Maintenance of SUDS

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ABSTRACT

Since the last decade, water management in new housing developments is focussed on infiltration and storage of storm water into the soil, rather than discharging it by sewers to purification plants. This new policy has brought many of innovative systems for infiltration of storm water in Dutch municipalities, so-called SUDS (Sustainable Urban Drainage Systems). Some of these systems are monitored quite accurate, which brought valuable insight in the quantitative and qualitative functioning on the mid-long term. But, after the design and construction, most municipalities pay little attention for management and maintenance. To change this situation, the Dutch RIONED Foundation set up Guideline C3200 for the management and maintenance of infiltration facilities. This guideline states which research and which practical management measures are necessary. The guideline is based on knowledge about daily practise and on specifically performed analysis which has been carried out to identify the important degradation mechanisms. In this paper we first give a brief overview of the various types of common infiltration devices and the results of Dutch experiments on those systems. Then we describe the essence of Guideline C3200 and present management diagrams, which for each object mention the possible management activities and frequencies.

KEYWORDS

Sustainable urban drainage systems; infiltration facilities, storm water, pollutants; maintenance; management

INTRODUCTION

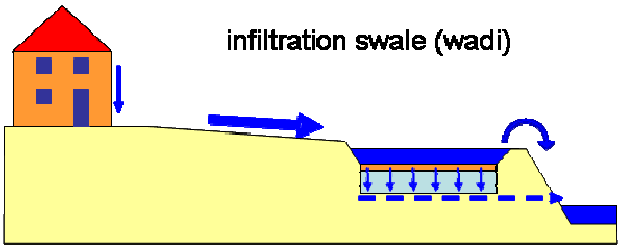
New policy guidelines regarding the design and operation of urban drainage systems have brought many innovative systems for infiltration of storm water in Dutch municipalities. But, after the design and construction, most municipalities pay little attention to management and maintenance. And only a few (pilots) have an extensive monitoring program to follow the qualitative functioning in the long term. In practice, maintenance is only performed when calamities (flooding or damages) occur. Although the concepts of SUDS are widely spread, yet little practical knowledge is available for operation and maintenance of infiltration systems.

In the first part of this paper we will present a short overall view of the types of infiltration systems, used in the Netherlands and the most important monitoring programs. In the second part we will focus on the maintenance of infiltration devices.

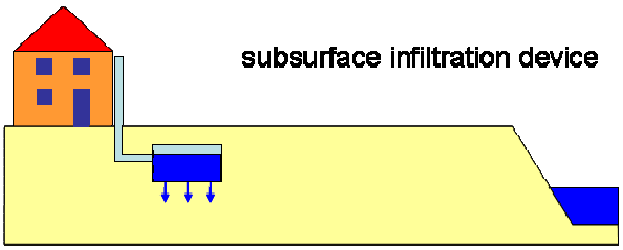
SUDS IN THE NETHERLANDS

Infiltration devices are subdivided by the ways they infiltrate the rainwater.

- *Surface-infiltration*
  Stormwater flows over streets to a swale. In the swale, the stormwater infiltrates into the underlying soils. In the Netherlands, surface-infiltration is considered to be potentially the best way to infiltrate stormwater. The topsoil matrix functions as a filter and causes an efficient removal of several pollutants. Theoraticcaly, the removal rate is higher than from the other systems, due to the precence of the topsoil layer. Because the facility is visible, the maintenance is rather easy. Also, wrong connections will not easily occur. Implementation of swales requires skilled spatial planning in densely populated urban areas in the Netherlands.



- *Subsurface-infiltration*
  Stormwater flows through a pipe in a subsurface infiltration device. This device stores the water and drains it into the ground. Subsurface infiltration systems are easily applicable in dense populated areas. Most common are infiltration sewers and infiltration boxes (soakaways). Maintenance in case of cloaking or pollution is difficult and often only effective in a limited way. High groundwater tables in some parts of the Netherlands limit the application of these systems.



- *Permeable pavement*
  A system with permeable pavement contains in most cases two elements. The pavement (mostly paving stones) has a very high permeability. Under the pavement lies a foundation layer, consisting of granulate. This layer stores the water and drains it into the ground.or on surface water. The system is applicable in densely populated areas and also in areas with high groundwater tables and a low permeable soil.

