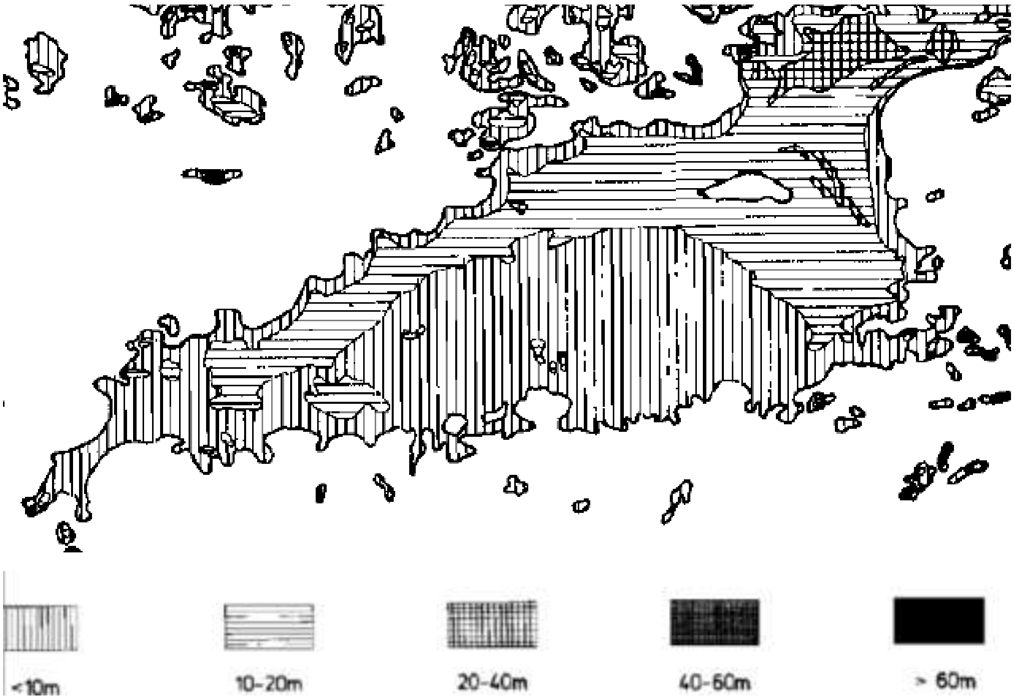

FIGURE 15. The altitudinal ranges in Hanko according to Kielosto et al. 1996.

Taking a closer look at the area, Kappelisatamatie runs all the way up to Linjakatu approximately in the middle of Salpausselkä ridge formation where the soil consists of mostly sand but often also some till layers. After Hangonkyläntie the formation runs between Luotsikatu and Tulliniementie all the way to the tip of the peninsula. To the north and south of this formation soil is mostly sandy except for the bedrock formations. (Hangon kaupunki 2013.)

The soil to the northeast of Halmstadinkatu and Hirvikalliontie is also formed by the ice age belonging to the Salpausselkä ridge and it consists of silt with some coarse-grained soil layers. The silt formation runs on the norths side of the exposed bedrock formation near Riilahdenkatu to the intersection of Katajapolku and Panimokatu and from there parallel to Tenholankatu. Silt formation can be found also to the south of the sandy ridge formation from the intersection of Appelgrenintie and Esplanadi continuing northeast parallel to the railway. Several bedrock formations in the city area are basically undetectable while others are more exposed and significant in size. (Hangon kaupunki 2013.)

4.3 Hydrology

During the approximately six-month long growing season in Finland, majority of the precipitation is taken up by the vegetation or is evaporated. During the other part of the year the impact of vegetation decreases and more water is absorbed as groundwater. (Hänninen & Äikää 2006.)

It is estimated that precipitation and weather extremes will increase due to climate change. Some estimates give a 10-25% increase in May-September rainfall in Finland before year 2100. (Ilmasto-opas 2013.) Short but very heavy rainfall events will also increase even up to 40%. The frequency of very short tropical showers cannot be estimated but even a 15-minute shower can cause severe flooding. (Kuntaliitto 2012.) Average winters will be warmer, shorter and rainier than before. Especially the southern and southwestern Finland and places such as Hanko will see less snow and for a shorter period of time. More of the winter precipitation will be falling as water. (Ruukki 2016.)

The first Salpausselkä ridge formation mainly consists of sand but has also layers of silt and clay, which significantly slow down the water flow. Near the city centre, the top layer of Salpausselkä is gravel and the thickness of the layer is approximately 2-4 metes. There are bedrock formations that prevent water flow thus dividing the area into smaller water catchment areas. (Kielosto, Kukkonen, Stén & Backman 1996.) Gravel lets water run straight through into the soil layers beneath it. Water is going also rapidly through sand or a mix of sand and gravel. Some clay, mud, peat and gyttja are also found in the city area but the deposits are small. Areas that consist mainly of these soil types have low perviousness to water. Topsoil retains approximately half of the water while infiltrating the rest into the following soil layers. (Broomfield 2013.) In the area of Salpausselkä ridge formation where the topsoil consists of sand, approximately 70% of precipitation is absorbed into soil and as groundwater (Etelä-Suomen aluehallintovirasto 2013).

Hanko belongs to the drainage basin of the coastal area of the Archipelago Sea. The Finnish Environment Institute (SYKE) has published a tool called VALUE for defining water catchment areas in Finland. The tool shows only two catchment areas in Hanko, both outside of the city center (Figure 16). (SYKE 2015.)

FIGURE 16. The VALUE tool does not give a water catchment area for the downtown area (SYKE 2015).

There have originally been a few natural ditches in the city area but residents have blocked some of them (Varjus 2016). Altering the natural path of the water flow has resulted in wet conditions in those locations.

4.3.1 Groundwater discharge points

Groundwater resources in Hanko are quite good. The area has six groundwater areas classified as I-class and one classified as II-class (Figure 17). The quality of groundwater has, however, been compromised in some areas due to low oxygen content and impurities such as traces of pesticides. Contamination has led to closing of two groundwater pump stations. (Töyrylä 2012.) Also the iron and manganese contents are high in some areas (Oy Forcit Ab 2015).

