Stadt Karlsruhe Tiefbauamt

City of Karlsruhe Civil engineering department

Die Stadtentwässerung in Karlsruhe

The urban wastewater management of Karlsruhe

Karlsruhe
viel vor. viel dahinter.

Karlsruhe

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Foreword

Water is one of our most important resources. We will only be able to possess clean water in the long term if we succeed in preventing harmful pollutants in ground water, rivers, lakes and seas. Water pollution control is not an end in itself, but rather serves as self protection. The flowing water does not stop at any city or country borders. Pollution on the upper reaches cause stresses and strains on the lower reaches. An effective water pollution control can only be achieved with cross border efforts.

An efficient wastewater system and highquality technical wastewater purification are important requirements here.

In the post-war years, the first task was to establish and develop the cities that were destroyed in the war. The amount of pollution in water increased drastically with growing industries and the construction of high capacity canal networks in the cities. Within a few years, the Rhine had changed from bathing and fishing waters into a "cesspool". The cities in Niederrhein (Lower Rhine region) and in the Netherlands, where drinking water predominantly comes from filtered water from the Rhine, raised an alarm. They saw that the abstraction of their drinking water was at high risk. The legislator had to act.

In several initiatives, the legislature, gradually and chronologically offset, demanded high quality technicalwastewater purification. This mainly concerned the communities and large industries.

Through extensive efforts it has been possible to considerably improve the quality of the water. As the example of the Rhine has shown, a lively, clean river and a habitat for many species of animals and plants can be recovered within a few years through efficient wastewater purification. In the meantime salmon have even been sighted again on the fish ladder of the Iffezheim weir.

Karlsruhe also complied to full extent with this obligation regarding water protection. The wastewater treatment plant, which was already in commission in 1913, was extended in several stages. Since 1962 more than 140 million Euros have been invested in Karlsruhe's wastewater treatment plant. At the same time, around 230 million Euros were needed for the extension and rehabilitation of the canal network.

An end to the construction plans is not yet foreseeable. In 2002 the legislators once again made stricter the requirement for the elimination of nitrogen. For large cities like Karlsruhe, a final nitrogen value of less than 13 mg/L has been required since 2007.

In the future a substantial amount must also be invested in sewage disposal, to maintain a leak-proof and functioning canal system and to fulfil the high requirements of wastewater purification.

The money, which has been spent with foresight and expertise, has led to Karlsruhe having a high quality drainage standard which simultaneously shows one of the lowest sewage charges of the big German cities.

Karlsruhe City Council strives to maintain the following two goals: Good service and low charges.

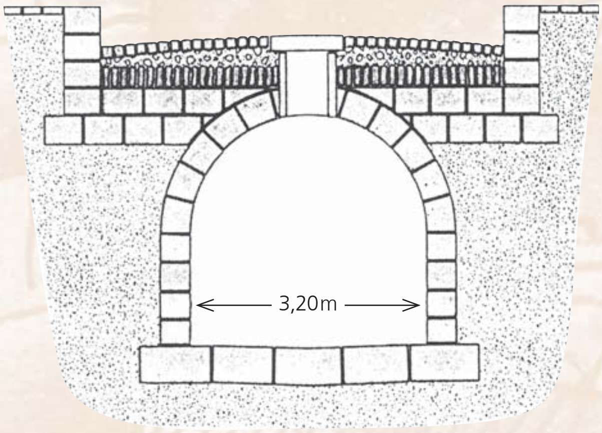
Heinz Fenrich
(Lord Mayor until 2013)

Michael Obert
Mayor

Wastewater was canalised as far back as in ancient Roman times

The first advanced civilisations arose in places where there was sufficient water, on large rivers like the Indus, Nile, Euphrates and Tigris. These cultures had already recognised that an efficient wastewater discharge system i.e. canalisation was essential for a good water supply. The first canals were therefore built more than 3,000 years ago in India and Babylon. At that time the power of selfpurification of the waters was sufficient to break down the accruing pollutants.

The water supply and wastewater discharge techniques reached a peak in the Roman Empire. Many building still stand as testimonies of this. Today, the 2,000 year old main sewer **»Cloaca Maxima«** can still be seen in Rome. Striking examples of canal structures also remain preserved in other former Roman settlements such as Cologne, Trier and Ephesus.



Cloaca Maxima in Rome

Ancient domestic drainage in Ephesus

Public toilet facilities in Ephesus

Stoneware jugs used to form a water pipe in the Middle Ages.

These skills and techniques were lost during the confusion of the Migration Period.

In the **Middle Ages**, no great importance was attached to the problem of wastewater. Quite the opposite: the hygienically inadequate circumstances contributed greatly to the spread of the pest epidemics. The problems of faecal removal were especially significant in the narrow, densely built cities of the Middle Ages. There were communal garderobes in the city walls. The moat around the city walls thus became a "shitpit". Only in the houses of prosperous citizens were there single privies. These **"pit latrine"** were mainly built to be detached from the buildings on account of the stench. In many city chronicles one can find the invocation to the citizens, "not to empty the contents of the chamber pot into the street". The topic of the evil smells in the cities is a common topic in the literature of previous centuries.

Cities grew exceptionally fast as industrialisation set in **at the beginning of the 19th century**. In large cities there were repeated epidemics of cholera and typhoid. In the mid 19th century, it was realised that these epidemics in the cities could only be avoided through strict hygiene, in particular through the construction of sewage canals. An effective spreading of information was achieved, most significantly by the doctors Virchow in Berlin and Pettenkofer in Munich.

From the **second half of the 19th century** the systematic upgrading of effective sewage networks began in all large cities. The introduction of water closets and the building of water sewers dispensed with the faecal removal from the cities which was associated with strong smells. The distinctly noticeable fall in the population's mortality rate – in particular the mortality rate of children – is also due to these city hygiene measures.

Initially all efforts were focussed on the fast and odourless transportation of wastewater out of the city. The new problems, which arose with discharging wastewater into the rivers, were at first only recognised by a few.

Development of the sewer system in Karlsruhe

1588 Construction of the artificial river **Landgraben** (name of an open drainage canal) from Gottesaue Castle to the River Alb in Mühlburg begins under Margrave Ernst Friedrich. The **open Landgraben** was used to drain the low lying areas between Durlach and Ettlingen as well as the high Alb water.

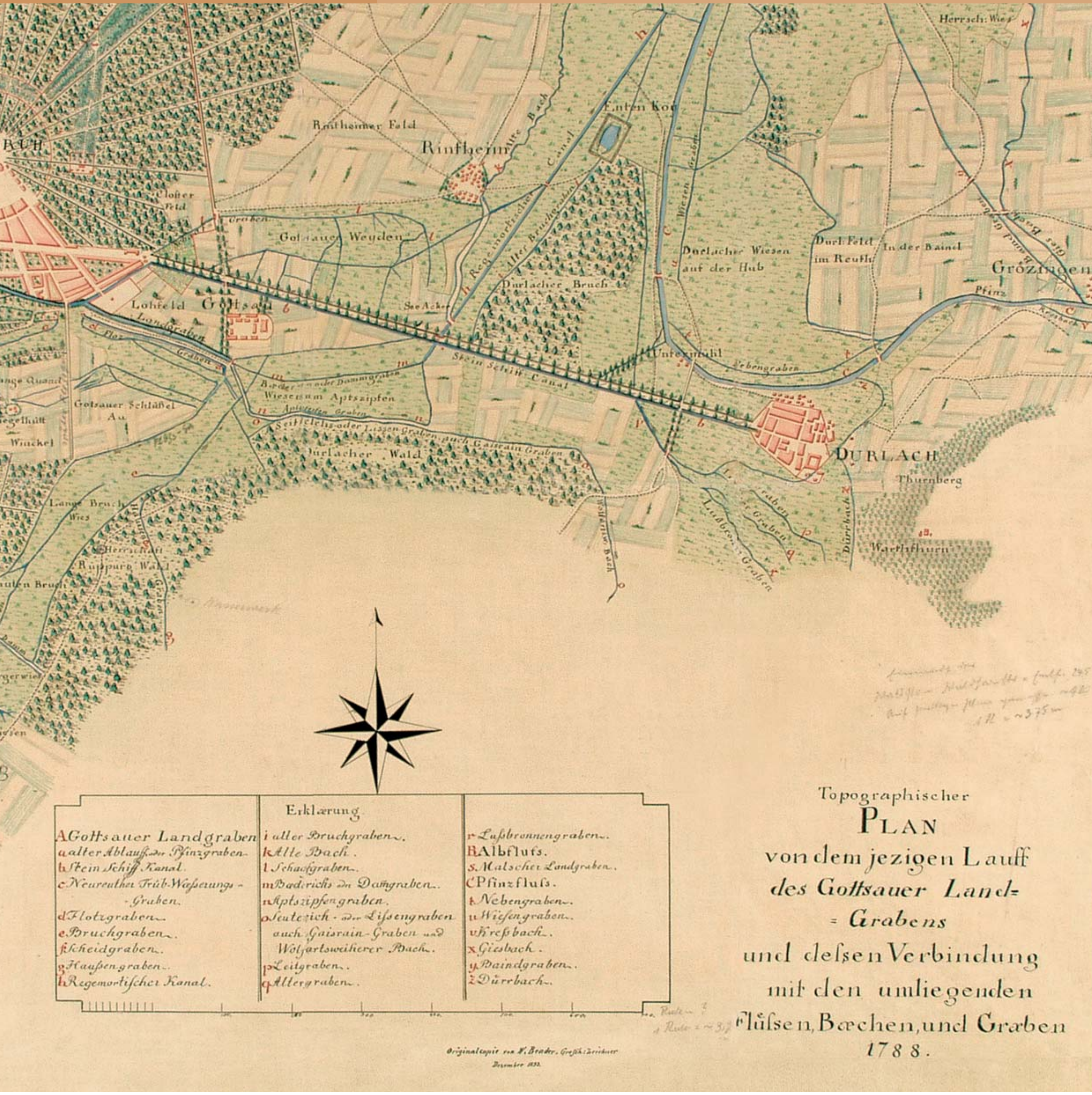
1715 The Landgraben flowed through the newly established city and was the only stretch of water to cross the city area from East to West.

