Swales: guidelines for design, construction, and maintenance

Based on a six year monitoring programme in Enschede, The Netherlands

Introduction

Urban drainage can cause problems such as peak discharges into surface water, combined sewer overflows, shortage of water during summer, and high ground water tables in the winter period. In the late nineteen nineties the Dutch municipality of Enschede designed a new drainage system for a new housing estate called '*Ruwenbos*'. This publication describes a six year monitoring programme and recommends a set of guidelines for the planning, design, construction, and maintenance of swale systems.

Design of a sustainable urban drainage system

The most typical elements of the drainage system in '*Ruwenbos*' are the swales infiltrating rain water into the soil. All run-off is guided through gutters along the streets and in this way is kept visible on the surface. The gutters guide the rain water to the swales. In each swale the water is stored to a level of approximately 0.25 metres, a level designed to be exceeded only once every two years. Above this level gullies, also called 'gluttons', discharge the surplus to a subsoil infiltration body made up of expanded clay grains wrapped in a geo-textile. Once every twenty-five years the water level in the swale reaches a depth of 0.35 metres. Above this level the water is discharged into the next swale and, in the end, into the surface water. At the bottom of the infiltration device underneath the swale drainpipes spread the water through the infiltration body and drain the area when ground water tables are high. In this manner the swale system combines the drainage of ground and rain water in the wet winter periods with storage and infiltration during the dry summer periods.

Maintenance of swales

Due to the use of mowing machines, playing children, and the sedimentation of silt some parts of the grass vegetation in the swales have become bare. Mowing when the soil is still moist leads to tracks. Using heavy machinery also causes reduction of the infiltration capacity of the upper layer of the bottom due to condensing. Furthermore experience showed that the slope between the swale and the surrounding field should not exceed 1 to 3 in order to allow mowing machinery to enter the swale.
For good functioning the sweeping up of fallen leafs and rubbish is recommended. The municipality cleans the gluttons twice a year and the drainpipe once every year. Maintenance of the swales systems needs good gearing of the different activities to one another.

Monitoring

The municipality of Enschede conducted a monitoring programme in one swale from May 1999 until May 2005. In the first three years many samples were analysed. The last three years the swale was monitored less intensively. In the latter period the focus was on long term processes such as the accumulation of pollutants.

Hydraulics

The period from May 1999 until May 2002 was wetter than average. Almost all run-off (about 99%) infiltrated into the soil and ground water instead of being discharged to surface water or the waste water treatment plant. The swales are mostly emptied within 24 hours. These measurements are confirmed by observations of the inhabitants. Analysis of times to empty with infiltration capacity tests shows no loss of infiltration capacity at the site of the monitoring programme.

Pollutants

Run-off is contaminated by the surfaces. Concentrations in rain water vary greatly by type of pollutant or by type of water, but in general run-off from roofs is cleaner than from streets. High concentrations of some pollutants can be explained by high concentrations in the ground water. PAH's and heavy metals accumulate in the top layer of the soil of the swale. These pollutants attach strongly to floating particles in the runoff and are deposited in the soil because of infiltration and adsorption processes. The

pollutants are also deposited outside the swale but there the concentrations are not as high as in the bottom of the swale.

Geo-textile
In 2005 three samples of the geo-textile around the expanded clay grains were taken and analysed. This showed a strong reduction in its infiltration capacity. Nevertheless the infiltration capacity was still higher than in the surrounding soil.

Costs
For construction of a swale system the costs per square metre of discharging area in *Ruwenbos* are a slightly less than the costs of a traditional sewer system. Costs for maintenance though are a bit higher compared to a traditional rain water system.

Inhabitants enquiry
Two enquiries (one in 1999 and one in 2005) have mapped the experiences of the inhabitants. In general the inhabitants were more satisfied with the swale system in 2005 compared to 1999: 98% of the inhabitants in 2005 to 94% of the inhabitants in 1999 declared they were satisfied with the functioning of the swales. If they move, only a 2% (2005) respectively 6% (1999) of the inhabitants wouldn't chose again for an area drained by swales.

Experiences of the inhabitants
Moist and soggy gardens are the main reason for complaints in the housing estate. The majority of the residents maintain the recommendations about not using weed killers and about not washing their cars in the street.
Inhabitants accept the conditions more in 2005 compared to 1999. Most are unconcerned about puddles of rain water on the street or slippery paths during times of frost. The residents have had problems with the design of how the swales cross the streets. As they are made of pebble stones they have caused some minor accidents with pedestrians and cyclists. The same has happened due to the poor design of the gutters.
More than 50% of the inhabitants would appreciate complementary measurements to make the urban drainage system in their area more sustainable. Popular ideas concern re-use of rain water for toilet flushing, a rain barrel, or the construction of ponds.
The inhabitants have put forward some recommendations about the swale system. They have noticed that swales are sometimes abused as parking lots or a place for walking the dog. Furthermore they are not always sure what to do or not do to stimulate the effective functioning of the swale system. Some residents would appreciate a more natural type of vegetation in and around the swales. In general though most inhabitants find the swales contribute to the scenery and their living environment.

Experiences of the municipality of Enschede
During the planning, the development, the construction, and the maintenance of *Ruwenbos* the municipality has gained a lot of valuable experience. Communication skills during planning turned out to be very important. Through the early integration of all the involved parties and other organisations, chances were created for coherent design instead of transferring some problems to the future.
Construction and maintenance demand special attention, among other things, the drainage during the construction phase, loss of infiltration capacity due to construction activities, the way the mowing is managed, the policy for gritting icy roads, and the maintenance of drainpipes. In practice it appears very difficult to integrate all parties involved at an early stage. This calls for extra investment of which not everybody sees the short term returns.
Technical knowledge of sustainable urban drainage systems is far from completed. National and some local policies don't keep up with good practices. In *Ruwenbos* the design of the urban drainage system turned out to be quite a job. On the other hand people appeared willing to discuss the issue of water. This can improve the social commitment of the inhabitants.

Design guidelines
The combined experiences from *Ruwenbos* and the application and evaluation of a lot

of other swale systems for sustainable urban drainage systems in The Netherlands have added up to some design guidelines as shown in the table below.

Parameter	**Unit**	**Recommended value**
Infiltration capacity	m/day	> 0.5
Distance to average highest ground water table	m	> 0.5
Thickness of filter soil	m	0.3 – 0.5
Area swale to drained area	%	5-10
Distance to houses	m	> 1
Infiltration percentage	%	70 - 99
Swale water depth	m	0.3
Spare capacity	m	0.1
Time to empty	hour	< 24
Width of bottom	m	> 0.5
Width of water surface at discharge level	m	4
Slopes	-	1:3 or less