The water table is currently close to surface in many places in Hanko partly due to natural causes but partly due to gravel take. When the filtrating soil layer is very thin, pollutions in the runoff water do not filtrate properly but end up in the groundwater. (Backman, Luoma, Klein 2015.)

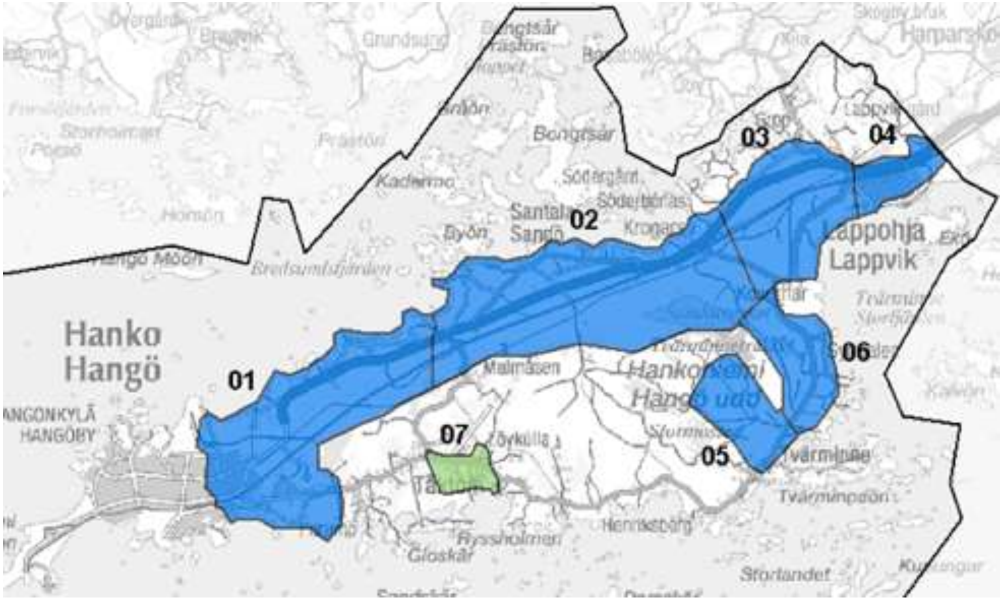

FIGURE 17. Ground water areas in the city of Hanko. The areas are Hanko (01), Sandö (02), Isolähde (03), Lappohja (04), Tvärminne (05), Syndalen (06) and Täktom (07). (Environmental Administration 2014.)

Some of the groundwater is directly discharged to the Baltic Sea on the north coast of the peninsula. There are locations with submarine groundwater discharge and groundwater is also seeping to surface water near the shoreline. In addition, some of the groundwater is running to sea through ditches also on the south side of the peninsula. Salpausselkä ridge formation devides the flow direction of groundwater. The recharge area for groundwater is about 30 m^2. (Peltonen 2002.)

4.4 Land-use planning

Uusimaa regional plan includes also the city of Hanko. The plan was approved in 2006 and the first phased regional land use plan in 2010. (FCG Finnish Consulting Group Oy 2012.)

The aim of the local component master plan for Hanko is to develop the city center as an active and functional part of the urban structure. The 1987 version of the master plan for the downtown section was updated in 2013. Urban area expands to the east especially on the south side of the railway, towards Täktom area, where a new small-house district is established. On the north side of the railway the plan is to densify the already existing district of detached houses. The master plan coverage includes several city plans from a wide time frame, some being several decades old while others are currently under work. (FCG Finnish Consulting Group Oy 2012.)

4.5 Precipitation

The annual rainfall in Uusimaa region can vary significantly from less than 300 ml to over 1000 ml. Coastal areas are the driest. (Ilmasto-opas 2013.) In the wintertime, snowfall can be equally variable. Both temperature, especially the sea temperature, and the direction of winds dictates how much and how often it will snow. Snow can also melt several times during a winter. Winds from southwest bring warmer weather while easterly winds usually mean cold fronts and more snow. During years 1981-2010 the average date for permanent snow cover in Hanko was January 16. This is several weeks later than the average for the rest of the country. The snow cover usually melts in Hanko at the end of March or beginning of April, but even this can vary with several weeks depending on the winter conditions. (Ilmasto-opas 2013.) There have been winters during which Hanko had no permanent snow cover but, for example, in winter 2012-2013 first snow arrived already in October. That winter also the permanent snow cover came before Christmas and it melted in mid April. (Ilmatieteen laitos 2015.)

The longtime average for precipitation during period 1971-2000 was in Hanko 620 mm while both yearly and monthly variations were significant. For example, in 2009 the rainfall in April was 2.1 mm while it in October was 97.3 mm. Yearly rainfall increased during the 29-year period with approximately 15%. The biggest changes occurred mostly during fall and winter. (Backman et al. 2015.)

4.5.1 The city’s management practices for stormwater

According to the development plan for water services in Hanko (2012), the portion of stormwater piping in the town is still quite small compared to wastewater sewers. The sewer system has been almost completely a combined one where both storm- and wastewater flows in the same piping. Stormwater can enter the sewer system also through rundown piping and from properties where water from under drains or rooftops is falsely directed into the sewerage system. New construction areas in Hanko have separate sewer system with separate sanitary and storm sewers. The city has also changed some of the existing sewerages to separate ones. (Töyrylä 2012.)

The development plan also states that the dimensioning of storm sewers is usually designed according to a heavy rain event recurring every two years and lasting for 10 minutes, and thus has the flow of approximately 120 l/s per hectare. It is not economical to dimension the sewers according to the maximum rainfall predicted. As the report also noted, the majority of rain- and stormwater would be best to immediately treat as close to the source as possible. This factor should be taken into account in the town planning in order to leave enough pervious surfaces for water infiltration. (Töyrylä 2012.)

Approximately 95% of the residents in Hanko are connected to the town’s sewer system. The entire sewer system, including stormwater sewers, is 137 km long. Majority of the pipes is still old and made of concrete while the newer ones are plastic. (Töyrylä 2012, Varjus 2013.)

