Hannover Kronsberg - The Rainwater Management Concept

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1. Initial Situation

On Kronsberg hill, located to the southwest of Hannover close to the trade fair and world exposition grounds, a residential area of about 150 hectares, which will eventually contain 6,000 homes for about 15,000 people, is taking shape.

Based on two design competitions, a concept was developed that included the EXPO grounds, the Kronsberg district and the adjoining countryside. The new Kronsberg settlement has a grid layout with avenue-like streets, parks, open spaces and green inner courtyards. It runs north-south between the established district of Bemerode and the EXPO and exhibition grounds.

The new district is compact. Built structures become less dense and lower as one ascends the 4-6% gradient on the western side of Kronsberg hill and approaches the countryside and the crest of the hill; from west to east there are three zones of different storeys, building density and construction type. In the west of the district, along the main access road Kattenbrookstrift/Oheriedentrift and the tramline, are the highest buildings of 4½ storeys in rows and blocks and thus the highest use intensity. The middle of the district mainly contains 3½-storey buildings, and on the upper edge of the development are 2½-storey terraced houses.

Ariel view of Kronsberg (south area), 2006

2. Framework Conditions for Water Management

2.1. General Conditions

Kronsberg demonstrates alternatives for sustainable urban development.
Formerly agricultural land, when compete the new Kronsberg settlement will cover 150 hectares (1,500,000 m^2). This land take, covering the ground with streets, residential and commercial buildings, represents an unavoidable intervention in the natural water balance, as increased rainwater runoff and reduced infiltration causes higher flood peaks and less groundwater renewal. Careful stewardship of water takes a central role in any ecological housing development – ecologically minded urban development and water management services have to reorient themselves. Standard technology conveys runoff from residential areas as quickly as possible through a system of pipes and canalisation into a river. This method, which needs extensive technological fixes and whose overall ecological impacts presents serious water management disadvantages as it increases runoff and reduces ground water renewal, must be regarded critically. Rain should be seen less as a potential hazard; rather, the urban construction and design possibilities of rainwater management should be exploited. The need to put this reorientation into practice has become clear as we have seen exceptional flooding in Germany in recent years. One opportunity to reduce flooding, by addressing the problem at its source, is offered by rainwater management within the residential development. It won't be possible to solve the flooding problem completely in this way, but by consistently applying these principles to future residential water management measures, we can expect significant improvements in flood control.

Until Kronsberg, however, there had been no practical applications to a large new development. In the district, a water concept has been implemented that infiltrates and retains rainwater falling within the settlement and delays its release into the feeder stream. Our 'Hollow-and-Soakaway' system copies and enhances the natural geological situation on Kronsberg.
This management system maintains the groundwater renewal balance and the flow through the existing ditch and stream system. It makes an important contribution to ecologically oriented groundwater protection and flood prevention. The Kronsberg water concept thereby shows the shape of things to come for urban hydrology and

settlement drainage. Its network of open rainwater channels also becomes an important urban design element, improves the urban climate, moderates the temperature and creates recreational spaces.

Retention area

Rainwater retention basin

2.2. Water Management Imperatives

As Kronsberg had always been designated as one of Hannover's development areas, from 1971 the maximum flow from the 'Rohgraben' feeder stream at the foot of the hill into the 'Landwehrgraben' was fixed in the planning regulations at 200 litres a second. To adhere to this limit, along the Rohgraben three rainwater retention basins, like pearls on a string, were planned:

name	**location**
Anecamp basin	at the foot of Kronsberg hill
Ohe basin	south of the B 65 highway
Hasenkamp basin	just before Rohgraben flows into Landwehrgraben

Problems with acquiring the land have meant that the Ohe basin hasn't yet been built; the Hasenkamp basin is at full capacity, and only the Anecamp basin could handle greater volumes.

2.3. Hydrogeological Conditions

In 1983 preliminary hydrogeological investigations by the University of Hannover Institute of Water Resources Management under Professor Sieker showed that conventional development on Kronsberg, sealing the ground surface, would have a massive influence on the groundwater balance.

