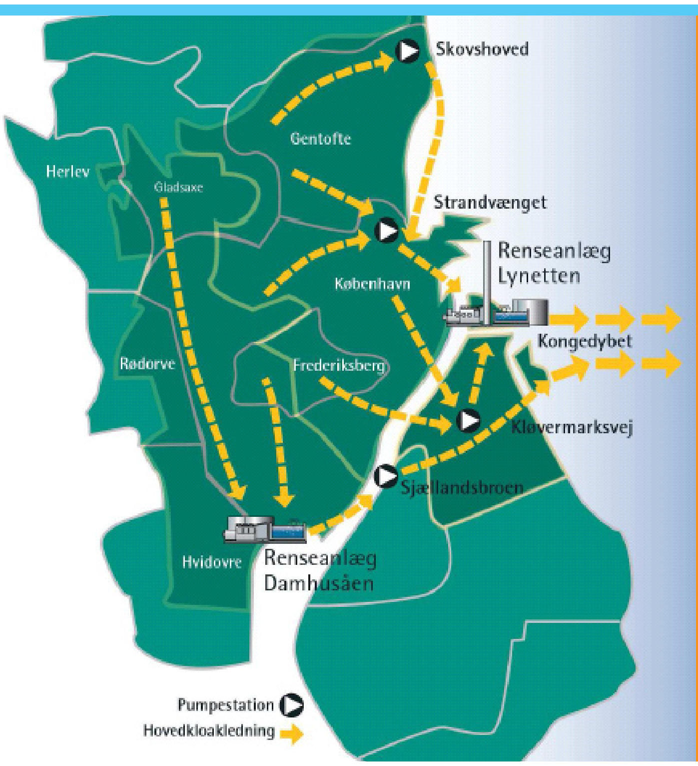
Case Area Baseline Report

Copenhagen Energy and Lynette Fællesskabet



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Storm- and Wastewater Informatics

Storm and Wastewater Informatics "SWI" is a strategic Danish Research Project with an overall aim to close the knowledge gaps within prediction and control of current and future conditions in integrated urban wastewater systems.

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Contents

1. Objective with this document

The objective with the “Case Area Baseline Report” is to:

- Give an introduction to the Storm- and Wastewater System (SWS) of Copenhagen Energy A/S (KE) and the wastewater treatment plants, Damhusåen and Lynetten managed by Lynettefællesskabet I/S (LF).
- Describe relevant issues of KE and LF that relate to the research project SWI
- Give a short introduction to the parallel projects relevant to SWI.
- Provide references to more comprehensive literature.

This report will thus benefit both the SWI Management Group and the Work package Leaders in planning the overall work for the coming years and furthermore benefit the researchers/students who will be involved with the SWI project.

2. Expected outcome of the SWI project

According to LF and KE the expected outcomes of the SWI project are[1]:

- The main expectation is that SWI will provide ways and means to utilise existing assets more optimal, e.g. by more advanced regulation procedures.
- Illustration of real-time modelling and control of integrated and optimized operation of sewerage system and WWTP for minimisation of damages (in a broad context: flooding, pollutant emission, resource consumption).
- Radar is seen as an interesting component to be used for control of SWS.
- There is currently a need for more storage volume (130.000 m3) to secure the systems compliance with regulations due to recipient protection and backwater effects. It is expected that SWI will contribute with solutions and technologies that will reduce this need.
- Reduction of microbial pollution.
- The potential of selecting discharge locations depending on the water quality i.e. discharging less polluted wastewater (thin wastewater) to streams or lakes before its being mixed with denser wastewater. The wastewater quality is defined by the concentration of N, P, COD and E-Coli.
- At least 1 case that illustrates improved performance by simulations at a level of confidence sufficient to convince plant owners and other stakeholders to proceed with demonstration in practical real life.
- Come up with solutions that contribute to improved bathing water quality in Copenhagen harbour area and improved warnings systems
- Ideas for detainment of first flush in the wastewater system.

[1] Answers are base don the questionnaire (Copenhegen Energy & Lynettefællesskabet, 2009a) and the material received following the interview.

3. General information about KE and Lynettefællesskabet

3.1 Organisation

KE and LF are two separate organisations. KE plans, designs, runs and construct the sewerage system of Copenhagen Municipality, whereas LF owns and runs the two wastewater treatment plants Lynetten and Damhusåen.

KE is a joint stock company 100% owned by Copenhagen Municipality. It includes a number of separate legal entities, but for all practical purposes it can be divided into two divisions: KE Water&Sewerage and KE District Heating&Gas.

LF is a joint municipal company owned by 8 municipalities: Frederiksberg, Gentofte, Gladsaxe, Herlev, Hvidovre, København, Lyngby-Taarbæk og Rødovre and is Denmarks largest wastewater treatment center. 90 mill. m^3 of wastewater (households, industry, runoff) is treated yearly at Lynetten and Damhusåen with a catchment area of 123 km^2 and population of 1.1 mill.

Practically speaking LF is a subcontractor to KE (and the other utility companies in the catchment).

3.2 Responsibilities

Copenhagen Municipality is the environmental authority who set the targets for the sewerage system securing compliance with municipal, national and EU regulations within the boundaries of Copenhagen.

KE is responsible for collection, transportation and treatment of wastewater. Treatment is thus sub-contracted to LF according to the regulations for LF.

The Agency for Spatial and Environmental Planning, Environmental Center Roskilde set the discharge permits for LF and it is also this agency which controls whether the WWTPs have fulfilled the requirements.

Discharge permits for overflow structures and separate system outlets are set by the Copenhagen Municipal Environmental Authority

3.3 Focus area of SWI

The coloured catchment area in Figure 3.1 shows the focus area of SWI covering the 8 municipalities that own LF. The area between the two thick red polygons is the area of Copenhagen Municipality covering 9000 ha and the SWS in this area is managed by KE. The sewer systems in the other municipalities are managed by the municipal utility companies, except for Gladsaxe and Gentofte, where Nordvand manages water and wastewater. These municipalities are directing waste water through KE´s sewer network before treated at either Damhusåen or Lynetten WWTP.

Figure 3.1: *The coloured area is the catchmearea in focus of SWI project. The area between the two red polygons is the catchment of KE. Adapted from (Lynettefællesskabet, 2008).*

A new project called "Intelligent wastewater control" (in Danish: Intelligent spildevandshåndtering) "ISH" was initialized in 2008 by Lynettefællesskabet and KE (Lynettefællesskabet, 2008) with the intension to develop a state of the art for integrated control of sewer and WWTP for the catchment depicted in Figure 3.1. Therefore the results from ISH project will give updated and consolidated information about the catchment area. The project is explained in section 7.2.

4. The Storm- and Wastewater system of KE and Lynettefællesskabet

4.1 The catchment area

The total catchment area draining to Lynetten and Damhusåens WWTP´s is divided into 4 catchment areas: Strandvænget, Skovshoved, Kløvermarken and Damhusåen (see Figure 4.1) where the first 3 catchment areas are connected to WWTP Lynetten and the last one to Damhusåen. Each catchment area is connected to at least one pumpingstation. Table 4.1 summarises the total area and the reduced area of each sub catchment (extracted from Lynettefællesskabet, 2008 and PH consult 1999). Figure 4.2 show the runoff direction of the catchments to the larger pumping stations (Skovshoved, Strandvænget and Kløvermarksvej) and the treatment plants. As it can be seen from table 4.1 the reviewed data are not always consistent. A complete map for each catchment area with details of pumping stations, weirs, pipes, etc will be developed as a part of the ISH project (this project is described in chapter 7.2) in phase 3. It is expected that ISH will provide consolidated information and the information will be available from middle of 2010 by LF. (Thirsing, 2009). A generalised map and description of each subcatchment area is presented in Appendix 1.

Table 4.1 *Overview of total area and the reduced area of each sub catchment (extracted from Lynettefællesskabet, 2008 and PH consult 1999. * data from Lynettefællesskabet, 2008 and ** data from PH consult 1999). As it can be seen the reviewed data are not always consistent, ISH will provide consolidated information.*

Municipality	Strandvænget Total area; *Reduced area* (Reduced area)**	Skovshoved Total area; *Reduced area* (Reduced area)**	Kløvermarken Total area; *Reduced area* (Reduced area)**	Damhusåen Total area; *Reduced area* (Reduced area)**
Gentofte	360;*105 (148)*	2165;*665 (493)*	0;*0*	0;*0*
Gladsaxe	475;*140 (131)*	0;*0*	0;*0*	361;*170 (181)*
Frederiksberg	11;*8 (9)*	0;*0*	493;*206 (253)*	301;*117 (111)*
Copenhagen	1700;*668 (337)*	0;*0 (9)*	4600;*1518 (1399)*	2600;*1075 (834)*
Lyngby-Tårebæk	0;*0*	92;*25 (8)*	0;*0*	0;*0*
Rødovre	0;*0*	0;*0*	0;*0*	595;*189 (191)*
Hvidovre	0;*0*	0;*0*	0;*0*	100;*42 (266)*
Herlev	0;*0*	0;*0*	0;*0*	272;*100 (92)*
Total	2546;*921 (625)*	2257;*690 (510)*	5093;*1724 (1652)*	4229;*1693 (1677)*

Figure 4.1 *Catchments of Lynettefællesskabet. Catchment of WWTP Lynetten consists of Skovshoved, Strandvænget and Kløvermarksvej and catchment of WWTP Damhusåen consists of Damhusåen.*

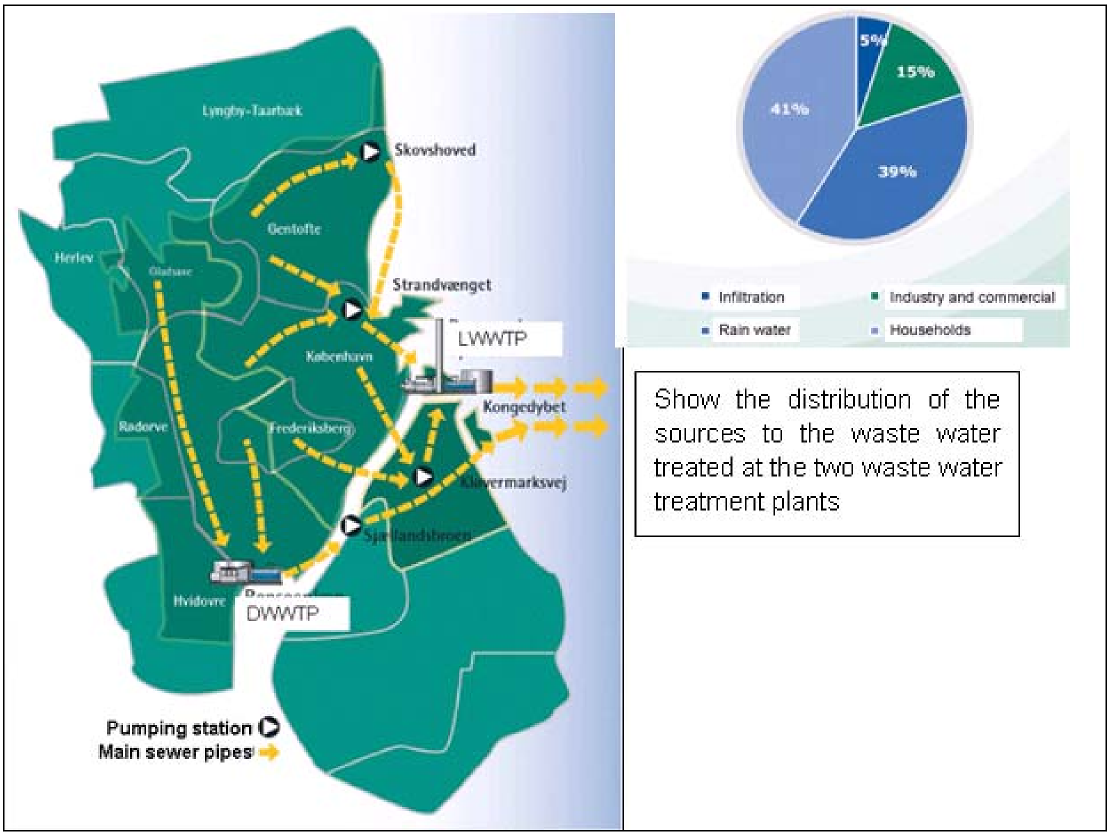


Figure 4.2: *Flow direction of each sub catchment to WWTP's, main sewer pipes, pumping stations directing water to the WWTPs and composition of wastewater. . DWWP: WTTP Damhusåen LWWTP: WWTP Lynetten. Adapted from* (Lynettefællesskabet, 2009c).

4.2 Sewerage components

Figure 4.3 show a map of all existing and planned storage tanks in the whole catchment area of Lynettefællesskabet and Appendix 2 gives details about volumes of the existing and planned storage tanks (Lynettefællesskabet, 2008). As mentioned earlier a complete map for each catchment area with details of pumping stations, weirs, pipes, etc, is not available, but a generalised map and description of each subcatchment area is presented in Appendix 1.