Treated waters from both the city’s Suursuo wastewater treatment plant and the private Hangon Puhdistamo Oy are directed into the Baltic Sea approximately 1.5 km from the coastline on the south side of the city (Töyrylä 2012). Where there is a separate pipeline for stormwater, the water is discharged directly to the sea both on the south and north side of the city (Figure 18) (Varjus 2013).

FIGURE 18. Map of stormwater drainage in the city of Hanko (Varjus 2013).

In the 2016 action plan for the water and wastewater department it is noted that the environmental permit for the wastewater treatment plant requires the sewerage system to be renovated. The city’s technical board has made a commitment to fulfil the requirement with the aim to decrease the amount of stormwater coming to the wastewater treatment plant. The work is costly and will be done in sections. The action plan also states that the city should make an agreement with the water supply plant for managing urban runoff and collecting payments according to costs. The other alternative is that the city takes care of the stormwater management and collects a fee from the residents to cover the costs. It is still undecided which alternative will be chosen but a decicion in the matter needs to be made during 2016. (Varjus 2015.)

The city is currently in a transition phase regarding stormwater management. A responsible actor for handling urban runoff is not officially decided or mentioned anywhere. The Hanko Water and Wastewater Department has in practice taken care of stormwater but now, since urban runoff is not part of water services, wants to pull away from it. Ideas such as the city's Environmental Board as guiding and supervising and the Technical Board as implementing and maintaining actors have been brought under discussion regarding new stormwater management planning. (Varjus 2016.)

4.5.2 Problems

Stormwater flooding incidents have been recorded in Hanko especially during the last nine years. The pattern is usually the same, a short-term heavy rain event (20-30 mm/h) cause basements especially in the districts 6 and 7 to flood and in some cases a couple of roads have been closed. Flooding has also been recorded in districts 1, 2, 3 and 8 (The city of Hanko 2010) as well as in district 4 on Veturinkuljettajankatu and Kappelisatamantie (Holm 2014). Costs for the flooding have been around a few hundred thousand euros (ELY-keskus 2013).

As a result of the heavy rain event in 2007, Hanko has decided not to compensate for damages caused by stormwater to properties that are not built according the National Building Code of Finland, part D1 (Västra Nyland 21.2.2013). Various areas in Hanko are built differently and in some places nothing has been done regarding runoff waters. Problems have occurred with stormwater also in areas where there are no sewer system. (Takala & Varjus 2013.)

Due to combined sewerage, the amount of stormwater has caused problems in the nutrient removal capacity at the wastewater treatment plant (Länsi-Uudenmaan vesi ja ympäristö Oy 2012). According to the Manager of the Water and Wastewater Department in Hanko, stormwater accounts for approximately 60% of the water coming to the wastewater treatment plant (Nykänen 2014). However, in 2015 the portion was even more significant since as much as 70% of the annual 2.3 Mm^3 of wastewater treated at the plant consisted of stormwater (Varjus 2016).

Stormwater often causes peaks in the incoming water amount at the wastewater treatment plant. These peaks are a result of heavy rain or fast melting snow or, in some cases, both at the same time. Also underdrains are connected to combined sewer system adding to the water volume. (Varjus 2016.) When a peak occurs, it often leads to overflows at the treatment plant, which means that insufficiently treated or even untreated sewage is released into the sea. Stormwater is also usually colder than wastewater. The quantity, quality as well as coldness of the water disrupt the biological processes of the plant. This will result in the release of raw or poorly cleaned sewage. (Itämerihaaste 2012.) Pumping large amounts of stormwater is also not economical. In some cases water goes through eight pump stations before reaching the treatment plant, which takes up a lot of electricity. Some stormwater is even transferred through sewer system almost 20 kilometers from Lappohja. (Varjus 2016.) Urban runoff is also partly the reason for the Centre for Economic Development, Transport and the Environment (ELY-keskus) urging the city’s wastewater treatment plant to fix without delay the problems that occurred in 2014 debilitating the water treatment process. (Västra Nyland 18.9.2015.)

Rainfall in wintertime is problematic because even if no ground frost is present, there is often a layer of ice on top of the soil as well as other surfaces. Ice makes soil impervious and may also block gutters. Another issue related to water volume is seawater that is coming to the sewer especially when sea level rises above normal during a low pressure or storm. There are ways to block the access for seawater but by doing it water in the piping will also be blocked from entering the sea. That results in a problem should there be a disruption requiring the piping to be used for sewage overflow discharge. (Varjus 2016.)

Hanko has begun a project to separate the rainwater and wastewater drains while renewing the pipes. The plan is to increase the amount of rainwater drains and direct more of the runoff water straight into the sea. The project will continue until 2020. (Varjus 2013.) According to United States Environmental Protection Agency (EPA), sewer separation work is more cost effective if combined with other infrastructure work in the city. The results of separating the combined sewer system may not be unequivocally only positive since untreated stormwater discharge will increase. Without any mitigation methods, all the pollutants in the urban runoff will end up in the sea. (EPA 1999.)

Some green areas for natural stormwater management have been implemented in the city, but due to unsuccessful planning they have not functioned as desired. As a result some negative attitudes towards LID/IMP methods have been formed. (Varjus 2016.)

Flooding in the city area disturbs traffic. Even if the amount of water on the roads does not necessarily stop the traffic, it will make it difficult for pedestrians and cyclists to move around. For example, right in Hanko city centre, next to the city hall, a combination of manmade impervious surfaces, surface bedrock, altitude differences and old drain pipies result in street flooding during rain. (Varjus 2016) Rainwater runs along the street and bedrock next to the street accumulating to the nearest lowest point located in the street corner. (Figure 19) A pervious park area located next to the street is slightly elevated and the street tilts away from the grass preventing water from entering it.

FIGURE 19. Big and small altitude changes together with impervious surfaces direct precipitation to the street corner (The city of Hanko 2013).

In some cases, as happened for example in Karjaa in July 2013, heavy rain can seriously disrupt traffic and cause expensive structural damage to the roads (Keskinarkaus 2013). It is also possible that a combined or stormwater sewer pipe cannot handle the pressure during a torrential rain event. If more keeps pouring in when drainage is already full of water, a pipe might burst resulting in flooding either inside buildiings or on the street. (Karlsson 2013.)