1768 Extension of the Landgraben to the East unto the Pfinz by the so-called **Steinkanal** (stone canal). This canal was used to transport stone and wood from the valley of the Pfinz and to the high water discharge of the Pfinz.

1794 The citizens were allowed to discharge all liquids such as kitchen water and bath water, with the exception of sewage disposals, into the Landgraben. The drainage canal became a **wastewater trench**. The situation worsened when the margrave granted a miller in Mühlburg a concession to build a mill. Thus a constant congestion of water a metre in height was generated, which caused a quick accumulation of sludge in the water. With low levels of water in the summer months there came serious odour issues. High levels of water caused neighbouring buildings to become easily sodden or flooded. However, there was a lack of money for the urgently needed cleaning of the canal.

1866 Around the year 1866 Karlsruhe`s poet Heinrich Vierordt described the state of wastewater disposal with these words: "Still flew, dull and cloudy, the foul-smelling Landgraben, non-vaulted and visible everywhere, through the city. If one looked down from the street to the blackish sinister waters, where torn newspapers, broken broomsticks, dead cats and similar proud squadrons were floating on the River Rhine and towards the Netherlands, one would almost believe to be staring into the valley of the Styx…".

1877 A vault over the trench reduced annoyance. The residents paid for the construction works, therefore obtained ownership of the area and, simultaneously, got rid of the stench. By 1877 fourteen kilometres of street canals, or so-called **Dohlen**, had been built, which discharged the street water along the shortest route from the city centre to the Landgraben.


Erklærung
A Gottsauer Landgraben
a alter Ablauff der Pfinzgraben.
b Stein Schiff Kanal.
c Neureuther Trüb-Wäßerungs-Graben.
d Flotzgraben.
e Bruchgraben.
f Scheidgraben.
g Haußengraben.
h Regemortischer Kanal.
i alter Bruchgraben.
k Alte Bach.
l Schafgraben.
m Baderichs oder Damgraben.
n Aptszipfengraben.
o Seuteich - oder Lissengraben auch Gaisrain-Graben und Wolfartsweiherer Bach.
p Leitgraben.
q Altergraben.
r Lußbronnengraben.
B Albfluss.
s Malscher Landgraben.
C Pfinzfluss.
t Nebengraben.
u Wiesengraben.
v Kreßbach.
x Giesbach.
y Baindgraben.
z Dürrbach.
Topographischer
PLAN
von dem jezigen Lauff
des Gottsauer Land-
- Grabens
und dessen Verbindung
mit den umliegenden
Flüssen, Baechen, und Graben
1788.
DURLACH
Rintheim
Grözingen

The Landgraben: the "heart" of the sewage system

Steinstraße on the open Landgraben (Watercolour painting by Heinrich Meinelt, 1840)

From the beginning of the 19th century experts tried to find a solution for the problem of the Landgraben. **Colonel Tulla** was also involved. Any implementation failed because of the need to deepen this disposal channel. Resistance also was made by the resident owners of the houses who feared that the buildings would be damaged as a result of the deepening of the Landgraben, and also resisted a deepening of the basement. Furthermore, the municipality lacked the required funding.

On the Landgraben in 1870

1877 In 1877, the **town architect Hermann Schück** received a request from the City of Karlsruhe to draw up a sewage canal project "under the authorisation with necessary funds to carry out extensive preparatory work". Schück proposed that the Landgraben be made into a main sewage canal, have its floor lowered and be built into a low water chute.

1883 By correcting the Landgraben, the cornerstone of a modern sewage draining system was put in place. From 1883 the systematic **extension of the network of canals** had begun. The old "Dohlen"-system had to be almost completely abandoned, as it did not fit into the planned canal network. Schück's solution did not initially plan to provide means of faecal matter disposal from houses. Toilet pits remained because it was considered that the building of WCs was too expensive for the working population. On the other hand, the city was afraid of discharging faecal matter directly into the rivers. Nevertheless, Knielinger laundry women – for example – complained that faecal matter swam past in the river Alb.

"Inspection of the amended Landgraben by His Royal Highness the Grand Duke on 3 January 1885"

1885 After the city had purchased the water rights of the mill by the Landgraben for 70,000 Marks, this "Landgraben correction" could be carried out until 1885. It resulted in a wastewater canal with a cross section of 17m², which at that time was the second largest in Europe. During an **"excursion on a barge"**, Grand Duke Friedrich I officially inaugurated this underground structure.

1893 As a result of the introduction of the **flushing water toilet** having been achieved faster than expected, the civilian committee permitted the upgrade of the construction of the sewage canals for the scouring of faecal matter in 1893. The planned construction included:

- an effluent channel to the Rhine,
- eastern and western canals in order to relieve the strain on the Landgraben,
- a so called Pfinzspülkanal from the East of the city to Durlacher Tor,
- a mechanical sieve plant at the current location of the wastewater treatment plant.

The total cost stood at 4.2 Million Marks.

1913 The **wastewater treatment plant** began its operation in 1913. The extension of the main sewers was not completed until 1920.

2002 Since October 2002, interested visitor groups have been able to take a look at the "underworld". In an underground, air conditioned visitors' room near the entrance to the Landgraben in Lameyplatz, the Tiefbauamt (Civil Engineering Department) presents the history of Karlsruhe's urban drainage and the Landgraben. Following this, it is possible to view the historical Landgraben on a visitors' bridge directly over the flow of the chute.