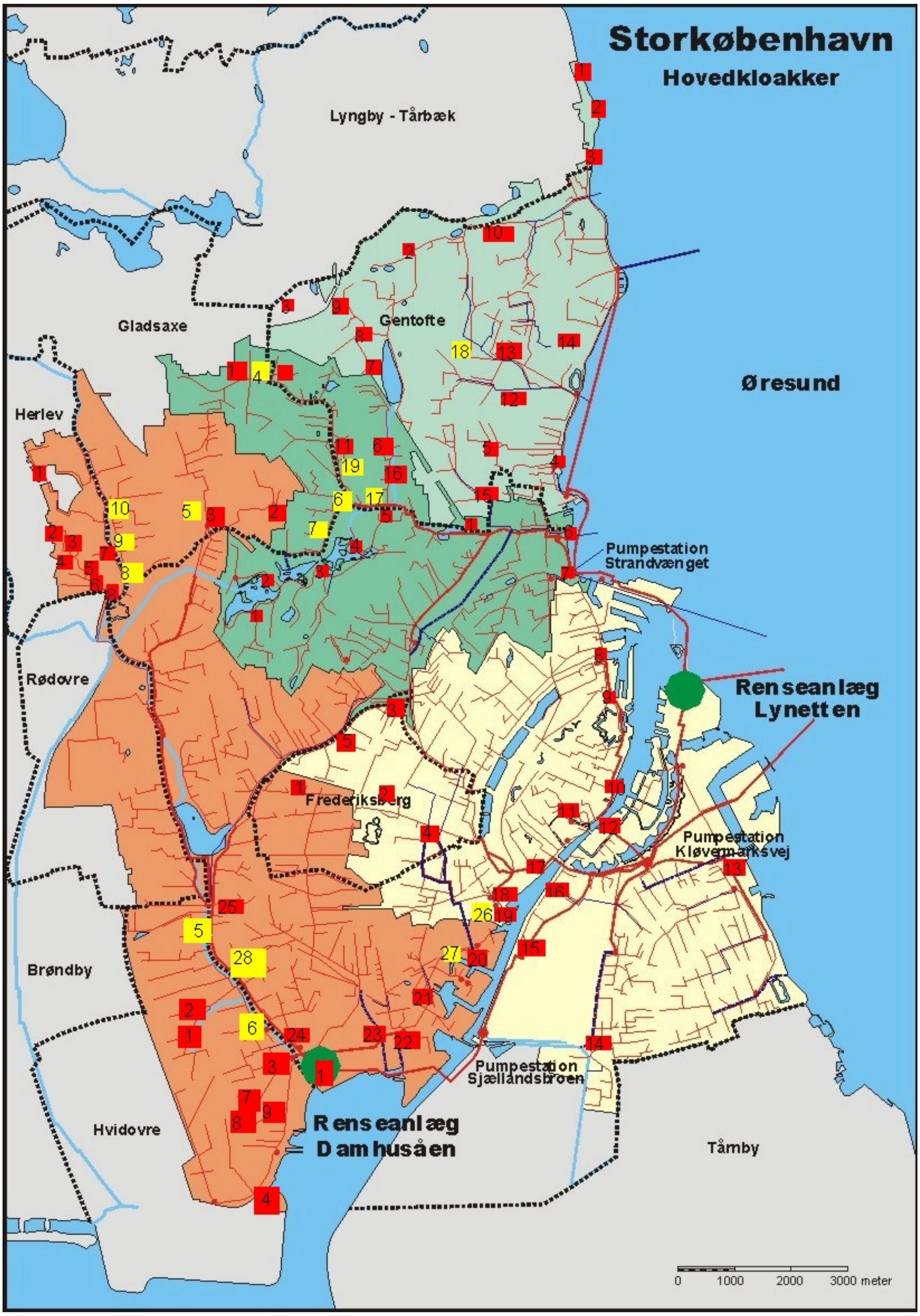


Figure 4.3: *Existing and planned basins in the catchment of Lynettefællesskabet (Lynettefællesskabet, 2008). Red squares: existing. Yellow squares: planned. For a list of the volumes of the basins, see* (Lynettefællesskabet, 2008).

4.3 Waste Water Treatment Plants

As mentioned earlier LF manages two of Denmarks largest WWTPs called Lynetten (The largest in Denmark) and Damhusåen (one of the largest) (Lynettefællesskabet, 2009d). Their total catchment area is shown in Figure 4.1 and figure 4.2 shows the inlet sources to both plants. The inlet sources are divided into 4 categories: Households, Industry and commercial, infiltration and rainfall (Lynettefællesskabet, 2009d) and the figure shows that the rainwater contribution is almost equal to household contribution on yearly basis. The figure further shows that treated water from both treatment plants is discharged in Øresund 1.5 km away from the coast.

Table 4.2 gives an overview of the most important substances of concern in wastewater and their effect on the recipients and table 4.3 shows the removal efficiencies obtained in 2008 from both the treatment plants. Table 4.4 shows regulation criteria in the outlet and the actual achieved concentrations (Lynettefællesskabet, 2009b). There is a requirement to the annually amount of treated wastewater and the amount of waste water bypassed the biological treatment process, but no requirement to E.Coli in the outlet. (Thirsing, 2009). Table 4.4shows that the achieved concentrations are far below the requirements and is mainly due to green taxes, since WWTP pays green taxes based on the amounts discharged and the lower the concentration the lower would be the green taxes.

Table 4.2. *Treatment indicators and their consequence if untreated. Adapted from (Lynettefællesskabet, 2009b).*

Indicator	**Consequence**
Untreated wastewater	Odors, unclear water and disgusting water
Patogenes (bacterias, viruses, etc.)	Corrupts bathing water quality, disease spreading
Organic matter	Oxygen consuming. Ruins environment for plants and animals
Nutrients (N,P)	Algae growth, oxygen depletion and poisonous algaes
Heavy metals	Acummulates in the food chain and ends up at the dining table
Xenobiotics (from households to industry)	Might be toxic to animals and plants

Table 4.3. *Removal efficiency of important parameters. Adapted from (Lynettefællesskabet, 2009b).*

Parameters	Removal efficiency
Organic matter	≈98%
Nitrogen	≈80-90 %
Phosphorus	≈90%
Pathogens	≈90-99%
Heavy metals	≈40-93%
Xenobiotics	≈0-99%

Table 4.4: *Discharge permit and measured values in 2008 for Lynetten and Damhuåen WWTPs. Based on the homepage of Lynettefællesskabet (http://www.lyn-is.dk/Lynetten/Kravoverholdelse.aspx).*

Parameter	Requirement	Meassured, 2008 Lynetten	Meassured, 2008 Damhusåen	Unit
COD	75	26	24	mg/l
BOD_5	15	2	2.6	mg/l
Total-N	8	3.6	6.2	mg/l
Total-P	1.5	0.5	0.5	mg/l

4.3.1 Lynetten Waste Water Treatment Plant

The WWTP was originally designed in 1980 for mechanical and organic treatment and sludge incineration. In 1997 the treatment plant was expanded to remove the nutrients phosphorus and nitrate (Bio-Denipho system) (Lynettefællesskabet, 2009b). The present catchment of Lynetten WWTP covers an area of 76 km^2 and 531,000 inhabitants (Lynettefællesskabet, 2009d). The designed capacity of Lynetten WWTP is 750,000 PE and in practice the WWTP handled upto 758,000 PE. Table 4.5 gives an overview of designed capacity and key performance parameters from 2008 are shown in table 4.6.

Table 4.5. *Design specifications and key performance indicators (2008) of Lynetten WWTP. (Lynettefællesskabet, 2009d)*

Design Parameters		
Flows		
Max flow, inlet	41,500	m^3/h
Max flow, inlet biology	23,000	m^3/h
Volumes		
Sand and grease	3,450	m^3
Primary tanks	19,200	m^3
Bio P tanks	24,000	m^3
Aeration tanks	147,000	m^3
Secondary clarifiers	62,000	m^3
Digester	18,000	m^3
Hydraulic Retentiontime		
Biological treatment	30	h
Total	40	h

__Table 4.6.__ Key performance parameters from 2008 at Lynetten WWTP. (Lynettefællesskabet, 2009d)

Key performance parameters per year in 2008		
Water (inlet)	65.5	mill.m^3
Bypass	2	mill.m^3
Reject water	1.2	mill.m^3
Grates	222	ton
Sand	219	ton
Primary sludge	11,000	ton
Secondary sludge	11,500	ton
Ashes	6,234	ton
Biogas production	6.3	mill.Nm^3

Figure 4.4 show the process diagram of Lynetten WWTP and explained below (Lynettefællesskabet, 2009b).

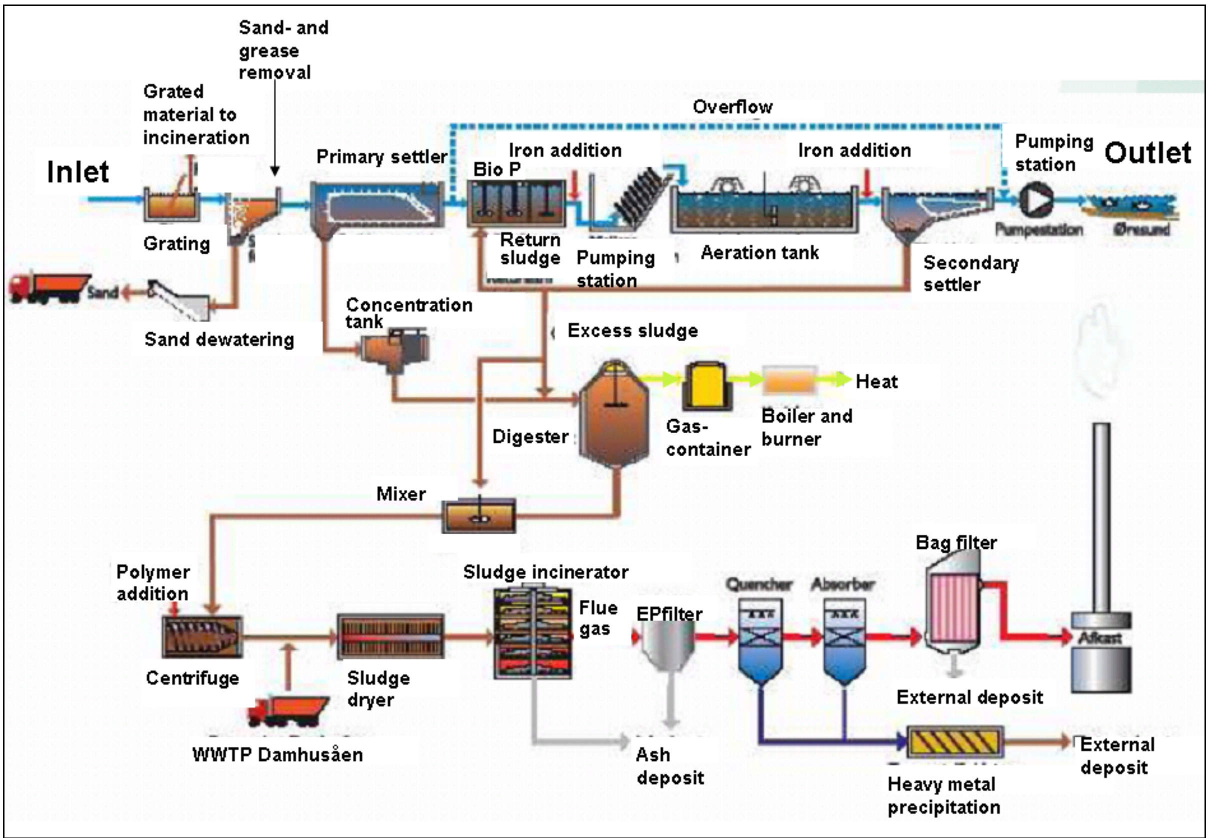


***Figure 4.4:** Process diagram of WWTP Lynetten. Adapted from (Thirsing, 2009)*

The inlet is led to mechanical treatment, where first step is removal of larger parts like rags, paper, condoms, towels etc by 10 mm grates. Removed parts are transported for incineration to Amagerforbrændingen I/S. Next step is removal of sand and grease. Sand is removed by settling. The settled sand is pumped to a sand washer and is either recycled or deposited at Lynetten. Grease is separated by aeration, scraped away and pumped to the digester. Final step of the mechanical treatment is settling of organic and inorganic particles in primary clarifiers and primary sludge is pumped to digester tanks (Lynettefællesskabet, 2009b).

Wastewater from the primary clarifiers is biologically and chemically (for phosphorous removal) treated before it is led to the secondary clarifiers. The treatment is based on Bio-Denipho principle and WWTP installed advanced online-process control module STAR (Superior Tuning and Reporting) in 2008 controlling nitrogen and phosphorus removal. Iron coagulant is added for phosphorous removal both before and after the aeration tank. If the sludge settling capacity is poor, aluminum is added as coagulant to increase the settling capacity of the activated sludge. Treated water from the secondary clarifiers is discharged through two pipes 1.5 km away from the coast of Øresund and diffusers are installed at the discharge point to secure quick mixing with the seawater (Lynettefællesskabet, 2009b).

Both primary and activated sludge is digested and the produced biogas is used for heating, sludge drying, sludge incineration or district heating.

Sludge from both Damhusåen and Lynetten is incinerated at Lynetten WWTP.

4.3.2 Damhusåen Waste Water Treatment Plant

The WWTP was built in 1930 for mechanical treatment only and in 1980 to1996 the mechanical treated wastewater was led to Lynetten. The WWTP was expanded for removal organic matter and nutrients (nitrogen and phosphorous) in 1996. The designed capacity of the plant is 350,000 PE however operational maximum capacity is only 270,000 PE (Lynettefællesskabet, 2009d). Table 4.7 gives an overview of designed capacity and and key performance parameters from 2008 are shown in table 4.8. Figure 4.5 shows the process diagram of the plant and the treatment processes are similar to the treatment process of Lynetten with few exceptions and hence only the main differences are explained here:

- a bio- scrubber that removes odours from the grating process and sand- and grease treatment
- biogas is used for both electricity and heat production.
- Sludge is taken to Lynetten WWTP for treatment.
- After treatment the water is discharged through two pipes 1.5 km off the coast of Øresund. Diffusers secure a quick mixing with the seawater.
- The biological treatment is achieved by Envidans advanced online control (for more information about Envidans online control see Lynettefællesskabet 2007) in contrast to STAR at lynetten.