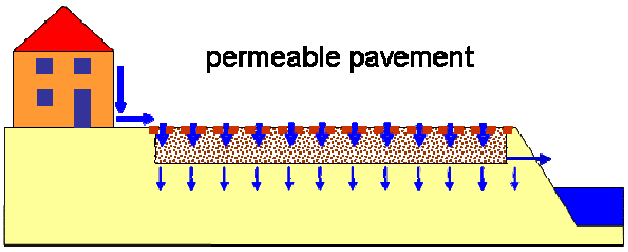


Table 1. Matrix infiltration systems and objects

objects	systems		
	surface infiltration	sub-surface infiltration	permeable pavement
topsoil layer	x		
infiltration pipe (with holes)		x	
infiltration pipe (pervious concrete)		x	
infiltrationwell		x	
infiltration box	x	x	
infiltration trench	x	x	
permeable pavement (porous concrete elements)			x
permeable pavement (open jointed elements))			x
groundwater drain	x	x	x
rainwater sewer	x	x	x
open street gutter	x		
slotdrain	x		
gully pit		x	
geo-textile	x	x	x
control unit	x	x	x
overflow weir	x	x	x
silt trap / filter	x	x	x

An infiltration system consists of several objects. These objects play a major part in the management and maintenance of the system. **Table 1**table 1 shows the objects of which infiltration systems exist.

OVERVIEW DUTCH EXPERIENCIS

In the last decades, several researches have been done in the Netherlands to get insight in the long run functioning of infiltration systems. Some of these research projects are shown in table 2.

Table 2. Research projects in the Netherlands

year	name/location	reference	type of infiltration facility	Research aim	
				quantity	quality
1999-2002	Ruwenbosch, Enschede	Boogaard (2006)	infiltration swale	x	x
2001	Loerik, Houten	Schipper (2003)	infiltration swale		x
2003	Motorways, Province Utrecht	De Best (2003)	verges	x	x
1997-2007	Geren en Schellerhoek, Zwolle	Beenen (2008)	infiltration trench	x	
1999-2007	Runstraat, Eindhoven	Beenen (2008)	soakaway		x
2001	Labscale survey Dyka	Lemmen (2001)	infiltration pipes	x	
1999-2007	Delft		infiltration device		x
2001-2002	Den Bosch, de Vliert		infiltration pipes		x
2007	Arnhem	Langeveld (2008)	infiltration swale/ mechanical sand filter		x
1997-2007	Hilversum	Beenen (2008)	soakaway		x

Some specific research at the impact of infiltration of storm water on the groundwater- and soil quality has been done at 12 different sites in Holland (Beenen 2008) which mainly consisted of locations with high groundwater levels and low permeable soil. After twelve years of monitoring neither significant loading of pollutants nor a significant loss of infiltration capacity has been discovered at the infiltration facilities. This means that no ecological or health risk to the local population for a period of at least forty to fifty years has been found. Therefore subsurface infiltration with relatively high ground water tables is possible, and the useful life span of these constructions is comparable to those of normal sewer systems.

Most of the projects shown in table 2 are funded by municipalities and water authorities to get insight of the functioning of infiltration facilities. The researches are mainly to do with studies to predict the amount of storm water they infiltrate, the impact on the environment or the social relevance of these structures.

Next to this research projects, several municipalities have gathered information on a smaller scale. Based on the conducted researches, the following conclusions can be drawn.

Water quality

- The topsoil layer of an infiltration swales en verges collects a considerable part of the pollution in the infiltrating storm water. Based on monitoring of the storm water before and after nfiltrating, the following removal rates have been measured:

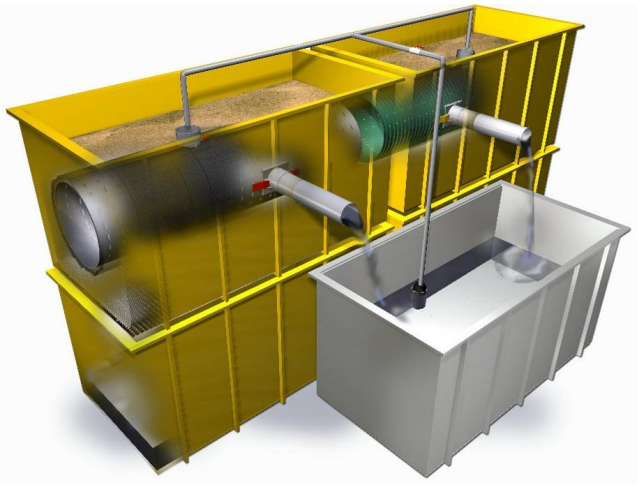
	Utrecht (De Best 2001)	Arnhem (Langeveld 2008)
Copper	74%	74%
Lead	81%	65%
Zinc	76%	85%
Kjeldahl-nitrogen		55%
Phosphorous		40%