Because of these restrictions, the Kronsberg development was initially shelved, but when Hannover won the competition to stage the EXPO 2000 World Exposition, the hydrogeological conditions on Kronsberg were explored and quantified in more detail.

The flow direction of the groundwater was charted again in 1992 by the University of Hannover Institute of Water Resources Management under Professor Mull. 18 new observation wells were added to the few existing metering stations in autumn 1990.

The effect of a conventionally drained Kronsberg development on the groundwater balance was estimated as follows.

in Seelhorst	depending on the degree of surface sealing	20 - 30 cm lower
in Mastbrucher Holz	depending on the degree of surface sealing	50 - 100 cm lower
in the southern Eilenriede woodland	reduction in underground groundwater flow	reduction in the base flow of the Landwehrgraben, groundwater table bound to sink
Rohgraben	(impossible to compensate with semi-natural widening)	increased flood runoff from heavy rain and reduction in low water runoff in dry periods.

Such negative effects of building development are the results of tampering with the natural water cycle.

3. The Concept

Considering these expected consequences, a drainage concept had to be found for Kronsberg that would have minimal effects on the natural water balance.
For the natural situation before development, a maximum runoff into Rohgraben from annual exceptional rainfall was set at 3 litres per second and hectare. This figure was taken as the regulated discharge per unit area for the entire Kronsberg development.
The findings from the previous studies indicated the desirability of consistent rainwater infiltration, but the soil on Kronsberg presented difficulties; the substratum is mainly limestone marl of poor permeability:

$k_f = 3 \times 10^{-6}$ m/s - 10^{-8} m/s.

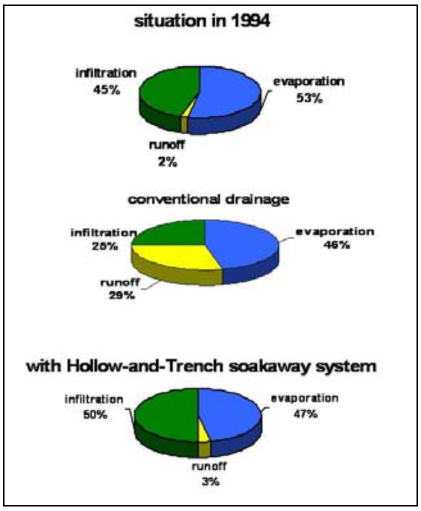
We had to, however, slow down the path of each raindrop, from hitting the ground to the next receiving water, and so the concept had to combine infiltration, decentralised and semi-centralised retention, and delayed release. This resulted in a semi-natural rainwater management solution with both surface and underground components. It comprises:

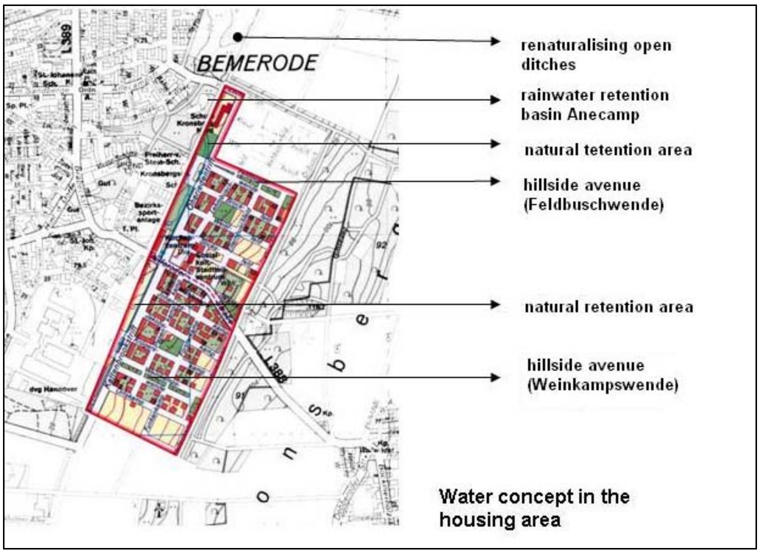
- Hollow-and-Trench soakaway system
- restricted discharge canalisation
- retention areas
- rainwater retention basins
- receiving stream

