12/19

Høgskolen i Østfold
Avdeling for ingeniørfag

EXAM

Subject: IRB36012 000 **Teacher: Geir Torgersen**
Water and environmental engineering

Groups: **Erasmus students 2012/13**	**Date: 03.12.12**	**Time: 0900 - 1300**
Problem pages: 4	**Attachment pages: 4**	
Permitted aids: Pocket calculator (handed out), English - Spanish language dictionary without any notes, No electronic dictionaries are permitted. No books, notes or notepaper except the dictionary are allowed.		
Comment: All sub tasks (a, b, c etc.) has the same value **Relevant formulas are shown in attachment nr 1 and 2.**		
STUDENT MUST MAKE SURE THAT THE PROBLEM SET IS COMPLETE		

Task 1 – WATER SUPPLY

Figure 1 shows a sketch of water supply system to a village in eastern Norway. By the water source, there is a water treatment plant and a pumping station. A tank is located at A. In B the pipe from the tank reach the upper part of the village. The countryside fell with a constant slope from the tank A, to B and down throughout the whole village.

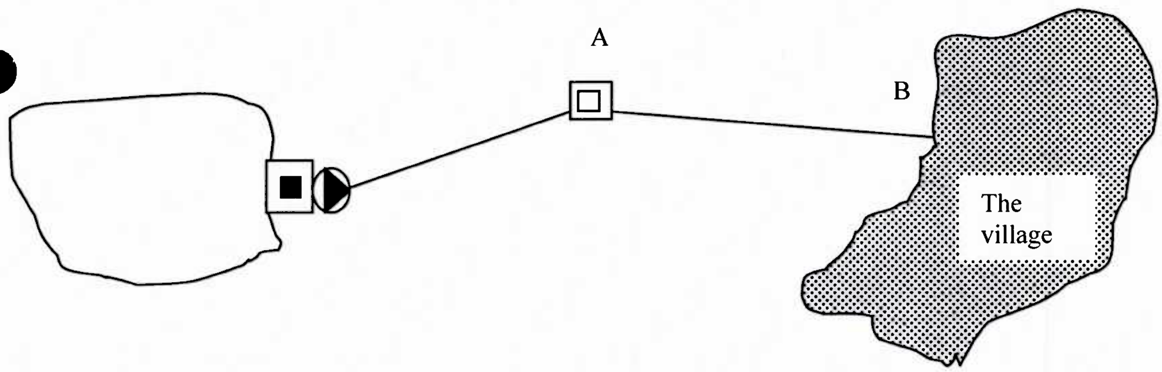

Figure 1

Tank (A) (maximum water level in the tank)	115 m AMSL (above main sea level)
Upper part of the village (B)	80 m (AMSL)
$Q_{average\ consume}$ (persons and industry)	20 l/sec
Q_{leak}	10 l/sec
Max consume per day (factor) f_{max}	1,5
Max consume per hour (factor) k_{max}	2,0
$Q_{fire\ fighting}$	12 l/s
Length from A to B	1500 m
Darcy friction factor f (incl. singularity losses)	0,02

It is planned a new PVC pipe from A to B. The tap pressure by the customers living at B must have at least 10 mVS (metres of water) at maximum tapping incl. fire water. Possible dimensions of the pipe are shown in the table below:

Dimension (external diameter) PVC mm	*Thickness of the pipe PVC Mm*
ø110	*5,3*
ø160	*7,7*
ø250	*11,9*
ø315	*15,0*
ø400	*19,1*

a) Find Q_{dim} for the pipe from A to B.

Find by using the Darcy Weisbach formula the required dimension of the pipe from A to B.

b) The tank in figure 1 should have a volume reserve for a maximum daily consume in 24 hours and 4 hours for fire fighting.

Find the required volume of the tank.

c) Draw a typical section of a trench with water pipe, sanitary sewer and storm sewer.

Explain the reason for the order of the pipes in both horizontal and vertical direction.

d) Why is disinfection so important in a water treatment plant?

Name the two most used methods for disinfect water in Norway.

Name one advantage and one disadvantage with each method.

Explain what is meant when it's required that a water supply system needs two hygienic barriers.

