Dimensioning of Sewerage and Drainage Systems in the Nordic Countries

Av Oddvar Georg Lindholm and Jarle Tommy Bjerkholt

Oddvar Georg Lindholm is Professor
and Jarle Tommy Bjerkholt is asc. prof.,
at Norwegian University of Life Sciences. Dept. of
Mathematical Sciences and Technology

email corresponding author: oddvar.lindholm@umb.no

Abstract
In this article the engineering practices for dimensioning the urban drainage and sewerage systems in the Nordic countries are presented and compared. Comparison with the European standard EN-752 "Drain and sewer systems outside buildings - Part 4: Hydraulic design and environmental consideration", is made. Large deviations between the engineering practises are observed.

This article is made in connection with the ongoing European COST C22 "Urban Flood Mangement".

Sammendrag
Avløpssystemer for drenering av overvann fra tettesteder tar oftest utgangspunkt i valg av et visst gjentaksintervall i antall år mellom hver gang det dimensjonerende regn oppstår. Denne artikkelen sammenligner praksis for dette i de nordiske landene og med den europeiske standarden EN-752. Det viser seg at praksis i de nordiske landene er meget forskjellig og Norge har de strengeste anbefalingene. Disse ble lansert av NORVAR i 2005 i "Veiledning i overvannshåndtering" NORVAR-rapport 144.

Background situation
Impermeable surfaces in a city are causing storm runoff and even floods during heavy rain. To avoid damages this flood water must be conveyed through the city in adequate pipes or in open water ways. The normal engineering practise is to calculate the diameters of the pipes so that the water does not fill the pipes more than to the top of the pipe. This should be done for a rain that do not repeat more often than, for instance, once in every 10 year. This means flood damages on average will occur more seldom than every 10th year, because the water must back up the basement floor to do any damage. In figure 1 the principle of how to find the optimal return period of the rain is shown.

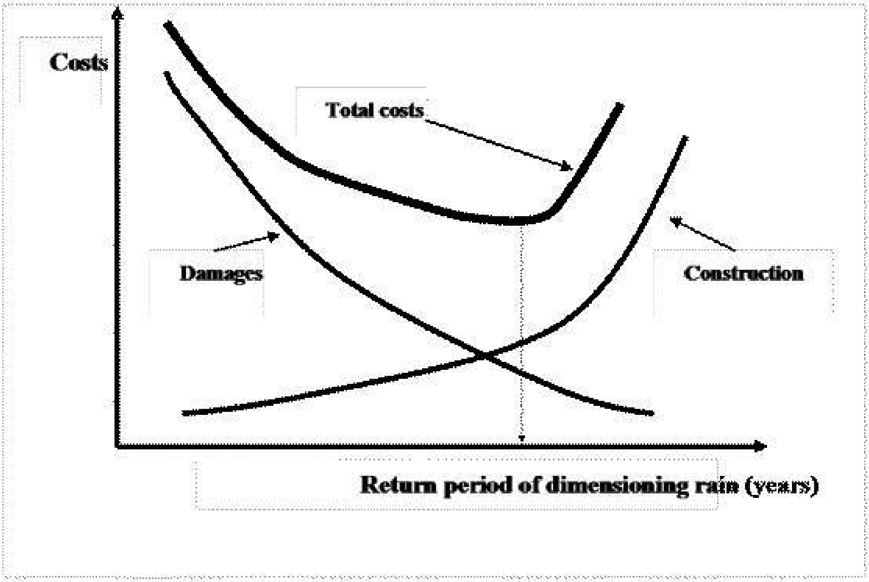

Figure 1. Optimal return period of dimensioning rain.

Most countries and EU have guidelines on optimal return periods. The guidelines are given in form of tables that differentiate between different types of areas, characterised by the damage potential. The areas given the shortest return period are those with the lowest potential for damages, e.g. rural-like areas. The areas with the longest return periods are those with very high potential damages like city centres and underground shopping centres etc. The publishers of the guidelines of return periods had usually in mind that they should be close to what was most economically favourable for the society over a time period of several decades. However, guidelines in some countries are based on a minimum level of service or a minimum average period the most exposed buildings shall experience the criteria fulfilled (e.g. water flooding to basement floor level or pipes that are filled to the top).