Precipitation flows into grassed hollows for intermediate storage. It soaks through a layer of topsoil, being cleaned on the way, into a soakaway trench filled with pebbles from whence it infiltrates into the surrounding soil. Overflow water runs into a shaft, gradually released into the limited-flow discharge pipe and into the retention areas, green corridors, rainwater retention basins and finally into the receiving stream.
Thus, across the whole district, we built a semi-natural rainwater management system that keeps the water balance close to what it was in its natural state.

Only the combined effect of all components can guarantee this, retaining the natural rainwater discharge from Kronsberg.

The balance of the water system





4. Implementation

4.1. Planning and Construction in Public Areas

4.1.1. Road Drainage

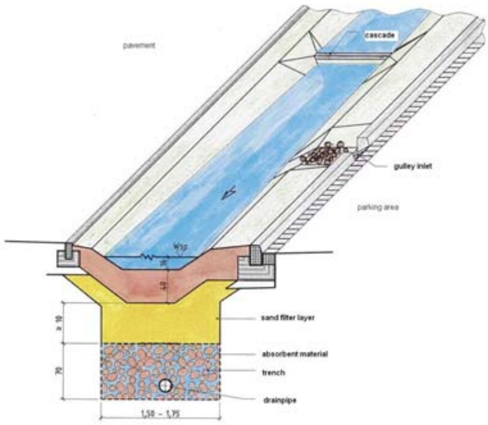
To fit in with the grid layout determined by the urban planners for the residential area, placing the Hollow-and-Trench soakaways along the streets turned out to be the best solution.

The Hollow-and-Trench soakaway system collects all precipitation in 30-40 cm-deep grassed hollows to a depth of 15-20 cm water. It is temporarily stored here, and soaks through 30 cm of topsoil, being cleaned on the way. The water infiltrates further, into the pebble-filled soakaway trench below.

The water leaves the trench via a drainpipe into a shaft, from whence it can only pass into the public drains through a narrow pipe at the determined rate of 3 l/(s x ha). A choke element is built into the shaft to ensure this. The shaft was developed by Hannover water treatment services from the 'Modell Hannover' street drains.
The public drains are dimensioned according to the size of the limited discharges and laid, as for conventional rainwater drainage, under the streets.

Use of the Hollow-and-Trench system is compulsory for all public traffic areas. It is laid parallel to the streets in the grass verges between the pavements and the parking spaces, where there is a total gap of 2 metres. To calculate the extent of the hollows, 10 percent of the adjacent runoff area is sufficient. During occurrences of design rainfall, the hollows back up to a calculated depth of just 16 cm.

Roadside Hollow-and-Trench soakaway system



Section through drain-gulley

If the system is to absorb as much water as possible, evenly spread, the base of the hollow and trench must be level, and so, with road gradients of up to 6%, inserting cascades is unavoidable. In the case of a cloudburst that fills the hollows and trenches completely, the water will run directly into the public drain via an emergency overflow in the shaft.

The hollows are dimensioned to cope with a once-a-year exceptional rainfall and the trenches for a once-in-five-years occurrence. The new retention areas at the foot of the hill to the west of the main access roads Oheriedentrift and Kattenbrookstrift and the tramline, and the Anecamp rainwater retention basin, whose semi-natural quality is limited by the tramline construction, are each designed to handle a once-in-ten-years rainfall.

The 18 to 35 metre-wide retention areas, which sometimes back up, are laid out in park style. They retain runoff from the main roads Oheriedentrift, Kattenbrookstrift and Wülferoder Straße, and receive the discharge from the limited flow network.

Rohgraben, the receiving watercourse at the foot of Kronsberg hill, still flows in a regulated standardised profile. Creating marginal strips should give the stream space to develop its own dynamic and reduce flow velocity. Sufficient marginal strips have already been created along 500 metres of the banks, which also protect the water from surrounding grazing uses. Apart from bridging and outlet structures there will be no further construction measures. For local residents a leisure and recreational area has taken shape almost on the doorstep.