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Task 2 – WASTE WATER

A new residential area is planned in Fredrikstad. For the sewer it will be a separate system. Figure 2 shows the drain area and the sewers in the area. From B the storm water is directed to the stream in C while the sanitary water is directed to the waste water treatment plant.

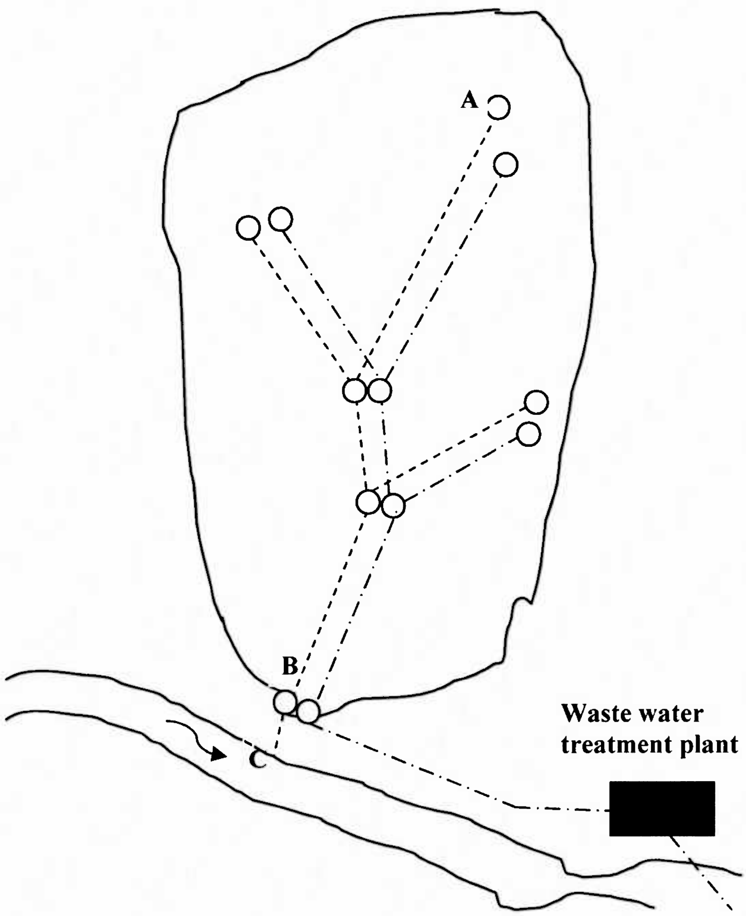

Figure 2

The whole area is 20 hectares (ha). All the water in the area is collected in B. It's calculated that with a maximum rainfall it will take 4 min for a drop of rain from the outer edge of the field until it reaches the manhole in A. Furthermore, it takes about 11 min for the rain drop in the storm sewer from A to B.

a) Assume that Imhoff's sentence applies to this area. Attachment 3 shows the intensity-duration-frequency curves for Fredrikstad (use 5-year frequency, second lowest curve).
Use the table at the bottom of Attachment 3 and find a suitable runoff coefficient. Then find the maximum storm water flow at B (l/sec))

b) Storm water from B will be led in a storm sewer to the nearest stream in C. The pipe has a roughness k= 1.0 mm and the slope is 3 ‰.

Design the pipe from B to C by using Colebrook's diagram in attachment 4.
(Standard diameters 800 mm, 1000 mm, 1200 mm, 1400 mm, etc.).

c) After some years the area is fully developed, and it appears that there is much more water from the drained area to the storm sewer than expected. When heavy rainfall, there will be basement flooding for those living in the lowest part of the area.

Describe some possible technical solutions to reduce and delay the flooding from this area.

d) In a city in Eastern Norway it has been calculated the following amounts during the year:

- Drinking water out of the water treatment plant to the water pipes: 9.7 million m^3pr. year
- Drinking water to the consumer: 5.5 million m^3pr. year
- Waste water that comes to wastewater treatment plant: 14.5 million m^3pr. year

Explain, preferably with a sketch, why the amounts are different and where the water in and out of the pipeline system comes from.

Task 3 WASTE

a) What is meant by Municipal solid waste (MSW) and industrial waste?