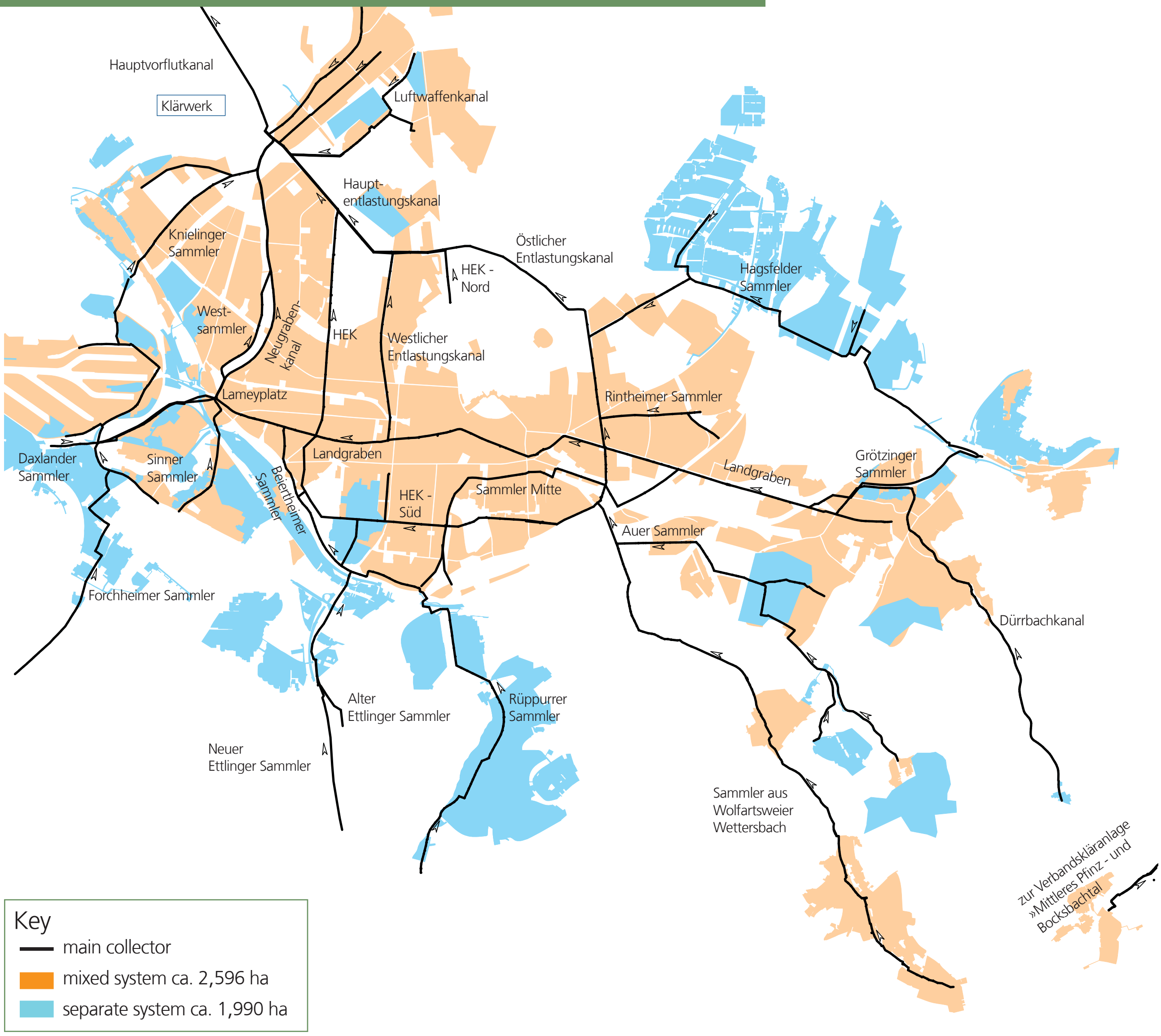
Steam powered pumps in operation during the " correction of the Landgraben"

Construction site in Kapellenstraße, 1919

An insight into the underworld
Please arrange an appointment to visit the Landgraben on telephone number 0049 721 133-7441 (Kanalbetrieb)

Lord Mayor Heinz Fenrich and an employee of the Stadtentwässerung (city's department for drainage) at the opening of the visitors' area of the Landgraben in Lameyplatz in 2002

The sewer system at a glance



The city of Karlsruhe has a **sewer network** of about 1,100 kilometres long. Besides the many small pipes, the main sewer network includes (with a diameter of up to 2.4 metres in parts) a length of 71 kilometres with a retention volume of many thousand cubic metres of wastewater.

The sewer system was radically adjusted once the location of the wastewater treatment plant had been determined in the year 1908. It was necessary to place the new collectors deeper. Besides the Landgraben, the Östliche Entlastungskanal, the Westliche Entlastungskanal the West-Sammler and the Neugraben were the backbone of Karlsruhe's sewersystem.

A modern sewer system must show a high amount of efficiency and reliability. The longterm goal is to convert the existing sewer system into a unified combined system, which has long been the norm in the field of supply (e.g. drinking water, electricity).

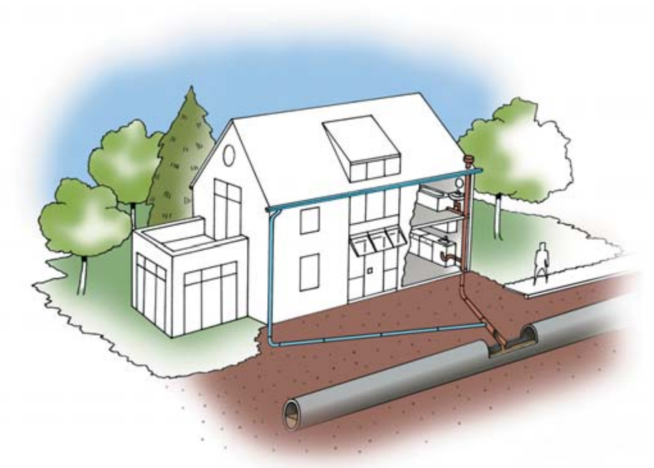
The route of rainwater

A **mixed system** is the term for the joint discharging of untreated wastewater and rainwater via one pipe. Initially all parts of the city were canalised according to this principle. The mixed system simplifies the installation on the plots. Furthermore, only one pipe in each street is necessary. However, during rainfall large streams of wastewater flow to the wastewater treatment plant. Upon rain overflow during heavy rain, the diluted mixed water flows directly into the bodies of water in order to reduce the afflux to the wastewater treatment plant.

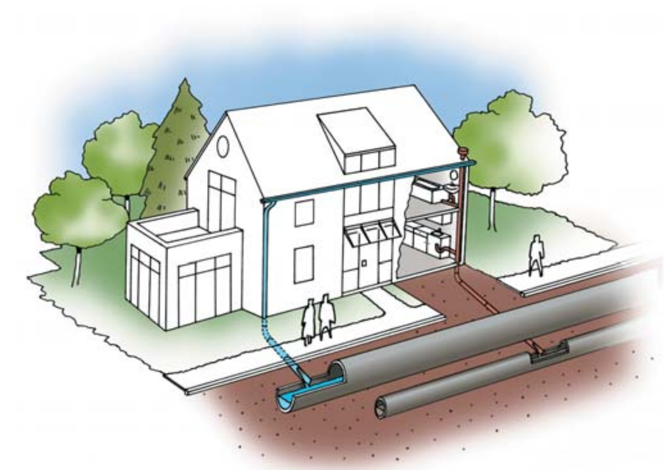
The **separate system** comprises two pipes in the street. The smaller and (usually) deeper pipe takes the quantitatively less untreated water to the wastewater treatment plant. The bigger rainwater pipe collects the rainwater from roofs, paths, roads and squares and leads it by the shortest route to the public waters, e.g. the Alb or the Pfinz. In the last thirty years the development areas, which lie mainly in the periphery, have been made ready for the construction of the separate system.

Today the aim is to transport the accruing **rainwater** back into ground water by the shortest possible route through **infiltration.** Therefore with every application for planning permission it is checked, whether the rainwater can trickle off harmlessly.

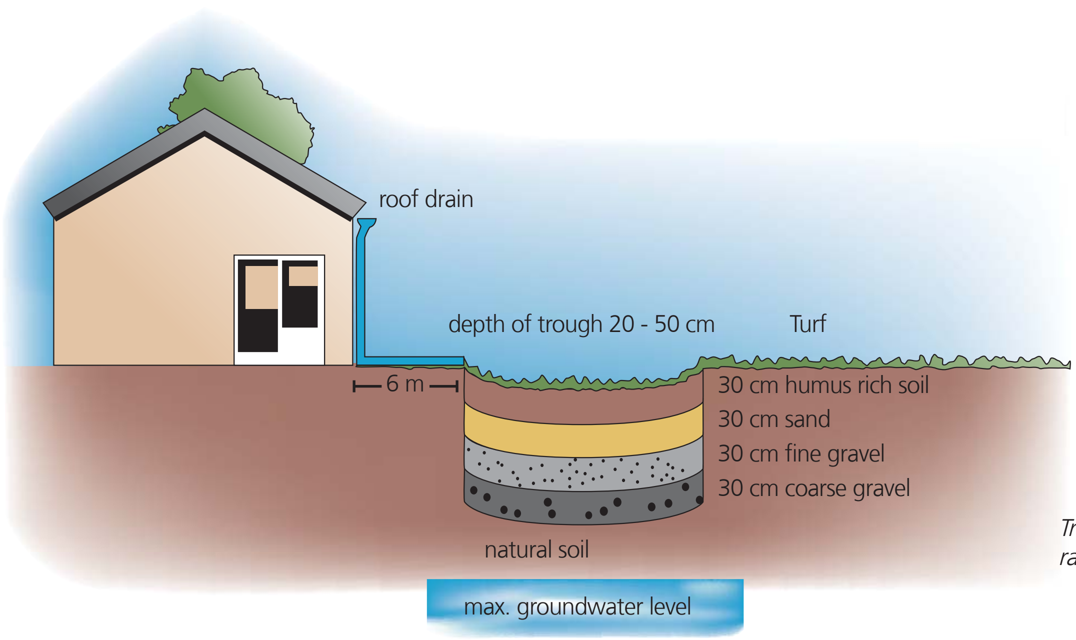
One possibility of the near-natural rainwater management are the **seepage basins**. The troughs must hold a microbiologically active soil layer (humus) of 30 cm in order to be able to hold back the harmful substances.