Groundwater infiltration is affected due to stormwater runoff. The amount of groundwater decreases when rainwater runs on the surface instead of soaking into the ground. Also the quality of groundwater is affected while flooding increases erosion taking away some of the filtrating soil. When rainwater that does soak into the ground is going through less filtration, it will contain more impurities when it reaches groundwater. (EPA 2001.)

Impurities are also running into the sea. The warehouse field areas especially in Hanko West Harbor are covered with asphalt. There is a lot of traffic in that area and impurities such as oil ends up in the sea together with stormwater. (Ympäristölautakunta 2012.)

4.5.3 Observations

Hanko is a small city with still quite a lot of greenery left. The trend seems to be, however, that greenery needs to go from the way of urban development such as parking lots (Figure 20) and buildings.

FIGURE 20. A parking lot on a rainy September day (Komulainen 2015).

When an entire parking lot is impervious and rainwater from the roof is directed to the asphalt by several drainpipes, it will cause excess surface runoff. This runoff flows following the topography until it reaches either a pervious place or an impervious pothole of some sort. Because the building in the Image 20 is located higher than the adjacent street and because of the sloping of the parking lot, water runs straight towards and on to the nearby street. There are a few drains in the middle of the parking lot and a big portion of the water is going also into them. There is a grassy area between the parking lot and the street, but the area is bordered with bricks preventing water from accessing it. The gravel section on the side of the building does not in this case seem to have any function regarding the stormwater.

The intersection between Korsmaninkatu and Appelgrenintie (Figure 21) is sometimes flooded during rain. There is a small, elevated green strip between the lanes on Korsmaninkatu but surface runoff does not have access to it. Shrubs or plants on the strip would also help by taking advantage of rainwater. Even though it looks nice and green, the curbs prevent water from flowing off the street. This area is flat (Figure 22) with no altitude changes except for a cliff just on the north side of the intersection. During heavy rain, water might run down towards the street.

FIGURE 21. There is a green median strip on Korsmaninkatu but runoff water does not have access to it (Google Maps 2015).

FIGURE 22. The intersection and its surroundings do not have any noticeable altitude changes (The city of Hanko 2013).

Another intersection often flooded during heavier rain is located between Kappelisatamantie, Lähteentie and Santalantie. Here the area is sloping from the north towards the intersection (Figure 24) and the impervious asphalt functions as a channel for the surface runoff. The greenery between the lanes has been removed and replaced by concrete tiles (Figure 23). Even though there are small gaps between the tiles, the divider is elevated from the street level and street runoff does not have access to it. There are pervious areas on both sides of the road but the curbs prevent water from from exiting the street.

FIGURE 23. Runoff water has nowhere to be absorbed (Google Maps 2014).

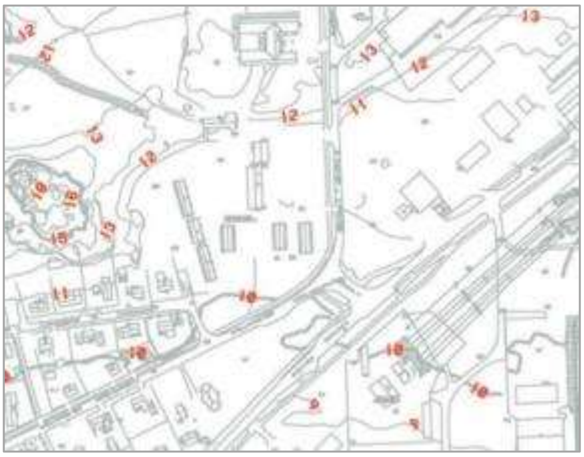

FIGURE 24. Due to the sloping and imperviousness of the area, Lähteentie carries surface runoff towards the intersection (The city of Hanko 2013).

Especially in older buildings the driveway often slopes down toward and into a basement garage (Figure 25). Usually both the driveway and its surroundings are impervious, which can easily cause stormwater entering the basement.

FIGURE 25. Impervious surfaces lead the way down to the basement (Google Maps 2014).

Water finds lower places, dimples, even if the altitude differences are almost invisible to the human eye. If water has nowhere to go, it will stay on the impervious dimple until it evaporates. (Figure 26)

FIGURE 26. An example of how water cannot penetrate impervious surfaces but flows downhill to the lowest point (Komulainen 2014).

5 VIEWS ON POLICIES AND PRACTICES FOR MITIGATING URBAN FLOODING

There are no lakes or rivers and not many natural ditches in Hanko city center (SYKE 2015). Rainwater would thus naturally be mostly absorbed by vegetation and into the soil and further to groundwater while part of it would run into the sea. The city as well as the entire peninsula is less than 20 meters above the seal level and it is gently sloping toward the sea. (Kielosto, Kukkonen, Stén & Backman 1996.) While the soil in Hanko predominantly consists of sand, there are also quite a large amount of naturally impervious areas with surface bedrock (Saarnisto, Rainio & Kutvonen 1994).

As an example of topography changes and human impact on stormwater, an area bordered by Panimonkatu to the west, Esplanadi to the south, Tvärminnenkatu to the north and Santalantie to the east in the city district number four is looked at more closely (Figure 27).

FIGURE 27. An area of approximately 307 700 m^2 in the city district number 4 (LIITERI 2015).