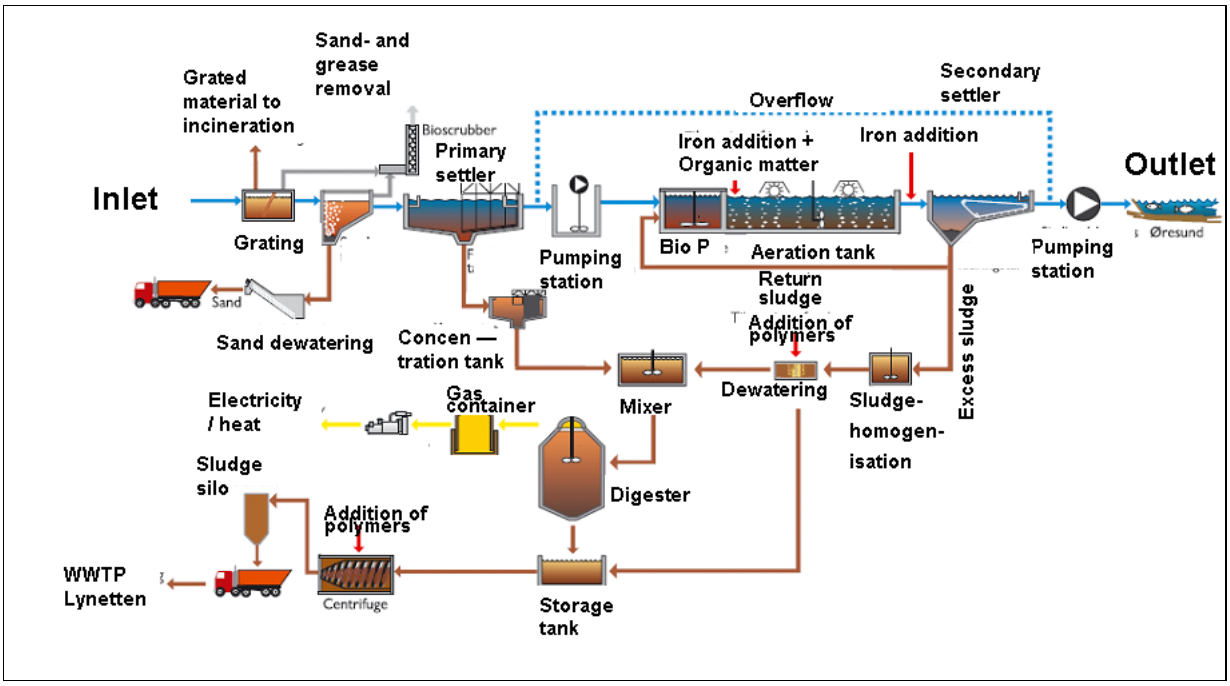


Figure 4.5: *Process diagram of WWTP Damhusåen (Thirsing, 2009)*

Table 4.7. *Design specifications of Damhusåen WWTP. (Lynettefællesskabet, 2009d)*

Design Parameters		
Flows		
Max flow, inlet	28,500	m^3/h
Max flow, inlet biology	10,000	m^3/h
Volumes		
Sand and grease	3,680	m^3
Primary tanks	11,500	m^3
Bio P tanks	8,300	m^3
Aeration tanks	71,000	m^3
Secondary clarifiers	27,000	m^3
Digester	7,600	m^3
Hydraulic Retention time		
Biological treatment		h
Total	30	h

Table 4.8. *Key performance parameters from 2008 at Damhusåen WWTP. (Lynette-fællesskabet, 2009d).*

Key performance parameters per year		
Water (inlet)	27.4	mill.m^3
Bypass	1.9	mill.m^3
Reject water	1.3	mill.m^3
Grates	308.0	ton
Sand	826.0	ton
Primary sludge	4,400.0	ton
Secondary sludge	3,300.0	ton
Biogas production	6.3	mill.Nm^3

4.4.2 Risk of sludge escape/overflow and wetweather strategy at Lynetten and Damhusåen

Figure 4.6 show the hourly inlet variation in 2007 and the maximum hydraulic capacity of the biological treatment at the two WWTPs. It is seen that the hydraulic capacity of the biological treatment is exceeded approximately 2.5% times at Lynetten and 6% at Damhusåen. The two treatment plants have different wetweather strategies and these are presented here. Both the plants are increasingly experiencing long hydraulic tails following rain events because of increasing storage volumes in the catchment and changed rainfall pattern. Earlier a tail of 4 hours was common whereas today 12 hours is not unusual.

Lynetten WWTP:

In 2008 the plant has installed STAR with ATS as wet weather control strategy (for more details on how ATS works see the SCA Casereport). At present the wet weather control is switched on at 17.000 m^3/h and the flow to the biological treatment is gradually increased over 1.5 hour to 23.000 m^3/h. The secondary tanks are not dimensioned to a hydraulic load of 23.000 m^3/h for more than 6 hours. When inlet exceeds the biological hydraulic capacity of 23,000 m^3/h the mechanically treated water is bypassed. It is expected that with good settlement properties and wet weather control the time with high hydraulic load of the secondary tanks can be increased significantly (Thirsing, 2009).

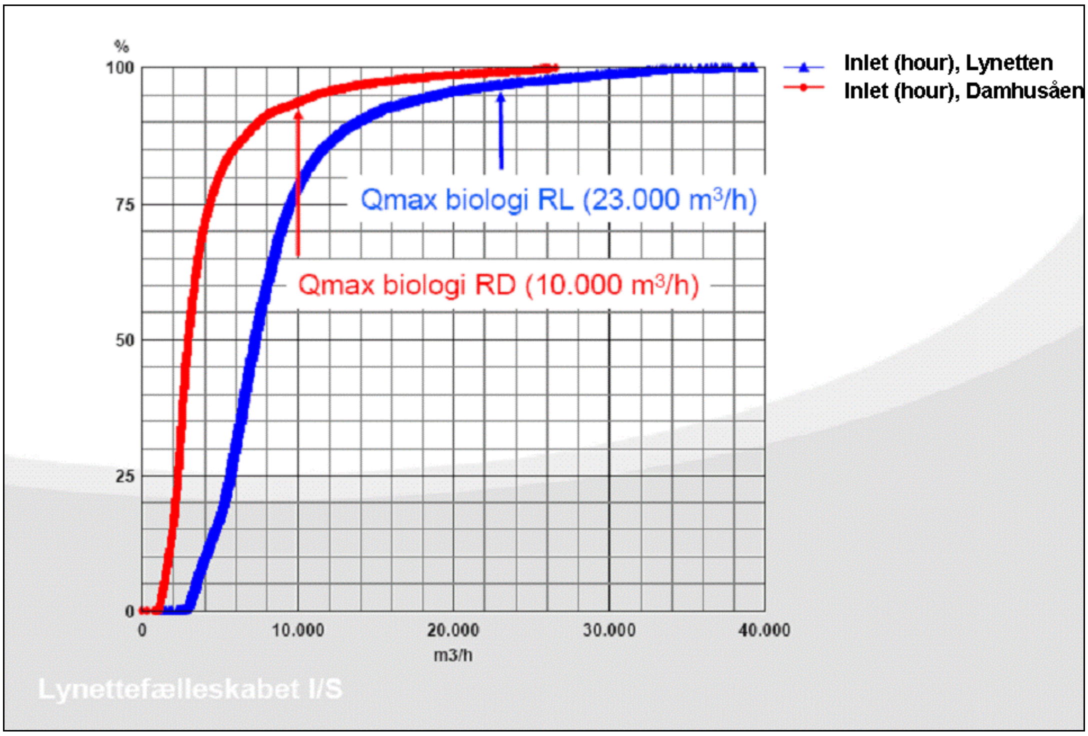


Figure 4.6: *Show inlet variation over the year 2007 in percentage. Maximum biological capacity is also shown. Adapted from (Lynettefællesskabet, 2009c).*

WWTP Lynetten has reached full capacity with respect to both flow and substance load (Lynettefællesskabet, 2008).

Damhusåen WWTP:

There is wet weather control of WWTP Damhusåen and wet weather control is initiated based on the flow measurement at Dæmningen, which gives about 30 minutes forewarning. It is believed that the hydraulic capacity to the biological treatment can be increased further (Lynettefællesskabet, 2008). There are 4 lanes in the biological treatment process and each lane consists of 2 aeration tanks. During the wet weather control one of the aeration tank in each lane is converted to sedimentation tank and the other tank functions as aeration tank with nitrification.

The maximum flow to the biological treatment is 10,000 m^3/h and to avoid sludge escape the inflow to the biological treatment is reduced to 7,000-8,000 m^3/h after 4 hours of operation at maximum capacity. This happened 22 times in 2008 and lasted 3 – 24 hours each time (Lynettefællesskabet, 2008). There is a storage capacity of 45,000 m^3 at the plant. (Thirsing, 2009). Figure 4.7 shows the bypass strategy at Damhusåen and is explained below, where Q is inlet to the WWTP.

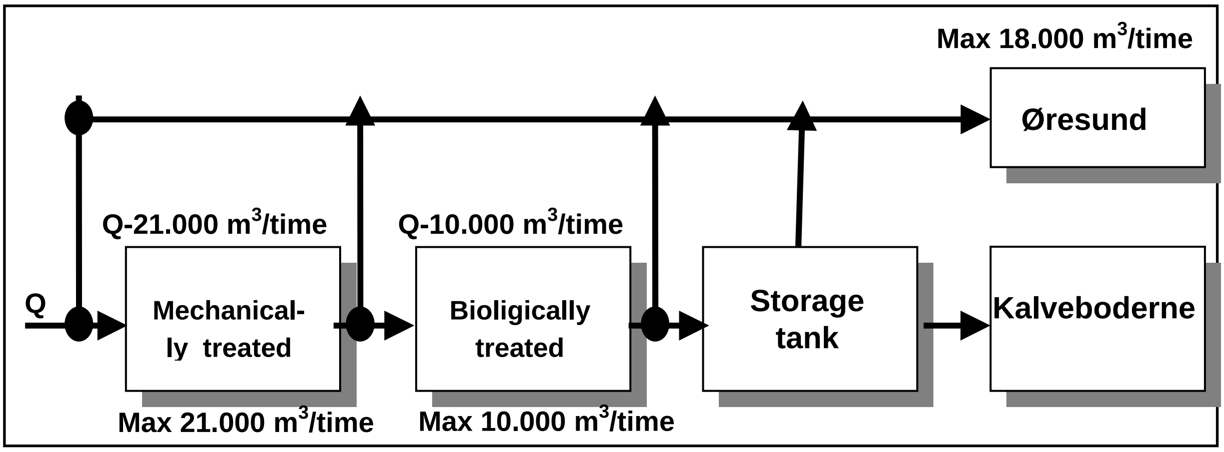
Q<10.000 m3/h only biological treated waste water is discharged Øresund.

Q>10.000 and <18.000 m3/h: Q-10.000 m3/h mechanically treated waste water is discharged to Øresund along with 10.000 m3/time biologically treated wastewater.

Q>18.000 and <21.000 m3/h: Q-18.000 m3/h biologically treated wastewater is stored in the storage tank. 10.000 m3/h mechanically treated water and 10.000-(Q-18.000) m3/h biologically treated water is discharged to Øresund. When the load to the storage tanks exceeds the storage capacity of 45000 m3, biologically treated waste water is discharged to Kalveboderne.

Q>21.000 and <28.000 m3/h: Q-18.000 m3/h biologically treated wastewater is stored in the storage tank. And the discharge to Øresund will be: 10.000-(Q-18.000) m3/time biologically treated wastewater, 11.000 m3/h mechanically treated wastewater and Q-21.000 m3/h untreated wastewater. When the load to the storage tanks exceeds the storage capacity of 45000 m3, biologically treated waste water is discharged to Kalveboderne.

Q>28.000 m3/h: In these situations it will become necessary to discharge mechanically treated wastewater to Kalveboderne, however, Q>28.000 m3/h was never observed at Damhusåen.



Figur 4.7. Strategy for wastewater handling depending on the hydraulic load at Damhusåen

4.4 Recipients

Figure 4.7 gives an overview of the larger water bodies and their catchments in the area considered in this project and consist of both Marine and fresh water recipients. The Environmental condition of these waters is not only determined by current pollution loads but is severely influenced from past discharges of more or less purified water. PH-Consult (1999) looked at the sensitivity of the water bodies and categorised them as shown in Figure 4.7 by colouring polygons using green as the most sensitive and blue as the less sensitive recipient.

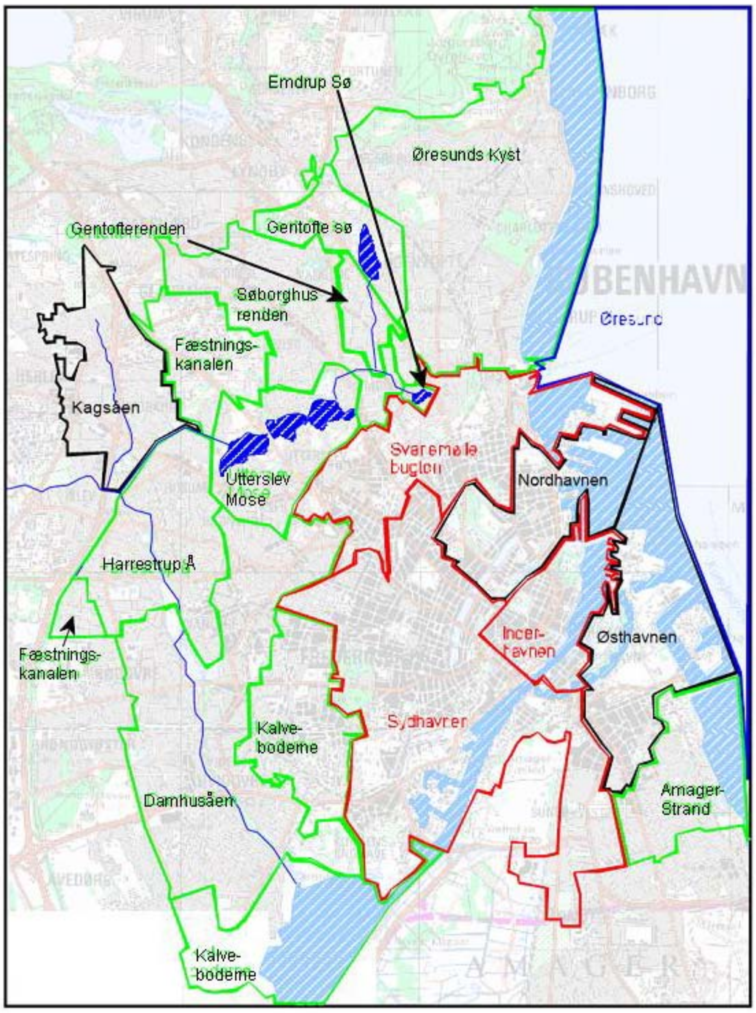


Figure 4.7: *Larger water bodies and their catchments of greater Copenhagen. Adapted from (PH-Consult, 1999). Green (most sensitive); Red; Black; and Blue (less sensitive)*.

The present case report gives a brief description of the various recipients managed only by Copenhagen municipality, as the information in other municipalities was not easily available at the time of writing this report. These recipients receive discharges from CSO's and separate sewer overflows, and since the pollution not only comes from Copenhagen municipality but also from neighbouring municipalities, these municipalities are obliged to co-finance necessary activities to realise objectives with marine and freshwater bodies (Københavns Kommune, 2008).

The overall investments and goals for a planning period of 12 years are stated in the Wastewater Masterplan 2008 (Copenhagen Municipality, 2008a) and according to this 2.139 million DKK are allocated to secure a cleaner and safer handling of the wastewater in Copenhagen Municipality. The planned targets for the various water bodies in the Copenhagen Municipality is divided into 3 categories based on water quality and objective of the recipient as: General, Relaxed and Restrictive.

General Target: Is a term used for the planned condition of a water body and used in case of

- ***Lakes:*** where the wastewater and other cultural determined discharges do not affect or have a very slight effect on the natural and variety of plant and animal life
- ***Streams:*** Able to be used as spawning, upbringing and living place for Eel, Perch, Carp, Pike, Trout and Salmon fish.
- ***Marine water bodies:*** Good hygienic water quality and with a animal and plant life, which is not affected or slightly affected by cultural detemined factors.