Describe some differences between these two groups of waste from the origin, quantities and fractions.

b) Sludge is a residual product of the wastewater treatment plant.

Describe how the sludge can be treated and dispersed so that resources could be used in the best possible way.

FORMULAS (1) –

(Not all formulas are necessary to use on the exam)

WATER CONSUMPTION

Peak factors:
f is the peak day factor, Q_d is the daily water consumption
k is the peak hour factor, Q_h is the hourly water consumption

$$f_{maks} = \frac{Q_{d\ maks}}{Q_{d\ average}}$$

$$f_{min} = \frac{Q_{d\ min}}{Q_{d\ average}}$$

$$k_{maks} = \frac{Q_{h\ maks}}{Q_{h\ average}}$$

$$k_{min} = \frac{Q_{h\ min}}{Q_{h\ average}}$$

HYDRAULICS
Bernoullis equation

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + \Delta h_{tap}$$

- z_1 is the height above sea level in 1, z_2 in 2
- The pressure head $\frac{p_1}{\gamma} = h_1$ og $\frac{p_2}{\gamma} = h_2$
- The velocity head in 1 and 2 are very little in this example
- Δhl_{oss} er the loss from 1 to 2
- The equation can be simplyfied like this:
- $z_1 + h_1 = z_2 + h_2 + \Delta h_{loss}$

Continuity equation:

$$Q = A_1 * V_1 = A_2 * V_2$$

Where:
Q = the volumetric flow rate
A = the cross sectional area of flow
V = the mean velocity

Darcy Weissbachs formula:

$$h_f = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

where
h_f is the head loss due to friction;
L is the length of the pipe;
D is the hydraulic diameter of the pipe (for a pipe of circular section, this equals the internal diameter of the pipe);
V is the average velocity of the fluid flow, equal to the volumetri flow rate per unit cross-sectional wetted area;
g is the local acceleration due to gravity;
f is a dimensionless coefficient called the Darcy friction factor.[citation needed] It can be found from a Moody diagram or mor precisely by solving the Colebrook equation.

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ATTACHMENT 2

FORMULAS (2) –

(Not all formulas are necessary to use on the exam)

SEWAGE FLOW

Sanitary sewer

- $Q_{dim} = Q_{ave} * f_{max} * k_{max} + Q_{inf}$

Q_{inf} = maximum infiltrated flow

$f_{max} = Q_{max\ 24\,h} / Q_{ave\ 24h}$

$k_{max} = Q_{max\ hour} / Q_{ave\ hour}$

combined sewer

- $Q_{dim} = Q_{ave} * f_{maks} * k_{maks} + Q_{inf} + Q_o$

Q_o = storm water

Calculating storm flow

Rational method $Q = c\ A\ i$

Q = drained waterflow from the area (l / s)
c = Rational method runoff coefficient
i = Rainfall intensity, l/s*ha
A= Drainage area (ha)

Time of concentration

t_c is the time of concentration. That means the time for a raindrop to fall from the outer edge of the area until the outflow from the area.

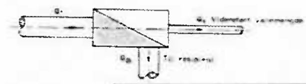
$t_c = t_s + t_t$ where

t_s is the time rainwater for overland flow from the most remote point in the drainage area until the pipeline
t_t is the time for flow the pipeline

OVERFLOW

Critical flow

Critical flow in an overflow



The flow to the overflow: $Q_T = Q_S + Q_{inf} + Q_O$

The critical flow is the storm sewer Q_O:

$Q_{O\,kr} = \phi * A * i_{kr}$ (the rational fomula)

(For convenience we write: $\phi * A = A_{red}$ reduced area)

When Q_T has reached an predefined limit then water will go through the overflow. This is called critical flow Q_{Tkr}:

$Q_{Tkr} = Q_S + Q_{inf} + (A_{red} * i_{kr})$

i_{kr} Is the critical intensity of the rainfall (l/s*ha) . When $i > i_{kr}$ water is in the overflow