Mixed system

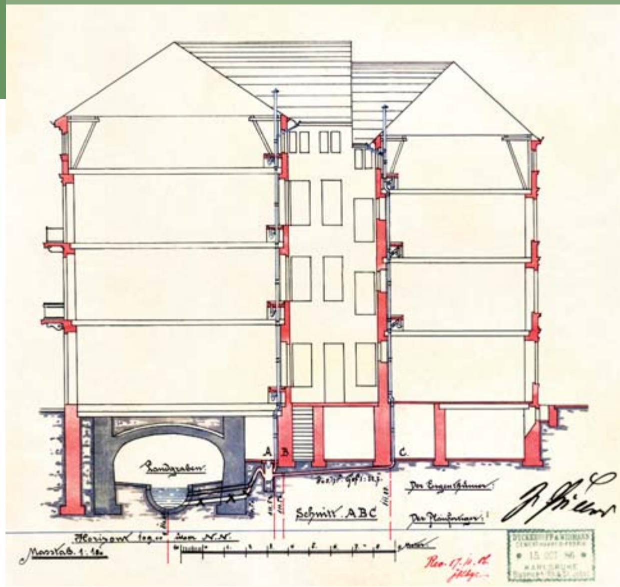


Separate system



Trough structure for rainwater infiltration

Drainage according to plan

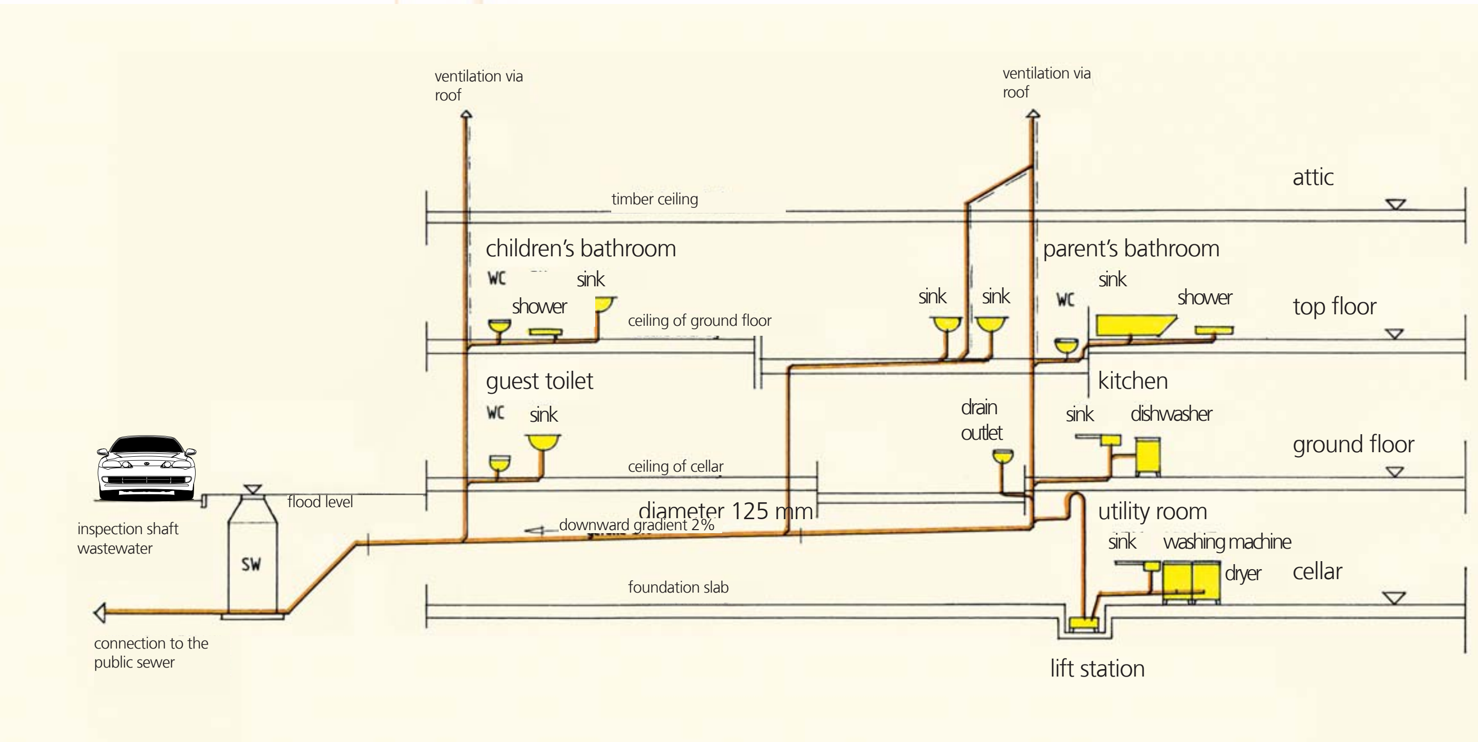


Drainage plan 1886

A proper sewage disposal starts with correctly dimensioned **plot drainage**. The aim is to lead the accumulating wastewater quickly and without deposition from the plots into the public sewers.

According to the **drainage statute** of Karlsruhe, home owners are obliged to connect the buildings to the public sewers (connection dictate). Meanwhile, for the planning of domestic discharge pipes there are very exact guidelines.

For the construction of a building, a **drainage plan** must also be submitted. These drainage plans have been required from the beginning of the canalisation and are checked, passed and kept on file by the Tiefbauamt.



Drainage plan 2003

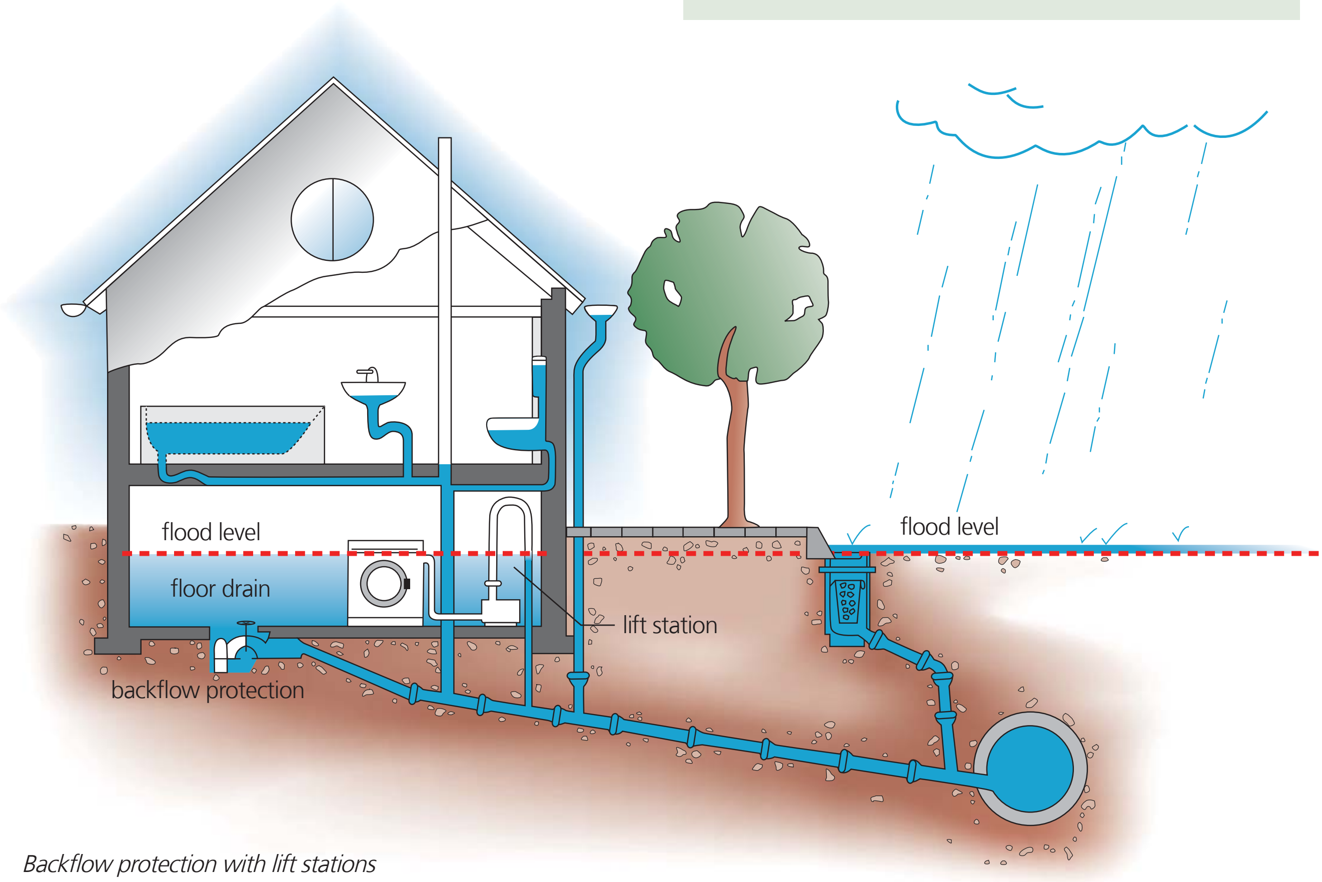
The city sewer system is constructed for a specific design rainfall intensity. During increased rainfall, a backflow forms in the sewers. For economical reasons, the capacity of the sewers can not be enlarged for every torrential rainfall. It is the task of home owners, to take precautions against deluges of rain by means of installation of **backflow protection.**

Rainwater and sewage that accumulate under the top edge of the streets, the so-called flood level, must be pumped via an automatic **lift station** into the public sewer. In doing so, it must be observed that the pump line is guided over the level of the flood level. In this way, there is also a security against backflow during power cuts.