Relaxed Target: Is a term used for the planned condition of a water body and used in case of

- ***Lakes:*** where the general target can not be achieved and the effect of wastewater, water extraction and other physical intervention is allowed
- ***Streams:*** where the general target can not be achieved and the effect of wastewater, water extraction and other physical intervention is allowed
- ***Marine water bodies:*** where the general target can not be achieved

Enhanced Target: Is a term used for the planned condition of a water body and used in case of

- ***Marine water bodies:*** special interests like bathing or other recreational uses

Marine water

Table 4.8 and Figure 4.8 shows the current status and planned targets for the various marine water bodies formulated by the Municipality, in “Regionplan 2005”, and Agenda 21, see Table 4.8 and Figure 4.8 (Copenhagen Municipality, 2008). Green colour in table 4.8 indicates that the target met, whereas red colour indicates that the target is not yet met. It is seen that a few targets are not yet realised. Table 4.9 shows where the rain induced overflows and outlets are taking place and the magnitude hereof. The outlets/overflows impact the water areas with pollution of organic matter, nutrients, bacteria, heavy metals and xenobiotics. A detailed geographical overview of the overflow/outlet locations can be found in (Copenhagen Municipality, 2008).

In 2006-2007 a larger planning work coordinated among the relevant municipalities was carried out to improve the water quality in the stream of Harrestrup and Kalveboderne. The municipalities agreed to limit the number of overflows to 1-2 overflows per year. In Copenhagen Municipality one overflow per year has been adopted in the Wastewater Masterplan.

__Table 4.8:__ Target and status of marine water bodies. Red colour indicates objectives not yet met and green that objectives already are met.

Water area	Targets	Remarks
Svanemøllebugten	General	Recreational value to be preserved and promoted
Nordhavnen	Relaxed	Remediation and pollution from shipping traffic
Inderhavnen	General/Relaxed	Future recreational functions served/pollution from shipping traffic
Sydhavnen	General	Future recreational functions served/eksisting bathing facilities
Kalveboderne	Enhanced	Recreational value, bird protected area, habitat area, new bathing facilities planned
Amager Strand	Enhanced	Recreational value, only beach in the Municipality
Østhavnen	General/Relaxed	***Relaxed:*** eastern part of the east-west going branch of Østhavnen as well as the area east of Prøvestenen. Remediation and pollution from shipping traffic, temperature increase because of cooling water impact ***General:*** North-southern branch as well as western part of east-western branch
Øresund	General/Relaxed	***Relaxed:*** Area at Middelgrunden with respect to physical impact, landfilling and dumping of uncontaminated material and area around outlet from Lynetten

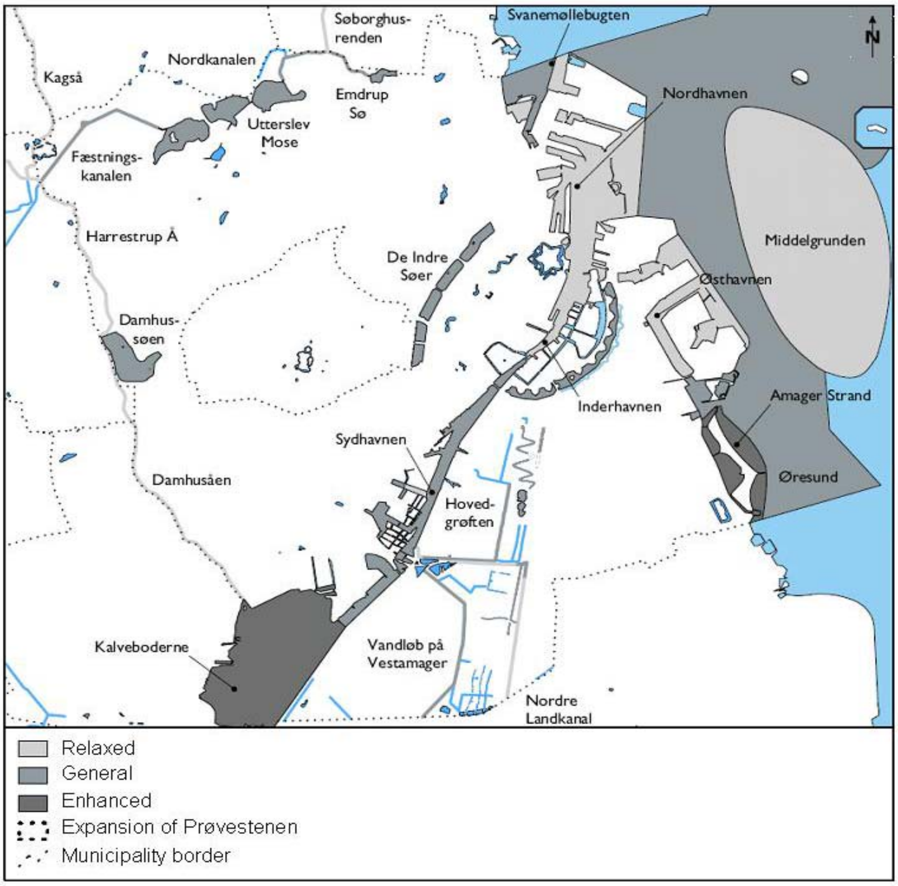


__Figure 4.8:__ Targets for the water bodies in greater Copenhagen. (Copenhagen Municipality, 2008)

Table 4.9: *Overview of places with rain induced overflow/outlet to marine waters.*

Water area	Type of outlet			Total outlet	Overflow [1000 m3/year]
	Overflow structure	Herof Basin	Separate rainwater		
Svanemøllebugten	5	1	0	5	63
Nordhavnen	2	5	6	8	106
Inderhavnen	14	3	4	18	19
Sydhavnen	10	8	4	14	262
Kalveboderne	2	2	1	3	152
Amager Strand	0	0	0	0	0
Østhavnen	1	5	1	2	1
Øresund	1	1	0	1	12
Totally	35	25	16	51	615

Freshwaters

Table 4.10 show the planned targets and status of the fresh water bodies and figure 4.8 shows the geographic location of the recipients. Totally there are 69 rain induced outlets to the fresh water bodies. The distribution of these outlets on each water body and the type of outlet is seen in Table 4.11. The targets should be achieved latest in 2015 according to Miljømålsloven (Copenhagen Municipality, 2008).

Table 4.10: *Targets and status of the freshwater bodies around Copenhagen*

Water bodies	Target	Remarks
Streams:		
Kagså	Relaxed	Influenced by waste water, ground water infiltration or physical interventions
Harrestrup Å	Relaxed	Influenced by waste water, ground water infiltration or physical interventions
Damhusåen	Relaxed	Influenced by waste water, ground water infiltration or physical interventions
Fæstningskanalen	General	
Søborghusrenden and Nordkanalen	General	
Nordre Landkanal	Relaxed	Influenced by run-off and waste water
Hovedgrøften på Amager Fælled	General	
Lakes:		
Damhussøen	General	Habitat for flora and fauna
Utterslev Mose	General	
Lake Emdrup	General	
De indre søer	General	Habitat for flora and fauna

__Table 4.11:__ Overview of rain induced outlets to fresh water bodies.

Water area	Type of outlet				Total outlet
	Overflow structure	Herof Basin	Green treatment	Separate rainwater	
Kagså	3	0	0	0	3
Harrestrup Å	5	0	0	0	5
Damhusåen	17	2	0	0	17
Fæstningskanalaen	0	0	0	0	0
Utterslev Mose	7	4	1	1	8
Søborghusrenden	3	1	0	0	3
Nordre Landkanal	1	3	0	14	15
Hovedgrøften på Amager Fælled	0	0	0	18	18
Totally	36	10	1	33	69

The lakes and streams in the greater Copenhagen area are polluted by urban run-off and CSOs for many years either directly or indirectly. As a result the lakes except Damhusåen appear today eutrophic with algae blooms and unaesthetic conditions during late summer-time. Similarly, streams are experiencing oxygen depletion and high ammonium concentrations due to rain induced combined overflows, which potentially harms the aquatic wildlife. Furthermore overflows are causing hydraulic problems in streams and the physical layouts of the streams are strongly influenced by requirement of transporting large quantities of water away in a short time to avoid flooding problems. One such example is the streams “Harrestrup Å” and “Damhusåen”. The physical appearance of these streams strongly shows that that they are used for transporting of rain- and wastewater. They have a straight course and a broad cross-section with tiled bottom and sides.

The lakes Kagsmosen, Damhussøen (only recipient in dry weather), Emdrup sø, De Indre Søer “DIS” (only inlet of treated water), lakes in Ørstedsparken (from DSI), Botanisk have (from DSI), Østre anlæg (from DSI) and Kastellets voldgrav (from DSI) indirectly receive CSO’s and SSO. The lakes “Kirkemosen” and “Fælledpark Sø” are slightly influenced by indirectly because of pipe connections to “Utterslev mose” and “Sortedams Sø”. The lakes uninfluenced by the sewer system are “Grønjordssøen”, “Degnemosen” and “Ryvangs Sø”.

There is no established water management plan for the western water bodies but as already mentioned a coordinated planning basis was prepared in 2006-2007 for the whole catchment of “Harrestrup Å” and “Kalveboderne”. All municipalities with discharge to “Harrestrup Å” and to the Copenhagen part of “Kagsåen” and “Damhusåen” have agreed to limit the outlets to 1-2 overflows per year. Copenhagen municipality has allocated 330 million DKK to improve the water quality of Harrestrup Å, Damhusåen and Kagsåen between 2010 and 2015.

The northern waters are classified with a general target. Despite a large effort the northern waters still have not reached the general target. This is due to large amounts of outlets/overflows from Gentofte and Gladsaxe Municipalities and large sludge sediments from many years of earlier waste water loads. The municipalities are now working on actions to secure the objectives. Other fresh water bodies meet their targets in terms of discharge from the sewers.

5. Major issues at KE and Lynettefællesskabet

The Storm- and Wastewater management of KE and LF are faced with many challenges because of:

- “Service check” of the Danish Water Sector
- EU Bathing Water Directive
- The Water Framework Directive
- Functional practice of storm- and wastewater systems under rainy conditions
- Urbanisation
- Climate change
- Recreative utilization of Damhussøen?

These are discussed below.

Service check of the Danish Water Sector

The overall target with the Service Check, an Act that will come to force by 1st of January 2010, is to secure a more effective water sector in Denmark, i.e. to cut costs. A central requirement of the new law is separation between authority and operation that will privatise the municipal water supply, sewerage and waste water treatment. This will have no effect on KE as KE was privatised already in 2005, whereas the consequences on Lynetten are not yet known. In 2011 a price cap will be introduced for the tariffs. The maximum price will be defined as the average price during the years 2003-2005 regulated for inflation.

EU Bathing Water Directive

This chapter only deals with the effect of EU bathing Water Directive in the harbour area of Copenhagen municipality, because the information was only available for this municipality.

Copenhagen Municipality:

The interest in achieving bathing water quality in the harbour area of Copenhagen was already stated in the waste water plan of year 2000 (Copenhagen Municipality, 2008) in connection with the planned development of the waterfront and their targets for bathing and water quality in the harbor area are (Thirsing, 2009):

- Before end of 2015 bathing water quality should be reached in the whole harbor area (Agenda 21-plan, 2008-2011)
- Copenhagen Municipality will work to secure that all water bodies are clean and clear with a rich flora and fauna and a high hygienic standard at latest by 2015. (Københavns Kommune, 2006)

Figure 5.1 shows the harbour area of Copenhagen and the status of the water quality (Copenhagen Municipality, 2008). Today the harbour area has achieved a satisfying bathing water quality at most places and two bathing facilities have been established at "Fisketorvet" and "Islands Brygge" attracting many visitors in the summer period. Svanemøllebugten will become a new bathing place by 2010. The inner harbour has reached a satisfactory water quality level while Sydhavnen (Enghave Brygge, Frederiksholmsløbet and Teglværkshavnen) is expected by 2014. Kalveboderne has not yet reached a sufficient water quality.

During heavy rainfalls, CSO (Combined Sewer Overflow) may still occur to the harbour area as well as to lakes and streams. The aim is to keep the number of overflows to the harbour area during summer months low enough to comply with EU Bathing Water Directive (EU Direktiv, 2006) by the end of 2009 (Copenhagen Energy, 2008) and the whole harbour area except from Kalveboderne by 2011(Copenhagen Municipality, 2008). The EU Bathing Water Directive classifies the bathing water quality into 4 classes: *poor, satisfactory, good* and *excellent* as shown in Figure 5.2.