Flow regulation factor in overflows

$$n = \frac{Q_{Tkr}}{Q_S}$$

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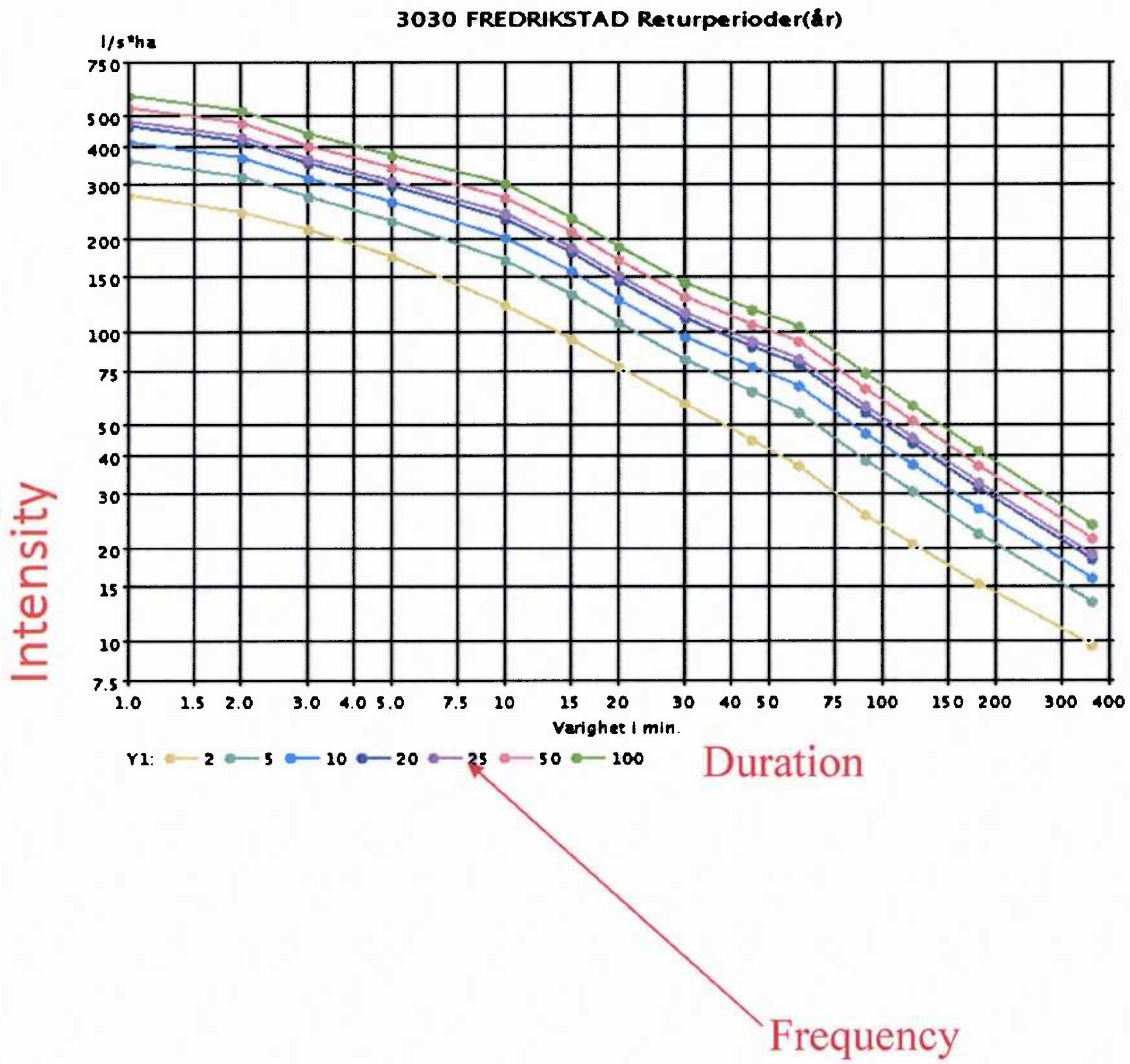
ATTACHMENT 3

Intensity-duration-frequency curves



Runoff coefficients:

Sealed areas (roof, asphalted places, roads etc.)	0,85-0,95
Inner city	0,70-0,90
Row houses, flats-areas	0,60-0,80
Residential areas	0,50-0,70
Gravel roads and places	0,50-0,80
Industrial areas	0,50-0,90
Lawns, parks, cultivated area	0,30-0,50
Highlands, mountains without vegetation and forest	0,50-0,80
Highlands, mountains with vegetation	0,30-0,50