This is an area that has had some flooding on Veturinkuljettajankatu and Kappelisatamantie (Västra Nyland 14.10.2014). There are a few meters higher grounds with some surface bedrock on the west of Veturinkuljettajankatu while it is flat on both sides of the road. The terrain is also higher on the north side of Tvärminnenkatu, sloping towards Esplanadi. (Figure 28)

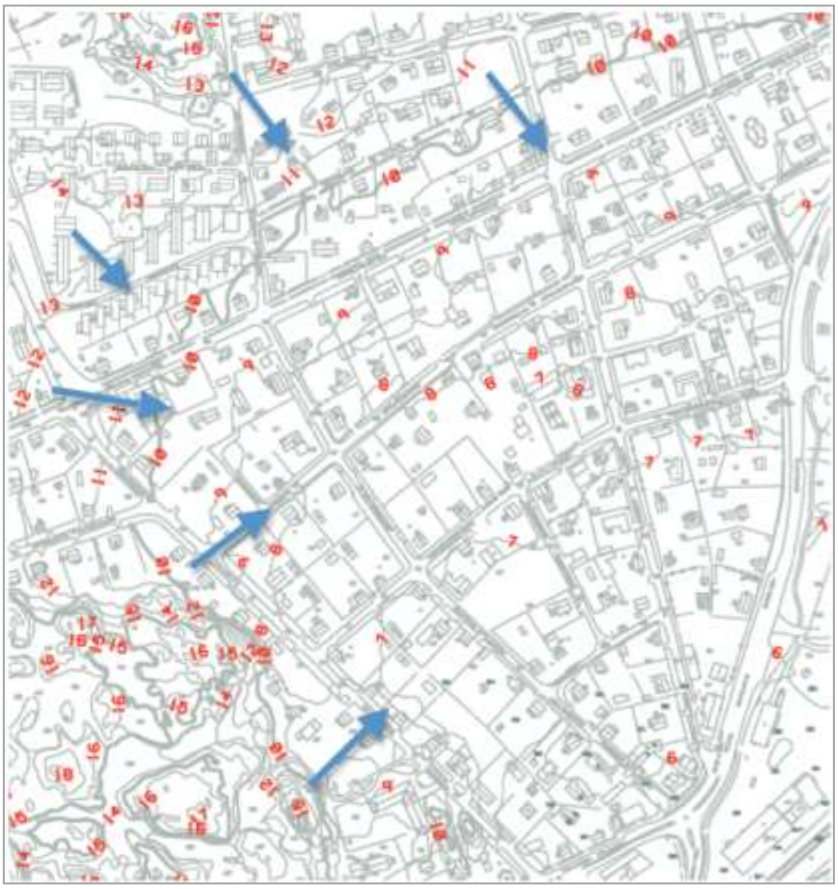

FIGURE 28. Estimated directions for surface runoff based on the altitude levels on the area (Hangon kaupunki 2013).

Rainwater is being directed from the rooftops directly or almost directly to the impervious sidewalk on several places in the area (Figure 29).

FIGURE 29. Some rain gutters on Kappelisatamantie (Google Maps 2014).

The part of combined sewerage on Kappelisatamantie, between Märsankatu and Panimonkatu, which will be renovated during 2016, is also in this area. The plan is to separate sewerage for stormwater replacing the combined sewerage system. (Varjus 2015.) It would be cost-effective to do stormwater mitigating green infrastructure work in the area at the same time with the sewer separation (EPA 1999).

Setting ground rules by having clear policies and regulations for stormwater handling in the city area, including private properties, is important. Educating the residents of green infrastructure ways to take care of stormwater on their own property would also be beneficial for the city and the environment. Education combined with a possible financial benefit for the residents from handling rainwater on site is even more efficient. (EPA 2014.)

5.1 Cooperation between different actors is important

Stormwater management is no longer just water removal and flood control. Emphasis is increasingly directed also to pollution mitigation, sustainability in water use, urban landscape improvements and reducing financial costs. In order to achieve results, policies need to evolve. Updated or completely new management systems, regulations, guidelines and arrangements that will meet all the desired objectives are also needed. Water management requires crossectoral cooperation between environmental, economic, technical, social and political departments, actors and authorities from planning to upkeep. A so-called hybrid governance structure for urban stormwater management helps to share responsibilities for actual measures and thus also the financial inputs among authorities, businesses and residents. Engaging residents in the management programs is important since individual landowners have a notable effect in both the quality and quantity of urban runoff. (Porse 2013.)

5.2 Examples of functional practical measures taken in some cities in the USA

Green infrastructure and IMPs have been proven to be efficient around the world. In Staten Island, New York City, a bluebelt system with built wetlands has saved millions of dollars in alternative sewer treatment systems. The bluebelt’s performance has been tested during major storms and hurricanes. In October 2005, tropical Storm Tammy and Subtropical Depression 22 combined produced 16 cm of rainfall over a 24-hour period. Areas that were previously flooded by much smaller precipitation amounts handled now the downpour without any issues. In addition to its economic and physical advantages, the bluebelt system is also valued for its environmental benefits. (Economides 2014.)

In Philadelphia, the city has a program to collect fees based on area of impervious surfaces. The program is called a “ratio of ‘Impervious Area to Gross Area’ on the property”. It means that owners of parking lots are charged a certain rate. The city has also released a stormwater retrofit guidance manual for the nonresidential customers who can benefit most from using GI/IMPs. Philadelphia has updated its stormwater regulations and new building developments have to be more effective in slowing urban runoff, handling water and improving pollutant reduction. The city is also educating its residents about green infrastructure systems. (Water Environment Federation 2015.)

The city of Phoenix has taken several steps to increase stormwater management through green infrastructure and has managed to decrease the amount of total runoff. The city codes, plans, and policies include, for example, requirements for progressive stormwater management standards for new developments. The standards emphasize the establishment and use of natural corridors. Open space is required for stormwater management, building code promotes rainwater harvest and plumbing code allowes graywater use. The city’s regulations for development and construction permits include green infrastructure requirements. The city also has pervious pavements in parking areas and sidewalks as well as bio-swales and small shallow depressions to retain runoff. (Economides 2014.)

6 DISCUSSION AND CONCLUSIONS

Urban building density is increasing, climate is changing, water systems are strained and increasingly vulnerable. In the future, there will most likely be a shortage of clean water also in areas where it has been taken for granted. It is an unfavourable equation when the area of impervious surface grows at the same time as rainfall increases, and it might have increasingly negative effects on the environment, comfort and health of humans and the economy. Stormwater used to be regarded as clean water but studies have shown urban runoff and melting snow to contain a variety of impurities ranging from bacteria and nutrients to heavy metals and harmful chemicals.

Conveying urban runoff through wastewater treatment plants into surface waters is not sustainable. It takes up a lot of energy, disrupts the treatment process of raw sewage, and results in impurities entering the water system. Channelling stormwater runoff directly into waterways also has negative effects due to the harmful substances and the sheer force of water discharged through the pipeline. It would also require a comprehensive network of stormwater pipes to keep all the impervious surfaces dry during rain.