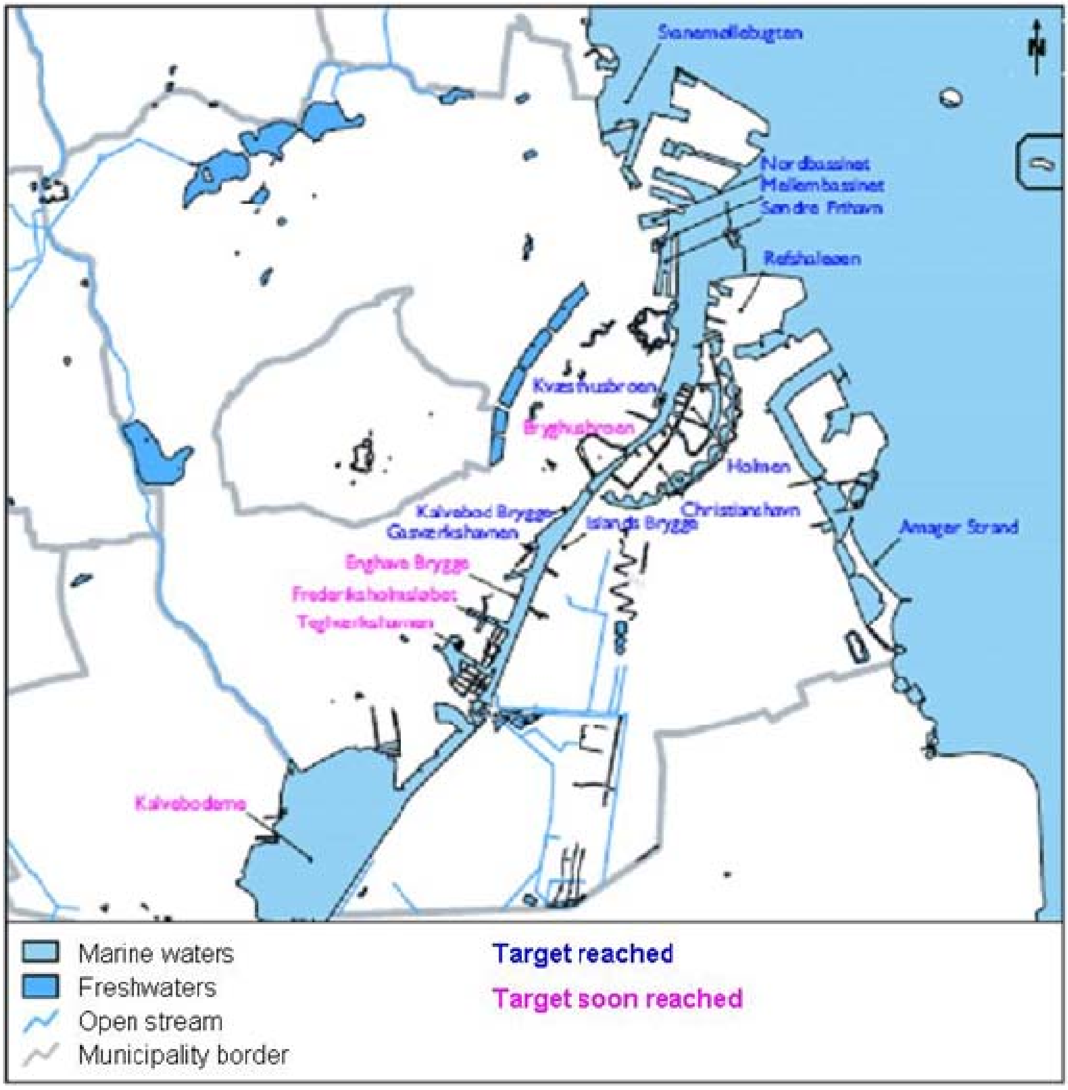


Figure 5.1: *Show the harbour area of Copenhagen where bathing water quality is wanted.*

Measurements conducted in the harbour area does not give reasons to believe that existing SWS and the planned activities will have to be expanded further to comply with the Directive, though during combined sewage overflows (CSO´s) there is risk of noncompliance. The challenge is to keep these incidents below 5% of the time. It is however important to recognize that low levels of pathogenic bacteria demands that diffuse discharges from ships, sailors etc. are kept at a limited level (Københavns Kommune, 2008).

Quality check according to EU Bathing Water Directive

Freshwater

	Excellent	Good	Satisfactory	Poor
	95% quantile	95% quantile	90% quantile	90% quantile
E.Coli/ 100 ml.	<500	<1000	<900	>900
I.e./ 100 ml.	<200	<400	<330	>330

Coastal water

	Excellent	Good	Satisfactory	Poor
	95% quantile	95% quantile	90% quantile	90% quantile
E.Coli/ 100 ml.	<250	<500	<500	>500
I.e./ 100 ml.	<100	<200	<185	>185

Other requirements to bathing water:

- Transparency
- Visual inspection
- Other

Statistics:

Exceedence with return periods of more than 4 years is acceptable

- Acceptance of exceedence with return period of 1-2 if warnings has been send out beforehand

Figure 5.2: Criteria of bathing water quality according to EU Bathing Water Directive. Adapted from (EU Directive, 2006). *I.e.: intestinal enterococci*

To secure the bathing water quality traditional solutions have been chosen. Some of the upgrading is listed below (KE, 2009a):

Implemented upgrading:

- Lersøgrøften 28-32.000 m^3 expansion of storage
- Colloseum (frihavnen) 33.000 m^3 expansion of storage
- Skt anna 8000 m^3 expansion of storage
- Østamager (42000 m^3) expansion of storage
- Scherfigsvej UV and particle filter treatment (500 l/s)
- Closement of overflow structures to inner harbour.

- Teglholm 10.000 m^3 expansion of storage

Planned upgrading before 2015:
- Construction investments: 330 mils DKK allocated to improve water quality from Harrestrup Å, Kagså and Damhusåen
- Reduction of overflow structures from 195 to 133
- Integrated control solutions of WWTP, sewer and recipient in connection with "Intelligent spildevandshåndtering".

The EU Bathing Water Directive (EU Direktiv, 2006) requires that a warning system is set up to evaluate the future bathing risk so that an early warning can be sent out beforehand.

The bathing facilities already in service are equipped with warning systems based on on-line measurements in the sewer from Hvidovre, Copenhagen and LF, and calculation of the hygienic water quality in the harbour. "Center for Park og Natur" has established the warning system. In case of poor water quality a red flag is hoisted. Warnings are sent out via internet (Copenhagen Municipality, 2008). The warning system is developed by DHI and available on-line. The model is forecasting the bathing water quality up to 4 days ahead. The warning system is based solely on registrations of actual discharges, not on forecasted discharges.

More about bathing water quality can be found on the following links:

http://www.kk.dk/Borger/ByOgTrafik/GroenneOmraader/badevand/badevandsvarsling.aspx
samt
http://www.waterforecast.com/BadevandsudsigtKBH/

The Water Framework Directive
The water plans (Vandplanerne) sets the framework for the water quality of the surface waters and sea waters, however the plans have not yet been published (expected in December 2009) and requirements are therefore currently unknown. However until then, objectives formulated in Regionplan 2005 are valid (Hovedstandens Udviklingsråd, 2005).

It is anticipated that the prerequisites for good marine biological conditions with limited algae growth and clear water with good transparency and diverse plant- and animal life comes with the actions taken to secure bathing water quality in the harbour area (Copenhagen Municipality, 2009). The governmental Water Plans are therefore unlikely to impose new enforcements concerning the marine environment. Kalveboderne was laid out as an EU habitat area and EU Bird Protection area and thus the water is classified with stricter requirements.

Functional practice of storm and wastewater system under rainy conditions
Table 5.1 shows the requirements to dimensioning of new sewer systems in Copenhagen Municipality. The municipality (Copenhagen Municipality, 2008) distinguishes between four types of drainage systems: *the combined system*, the *traditional separated system*, the *two ways system* and the *three ways system*. The two ways system leads dirty runoff (from roads) together with wastewater for treatment at the WWTP while the clean runoff (from roofs

etc.) is either infiltrated or transported to recipient. The three ways system sends only waste water to WWTP while dirty runoff is treated locally and clean runoff is either infiltrated or directly discharged to recipient.

In dimensioning new pipes and basins Copenhagen Municipality has decided to account for climate effects, urbanisation and statistical uncertainty as shown in Table 5.2. Therefore, dimensioning of new pipes are done by multiplying with a total safety factor of 1.56 for pipes, 1.2 for new pipes with critical economy, and 1.2 for new basins (Copenhagen Municipality, 2008). The status of the existing system can only be evaluated based on the information received from the citizens and according to them these experience basementfloodings, whereas terrainfloodings are insignificant. The aim is to achieve the same standard for the existing systems as for the new systems, however no commitments are made without a better knowledge about the capacity and investment needs.

Table 5.1: *Acceptable return periods for flooding to terrain*

Drainage Principle	Return period of flooding to terrain
Combined	Once per 10 year
Traditional separated	Once per 5 year
Two ways principle	Once every 10 year for pipes carrying waste water. Once every 5 year for pipes carrying runoff from roofs
Three ways principle	Once every 5 year for pipes carrying runoff from roads and roofs

Table 5.2: *Accounting for safety factors in pipe- and basin dimensioning*

Safety factors caused by:	Pipe dimensioning	Pipe dimensioning under critical economy	Basin dimensioning
Statistical uncertainty	1.20	1.20	1.20
Increased rain intensity	1.30	1.00	1.00
Urbanisation	1.00	1.00	1.00
Total uncertainty	1.56	1.20	1.20

6. Existing SWS models and measurement data

6.1 Modelling tools

6.1.1 Drainage models

The 8 municipalities have their own drainage models developed either in MOUSE (DHI product) or MIKE URBAN (MU) (newer version of MOUSE with GIS interface) for design and planning of sewer systems and use different GIS systems and databases. To have an over-

view and integrated drainage models in the catchment area of LF, LF decided to develop a simplified model of the whole catchment, which is expected to be ready by October 2009. This model is developed in MU by Rambøll and builds based on the existing models and data of different quality and platforms. MU models both hydraulics and substance transport and is used for dynamic simulation of the sewer system. All submodels (defined as sub-catchments) are adjusted to the same degree of detail i.e., number of nodes per area is the same. Figure 6.1 give an example of how the sub models look before simplified.
Some catchments are being reduced while others are detailed to a larger extent (see Figure 6.2). New catchments are digitalised with the detail level of the models and a new spatial analysis will be conducted directly in MU.

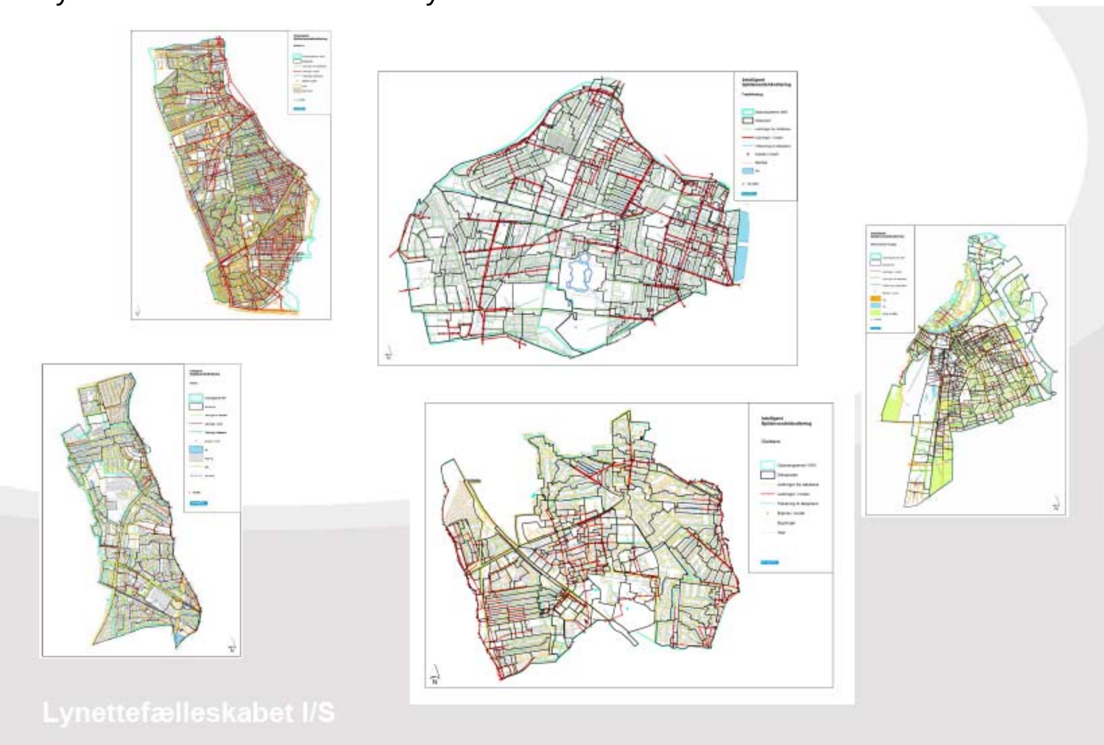


Figure 6.1: *Detailed sub models of sewer systems MIKE URBAN (Lynettefællesskabet, 2009c).*

It has been decided to limit the level of detail to approx. 4000 nodes totally for each sub model to limit calculation time. Each sub model diverts water to the WWTP and the density of the models has been chosen reasonably uniform.

Figure 6.2: *Examples of model simplification (top) and model detailing (bottom). Adapted from (Lynettefællesskabet, 2009c).*

The reduced area is calculated automatically using a catchment processing tool in MU for new catchments as well as information from basic maps etc. Buildings, roads, pavements, parking lots are all accounted for paved area (Figure 6.4).
Waste water amounts in the models are all based on consumption from water works as well as information from single emitters. The numbers from water meters is geo coded and added to the model as waste water using the load function. The largest single emitters in each municipality are treated separately.

Figure 6.4: *Catchment processing tool in Mike Urban automatically converts ortophotos to catchments with paved percentage (reduced area) in Mike urban (Lynettefællesskabet, 2009c).*

6.1.2 WWTP models

Simple WEST (DHI product) models are available for both Lynetten and Damhuåen (Lynettefællesskabet, 2009c) and figure 6.5 shows an example of the WEST model for WWTP Lynetten. WEST is useful for simulation of the processes in active sludge treatment and provides possibility of simulation of mechanical reduction in the primary sedimentation, biological/chemical reduction in the activated sludge treatment, settlement of activated sludge in the secondary settler and provides opportunities for simulation of bypass of each treatment step. Normally user defined static values for concentrations are used for characterising the waste water. In the ISH project dynamic flows and wastewater concentrations that take into account the catchment influence on the waste water will be used (Lynettefællesskabet, 2009c).

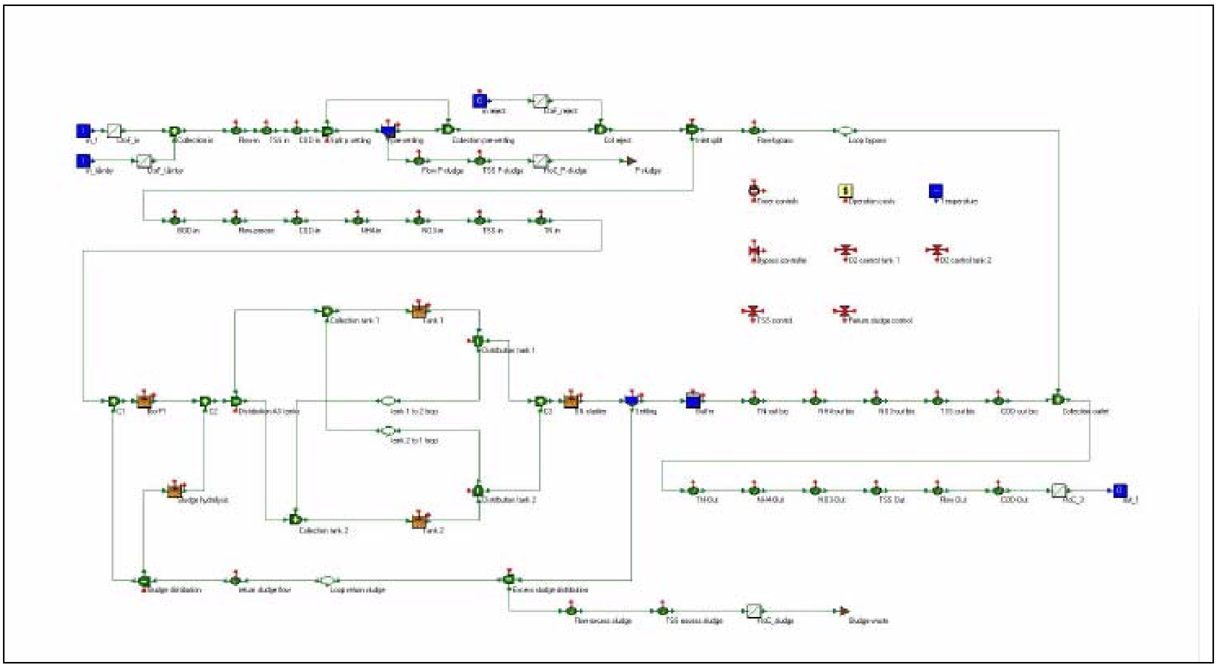


Figure 6.5: *WEST model of Lynetten WWTP (Lynettefællesskabet, 2009c).*

6.1.3 Integrated sewage and wastewater treatment model

A coupling module was also developed to couple MU and WEST on time step level and thereby integrated modelling of sewerage and wastewater treatment (se figure 6.6). Time step coupling is implemented to take account of the dynamics/interaction between sewer and WWTP. This will be implemented as part of phase 2 that is currently in progress (see project phases in chapter 7). A fractionation module (FM) is developed together with MOSTforWATER with the aim to calculate a number of necessary subcomponents; e.g., calculate different organic fractions based on COD. The FM is adapted to the two WWTP´s different waste water composition with multiple configurations for each flow (Lynettefællesskabet, 2009c). Four substance parameters in MU are used as input for the calculation of the detailed composition of the waste water in WEST. This development is also part of phase 2 and currently progressing.