4.1.2. Hollow-and-Trench Soakaway Demonstration Stretch

Before the main construction work, a full-scale demonstration stretch of the hollow and trench soakaway system was built to collect practical knowledge for planning and construction. The following issues, especially, were examined:

- reliability of discharge through small limiting apertures
- optimising the hollow run-in, considering the sloping site
- cloudburst simulations
- data for construction processes

This demonstration stretch was monitored by the University of Hannover as part of the research project funded by the federal construction ministry, 'Rainwater management at Hannover-Kronsberg'.

The demonstration strech

<u>Findings applied to the construction process:</u>
Because work on the Hollow-and-Trench soakaway system had to be precisely coordinated with road building, all involved realised quickly that both tasks should be carried out by a single construction company - otherwise, there would have been considerable problems, especially in coordinating the construction schedule, keeping to deadlines and demarcation of work to be carried out.

Therefore, for all construction phases, the call for tenders for roadbuilding and the hollow-and-trench systems was issued in a joint procedure by the City highways division.

<u>Findings for Operation and Maintenance:</u>

Points to be considered for later maintenance of the hollows arose from monitoring of the demonstration stretch, and considerable cost savings could be made.

Mowing:
- at least twice a year, with regular checks in between
- necessity to clear away grass cuttings, otherwise it would be carried into the limited flow shafts by heavy rainfall

Grass care:
- turf must be watered frequently in the early stages
- reseeding needed, especially on the edges of the hollows

4.1.3. Construction Handbook

Both for the planning and design phase and during construction work, two engineering bureaux were brought in as advisers.

To formulate the main principles for building the Hollow-and-Trench soakaway system on Kronsberg, and to make the construction stages and quality monitoring easier, a construction handbook with tabular summaries and detailed explanations was drawn up. It helped those involved in the project during tendering, granting of contracts and site supervision, and guided the construction companies through their work.

Separate leaflets were written on the following points:

- Specifications for materials selection, with installation instructions and descriptions of criteria for the suggested materials.

- Work schedule descriptions, with advice on the important principles of constructing a Hollow-and-Trench soakaway system

- Quality assurance concept containing introductions for construction companies and planners, deadlines and construction phases for partial handovers and function checks.

4.1.4. Surface Watercourses in the Hillside Avenues and Retention Areas

The two hillside avenues, Weinkampswende and Feldbuschwende, take up the theme of water in a special way. As part of the Kronsberg rainwater management system they have a leading role, as the water is not infiltrated by the hollows for practical reasons but is used as an urban design element. Rainwater falling in the adjoining blocks is led into wide avenues with trees, groups of shrubs and paths, where the water is discharged over the surface.

This creates:
- dammed water areas
- periodically water-conducting hollows
- stone benches
- streams
- wooden and stone bridges

Open water features, ponds, stone benches by little water areas and water games are examples of open water retention with limited flow discharge. These water elements create a healthier microclimate, as water stabilises air temperatures and reduces dust clouds considerably.
In the landscaping of the retention areas at the foot of the hill, too, local residents should recognise the importance of the system - the way that water is managed in surface facilities. Residents can use the embankments covered in vegetation and still water areas as recreational areas close to home. The retention areas were deliberately designed to make the water part of direct experience. They are given a parklike character and invite people to take their ease there.

Hillside avenues with dammed water areas and streams

Retention areas with periodic hollows and stone benches

4.2. Implementation on Private Property

An overall concept for private land and public spaces was applied right across the construction area of the new Kronsberg settlement, whose aim was to preserve the water balance after development to resemble that in the undeveloped state. For public spaces, the Hollow-and-Trench soakaway system and the retention areas were planned by Hannover water treatment services and built. The private development land, currently amounting to around 46 hectares, was divided into single blocks and sold to various property developers. Realising the water concept was linked to specific framework conditions both for the public and the private areas. In designing the rainwater infiltration areas, water was to be made apparent in many and varied ways. Including measures for the sparing use of drinking water completed the sustainability of the settlement design with regard to the water concept.