Domestic untreated water without faeces can be fed via a **double anti-flooding valve** for parts of buildings with secondary uses – e.g. from a washing machine in a cellar. The Tiefbauamt provides a special brochure regarding the question of whether or not a lift station must be incorporated.

Yes or no to lift stations?

To request an information brochure call: 0049 721 133-7453



Backflow protection with lift stations

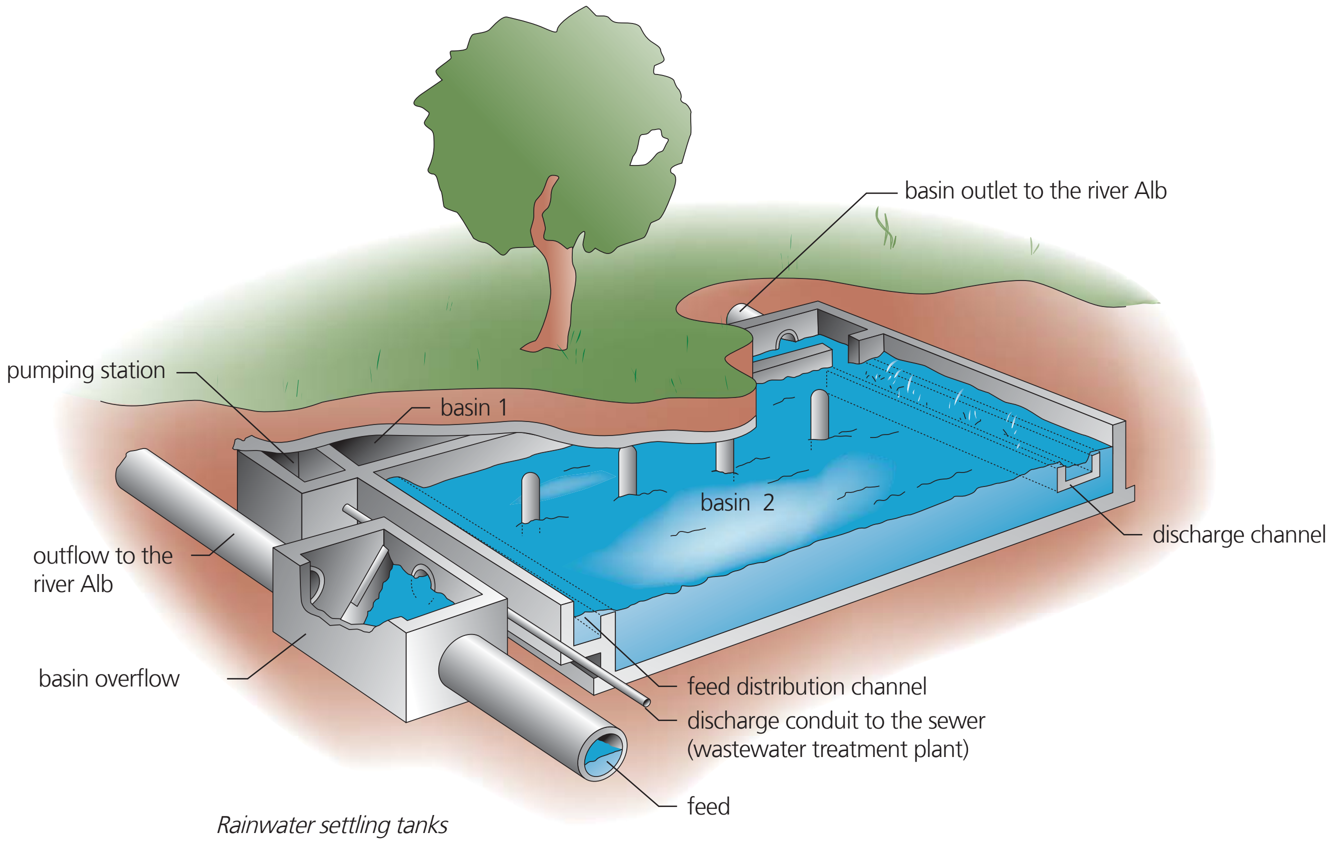
Precautions for wet weather

Rainfall recorder

In September 1991 the first **rainfall recorders** were installed in the city of Karlsruhe for **automatic data collection**. Now there are ten rainfall recorders which are scattered around the whole city area and the higher districts of the city. The rainfall recorders' data serves as the basic information for the plans and calculations of the city's drainage.

During heavy rainfall, the following **special constructions** in the sewer system enhance the safety of the discharge and protect the waters from additional pollution:

Rainwater settling tanks are cleaning plants, which are established in a rainwater canal of the separate system before the junction with public waters. Rainwater from roofs and yards as well as from streets and squares is partly contaminated through tire abrasion, oil residue, and street pollution. This especially concerns rainwater from trade and industrial areas. In the rainwater settling tanks the settleable solids, as well as lightweight liquids which float on the water (e.g. oil), are held back according to the concept of a petrol separator.

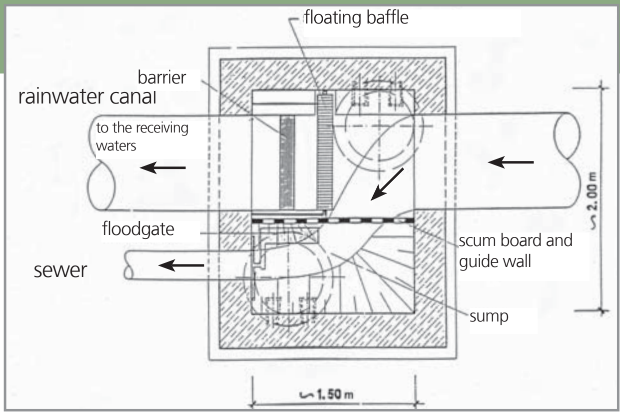


Rainwater settling tanks

For smaller drainage areas low-cost **wastewater-switches** were developed, which divert the introduced wastewater (which comes from incorrect connections) via a bypass to the wastewater pipe in dry weather. As it begins to rain, the bypass closes itself and, with the help of a baffle, stores the floating substances in the pipe. Once the rain has stopped, these substances are channelled off to the wastewater pipe and thus to the wastewater treatment plant.

Stormwater retention tanks are reservoirs openly constructed or underground, which fill up when the rainwater pipe cannot hold any more water. A set outflow amount is released into the canalisation via a throttle. This drainage delay prevents flooding.

In the mixed system there is a rapid rise of the wastewater levels during rainfall. With an adequate dilution ratio, this diluted mixed water may be carried into a body of water via a **rain-overflow**. From a hydraulic point of view, the rain overflow must be dimensioned in a way to ensure that at least 90 % of all pollutants flow off to the wastewater treatment plant.



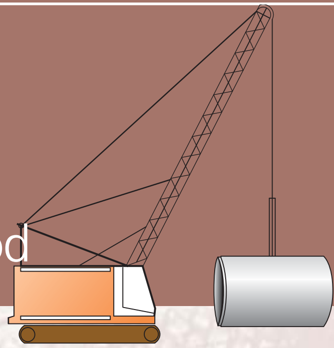
System layout of a wastewater switch

If this requirement cannot be met because the sewer system following the rain overflow is too small, a combined storage and sedimentation basin must be built. The **rain-overflow basins** disperse the wastewater flood into the mixed system and purify the diluted mixed water through sedimentation. The mud that remains in the basins must be removed at regular intervals.

Rain overflow basins in the wastewater treatment plant with an intake capacity of 18 000 cubic metres.