- Part of the pollution will reach groundwater. However, in common, measurements of the quality of the groundwater didn't show a large increase in concentrations.

Water quantity

- In the Netherlands, at many locations where infiltration devices are applied, the infiltration capacity of the soil is fairly low (k values of 0.5 to 2 m/day). At some locations, a few years after the construction, the infiltration capacity has a little decreased. This seldom leads to unacceptable situations.
  Incidentally it occurs that the infiltration capacity turns to almost zero. This happens generally by high freights of organic substances and very fine parts. Especially during the construction phase infiltration supplies can get heavily polluted in a short time.

- The above mentioned picture is confirmed by a laboratory study where several infiltration sewers (pvc, ø315 mm) have been charged with water mixed with high concentrations sediments of road surfaces. The infiltration capacity has been measured at a constant water depth of 67% of the altitude of the pipe. The length of the tubes was 2 m.



  First, the infiltration capacity decreased strongly. However, at a quantity of sediment that corresponded with a lifespan of a dozens of years, the infiltration capacity remained constant on a value of approximately 1 m/day.

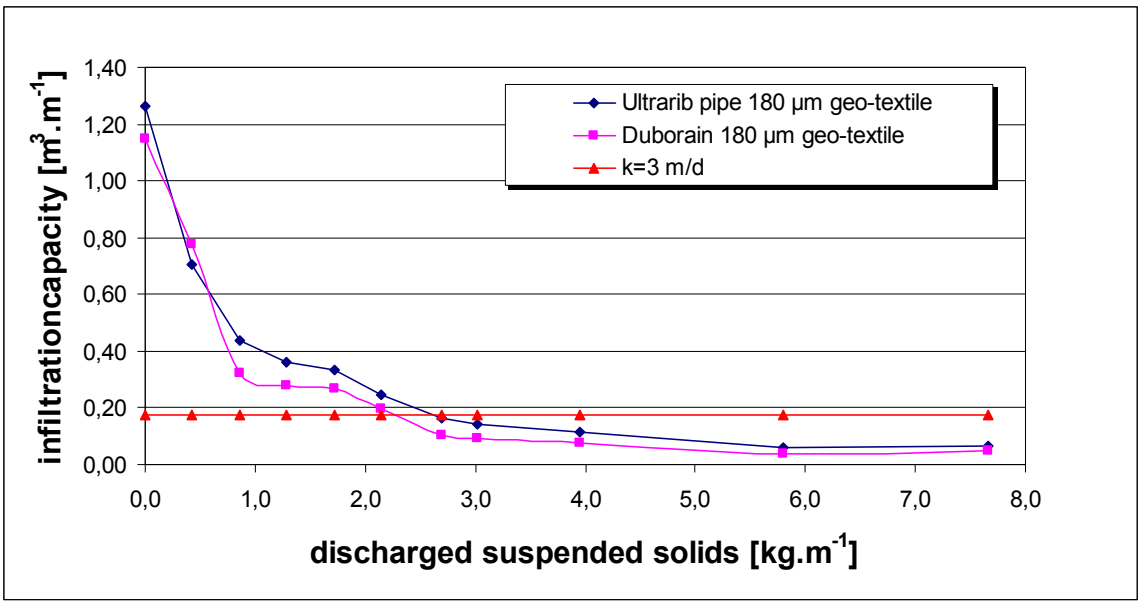


Figure 1. Relation pollution load - infiltration capacity

MANAGEMENT OF INFILTRATION FACILITIES

Towards a structural management

Relatively little experience has been obtained about the long time behaviour of infiltration facilities. Most facilities have been realised the last five up to ten years. The development of new systems is still going on. The needs for a professional way of management of infiltration facilities increase.