4.2.1. Framework Conditions

To achieve the above aims, binding conditions were applied based on various legal frameworks:

1. Development Plan
Rainwater runoff from sealed surfaces must be channelled into a Hollow-and-Trench soakaway system and infiltrated there and/or directed to limited-flow discharge to the public drains. This system achieved decentralised retention, combined with as much infiltration as possible and strictly controlled release into public drains. This was in accordance with the soil conditions on Kronsberg, with an average permeability of 1 x 10-7 m/s (determined by the Water Planning Team, 1995). Exceptions to this concept were possible according to the Development Plan if the rainwater was completely infiltrated on site, within the property boundaries, or could be diverted to controlled discharge in other areas. As impact minimisation measures according to the nature protection law, property owners were obliged to use permeable surfaces for car parking and their access roads, to plant the roofs of underground car parking and to plant roofs with a slope under 20% in certain parts of the development area.

Underground garages with roof planting

2. City of Hannover Drainage and Wastewater Bylaw, 16th May 1991.
The permitted rainwater discharge quantity and thus the regulated discharge from the properties was determined by the regulations on rainwater retention, which allowed 3 litres per second and hectare. This value was applied to built-up and sealed areas according to the guidelines of the Water Planning Team in 1995. Unsealed areas were included according to DIN-EN 725-4 (11.97) when, through impermeable soil and gradient, rainwater discharge happened through an infiltration facility. The ATV working paper A 138 (January 1990) was applied in assessing the infiltration plants. Since 1996, infiltration of rainwater has had priority over discharge into the sewage system for private properties if the prevailing conditions are suitable. Using this ATV working paper has proved effective and workable.

3. Lower Saxony Water Statute, 25th March 1998
A permit to infiltrate rainwater down to the groundwater was, after examination by the lower water authority, not needed due to the general impermeability of the soil.

4. Use of Environmentally Compatible Building Materials on Kronsberg,
such as using no PVC drainage pipes. The condition was imposed as a clause in the land sale contracts.

Additionally, there were also technical imperatives that demanded precise agreement and coordination between all involved in planning the facilities, for instance:

- The position of the canalisation connection was only allowed in the property entrances, away from the catchment areas of the public Hollow-and-Trench soakaway systems. Furthermore, connection to the sewers under the main access road Oheriedentrift/Kattenbrookstrift was not foreseen, because the road surface was completed before development began.

- Planning of communal infiltration facilities for the terraced houses as a limited flow discharge from each of the small properties was hardly feasible. Compulsion could not work here, and only a recommendation was made.

- Compared to other parts of the city the site has a steep gradient, and this had important consequences in planning the infiltration facilities. As infiltration trenches and hollows usually have to be dug horizontally, stepped systems and extra dam units were needed. Courtyards drains and gutters below the respective back-up level of the system had to be protected from release of rainwater. There were frequent difficulties in draining lower sealed surfaces with infiltration facilities located in the centre of the inner courtyards.

- The schedule to complete the development was extremely tight - all building work had to be finished within 2½ years, by the start of the EXPO 2000 World Exposition. The sequence in which service lines, road construction etc was therefore exactly determined and had to be kept to. Every delay or deviation from the schedule caused serious problems.

The land sale contracts set no other conditions. Property developers had, within the legal strictures already mentioned, the freedom to design and build their infiltration systems just as they liked as long as they met the technical requirements.

The constructions had to be monitored, and the regulations enforced, by the legally responsible bodies. The infiltration facilities fell within the responsibility of the City water treatment services, the impact minimisation measures were checked by the nature protection office and the use of environmentally compatible building materials by the environmental protection division.