Execution of construction work in pipe construction

Renovation by using the cut-and-cover method



Traffic obstructions during using the cut-and-cover method

In pipe construction, there is a distinction between open and closed construction methods. If the existing pipe shows severe damage or in case of hydraulic or static overload, it must be replaced using the **cut-and-cover method**. Normally this includes unavoidable emissions (noise, vibrations etc.) and traffic obstructions.

High groundwater levels, polluted soil and a large amount of supply lines crossing at angles (electricity, telephone, gas, water etc.) often considerably complicate the pipe replacement. On the other hand, a new, more efficient sewer develops through this procedure.

Pipe replacement using the cut-and-cover method

Supply lines complicate the work

Pipe jacking with trenchless construction method

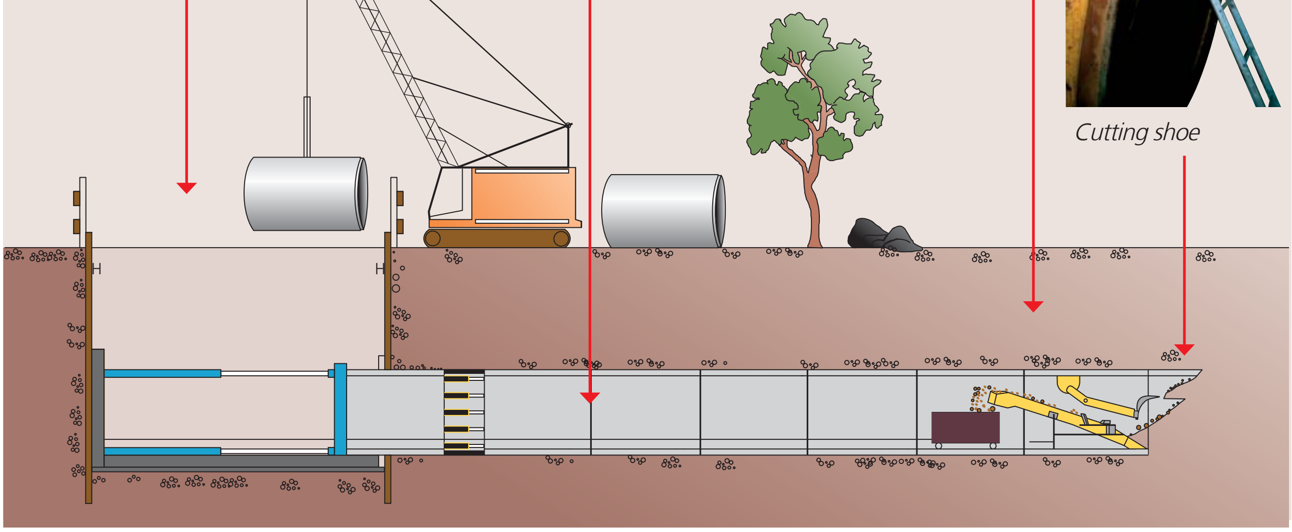
The large main collectors form the backbone of Karlsruhe's drainage system. These low-lying pipes (approx. 5 to 8 metres below ground level), with diameters of up to 2 metres, have been built since the sixties using the so-called tunnelling process, whereby the reinforced concrete pipes are driven several hundred metres into the ground with a hydraulic press using **the trenchless method**, starting from a thrust pit. The earth which blocks the pipe cross-section is simultaneously removed. The cutting shoe unit is finally removed from the receiving pit and the connection to the sewer system is established. These special techniques impose high requirements on the exact laying of the pipes in terms of location and height. Through this procedure it is possible to lay drainage pipes of different diameters over long distances. The intrusion into the ground is limited to the few thrust and receiving pits.

Excavating the soil at the site

Thrust pit with hydraulic presses

In the pipe

Cutting shoe



Construction site with thrust pit

Execution of construction work in pipe construction
Restoration of pipes through relining procedures

Tube relining

Besides the replacement of the pipes, there is also the possibility of renovating the existing pipes through the installation of plastic tubes, called tube liners or inliners. In order to benefit from this **internal renovation**, the old pipe is required to show no serious damage, like landslides, formation of shards, or deformations on more than 10 % of the existing cross-section.

In this procedure, an adaptable, resin-soaked plastic tube is introduced sector by sector, i.e. shaft to shaft, inflated by means of air pressure and pressed to the inner wall of the existing pipe. A source of heat (water, light, steam) is subsequently introduced, which hardens the resin and with it the plastic tube.

After the hardening process has finished, all existing pipe connections from the houses are opened by a milling robot.

Thus a pipe-in-pipe system is built within a short time. The old pipe then serves only as a surrounding shell.

Inserting the plastic tubing

Damaged sewer before the renovation

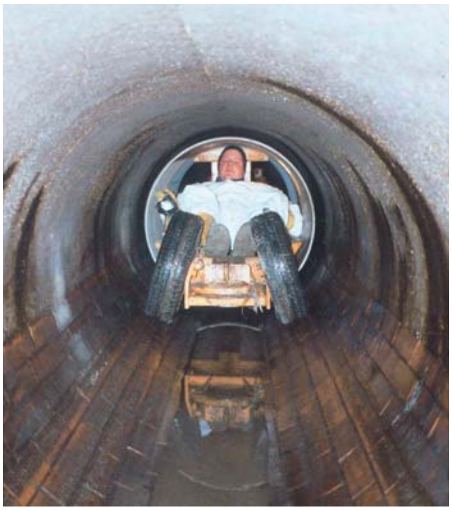
After renovation: a pipe lined with glassfibre-reinforced plastic

Pipe relining

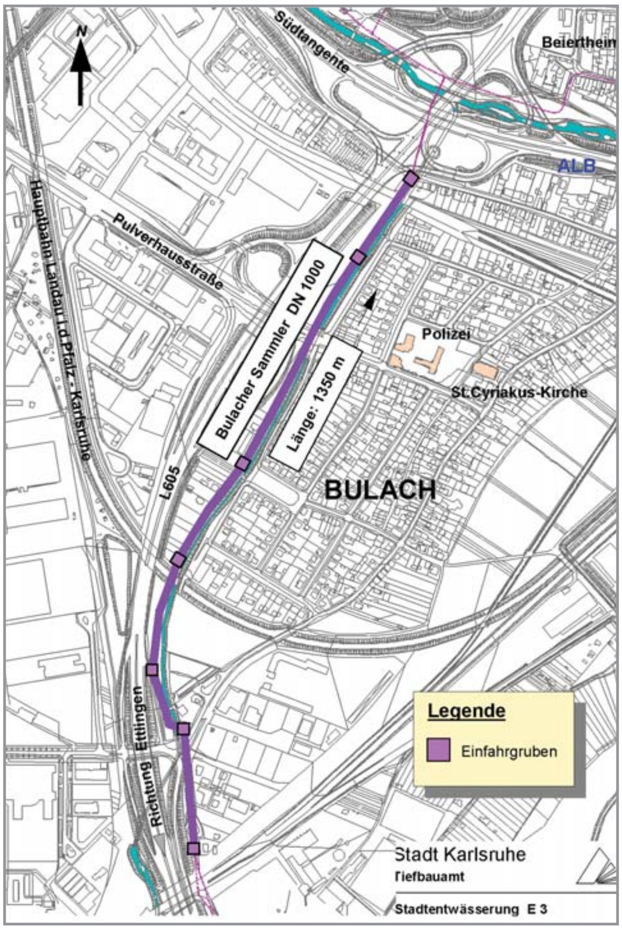
Pipe relining, in contrast to tube relining, uses factory manufactured plastic pipes. The plastic pipes provided are lowered over "tube sinking pits" and transported to the place of construction by a lifting carriage. At the destination they are fitted into place and coupled up. The remaining gap between the old and new pipes is then sealed up with a mineral mixture containing clay.

The advantage of relining procedures is that a new, fully stable and functioning drainage pipe is formed within a short space of time. The problems which arise from open construction (such as noise, vibrations and traffic obstructions) do not occur here. In addition, there is no accumulation of spoil, and the laborious moving of supply lines is not necessary.

Insertion pit for pipe relining



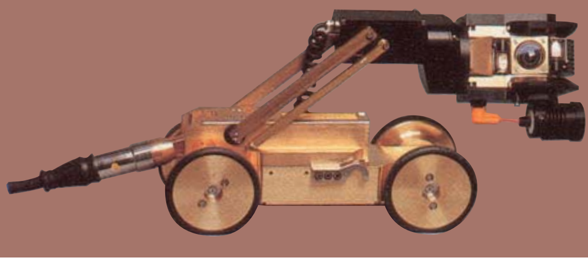
Inserting the pipe



Location plan : relining the pipes of the collector in Bulach

Each year a few kilometres of drainage pipes in Karlsruhe are replaced and renovated using the above described construction methods.