Although several monitoring programs have been executed, In practice most municipalities have little knowledge about the functioning of their infiltration facilities. Maintenance is only performed when calamities (flooding or damages) occur. Although the concepts for infiltration of storm water are widely spread, yet little practical knowledge is available for operation and maintenance of the facilities.

To change this situation, the consultancy firms Grontmij and Tauw have written the guideline C3200 for the management and maintenance of infiltration facilities. The guideline is part of the Urban Drainage Guidelines, published by the RIONED Foundation. The guideline C3200 appoints which research and which management measures are necessary.

Corrective versus preventive measures

Corrective maintenance is defined as maintenance work which involves the repair or replacement of objects which have failed or broken down. Preventive maintenance includes both condition-monitoring and life-extending tasks which are scheduled at regular intervals. The choice for one of both methods depends on the following criteria:

- direct damage and effects of failure;
- insight in causes of reduced function;
- effort for collecting and assessing data.

The direct damage and effects of failure of the objects ascertain whether a preventive or a corrective treatment is needed. To determine which preventive measures to take, insight is needed in the mechanisms which cause the objects to fail. At a preventive approach, there's a distinction between a situation dependant and a use (or time) dependent approach. At a situation dependent approach, research will take place into the state of the object. It is necessary that criteria for the

functioning of the object have been defined (e.g. “an emptying time of max. 24 hour” or “pollutants must not exceed the reference concentrations”). At a use (time) dependent approach, maintenance takes place after a certain time or a certain load. The choice between a situation dependant or use dependent approach depends on the effort which is necessary to collect and assess data about the state of the object.

To carry out maintenance measures effectively, insight is needed in the causes of a diminished function of the infiltration facilities. In the guideline, an analysis has been carried out into the degradation mechanisms.

Causes of diminished functioning of suds
Diminished functioning of SUDS can be defined such as:
- reduction of the infiltration capacity;
- reduction of the storage capacity;
- reduction of the discharge capacity (in an overflow situation);
- pollution of soil and groundwater.

In the guideline, the different processes, which are responsible for the diminished functioning, have been defined. To this the direct causes have been coupled. In table 3 these aspects have been incorporated in a matrix.

Table 3. Matrix causes diminished functioning

		causes															
dimished function of SUDS	**proces**	streetlitter	litter from construction sites	falling leaves	iron deposits	humid conditions	other grow conditions	entering of the object	lawn mowing	sinking of overflow weir	rising of bottom swale	roots	overgrowing of overflow constructio	uneven subsidence	pollution stormwater	loading of soil	de-icing salt
reduction infiltration capacity	silting up	●	●	●	●												
	deterioration of vegetation					●	●	●									
	compaction							●	●								
reduction of storage capacity	subsidence									●	●						
	deposits	●	●	●													
reduction of discharge capacity	clogging	●	●	●								●	●				
	reduced pressure gradient													●			
pollution	soil														●		
	groundwater														●	●	●

For all objects of SUDS an analysis has been made of the processes which are responsible for the diminished functioning of the objects and the direct causes. In the following framework, an example has been given for the top layer of an infiltration swale.

Example: Causes for diminished function of the topsoil layer of an infiltration swale

- *Reduction of the infiltration capacity*
  Pollution, caused by building activities, or falling leaves can cause clogging of the topsoil layer. Also, the vegetation can die in parts of the swale where water continues to stay (the lowest parts). By the dying of the grass, the infiltration capacity decreases further. This process reinforces itself.
  During time, the percentage organic matter in the topsoil increases slowly, caused by dead plant parts. Because of this the permeability of the soil can decrease. Compaction of the top layer, caused by playing children, parking cars, or lawn mowers, can also lead to a reduction of the infiltration capacity
- *Reduction of the storage capacity*
  Because of the small storage height of the topsoil layer, a small sinking of the overflow device, has a large impact on the storage capacity. Also the rising of the topsoil layer, due to plant rests, reduced the storage capacity. The influence of suspended solids in the storm water on the storage capacity is limited.
- *Change in quality*
  The amount of pollution in the storm water determines for a major part the pollution of the topsoil layer and the infiltrating storm water. Pollutants are more or less removed through i.e. filtering and sorption. Salt (de-icing) and fresh organic matter (plant rests) can lead to desorption.