4.2.2. Time Frame

The first plans for applying the water concept to the private properties of the new Kronsberg settlement were presented in autumn 1997. In March 2000, when it was completed, rainwater drainage concepts were available for 43 of the development blocks. Since then inspection of 40 drainage facilities has been completed. Construction of the infiltration facilities began in the second half of 1998. *Diagram 1* shows the state of construction in March 2000: 14 infiltration facilities had been completed, and another five were partially complete, so that 19 could be included in the assessment of how the water concept had been applied.

4.2.3. Permit Procedure

The permit procedure required extensive advice to the planning offices on the framework conditions. Detailed coordination between the various units of the City administration, the planning offices and construction companies (private areas, public utilities, road construction) was another essential precondition for completing construction subject to the technical imperatives, combined with a precisely determined and nonnegotiable schedule.

Permits were granted when the practical demands on the drainage system were met. However, other infiltration systems than the Hollow-and-Trench soakaway system could be installed. Only in this respect was there any deviation from the regulations in the Development Plan. This happened under the following circumstances.

In the course of the permit procedure, several property developers applied to use other infiltration systems than the Hollow-and-Trench soakaway system. This wish arose in connection with particular design briefs for the infiltration facility, internal cost analyses or use conflicts on the areas in question.

As long as the alternative system presented met the basic requirements of the Development Plan - decentralised retention with as much on-site infiltration as possible and strictly controlled discharge into the public drains, as with the Hollow-and-Trench soakaway system, permission was granted. In this way, the threat of legal wrangles could be avoided that would have endangered completion of the Kronsberg development on schedule before EXPO began.

All drainage systems are connected to an infiltration facility. Different parts of a property could be allotted to various facilities. One positive result of permitting other infiltration facilities was that it avoided uniformity of design and produced a variety of visually attractive grounds. *(Diagram 2)*.

In two cases we applied the exception clause in the Development Plan, whereby rainwater runoff was diverted in a controlled flow to other areas for infiltration, here the public retention areas. On one block that, according to the Development Plan, was to be completely built up, the rainwater was retained in a decentral storage drain before being released gradually into the public drain. In the second case a small proportion of the rainwater (balcony drainage) was connected to a storage drain because otherwise it would have had to be pumped back to the main infiltration area, consuming extra energy, because of the location of the building.

4.2.4. Practical Application

Within the Kronsberg district, all sorts of infiltration systems were planned. The constructions that resulted mostly conform to the drainage concepts that were submitted to us.

In a few cases there were deviations from the plans, in the construction of inspection shafts and sedimentation or pre-cleansing facilities. Without an inspection shaft it is not possible to carry out maintenance on underground infiltration systems such as soakaway trenches, and if there are no sedimentation or pre-cleaning stages before the trench this will affect performance, causing it eventually to fail and requiring expensive renewal by the owner. Coarse matter can also block the limited flow discharge apertures and cause the facility to overflow.

Limited functioning of the flow choke mechanism is especially caused by dirt or scraps of mortar from construction in the apertures or by mechanical failure.

These points had to be corrected to guarantee controlled flow of rainwater into the public drains.

On average, 56% of the ground surface was covered - 31 % by building and 25% by roads, parking spaces and other surfaces.

Where building density is greater, for instance in the terraced house developments, there were problems with the use of the areas which affected planning of the soakaways. Terraced house gardens are usually less than 50 m^2. Here, the tendency was to underground soakaways, so that the gardens could be used for other purposes. Some owners have covered the surface soakaways to extend the usable area of their small gardens.

Terraced house gardens

4.2.5. Brief Descriptions of some Projects

A tour of the properties on Kronsberg is the best way to see how varied the possibilities of construction and open space design are for infiltration facilities.
The following offers a random selection of the diverse systems, not selected as the best examples.
All the facilities are marked on the general plan.
Of course, the infiltration facilities on other properties are also worth a visit.

1. An Inner Courtyard Shaped by Water

Two identical rows of eight houses were built on a plot of 11.6 hectares. The eight houses are linked with a common basement level, and by a glazed microclimate zone which serves as a roofed and green inner court with many pools and a variety of other water features. Some of the balconies and terraces also look out on the microclimate zone. The open space between the two rows has been landscaped with a fruit tree meadow, playing field and pond. Additionally, the roofs are intensively and extensively greened. Rainwater falling on built-up surfaces is initially channelled into two cisterns, dimensioned to retain some of the water and each hold 35 cubic metres in reserve to water the microclimate zone (including its ponds and other features) and the green spaces.