The Nordic countries; Denmark, Finland, Iceland, Norway and Sweden have not co-operated intensively in sanitary engineering and urban flooding aspects in the past years. This is reflected in the fact that the engineering practises have developed somewhat different in these countries.

The return periods of dimensioning rains

In this chapter the different guidelines of the Nordic countries for the return periods of the dimensioning rains are presented.

Denmark

The Danish guideline of the dimensioning return periods of the rains are based on what is supposed to be a minimum level of service. They are the minimum return periods of flooding the most exposed buildings shall experience. This does not mean that the guidelines build on the principle of lowest costs from the society's point of view, as illustrated in figure 2.

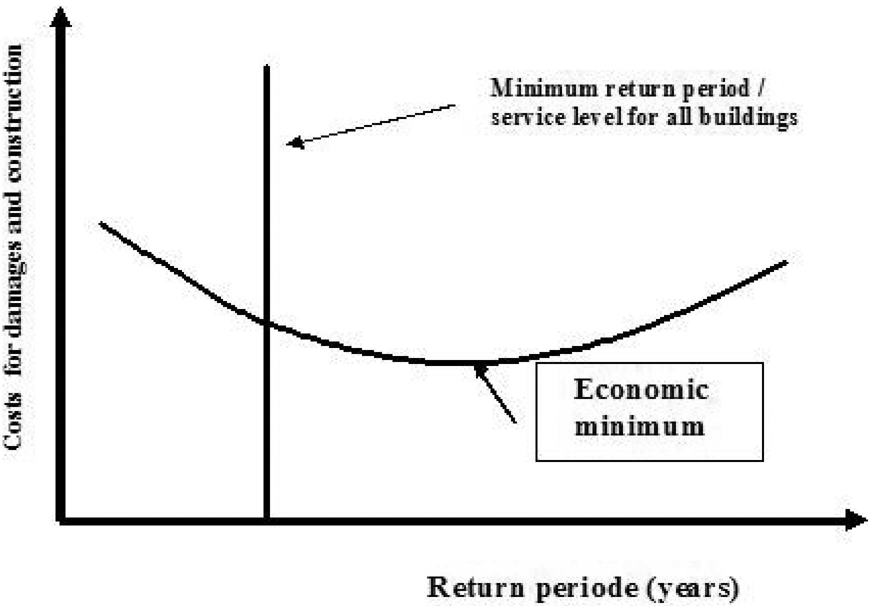

Figure 2. The principle of the Danish guideline for return periods.

The Danish guideline is not aiming at a return period that gives minimum cost for the society. This must be calculated individually for each municipality and location. Table 1 is showing the return periods used in Denmark. It is recommended that the calculations should be made as accurate as possible. Relevant safety factors should be evaluated concrete and explicitly before the calculation starts. The following issues to be considered are mentioned:

- The climate change may increase the rain intensity with as much as 15- 30 %.
- The area of impermeable surfaces in the future may be uncertain.
- Maximum water level in the receiving waters may increase.
- etc.

Type of system	Surcharge to critical level. (ground level)	Only full use of pipe capacity and no surcharge*
Combined sewers	10	2
Separate sewers	5	1

* It is presumed that the simple rational method is used in this case.

Table 1. Minimum return periods for dimensioning rains in Denmark in residential and commercial areas (years). (DANVA, 2005)

It is assumed that the use of the return periods for full running pipes may compare to the capacity one gets when using the return periods for surcharge to critical levels.

Finland

In most cities in Finland the sewers are not as old as in many other cities in Europe. Hence, the separate sewer system is the most common. The flooding problem in urban areas in Finland is therefore not as severe as in most other European cities.

In Finland it is not so common to build basements under residential buildings as for instance in Norway. However, if a basement is built, it is not unusual to install a pump to pump the drainage from the basement to the municipal sewer. The normal rain depth is also rather small compared to many other countries. A rain larger than 40 mm is exceptional. (Silander, 2006).

Table 2 shows the minimum return periods for dimensioning rains in Finland in residential and commercial areas. (Myllyvirta, 2005)

Type of system	Only full use of pipe capacity and no surcharge
Combined sewers	3
Separate sewers	2

Table 2. National engineering practise for return periods (years) in Finland

In areas that are vulnerable to surcharge and damaging flooding, the return periods should be 5 to 10 years. These requirements were formulated in the late 1970-ties and are not revised since.