Management diagrams

The directive presents practical guidelines for the management of infiltration devices. This is implemented in management diagrams, which for each object mention the possible management activities and frequencies. The management diagrams describe the possibilities for research, such as inspections or measuring.

Table 4 and table 5 show examples of management diagrams for the investigation and maintenance of the topsoil layer of an infiltration swale.

Table 4. Management diagram investigation topsoil layer

nmbr	investigation	periodic frequency	on the basis of investigation nmbr:
1	visual inspection	1/y	
2	simple measurement time to empty	1/y	
3	detailed measurement time to empty		2
4	measurement pemeabiilty topsoil		2
5	geosurvey	1/5y	
6	taking sample groundwater	1/5y	
7	taking sample soil	1/5y	
8	investigation false connections		1

In the management diagram about the investigations, you can see that visual inspection of the topsoil layer and a simple measurement of the time in which the water in the object has been infiltrated, once a year, is recommended. A simple measurement means that one day after a shower, there is a visual check if the object is dry already. A more detailed measurement is necessary, only if the simple inspection shows that there is water in the swale too long.

Table 5. Management diagram maintenance topsoil layer

nmbr	measure	ongoing	periodic freq.	on the basis of research nmbr:
1	preventing of entering and parking	x		
2	lawnmowing		2-26/y	
3	removal of mown grass		2-26/y	
4	removal of litter		2-52/y	
5	removal of leaves		2-4/y	
6	cleaning streets		4-12/y	
7	sowing			1
8	fertilising			1, 2, 3, 4
9	verticutate			1, 2, 3, 4
10	fill up low spots			1
11	removal of silt			1, 2, 3, 4
12	lowering (scraping) of the verge			5
13	replacing topsoil layer			6, 7

The management diagram about the maintenance of the topsoil layer shows three types of measurements. The first type is an ongoing process, like giving information to prevent entering the topsoil layer and parking on it. The second type of measurement follows the time dependent approach. These are repetitive actions like mowing and removing of litter and leaves. The frequencies in the table are an advice to start with. Once there is more information about the functioning of the object, the administrator can adjust the frequency. The third type of measurements will be executed on the basis of the results of investigations. This is the situation dependent approach. Sowing is necessary, only if visual inspection (investigation number 1) shows that there are bald spots in the swale. Replacing of the topsoil layer is necessary if samples of the groundwater or the topsoil show an unacceptable amount of pollution.

Basic rules for good management of SUDS

Good management starts with a good and univocal recording of the basic facts of the objects (amongst others location, dimensions, fabric, etc.). Also, the main points of the design have to be recorded, as the results of inspections and investigations.

The management diagrams give for each object an impression which activities are necessary and which frequencies. However, the administrator must fine-tune the management with his own experiences, bases on the local situation.

The management of SUDS has connections with several fields of expertise, e.g. sewerage, green, roads. In the Netherlands, these fields of expertise form separate organisational entities. For the management of SUDS harmonisation has been required between these organisational entities
It is important that one person is clearly designated as administrator of the SUDS. This person is responsible for the organisational and financial harmonisation. The management of SUDS is strongly in development, the recording of experiences is vital; therefore, the importance of a strong administrator is extra large. The management of infiltration supplies means more than only engaging services of others and prescribing frequencies for mowing grass. To obtain insight in the functioning of the objects an active role of the administrator is necessary. This active role implies:

- to give feedback to other departments after activities have been carried out (about characteristics and possible problems);
- to take specific action on reports and complaints (for example by visiting regularly the SUDS, observing how they function);
- to record clearly performed activities, complaints, observed failures and carried out actions.

MANAGEMENT OF SUDS IN PRACTICE

More than ten years ago, the municipalities Arnhem and Nijmegen started with the realisation of infiltration facilities. With the construction of new (large-scale) urban districts in both municipalities, the number of infiltration facilities increases the last years considerably. This large-scale development makes a professional management of the facilities essential. the municipalities have obtained a subsidy within the framework of the European IIIB project Urban Water. Grontmij and Tauw have been assigned to make a management plan for both municipalities.