ATTACHMENT 4

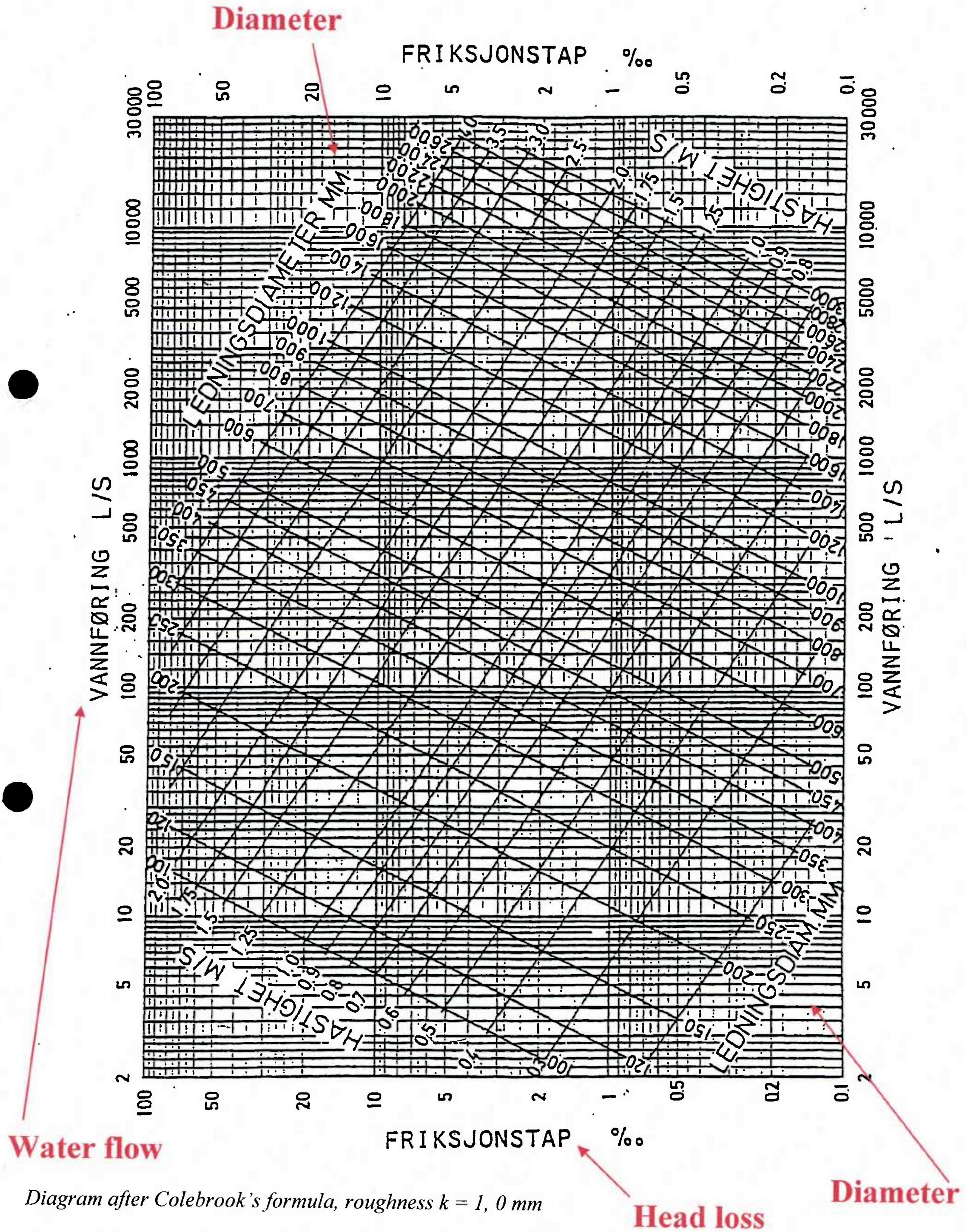


Diagram after Colebrook's formula, roughness k = 1, 0 mm