Increasing concern about the quality of surface water together with more frequent urban flooding incidents has led to the development of best management practices for stormwater handling. Especially Low Impact Development (LID) and Integrated Management Practice (IMP) methods have gained growing interest during the last few years. The key principle of the methods is to mimic a site's predevelopment hydrology. In practice it means systems that infiltrate, filter, store, evaporate, and detain runoff. Instead of seeing stormwater management as water disposal, water should be utilized in favor of both people and the environment. LID and IMP techniques are flexible and can be applied to nearly any location, both new development and infill/redevelopment sites. Using the methods and favoring green infrastructure is sustainable in many ways. According to researches, natural ‘green’ stormwater management is more favorable both ecologically and economically than conventional ‘grey’ stormwater management.

The city of Hanko is going through a transition period regarding stormwater management. There are currently no clear, consistent policies or rules regarding urban runoff. The sewer system in the city has to be renovated according to the environmental permit for the wastewater treatment plant. Some improvements are needed in order to decrease the vast amount of stormwater entering the sewage treatment plant. Partly also as a result of the new legislation, Hanko water and wastewater department wants to hand off the stormwater management to the technical department of the city. Different alternatives have been brought up in the discussions. One is that the city makes an agreement with the water supply plant for directing urban runoff from public areas and collecting payments according to costs. The other one is that the water supply plant is no longer involved in urban runoff issues but the city takes care of stormwater management and collects a fee from the residents to cover the costs.

Some sewer construction/separation and maintenance work will be needed no matter what the final management plan is. It is, however, more cost effective to carry out if combined with other infrastructure work. Without any mitigation methods, all the pollutants in the urban runoff will end up in the sea. Combining economical and ecological aspects is worthwhile. Planing and implementing LID/IMP methods together with the sewer work would turn a new leaf in the city’s overall stormwater management. This is the time to concentrate on the urban runoff subject at large and all concerning actors should be engaged in the project. Cooperation in planning and the practical implementation of a more sustainable stormwater management is essential.

City planning has an important role in stormwater management. It is also the most cost-effective tool. City planning and zoning need to pay attention on the natural and already altered as well as planned circumstances of the area. Topography, flow-routing, soil's absorption ability, and the amount of impervious areas all have an effect on urban runoff. Building permits as well as overall city policies and regulations are also integral tools. Defining land-use specific targets and minimum green factor levels for the city are useful guidelines in land-use planning. In infill development, when the building right on a property increases, a target green factor value can be placed for a certain property. Private properties need to be planned in favour of pervious surfaces in order for most of the precipitation to be absorbed in the property. Communication and information (Figure 30) is essential in order to bring attention to the issue in question. Green infrastructure and LID methods can also be enhanced through economic and aesthetic incentives, designed visualizations, maps and alternatives for city programs.The outcome should be that only exceptionally heavy rain requires some of the surface runoff to be directed to stormwater drainage. Again, cooperation and common ground rules have a strong interaction with the actual results.

FIGURE 30. Examples of somewhat unconventional signs, though not directly regarding stormwater that appeared effective and got the attention of people passing by (Komulainen 2016).

Due to the naturally pervious soil and topography of gently sloping towards the sea, there has most likely been hardly any flooding in Hanko in the area’s natural state. The main soil type is sand, which means that water is absorbed quickly into and through the soil layer. Preserving natural site features as much as possible mitigates urban runoff. In practice that is, however, difficult to actualize since space is valuable and wanted for housing, traffic and industry. Therefore also other solutions are required. Minimizing and disconnecting impervious areas with pervious surfaces for water infiltration, allowing water to access them and scattering small-scale LID/IMP methods throughout the urban area prevent large runoff quantities from being formed. For example, a pervious area of 2% can be enough to prevent urban runoff from a parking lot. That impervious stormwater management area would also have an aesthetic appeal and, with trees, offer shade from the sun in the summer.

Urban vegetation and multi-functional landscapes have several advantages in addition to managing stormwater. Many studies have shown that green spaces not only have aesthetic benefits but they also have a positive impact on public health. Greenery alleviates stress, lowers blood pressure and even improves cognitive functioning. Flowers benefit pollinators that are currently worryingly declining in numbers, vegetation helps to sustain the soil moisture balance. Also, since sand has a poor water holding capacity, the soil is more prone to drought. It is worthwhile to collect some of the rainwater and use it for irrigation. The groundwater level can sink during drier periods and using groundwater for irrigation is not sustainable.

The water intakes in Hanko are located outside the city center and due to the direction of groundwater flow, stormwater absorption in the downtown area does not jeopardize the quality of water for household consumption. Even the big areas cleared for cars to the east of downtown should not pose a threat to the city’s groundwater, and part of them could safely be used as a snow disposal site.

Even though stormwater management systems function as “first aid” to the problem regarding impurities, they cannot cure it. Pollution, nutrients, heavy metals and trash can be prevented from spreading or entering a certain area and be partly treated less harmful, but cannot be completely eliminated with any stormwater management method. That is why attention should also be paid on the issues that affect the quality of surface runoff. Avoiding chemical pesticides and chemical fertilizers, finding a biodegradable alternative for de-icing/road salt and ways to prevent littering are some of the challenges to tackle. Also, it should be as easy as possible for people to bring hazardous waste to a proper disposal collection so that dangerous substances are not disposed of in illeagal ways by dumping on the ground or in the sewer. Favouring and informing about more environmentally friendly alternatives, such as mowing fallen tree leaves for nutrients for lawns, is also one way to contribute. In some cases supporting the LID/IMP methods with technical designs, such as oil/water separators, can be beneficial. The antifreeze used in cars is toxic, motor oil contains heavy metals and chemical additives. Especially bigger parking lots are places where fuel residues and other chemicals from cars can often be seen on the asphalt.