The heart of the project will be the building of a software tool for the registration of the basic facts of the infiltration facilities, the main points of the design and the results of inspections and investigations. The software tool will be developed as a module of the software dg DIALOG of Grontmij, for the management of the rural area. Dg DIALOG consists of several modules for the management of e.g. sewers, roads and green zones. At this moment, there isn't yet a tool on the market for the management of infiltration facilities.

The software tool will consists of a general part, in which general properties of infiltration facilities and management activities will be stored and a operational part for each municipality. In the operational part, the facts of the objects will be stored. In figure 2, an idea is given of one of the screens of dg DIALOG.

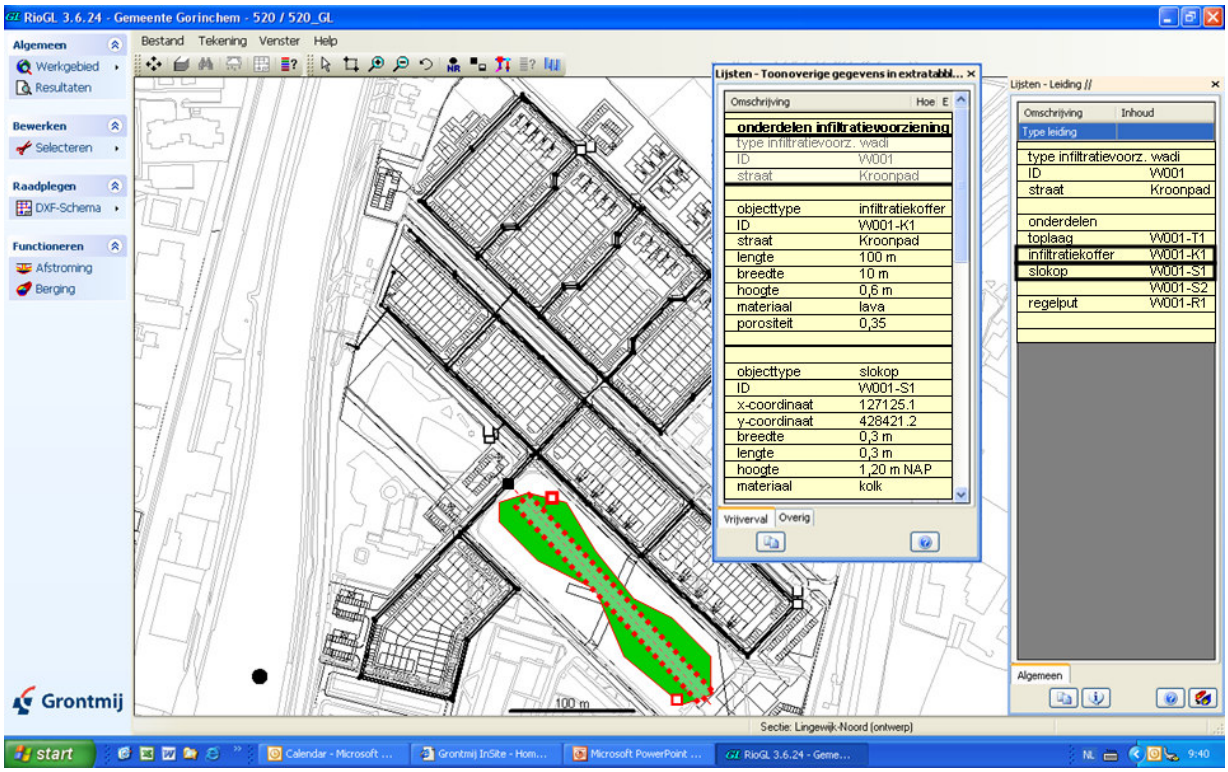


Figure 2. Indication of screen of dg DIALOG SUDS

On the basis of the standard frequencies, and the result of inspections and measurements, the tool will provide the user with an advice for a maintenance planning.

CONCLUSIONS

The results of research show that about ten years after the wide scale use of infiltration facilities in the Netherlands, most facilities function well. However, most municipalities pay too little attention to management and maintenance of infiltration devices.

The new guideline C3200 for the management and maintenance of infiltration facilities, as part of the Urban Drainage Guidelines, published by the RIONED Foundation, provides a framework for the management and maintenance of infiltration devices.

Implementation of the guideline on a practical level is just started in a few municipalities.
The development of a software tool for the registration of infiltration devices and making a maintenance planning has also started.

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