Iceland

The return periods shown in table 3 are what the Icelandic capital city, Reykjavik is using (Skarphedinsson, 2005). Because there is no national standard, most other cities in Iceland follow the practise of Reykjavik.

Type of system	Surcharge to critical level. (basement floor level)	Only full use of pipe capacity and no surcharge
Separate sewers	10	5

Table 3. National engineering practise for return periods (years) in Iceland.

If the drainage system is an older combined sewer system, the same criteria are used, but one should perform consequence analyses on potential damages and costs of constructions and the solution with lowest overall costs for society should be chosen.

Norway

The Norwegian association for water and sewer works NORVAR, issued national guidelines for dimensioning rain return periods in December 2005 (Lindholm et al., 2005).

These return periods are shown in table 4. The guideline also urges the municipalities to heed the following recommendations:

- Open nature based BMP-solutions should be preferred to conventional ones if possible.
- Urban drainage guidelines should be incorporated into all levels of the normal area planning of the municipalities.
- The municipality should plan for storm runoff that can not be handled by the pipe system to be conveyed in open floodways without causing damages. The dimensioning return period for the analyses of open floodways should be 100 years.
- Polluted storm runoff should be treated before discharging it to receiving waters.

Design rain * (1 in "n" years)	Main type of area of flooding**	Dimensioning occurrence (1 in "n" years)
5	Low damage potential Rural areas	10
10	Residential	20
20	City centre/Industry Commercial	30
30	Underground areas Areas with very high damage potential	50

*No surcharge above the top of pipes

**Flooding allowed to the basement floor level, usually 90 cm above top of pipes

Table 4. Minimum return periods (years) for dimensioning rains in Norway in residential and commercial areas. (Lindholm et al., 2005)

Sweden

In the Swedish national guideline P90 (Svenskt Vatten, 2004) there are many interesting statements concerning urban drainage. The following are mentioned:

- Open nature based BMP solutions should be preferred to conventional ones if possible.
- Urban drainage guidelines should be incorporated into the normal area planning of the municipalities.
- The municipality should demand new buildings to be located so high in the terrain that storm runoff in open floodways does not cause damages.
- It should be possible to temporarily store flood water on the surfaces without damages.
- Polluted storm runoff should be treated.
- The most exposed basements should not be flooded via the municipal pipe network more than once every ten years.
- The critical surcharge level in areas with basements is the floor of the basements. Otherwise the critical level is the ground level.

Type of area	**Surcharge to ground level. Separate sewer systems**	**Surcharge to basement level. Combined systems**	**Only full use of pipe capacity. Separate sewer systems**	**Only full use of pipe capacity. Combined systems**
Outside city area Open area	10	10	1	5
Inside city area Open area	10	10	2	5
Outside city area Closed area	10	10	5	10
Inside city area Closed area*	10	10	10	10

* Closed area = The storm runoff can only drain via the pipe network from this area.

Table 5. Minimum return periods (years) for dimensioning rains in Sweden in residential and commercial areas (Svenskt Vatten, 2004).

It is assumed that the use of the return periods for full running pipes may compare to the capacity one gets when using the return periods for surcharge to critical levels.

It is not common in Sweden that new houses in residential areas are constructed with basements, and if so, it is not common to install a gravity pipe from the basement to the pipes of the municipality, to get rid of the drainage water. A pump is usually installed to pump the water from the basement to the municipal network.

Discussion of the variations of the dimensioning return periods

The European Commission has worked out a CEN-standard for sewer and drainage networks. The dimensioning rain return periods are shown in table 6. This CEN-standard, as virtually all CEN-standards, is adapted in all the Nordic countries, but as stated in EN-752 the relevant authority in each case may decide that another standard should apply.

Design storm frequency* (1 in "n" years)	Location	Design flooding frequency** (1 in "n" years)
1 in 1	Rural areas	1 in 10
1 in 2	Residential areas	1 in 20
 1 in 2 1 in 5	City centres / industrial / commercial -with flooding check -without flooding check	1 in 30
1 in 10	Underground railway / underpasses	1 in 50

*For these design storms no surcharge shall occur

Table. 6. The return periods given in the CEN-standard EN-752.