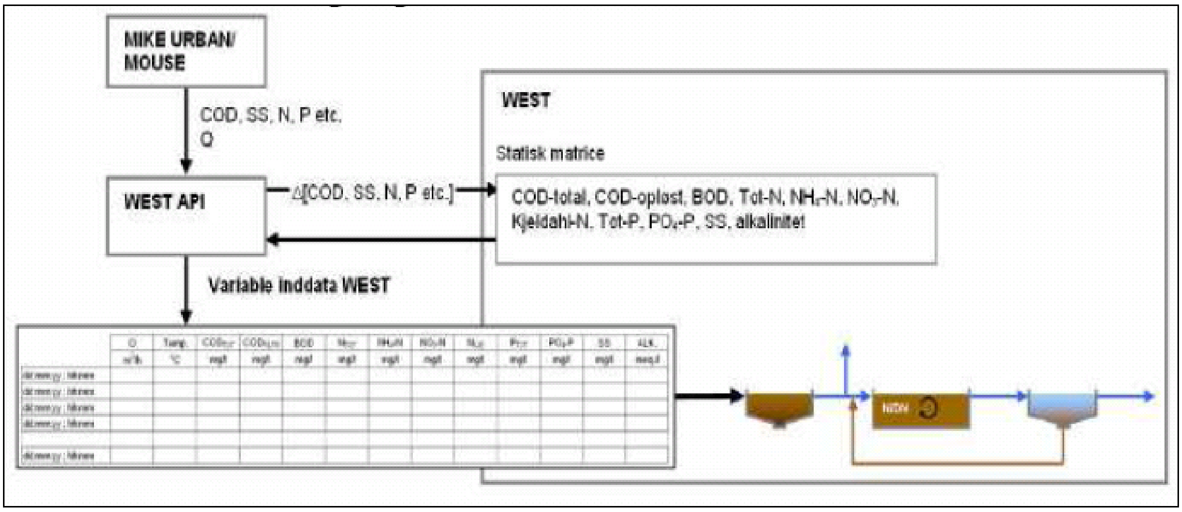


Figure 6.6: *Coupling of MIKE URBAN and WEST (Lynettefællesskabet, 2009c).*

6.2 Measurements

6.2.1 Rain gauges and radar

There are many SVK-rain gauges (see Figure 6.7) operated by Danish Meteorological Institute inside or nearby the catchment of Lynettefællesskabet and one high resolution X-band radar in Hvidovre Municipality and LAWR 25 from DHI Weather Radar Systems (for specifications see Table 6.8). The X-band is owned by Hvidovre Municipality and located on the roof of the Fire Department in Hvidovre. The radar covers a radius of 10 kilometres for predicting rain intensity, and 60 kilometres if used for rain forecasting. The radar has just recently been calibrated; however data still need to be verified before they become useful for urban drainage modelling. Lynggaard-Jensen (2007) mentions the advantage of using radar compared to rain gauge as rainfalls are so distributed spatially that rain cells need to be no larger than100x100 m^2 to get a precise rainfall description if rain gauges are used.

The municipalities in the greater Copenhagen are considering buying 1 or 2 radars to cover the rest of Copenhagen and for more details see chapter 7.1.

Most of the traditional tipping bucket rain gauges have been measured for many years and data can be withdrawn from DMI homepage provided the user is equipped with username and password.

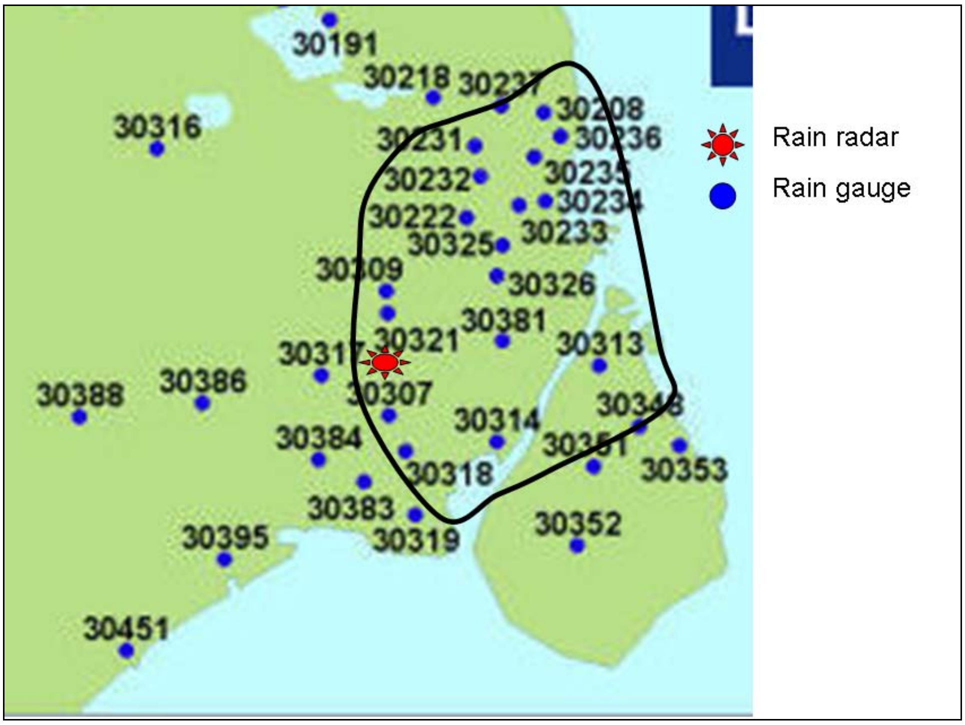


Figure 6.7: *Rain gauges and radar in the catchment of Lynettefællesskabet. Adapted from http://www.dmi.dk/dmi/svk-maalere_i_koebenhavn.*

Table 6.1: Specification of the LAWR 25 kW radar in Hvidovre.

	LAWR 25
Peak Power	25 kW
Wave length	X-band3.2 cm
Pulse Length	1.2 µs
Antenna	2.5 m slotted waveguide array
Receiver	Logarithmic receiver
Vertical and Horizontal opening angle	± 10° 0.95°
Range (forecast/QPE)	60/20 km
Spatial resolution	500x500m, 250x250m, 100x100m
Temporal resolution	1 or 5 minute
Scanning strategy	Single layer and continuous scanning

6.2.2 Flow- and level meters

Unfortunately there is no complete overview of where flow and level meters are placed yet but the work with providing such a map is progressing within the intelligent water management group. Therefore instead a qualitative overview will be given based on (Lynettefællesskabet, 2008). Flow and level meters are essential for a better control strategy.

WWTP

The wastewater treatment plants both register inlet flow with a time resolution of minutes, however these are only saved for 1 month, whereas measurements older than one month old are saved with a time resolution of 1 hour. Lynetten WWTP has a five year long time series of inlet flow. It is being considered to install level meters in upstream basins to control the filling and emptying of the basins from current and predicted capacity at WWTP Lynetten.

There is currently only one flow gauge at Dæmningen (between lake Damhussøen and WWTP Damhusåen) that is used for wet weather control at WWTP Damhusåen. This gives a warning of only 30 minuttes for change of operation which is too short (Lynettefællesskabet, 2008). It is investigated if other inputs could be used like flow from pumping stations or flow gauges from other places in the system to further increase the lead time.

Drainage system

Flow and levels of the pumping stations Kløvermarksvej and Strandvænget is measured (Lynettefællesskabet, 2008). Table 6.2 gives an overview of the available flow, level meters and gauges in the 8 municipalities (Lynettefællesskabet, 2008) and as it can be seen from the table the information is very scarce and it is expected that the phase 3 of the “Intelligent Spildevandsvandshåndtering” will give a detailed information about the flow, level meters and gauges.

Table 6.2: overview of the available flow, level meters and gauges in the 8 municipalities (Lynettefællesskabet, 2008)

Municipality	Flow, level meters and gauges
Gentofte	48 flow and level meters
Gladsaxe	Level meters at pumping stations and basins but no flow meters
Frederiksberg	None
Copenhagen	Many flow and level meters
Lyngby-Tårebæk	No available information
Rødovre	No available information
Hvidovre	There are many gauges in (50-100) in Hvidovre to control the system. The gauges measure level, electricity consumption, level of throttles and on/off of pumps, temperature etc.
Herlev	No available information

6.2.2 Other Measurements

The online sensors and measuring units placed at Lynetten and Damhusåen are listed here:

Lynetten:

The biological treatment is divided into 3 units and each unit contains a master lane and a number of slave lanes.

In each master lane there are NO_3-N and NH_4-N sensors. PO_4-P i measured in the outlet. SS is measured in the total outlet from each unit. SS, NO_3-N, NH_4-N og PO_4-P are measured in the total outlet after secondary treatment

Damhusåen:

NO_3-N, NH_4-N og PO_4-P are measured in the master lane, which is denoted as line B and the remaining 3 lanes are slaves with no measurements. SS i measured in all the 8 aerations tanks. SS, NO_3-N, NH_4-N og PO_4-P are measured in the outlet from all the 4 lines after the secondary settlers.

7. Projects of SWI relevant in the casearea

There are two projects, which are of SWI relevant and implemented parallel to SWI and these are radar project and intelligent wastewater control.

7.1 Radar project.

As mentioned earlier there is one radar in the Hvidovre Municipality and the Municipalities of greater Copenhagen are investigating the need for another radar to cover the northern part of greater Copenhagen. A radar working group with participation of the Municipalities connected to LF and SCA are now investigating:

- The potential control benefits at the WWTP´s
- The radars technological level and potential
- The economical and organizational aspects concerning collaboration on radar warning perhaps extended to the entire Metropolitan area.

Since this project is recently initiated limited information is available at the time of writing this report.

7.2 Intelligent wastewater control

LF and KE initialized a project in 2008 called “Intelligent wastewater control” (in Danish: Intelligent spildevandshåndtering) with the intension to develop a state of the art for integrated control of sewer and WWTP for the catchment depicted in Figure 3.1. The purpose of the project is to optimise the whole storm- and wastewater system (SWS) by reducing the pollution to the recipients surrounding the sewer system.

All the 8 municipalities are represented by one personnel and LF by two in the project organisation. Two steering groups and one project group has been established and the project leader is from KE. Rambøll A/S is consultants on the project. (Lynettefællesskabet, 2008)

The implementation period of the project is 2008-2012 and the project is divided into 4 planning phases. A detailed description of the objectives and these 4 phases is given below.

7.2.1 Objectives and Targets:

The objectives of the project are:

- Develop an optimal operational control of the whole existing waste water system that is connected to the catchments of Lynettefællesskabet I/S.
- To establish Lynettefællesskabet and its owner municipalities as the key implementers in developing the area.

Project targets seen from WWTP (Lynettefællesskabet, (2009c))

- Minimise SS in the outlet from the WWTP (avoid sludge escape from secondary settling tanks)
- Reduce overflows from untreated/mechanically treated wastewater
- Early warning of rain to switch to wet weather control in time
- Variable control strategy, treatment of first flush
- The capacity of the WWTP (Q bio max) is calculated dynamically and used to control upstream basins, pumping stations etc.
- Possible interaction between the two WWTP´s in order to direct water to the plant with largest current capacity.
- Optimal bathing water quality
- Less water to WWTP´s

Other project targets (Lynettefællesskabet, (2009c))

- Increased collaboration: Optimal planning of future investments, utilisation of sewage system/the whole system (Lynettefællesskabet) as well as a more optimal operation and maintenance
- Consider local vs. global solutions
- Minimising overflows in the existing situation (m^3/amount of substances) and make an optimized adaptation to climate change
- Control overflows
- Improve recipient water quality (freshwater, marine and bathing water)
- Robust solutions – robust system

7.2.2 Phases of Intelligent water management

<u>**Phase 1:**</u> To map the current control of the SWS of the whole system
(Finalised in 2008 and reported in (Lynettefællesskabet, 2008) & (Lynettefællesskabet, 2009a) .

- total overview of the drainage system and the two WWTP´s
  - Existing SCADA systems
  - Dimensioning practise/criteria's
  - Existing models
  - GIS
  - Etc.
- Description of main issues and current interactions between drainage systems and WWTP

- Low hanging fruits (big effects or improvements for small investment) (Lynettefællesskabet, 2009e)
  - Overview of measurement spots and control devices in the whole sewer system- should be mapped.
  - Possible common SCADA - this costs hours - there are many systems, and they "talk" badly together.