Plants used in different natural stormwater management systems should be tolerant and suitable for the specific soiltype and prevailing conditions in question. Especially places such as roadsides and parking areas need durable vegetation. Kuntaliitto has listed examples of some suitable plants (Appendix 3). Even though indigenous plants are to be favoured, Rosa rugosa is an invasive spieces extremely durable and cold-hardy shrub that tolerates drought, sunlight, rain, snow, cutting and even salt. It is also very disease resistant and prefers sandy or gravelly soils. Efforts have been made to get rid of it from the beaches in Hanko because it threathens the original species there. Maybe it still could be used in LID methods further away from the vulnerable shore areas, restricted to stormwater planters or rain gardens in parking lots.

Best results in reducing, delaying and purifying urban runoff will be achieved through a combination of different stormwater management practices. New information and material on stormwater management and especially the different natural methods is published every year. Internationally, there are already several examples of techniques and methods that have shown to be successful. Knowledge and experience can increasingly be found also in Finland.

6.1 Need for additional research

Updated information on stormwater flooding was not available for this study. It would be beneficial for stormwater management to map out the exact location, duration of rain event, precipitation as well as possible financial consequences regarding all flooding incidents.

Executing an analysis with a graphic picture of the topography as well as the ratio and locations of a built environment would also be useful. With a tool, such as ArcGIS information system, it is possible to get a visual idea of where water would naturally flow within the desired area. Combining all that information would be helpful in city planning. An analysis program such as ArcGIS was not available for this work.

The quality of stormwater in the city of Hanko has not been analyzed. Water is currently directed straight into the sea from the highway leading into the city, and partially from the city without any information on the water quality. Snow is also being dumped into the sea. An analysis of urban runoff in different parts of the city would be beneficial in order to determine what kind of management methods are suitable to handle the stormwater sufficiently.

There are many ways and channels to reach and involve the city’s different actors in stormwater management. The city should strive to find the best, most positive ways for achieving actual results.

Regarding the financial aspect, it could be worth exploring if some help with planning and building natural management systems for urban runoff might be available from the holticulture students doing their degree work.

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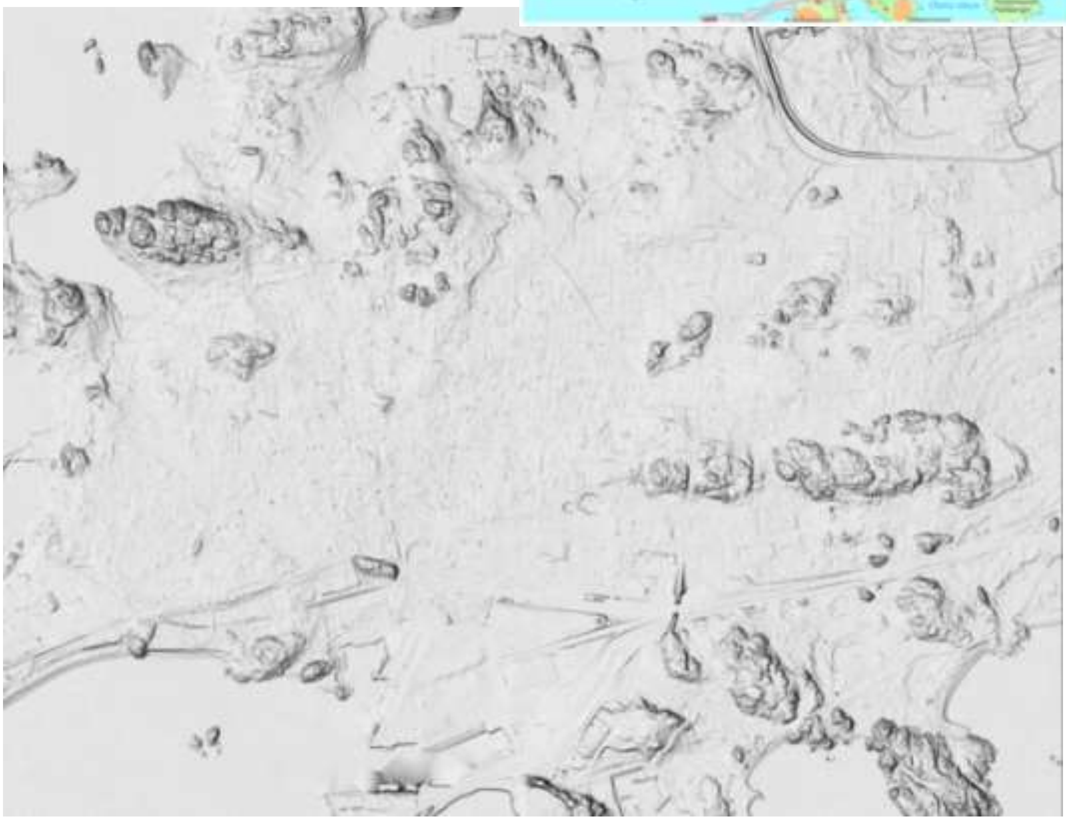
APPENDICES

APPENDIX 1



The online map service of Geological survey of Finland (2015) merges superficial deposits and bedrock maps with precise elevation data hillshading. The map shows the topography of downtown Hanko.

APPENDIX 2

Some maintenance examples for LID. (3 Rivers Wet Weather 2012)

Grassed swale

Task	Frequency	Maintenance Notes
Inlet inspection	Twice/year	Check for sediment accumulation and erosion within the swale. Remove accumulated sediment.
Mowing	2–12 times/year	Frequency depends on location and desired aesthetic appeal.
Watering	Once every 2–3 days for the first 1–2 months, then sporadically	Depending on the weather conditions. If drought conditions exist, watering after the initial year may be required.
Fertilization	Once	One time spot fertilization for the initial vegetation.
Remove and replace dead plants	1 time/year	Within first year 10% of plants may die. Survival rates increase with time.
Check dams	Monthly during the wet season	Check for sediment accumulation and erosion around or underneath the dam materials. Remove accumulated sediment.
Miscellaneous upkeep	4-12 times/year	Tasks include trash collection and spot weeding.

Vegetated fileter strip

Task	Frequency	Maintenance Notes
Mowing	2-12 times/year	As needed to maintain aesthetics. Grass height should be at least 3 cm.
Inlet inspection	Monthly during the wet season	Check for sediment accumulation to ensure that flow into the system is designed. Remove any accumulated sediment.
Miscellaneous upkeep	4-12 times/year	Tasks include trash collection and spot weeding.