Views of an inner courtyard

As the cisterns are not designed to cope with the entire retained rainwater, after heavy rain, water is fed from the cisterns into the pond and stored there (the water level rises). The pond outflow leads into a grassy hollow with a soakaway trench beneath it, and via a limited flow sluice into the public drain. Extra capacity can be created by damming the play area between the pond and the Hollow-and-Trench soakaway system.

2. Example of a Comprehensive Environmental Concept – the Passive House Development

The Passive House Development is a special Kronsberg feature, where a comprehensive environmental concept has been put into practice. The Low Energy House Standard applied across the Kronsberg construction area has here been enhanced by extra measures such as minimising heat loss, a solar installation and low-energy household appliances. The rainwater concept is, of course, part of the environmental concept - drainage is through a Hollow-and-Trench soakaway system with infiltration and restricted discharge.
All roofs are greened, which also contributes to the rainwater management concept.

Terraced houses with roof planting

3. Rainwater Concept for the Primary School

Water plays a central role at Kronsberg Primary School. All rainfall is retained in the grounds, infiltrated on site or collected in a cistern. Open surface gutters, retention and infiltration areas are important landscaping features, creating habitats for plants and animals in the school garden and recreational space. Much of the school's sloping roof is greened to slow down water runoff. Rainwater is used to flush the toilets and water the school garden, saving around 550 m^3 of drinking water a year.
As well as the exemplary technology, water and its sparing use is also an important teaching theme.

Kronsberg primary school

The schools rainwater management system includes several grassed hollows with an infiltration pond and a soakaway trench beneath it. Rainwater runoff from most of the greened roof initially runs into the cistern for service water use, and only the overflow runs to the pond. All other areas drain directly to the pond or the water is channelled through a metal box gutter, across hollows, around the school and finally to the infiltration areas. At the end of the hollows is a dam to regulate the retention volume. Most of the rainwater flows on the surface to the infiltration area, while some underground pipes come to the surface in the middle of the green space.

4. Examples of various infiltration facilities

Kindergarten I is drained with a Hollow-and-Trench soakaway system. Interior drainpipes channel the water from the gravel-covered roof into the hollow, where it is infiltrated through the soakaway trench. The paved paths also run off into the hollow. The few parking spaces are paved with permeable surfaces, so that rainwater can be infiltrated in situ.

Kindergarden: Hollow-and-Trench soakaway system

In plot **N42** a pond collects most of the rainwater, which is then channelled into underground pipes. Some permeable areas infiltrate the rain directly, or via planted areas.

On plot **M42** rainwater infiltrates via a pond and soakaway system. Some rainwater is led from drainpipes directly into the soakaway, the rest comes to the surface after a few days and is led through a chain of gravel hollows into the pond. Some permeable surfaces drain directly into the ground.

The facility on plot **M41** is a combination of pond, underground soakaway and hollow-and-trench. Drainpipes from the roof feed the water to gravel and grass hollows directly to the pond or via an infiltration hollow. The underground garage roofs drain through gargoyles and a box gutter into the pond. Smaller paved areas drain directly into the greenspace.

5. Economic Viability Analysis

Because of the market situation and the different sizes of the single projects, cost analyses are diverse.
Construction costs for an entire system, looking at the projects completed so far, are somewhere between 425 €/m and 575 €/m, including flow limiter shafts and grassed hollows.
To compare this with a conventional rainwater management system, Hannover water treatment services commissioned the University of Hannover Institute of Water Resources Management to model a conventional rainwater drainage network for the new Kronsberg development for economic comparison with the semi-natural concept actually implemented.
The study found that, leaving aside the ecological effects, the decentralised rainwater management system offered the more economical alternative. Cost comparisons showed an advantage over conventional drainage of more than 10 percent.