Modern technology for inspection and restoration



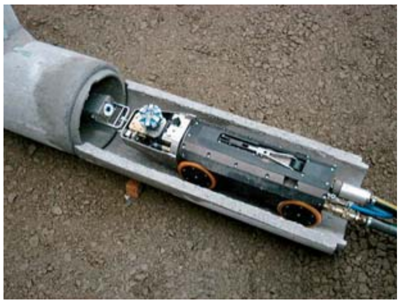
Robot with a sewer inspection camera (Kanalfernauge)

Today the urban area features a sewer system of approximately 1,100 kilometres in total length. Around 290 kilometres of this was already in place before the Second World War. The most modern technology is used for the collection of data and the restoration of the sewer system. Since 1975 the pipes have been inspected by a special robot, the so called **Kanalfernauge** (sewer inspection camera). The first complete inspection of all the pipes was completed in 1999. These investigations take place as follows:

Special cameras, which are mounted on the robots, pass through the canals and record their state. Sewers with diameters from 20 centimetres to 2.20 metres are inspected and checked by this method. The special camera transmits the images to a monitor in the observation vehicle. Damage is documented by means of digital images and video recordings, and classified into groups according to condition. Potentially necessary **renovation measures** are deduced from this information.

Before every restoration it must be checked whether the hydraulic performance of the pipe section is still sufficient. Spot damage can be repaired with modern internal renovation technology, such as canal robots, part-lining or bush-grouting, without need of excavation. These procedures spare costs and minimise the inconvenience to residents.

Experience shows that conclusions about the state and leaktightness or the overall condition of a sewer cannot be drawn from the age alone. In Karlsruhe there are sewers over a hundred years old which still lie undamaged in the ground. By contrast, reinforced concrete pipes that were laid between the two world wars, frequently display severe damage. In those economically difficult times, cement was used sparingly as a bonding agent, which had a noticeably negative effect on the quality of the concrete.



Milling robot with a pan and tilt camera

Root formation in a sewer

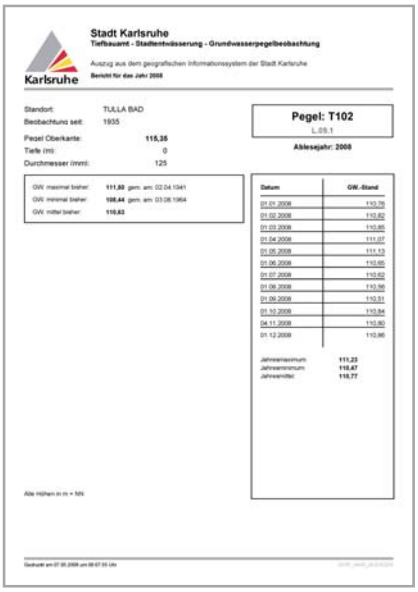
Sewer restoration vehicles in operation

Cadastral information

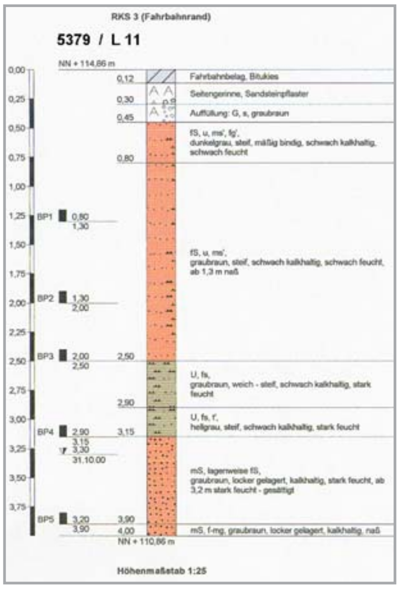
Since 1930 there have been measuring devices for groundwater levels in Karlsruhe. More than 140 groundwater observation wells spread across the entire urban area. The ground water levels are electronically read and recorded at regular intervals. For all of those who are interested, it is possible to receive information concerning the highest and lowest groundwater levels that have been occurring in a particular area from the Tiefbauamt.

Data extracts from the digital sewerage and borehole register are made available as either paper copies or in digital form.

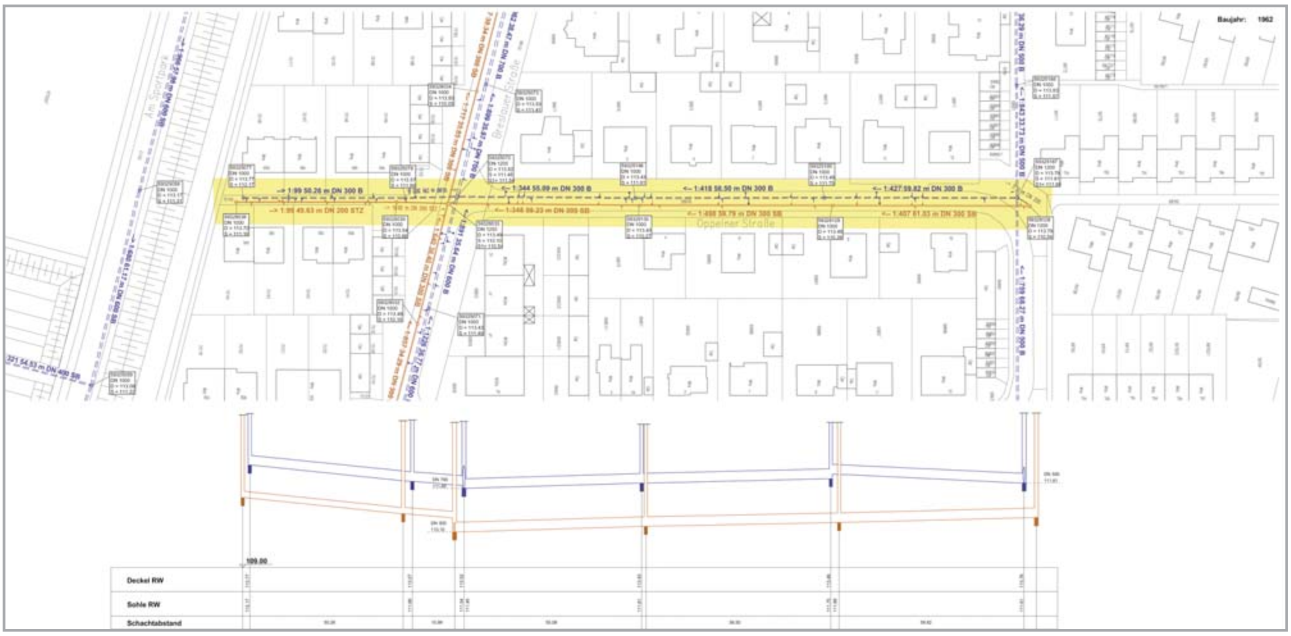
Information from the land registry of the Stadtentwässerung Karlsruhe is available for a fee from the Katasterbüro (Land Registry Office).
Telephone number: 0049 721 133-7425 or -7426.
Central e-mail address: kanalkataster@tba.karlsruhe.de



Data sheet of groundwater monitoring



Plan of bore-hole register

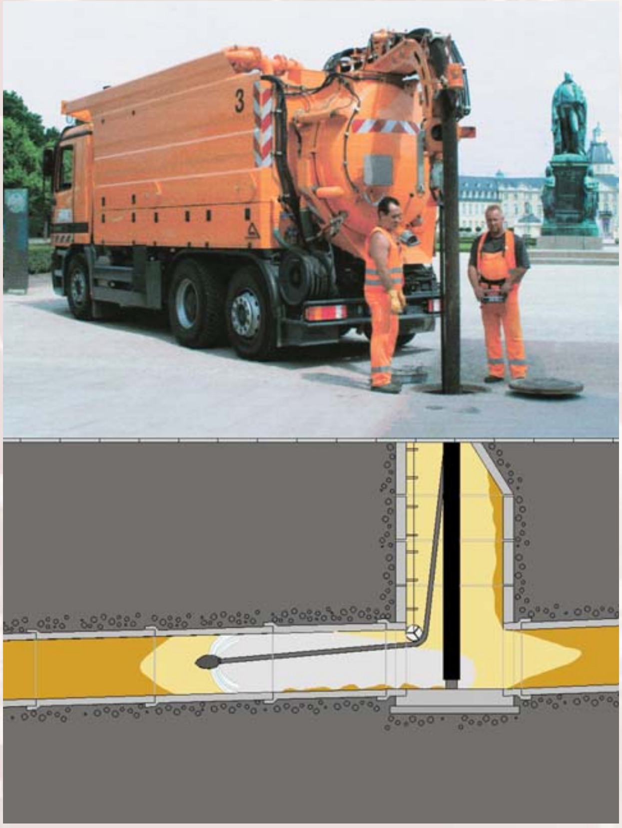


Plan of drain register

From manual operation to machine flushing

As the Rhine valley has only a slight downward gradient, the sewers in the Karlsruhe city area lay very flat. Accordingly, the wastewater flows slowly with a slight drag, whereby it can easily form sedimentary deposits. The sewers are cleaned at regular intervals so that they do not become blocked. At the beginning of the year, in particular, the grit which has accumulated in the sewers from the winter services must be removed. In previous years, the cleaning was carried out with a sewer brush attached to a cable winch.