- Identification of bottlenecks – downstream capacity? Basin constructers cite the need to know.
- Strandvænget as an experimental area + control (KE)
- Radar in the northern catchment (how far is Hvidovre?)
- LF can utilise radar measurements in a coarser model than owner municipalities
- Representative gauges in the system for wet weather Control of Lynetten WWTP (now at Dæmningen), possible signals from pumping stations.
- Calculations with distributed rainfall for assessment of control potential
- What is the potential for directing water between LWWTP and DWWTP (probably small potential, since there is temporal overlap) – look at the catchment boundaries between LWWTP and DWWTP and "Sydhavnsbassin" harbor basin in Copenhagen
- Connection with SCA (Spildevands Center Avedøre) ?
- Outlet right between municipalities
- Cooperation concerning unintended infiltration water
- Overall coordination of sewer upgrades in the municipalities
- Common position on separation? Discussion on technician level -> need for technician group!
- Overflow strategy: should overflows take place at WWTP or within catchments – distribution?
- Control of basin pipes, that are not controlled currently

Phase 2: Prepare for operational coordination - short term (Model for decision support); Scheduled: First half of 2010

- Collection of existing models and relevant measurement data
- Determine the level of detail
- Review and validation of existing models. Construction and calibration of composite models.
- Linking drainage system model (MU) and WWTP model (WEST).

Phase 3: Prepare a draft for optimal operation management (Strategy): Scheduled: End of 2010

- Proposal for optimum control and operation of drainage system and WWTP (scenario catalog)
- Calculation of selected scenarios / strategies
- Where in the SWS are potentials for improvements
- Establish tools for technical, economical and environmental assessment of strategies.

Phase 4: Explore opportunities for development cooperation in accordance with optimal operational management (development of new technologies). Scheduled: 2010-2012

- Need for development of new methods and tools to realise the chosen strategy (eg. In SWI or VBSS (Vejrbaseret Styring af Spildevandsssystemer).

Phase 5: implementation, not yet adopted. (Scheduled: Depends on the investment possibilities)

- Ongoing implementation
- The economic impact will be uncovered during the course of the project

7.2.3 Conclusion so fare

Phase 1 was completed in cooperation with all 8 municipalities and LF by early 2009. It was concluded that municipalities use different dimensioning criteria's, sub optimise their systems and have different service levels. The following was particularly important.

- Identify rain that gives bypass at the WWTP´s but no floodings or problematic overflows in the sewer system.

- Coordinated control of basins across municipality borders.

- Integrated control of sewer and WWTP´s.

- Connection between the two catchments of Lynetten and Damhusåen WWTP´s with possible overflow and emptying both ways

- Benefit in participating in the development of basins in neighbouring municipalities so that more water can be retained and downstream load thus reduced.

- Far from finished with the project, but greater understanding of the interplay between individual subsystems and especially perhaps among WWTP´s and drainage system.

- There is a need for more collaboration within the community, if the optimal / best solutions are going to be implemented.

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Anders Breinholt & Anitha K. Sharma, 4th January 2010

Appendix 1. Detailed information about the catchment area of Lynettefællesskabet

This appendix gives general information about the 4 catchments areas of interest for Lynetten and Damhusåen WWTP. However, the results from the project called Intelligent Spildevandshåndtering (ISH) will give an updated and more detailed information.

1. Skovshoved/Tuborg Nord catchment

The total catchment area 510 reduced hectares (according to PH-Consult, 1999)), cover most of Gentofte Municipality and a bit of Lyngby-Tærbæk Municipality as well as Copenhagen Municipality (see Figure 4.4). The catchment discharge/overflow to lake ”Gentofte Sø”, the marine coasts ”Svanemøllebugten” (via the stream ”Wilhelmdalsrenden”) and Øresund. Currently Rambøll is setting up a model of the whole system but this model is not yet finished why specifications from PH-Consult (1999) are used instead to provide an overview of the catchments. A SAMBA model (a simplified model) was used for modelling the catchments in PH-Consult (1999). In SAMBA all areas upstream basins, weirs or pumping stations are transferred to a time-area description and that leaves only a skeleton of the complete system as shown in Figure 1.

Storage basins (according to PH-Consult (1999))

- In Lyngby-Taarbæk Municipality there is a storage volume of 4 mm.
- In Gentofte Municipality there is a storage volume of 6 mm
- In Copenhagen Municipality 0 mm storage volume

It is noted that new storage basins might have been built since that time and figures might have changed in some areas.

In the downstream part of Skovshoved catchment the water is pumped via pumping station “Tuborg North” to the pumping station “Strandvænget” and from here further on to Lynetten WWTP. The catchments Skovshoved and Strandvænget are not completely separated. A connection from Skovshoved to Strandvænget exists via Rygaards-renden/Wilhelmsdalsrenden.

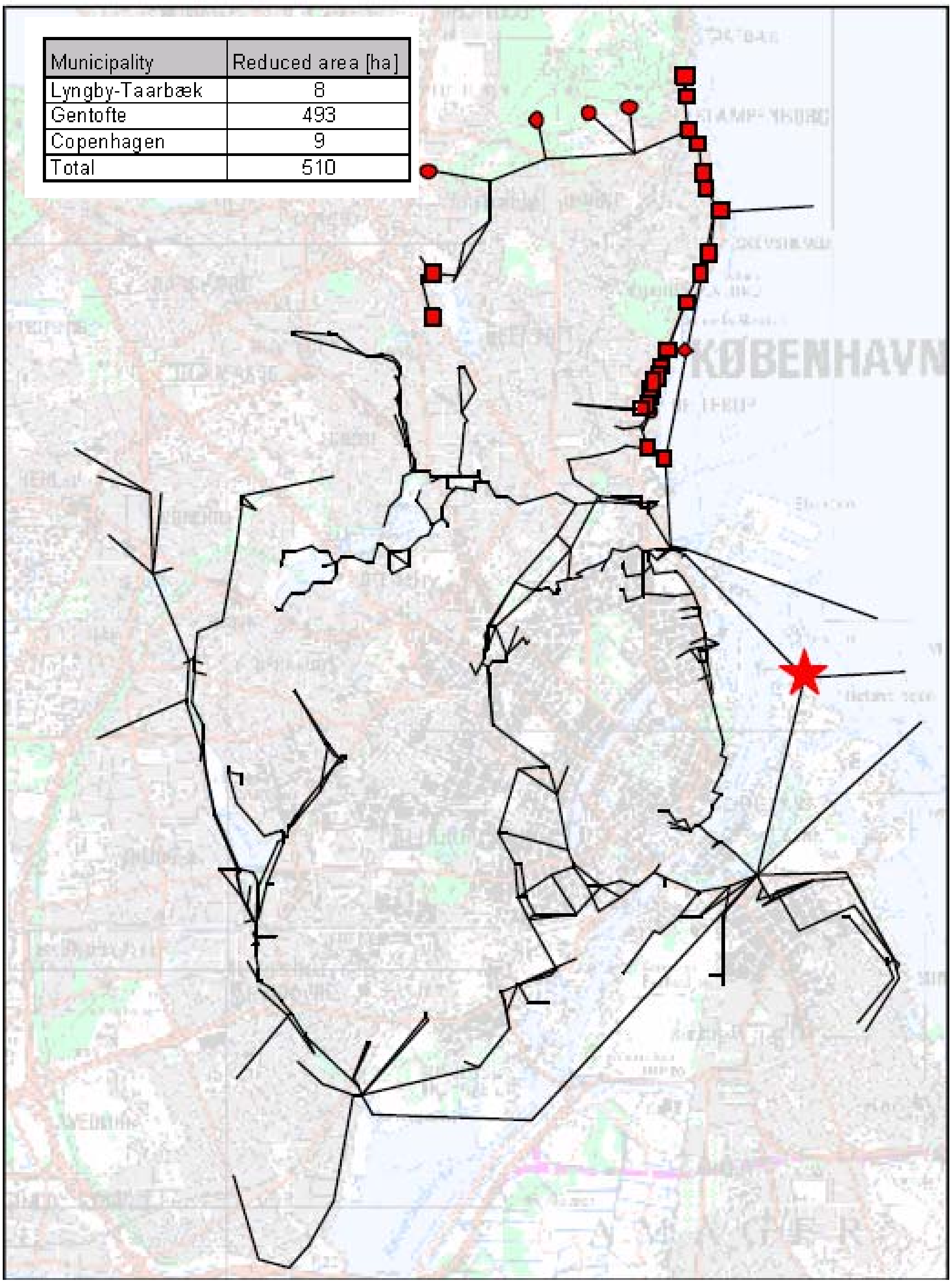


Figure 1: *Catchment of Skovshoved indicated with red squares. Total reduced area distributed on municipalities is also indicated. Adapted from (PH-Consult, 1999).*

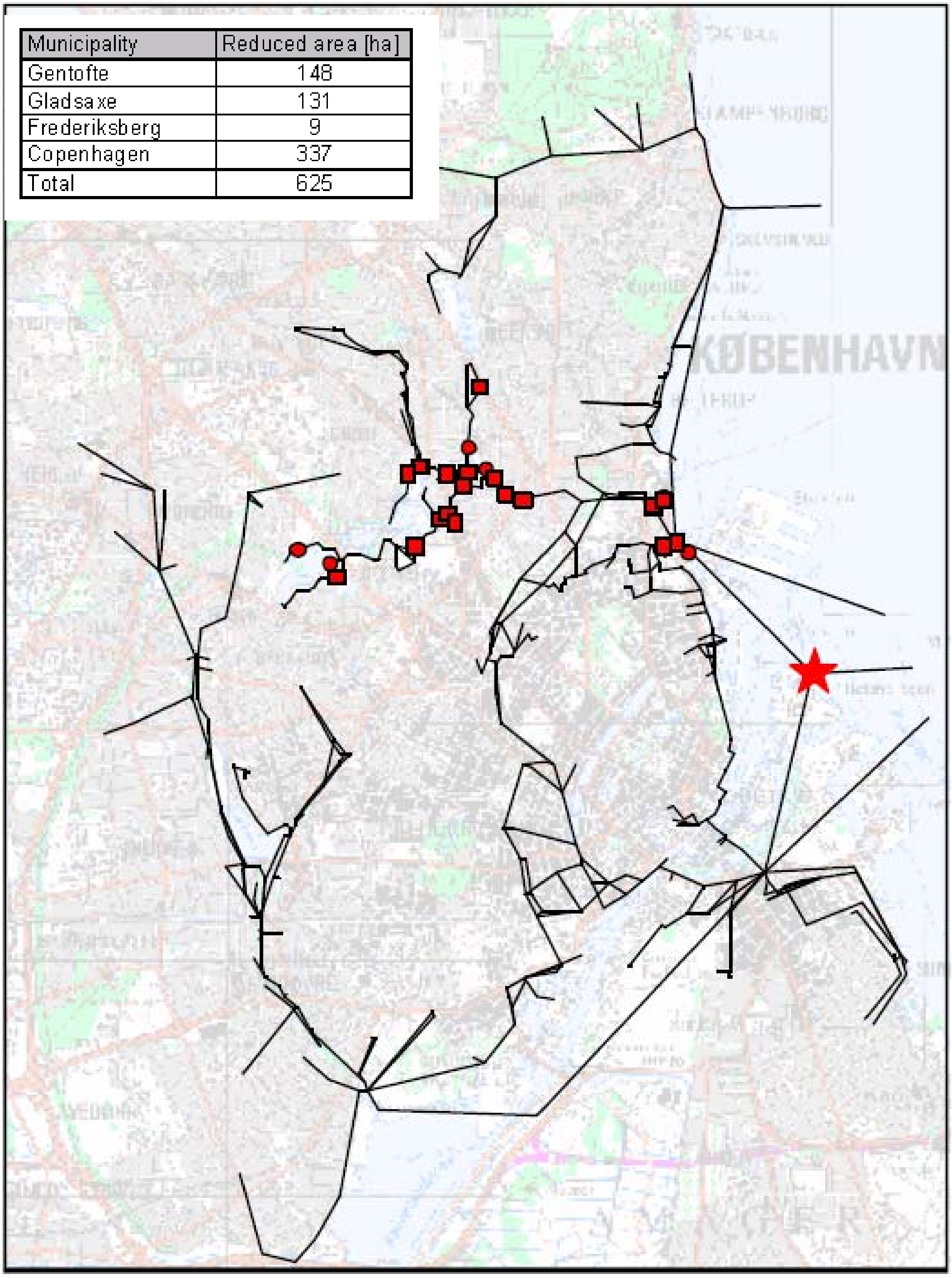
2. Strandvænget catchment

The catchment of totally 625 ha includes primarily Copenhagen, Gladsaxe and Gentofte Municipalities but also a bit of Frederiksberg Municipality (see Figure 3). The catchment discharges/overflows to Utterslev Mose, Søborghusrenden, Gentofterenden, Emdrup Sø, Svanemøllebugten and Øresund.

Storage basins (according to PH-Consult (1999))

- In Gentofte there is a volume of 5 mm
- In Gladsaxe there is a volume of 10 mm
- In Copenhagen there is a volume of 10 mm
- In Copenhagen there is a green waste water treatment plant that treats overflows to Utterslev Mose
- Rygaardsrenden/Wilhelmsdalsrenden are only partially used for storage volume (9000 m^3)

In the downstream part of the catchment the pumping station Strandvænget convey the waste water to Lynetten WWTP. The catchment is connected to Kløvermarken through an overflow at Østerbrogade.