In Table 7 the Nordic guidelines and the CEN-standard for return periods in central city areas are compared. The following conclusions on return periods may be drawn:

	Separate sewer system		Combined sewer system	
	Only full pipe capacity	Surcharge to critical level	Only full pipe capacity	Surcharge to critical level
Denmark	1	5	2	10
Finland	2	3		
Iceland	5	10	5	10
Norway	20	30	20	30
Sweden	2	10	5	10
EN-752	5	30	5	30

Table 7. Dimensioning return period (years) for city areas in the Nordic countries.

- Iceland, Norway and the CEN-standard do not differentiate between separate and combined sewer systems.
- Denmark, Finland and Sweden use a return period of 2 years or less for full pipes in separate systems, while Iceland and the CEN-standard use 5 years. Norway use 20 years, which is way above the other countries.
- For full pipes in combined sewer systems, Iceland, Sweden and Finland use 5 years, but Denmark use only 2 years and Norway use a return period as high as 20 years.
- For surcharge to critical levels in a separate system, we can see three classes. Denmark and Finland use 5 years or less. Iceland and Sweden use 10 years and Norway and the CEN-standard are way above with 30 years.
- For surcharge to critical levels in a combined system, Norway and the CEN-standard use 30 years and the other countries use 10 years.

It may seem odd that the Nordic countries being close in many ways differ so much when it comes to engineering practise in this field. The return periods of Norway are very long compared to the other countries. The following issues could explain these differences:

- Norway has the last 5 years experienced many big damaging floods in urban areas. This may partly be caused by rather unstable winter climate lately, caused by a global climate change.

During the last years winters it has quite frequently been sub zero temperature periods leading to frozen ground. Then the temperature rapidly rises above zero and the precipitation comes as rain. This rain will then run off completely with possible addition of snowmelt and with no infiltration into the ground.

A climate change has also resulted in higher rain intensities and more rain.

- The pipe networks are often old and not designed to the increasing areas of impermeable surfaces, and climate changes, which has contributed to costly flooding damages. The insurance companies have increasingly become annoyed and distressed by the increasing payments for damages and believe the municipalities are not doing enough to avoid these damages. The insurance companies are therefore suing the municipalities much more often to get repaid what they pay out to the house owners.

- In Norway house owners frequently invest a lot of money in decorations and furniture in the basements of their houses. This utilization of the basements causes high claims against the insurance companies after flooding.

The average claim for such basement damages was in a research project in 2003 found to be 164 000 NOK corresponding to 21 000 Euro. (SINTEF, 2004).

- In 2001 a new paragraph in the Pollution Control Act appeared which stated that:

> "The owner of a sewer or drainage system is responsible for the damages the drainage or sewer

system causes if the hydraulic capacity of the system is not sufficient to avoid flooding. The owner also has full responsibility if the damages are caused by inadequate maintenance and operation".

Even if the owner has dimensioned the system in accordance to the normal engineering practise he will be responsible.

However, the new law paragraph replaced an older paragraph that said the owner should be free of all responsibilities if the rain was bigger than what could be reasonable to plan for, so called "act of God" a situation which the owner could not possibly take into account. These events are called "force majeure". Former legal trials in courts acquitted the owners (the municipalities) for liability if the return period of the rains where higher than 10 years. In more recent years the acquitting return periods have increased from 10 years and up to 30 years.

In the new law paragraph the concept of force majeure is not mentioned. The lawyers of the insurance companies therefore claim that the municipalities now always are responsible if damages are cause by undersized capacity of the drainage systems. However, on the contrary the municipalities claim that the concept of force majeure is still valid. To avoid time consuming and expensive law suits this new law paragraph has made the municipalities more interested in using longer return periods for the dimensioning of rains.

- The Norwegian guideline is aiming at return periods that are close to an economic minimum sum of construction costs and damages for the society. The Danish guideline is explicitly saying that the return periods are a minimum service level and not an economic minimum.

- It is reasonable to assume that a guideline that differentiate between different types of areas (or different degree of potential damage) are aiming at a minimum economic cost for the society and that a guideline that do not differentiate between different types of areas are aiming at a minimum service level for the most exposed buildings. This fact also partly explains the differences between the Nordic countries.

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