Rain garden

Task	Frequency	Maintenance Notes
Pruning	1-2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on location and desired aesthetic appeal.

Mulching	1-2 times/year	Between 3 and 8 cm of mulch depth is ideal.
Mulch removal	1 time/2–3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	Once every 2–3 days for the first 1–2 months, then sporadically	Depending on the weather conditions. If drought conditions exist, watering after the initial year might be required.
Fertilization	Once	One time spot fertilization for initial vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10% of plants can die. Survival rates increase with time.
Inlet inspection	Monthly during the wet season	Check for sediment accumulation to ensure that flow into the bioretention is as designed. Remove any accumulated sediment.
Outlet inspection	Monthly during the wet season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	4-12 times/year	Tasks include trash collection, plant health, spot weeding and removing mulch from the overflow device

Disconnected downspouts

Task	Frequency	Maintenance Notes
Inlet inspection	2-12/year	Inspect for clogging (failure to drain). Remove any accumulated leaves, organic materials, and sediment.
Mowing	Periodically	Maintenance is similar to other landscaping and may require occasional mowing.
Miscellaneous upkeep	Periodically	Infiltration areas should be routinely checked to ensure that they are free of debris and trash. Receiving areas should be inspected for signs of channelized flow and compaction.

Porous pavement

Task	Frequency	Maintenance Notes
Inlet Inspection	Monthly during the wet season	Check for sediment accumulation to ensure that flow onto the permeable pavement is not restricted. Remove any accumulated sediment. Stabilize any exposed soil.
Vacuum street sweeper	Twice a year as needed	Pavement should be swept within a vacuum power street sweeper at least twice per year or as needed to maintain infiltration rates.
Mowing (for	2–12 times/year	Pavers filled with turf require mowing.

grass filled pavers)		Frequency depends upon location and desired aesthetic appeal.
Replace fill materials	2-4 times/year	Fill materials will need to be replaced after each sweeping and as needed to keep voids with the paver surface.
Watering (for grass filled pavers)	Once every 2–3 days for the first 1–2 months, then sporadically	Depending on the weather conditions. If drought conditions exist, watering after the initial year may be required.
Miscellaneous upkeep	4 times/year or as needed for aesthetics	Tasks include trash collection, sweeping, and spot weeding. One time spot fertilization for “first year” vegetation might be needed for aesthetics.

Bioswales

Task	Frequency	Maintenance Notes
Pruning	1-2 times/year	Nutrients in runoff often cause bioswale vegetation to flourish.
Mowing	2-12 times/year	Frequency depends on location and desired aesthetic appeal.
Mulching	1-2 times/year	Recommend maintaining a 2-7 cm uniform mulch layer.
Mulch removal	1 time/2–3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	Once every 2–3 days for the first 1–2 months, then sporadically	Depending on the weather conditions.
Fertilization	Once	One time spot fertilization for the initial vegetation.
Remove and replace dead plants	1 time/year	Within the first year 10% of plants can die. Survival rates increase with time.
Inlet inspection	Monthly during the wet season	Check for sediment accumulation to ensure that flow into the bioswale is as designed. Remove any accumulated sediment.
Outlet inspection	Monthly during the wet season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	4-12 times/year	Tasks include trash collection, plant health, spot weeding and removing mulch from the overflow device

APPENDIX 3

Examples of plants suitable for natural stormwater management sites. (Kuntaliitto 2012)

Plants suitable for drainage ditches and moist to wet areas	
Acorus calamus	Rohtokalmojuuri
Acorus gramineus	Heinäkalmojuuri
Alisma plantago-aquatica	Ratamosarpio
Astrantia major	Isotähtiputki
Butomus umbellatus	Sarjarimpi
Calla palustris	Suovehka
Caltha palustris	Rentukka
Cardamine pratensis	Luhtalitukka
Carex acuta	Viiltosara, keltasara
Carex nigra subsp. Nigra	Jokapaikansara
Carex pseudocyperus	Varstasara
Eriophorum angustifolium	Luhtavilla
Eriophorum angustifolium	Tupasvilla
Eupatorium cannabium	Punalatva
Euphorpia palustris	Rantatyräkki
Filipendula ulmaria	Mesiangervo
Glyceria maxima ’Variegata’	Kirjosorsimo
Iris pseudacorus	Keltakurjenmiekka
Iris sibirica	Siperiankurjenmiekka
Juncus conglomeratus	Keräpäävihvilä, röyhyvihvilä
Ligularia	Nauhukset
Lysimachia punctata	Tarha-alpi
Lysimachia tryrsiflora	Terttualpi
Lysimachia vulgaris	Ranta-alpi
Lythrum salicaria	Rantakukka
Matteuccia struthiopteris	Kotkansiipi
Menyanthes trifoliata	Raate
Myosotis laxa ssp. Caespitosa	Rantalemmikki
Myosotis trifoliata	Luhtalemmikki
Parnassia palustris	Vilukko
Persicaria amphibia	Vesitatar
Phalaris arundinacea	Ruokohelpi
Schoenoplectus lacustris	Järvikaisla

Sagittaria sagittaria	Pystykeiholehti
Salix	Pajut
Sparganium erectum	Haarapalpakko
Telekia speciosa	Auringontähti
Typha minima	Pikkuosmankäämi
Veronica longifolia	Rantatädyke, useita lajikkeita
Aquatic plants (floaters)	
Hydrocharis morsus-ranae	Kilpukka
Pistia stratiotes	Vesisalaatti
Trapa natans	Vesipähkinä
Elodea canadensis	Vesirutto
Potamogeton perfoliatus	Ahvenvita
Myriophyllum sp.	Ärviät
Aquatic plants	
Nymphea alba	Lumme
Nuphar lutrea	Ulpukka
Potamogeton natans	Uistinvita
Sagittaria natans	Kelluskeiholehti
Fast spreading plants	
Phragmites australis	Järviruoko
Sesleria caerulea	Sinilupikka
Scirpus sylvaticus	Korpikaisla
Typha angustifolia	Kapeaosmankäämi
Typha latifolia	Leveäosmankäämi