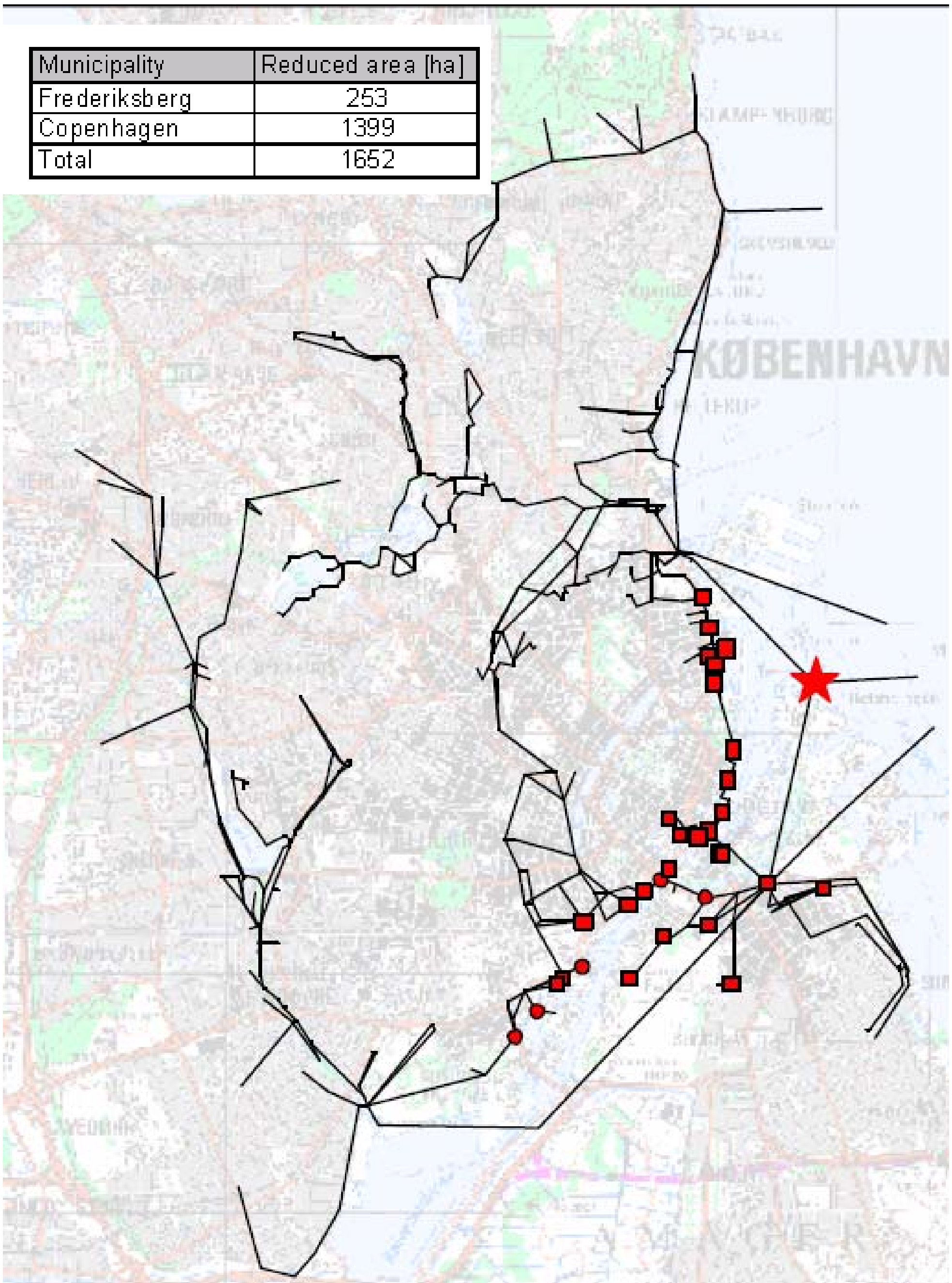


Municipality	Reduced area [ha]
Gentofte	148
Gladsaxe	131
Frederiksberg	9
Copenhagen	337
Total	625

Figure 2: *Catchment of Strandvænget shown with red squares. Total reduced area distributed on municipalities is also indicated. Adapted from (PH-Consult, 1999).*

3. Kløvermarken catchment

The catchment area of 1652 reduced ha cover part of Frederiksberg and Copenhagen Municipality, see Figure 3 The area discharge/overflow to northern, inner, southern and eastern harbour area, Amager Strand and Øresund.



Municipality	Reduced area [ha]
Frederiksberg	253
Copenhagen	1399
Total	1652

Figure 3: *Catchment of Kløvermarken shown with red squares. Total reduced area distributed on municipalities is also indicated. Adapted from (PH-Consult, 1999).*

Storage basins (according to PH-Consult (1999))

- In Frederiksberg Municipality there is no significant volume but no overflows either. All waste water is forwarded to Copenhagen Municipality.
- In Copenhagen Municipality there is volume of 9 mm at the Zealand side and 16 mm at the Amager side.

The catchment of Kløvermarken receives water from Strandvænget catchment at Østerbrograde and overflows into Strandvænget catchment at Wilhelmsdalsrenden. There is a connection between Kløvermarken catchment and the catchment of Damhusåen via the basins in "Sydhavnen". All water from the catchment is directed to Lynetten WWTP via Kløvermarken pumping station.

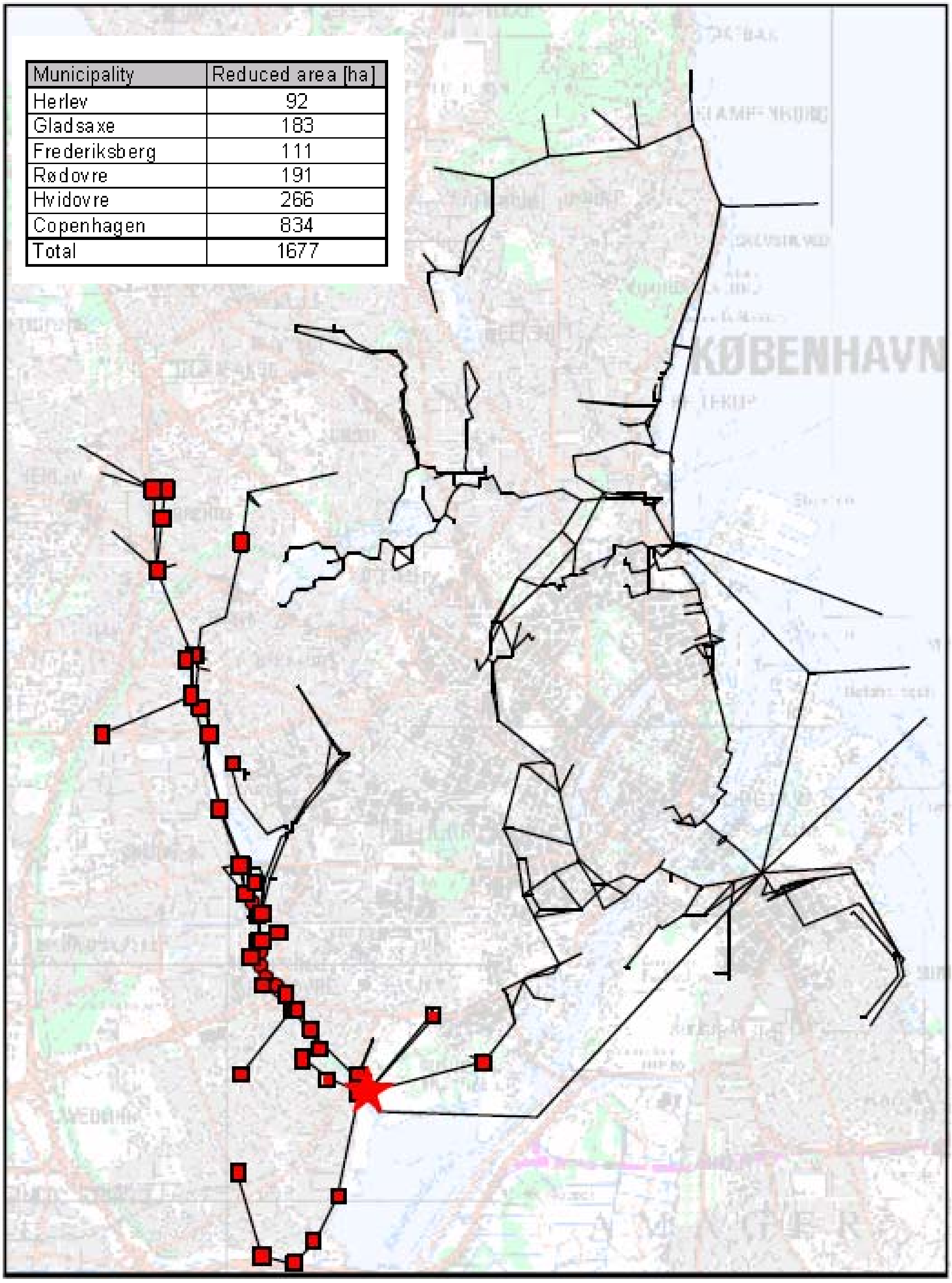
4. Damhusåen catchment

The catchment with a reduced area of 1677 ha covers a part of Gladsaxe Municipality, Copenhagen as well as Herlev, Rødovre and Hvidovre Municipality (see Figure 4). The catchment overflows to Kagsåen, Fæstningskanalen, Harrestrup Å, Damhusåen, Sydhavnen and Kalveboderne.

Storage basins (according to PH-Consult (1999))

- In Gladsaxe Municipality in the "Gyngemose" catchment there is a volume corresponding to 15 mm
- In Rødovre Municipality there is a volume corresponding to 8 mm.
- The pipes along Grøndalsparken consists of an interception pipe and a storage pipe where water can be stored according to some control strategy (3 mm)
- Hvidovre Municipality have a basin volume corresponding to 8 mm.
- Catchment of Gåsebæk has a storage volume of 7 mm

In the downstream part of the catchment the waste water is transported to DWWTP for treatment and then discharged in Øresund. There is a connection between Damhusåen catchment and Kløvermarkens catchment via basins in "Sydhavnen".



Municipality	Reduced area [ha]
Herlev	92
Gladsaxe	183
Frederiksberg	111
Rødovre	191
Hvidovre	266
Copenhagen	834
Total	1677

Figure 4: *Catchment of Damhusåen shown with red squares. Total reduced area distributed on municipalities is also indicated. Adapted from (PH-Consult, 1999).*

Appendix 2. Details about storage tanks in Lynettefællesskabets catchment area.

Municipality	No.	Name	Size (m^3)	Type	Existing/planned
Ejerkommune	nummer	evt. navn	Størrelse i m3	evt. type	eksisterende/planlagt
Frederiksberg	1	Flintholm	800	bassin	eksisterende
	2		180	bassin	eksisterende
	3	Bispeengbuen (Københavns)		bassin	eksisterende
	4		11.150	ledningsbassin	eksisterende
	5		3.545	ledningsbassin	eksisterende
Gentofte	1	Søholmlundbassin	670		eksisterende
	2	Hundesø Mose	1.500		eksisterende
	3	Nybrovej bassin	300		eksisterende
	4	Hellerup Strand	450		eksisterende
	5	Henningsens Allé	2.700		eksisterende
	6	Gentofterenden	2.300	ledningsbassin	eksisterende
	7	Søbredden	260		eksisterende
	8	Brogårdsvej bassin	2.900		eksisterende
	9	Ved stadion	1.700		eksisterende
	10	Den rørlagte Enghaverende	8.000	ledningsbassin	eksisterende
	11	Vangederenden	6.800	ledningsbassin	eksisterende
	12	Kildeskovrenden	6.600	ledningsbassin	eksisterende
	13	Bernstorffsrenden	2.000	ledningsbassin	eksisterende
	14	Regnvandsbassin i Char. S	3.200	ledningsbassin	eksisterende
	15	Rygårdsrenden	3.600	ledningsbassin	eksisterende
	16	Gentofterenden	925	ledningsbassin	eksisterende
	17	Ved Renden	5.500	ledningsbassin	planlagt 2009-2010
	18	Maltegårdsvej	850		planlagt
	19	Langs Vangederenden		ledningsbassin	planlagt
Gladsaxe	1	Vadgård	8.100		eksisterende
	2	Skolesvinget	3.000		eksisterende
	3	Gyngemosen	8.500		eksisterende
	4	(Vadgård, evt i Gentofte)	16.000		planlagt 2010 (ej vedtaget)
	5	Gyngemosen	5.000		planlagt 2011 (ej vedtaget)
	6	Nordkanalen (med Gentofte)	20.000		planlagt 2015 (ej vedtaget)
	7	Utterslev Mose	3.000		planlagt 2015 (ej vedtaget)
	8	Symfonivej (med Herlev)	3.000		planlagt 2012 (ej vedtaget)
	9	Kagså Syd	2.000		planlagt 2012 (ej vedtaget)
	10	Kagså Nord	1.200		planlagt 2012 (ej vedtaget)
Herlev	1		3.115	bassin	eksisterende
	2		500	bassin	eksisterende
	3		1.641	bassin	eksisterende
	4		4.400	bassin	eksisterende
	5		5.184	bassin	eksisterende
	6		240	bassin	eksisterende
	7		14	bassin	eksisterende
	8		90	bassin	eksisterende
Hvidovre	1	Biblioteksvej 43A	2.800	bassin	eksisterende
	2	Ved Materielgården	1.700	bassin	eksisterende
	3	Kystagerparken	6.000	bassin	eksisterende
	4	Strandengen	3.000	bassin	eksisterende
	5	Hvidovregade/Astrupgårdsvej	4.500	bassin	planlagt 2018
	6	Sydkærsvej	8.000	bassin	planlagt 2012
	7	Idrætsvej	100	bassin	eksisterende
	8	Frihedens Butikscenter	300	bassin	eksisterende
	9	Engstands allé	100	bassin	eksisterende

København	1	Pilesvinget	2.500	bassin	eksisterende
	2	Hareskowej	2.500	bassin+ledn.	eksisterende
	3	Folevadsvej	800	bassin+ledn.	eksisterende
	4	Ved Vigen	730	bassin+ledn.	eksisterende
	5	Rødkløvervej	750	bassin+ledn.	eksisterende
	6	Wilhelmsdalløbet/Lersøledning	29.000	bassin+ledn.	eksisterende
	7	Pst. Strandvænget	4.000	bassin+ledn.	eksisterende
	8	Colosseum	35.360	bassin+ledn.	eksisterende
	9	Amerikakaj	100	ledningsbassin	eksisterende
	10	Sct. Annæ Plads	8.000	bassin	eksisterende
	11	Boldhusgade	580	ledningsbassin	eksisterende
	12	Udenrigsministeriet	150	ledningsbassin	eksisterende
	13	Praghs Boulevard	42.000	bassin+ledn.	eksisterende
	14	Digevejsgrøften	17.500	bassin+ledn.	eksisterende
	15	Thorvald Borgsgade	445	ledningsbassin	eksisterende
	16	Havneparken	8.000	ledningsbassin	eksisterende
	17	Bernstorffsgade	2.050	ledningsbassin	eksisterende
	18	Godsbanegården	7.075	ledningsbassin	eksisterende
	19	Fisketorvet	2.000	ledningsbassin	eksisterende
	20	Belvederekanalen	28.000	bassin+ledn.	eksisterende
	21	Sydhavnsgade	1.550	ledningsbassin	eksisterende
	22	Kgs. Enghave	740	ledningsbassin	eksisterende
	23	Gåsebæksrenden	13.000	ledningsbassin	eksisterende
	24	Gl. Køge Landevej	1.700	bassin	eksisterende
	25	Vigerslevparken	13.000	ledningsbassin	eksisterende
	26	Fisketorvet		ledningsbassin	planlagt 2009
	27	Sydhavn 2		bassin	planlagt 2009-2011
	28	Harrestrup Å, Kalveboderne og åben afløbska		ledningsbassin	planlagt
LF	1	RD	40.000	bassiner (2)	eksisterende
Lyngby-Taarbæk	1	Stokkerup	30	bassin	eksisterende
	2	Sien	80	bassin	eksisterende
	3	Taarbæk Strandvej 39	157	bassin	eksisterende
Rødovre	1	Bassin Tårnvej	4.255	bassin	eksisterende