Hand cleaning team, 1959



Sewer cleaning with a high-pressure flusher

Today the predominant part of the pipes is cleaned with **high pressure flushers**. The sedimentary depositions in the sewer are loosened and flushed away with pressures of up to 150 bar. The vehicle uses a suction spout to draw the mud into a collecting tank. With this system, sewers with a diameter of up to one meter can be economically cleaned.

Like the Hauptentlastungskanal or the Landgraben, the main water-receiving canals must be cleaned with rinsing apparatus. **Flushing sleds** are set into the wastewater canal for this purpose. According to the principal of shifting blockages, the rinsing apparatus is moved by the available wastewater through the sewer.

If there is not sufficient wastewater, water can be piped to the inner city using special **rinsing-wells**, or so called rinsing canals, of about fifteen kilometres in length, which come from the Alb and the Pfinz. The rinsing apparatus are stopped at specific, easily accessible inspection points and the mud is scooped out of the sewer or a suction vehicle is used.

Despite an increasing mechanisation of the cleaning operations, inspections inside the sewers are essential. The work remains hazardous and requires full physical effort. Extensive safety precautions safeguard the employees from accidents.

High pressure cleaning jet

Flushing sled in the Landgraben

A total of 70 **Kanalbetrieb** (sewer operations) employees keep the whole sewer system functioning. Several handwork teams perform minor, instant repairs. Special vehicles are available to the sewer cleaning crews for high pressure cleaning, sucking up mud and catch basin cleaning.

Each year the employees clean some 87,000 catch basins and 1,300 kilometres of sewers in the city area.

The Kanalbetrieb is also responsible for the maintenance of the rain basins and rainwater overflow structures. Each year the employees conduct over 260 inspections of the basins. Some 1,300 tonnes of canal sand and mud are extracted from the city's basins, pipes and road gullies each year.

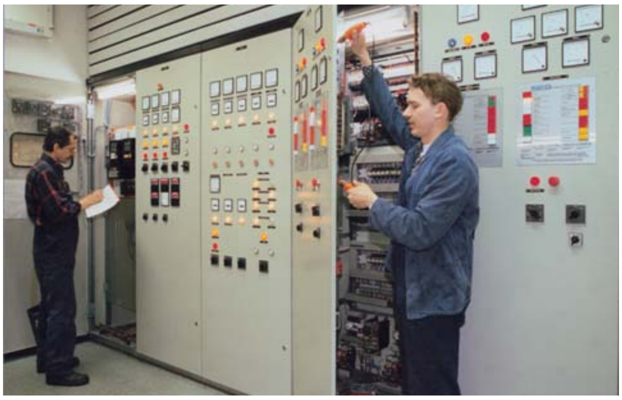
Employees of the Kanalbetrieb

Pumping stations ensure flow

There are drainage areas which lie so low that there is no sufficient free, natural downward gradient to the waters or main sewers. **Pumping stations** are therefore required. 29 rainwater pumps, 8 mixed water pumps and 15 wastewater pumps are operated within the city area. The pumping stations require intensive maintenance and regular inspection.

Several small settlements which lie outside of the city area and for which a standard connection to the canalisation would be too expensive, have been connected to the existing sewer network by means of pumping stations. The wastewater from these areas is pumped through plastic pipes with small diameters ranging from 80 to 100 mm. The construction costs amount to only 15 to 25 % in comparison to the cost of a sewer with a downward gradient.

Monitor used for remote monitoring



Control room for the Südtangente pumping station

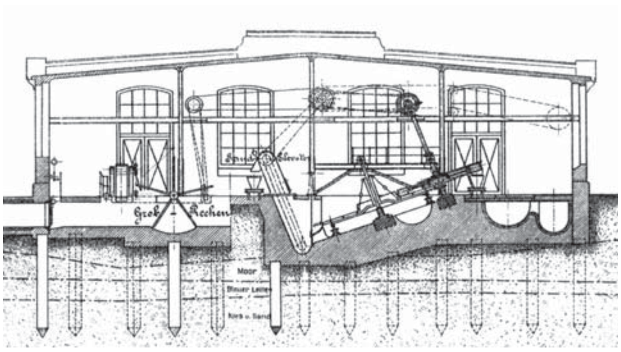
Pumping shaft with submersible pumps

Rainwater pumps

Everything ends up in the wastewater treatment plant

The wastewater treatment plant administrative building

All of these aforementioned efforts made by the Stadtentwässerung (wastewater authority) aim to ensure that the resulting wastewater from the combined sewers system – municipal wastewater, storm water and groundwater infiltrates – reach the treatment plant as fast and as safely as possible. During dry weather flow, the plant receives about 64,000 m³, which is equal to approximately 425,000 bathtubs. The plant can receive and treat about 340,000 m³ daily during wet weather.



Riensch's inclined disc screen, 1913

In 1913, the treatment plant first started using a coarse screen, which was followed by a rotating inclined disc screen, or alternatively a Siebschaufelrad (screening paddle wheel), for mechanical wastewater treatment. This simple technique was used until after the Second World War.

By the early 1950s, the performance of the mechanical treatment was significantly improved by the successive addition of screens, sand traps, settling tanks and drying beds.

A biological wastewater treatment (activated sludge process) has been carried out since 1977. The second biological treatment (trickling filter) was first used in 1984 and once again the purification efficiency was significantly improved.

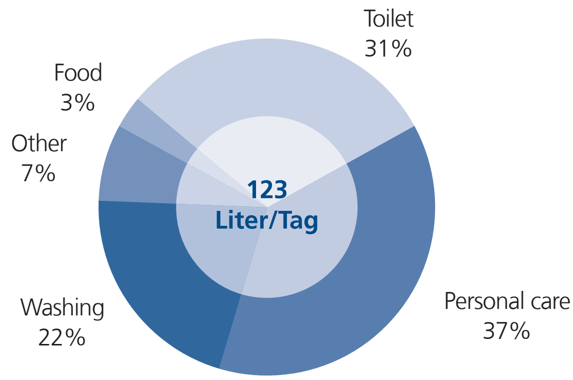
Between the 1970s and 1990s, the focus was on reducing as much as possible the amount of carbon compounds in wastewater.

The algae bloom and seal deaths in the North- and Baltic Seas of 1988/89 showed that dissolved nutrients – such as phosphorus and nitrogen – in wastewater effluent must be removed. In the following years, the focus was set on upgrading phosphorus and nitrogen elimination.

In principle, the performance of all planned steps of development of the Karlsruhe wastewater treatment plant has been tested in an extensive assessment prior to being implemented.

Automatic screening system, 1993

The results from the trials allowed for optimal, i.e. lean dimensioning. It was thus possible to find cost effective solutions.



Water use in households per person

Almost all the water used in households, such as drinking water, as well as ground- and stormwater, goes through the sewer system to the wastewater treatment plant.

History of the Karlsruhe wastewater treatment plant

1908 Determining the location

In 1908, the executive administration body of Baden stipulated that the city must treat their wastewater mechanically before discharging it into the Rhine. The selected site for this mechanical treatment plant – a coarse screen followed by a rotating inclined disc screen – lies as deep as possible at the district boundary near the Rhine. The deep location ensures that most of the wastewater flows to the plant by gravitational flow.

1913 Start of wastewater treatment

With the simple mechanical plant in operation in 1913, up to 76,000 m³ of wastewater could be treated per day. This was the start of an ongoing expansion of the wastewater treatment plant which continues to this day.

1942 No money for further development

In the mid-thirties, the capacity of the plant was exhausted. The regulatory authority requested that a new wastewater treatment be state of the art. Measures and investigations for a new plant began immediately. In 1942 the political leadership postponed the implementation of this plan because of the primary armament efforts.

1951 New sewage treatment plant west of B 36

In 1946 the plans were again taken up. As there was only sufficient expansion area west of the road B 36, the new treatment plant was relocated to this area. The new plant was designed to be purely mechanical with screens, grit chambers, sedimentation basins and dry beds. Operation started in 1952. Several extensions followed until the early 1970s.

1973 Implementing a thermal sludge dewatering line

Instead of building the four digesters for sludge stabilisation as planned, the city of Karlsruhe decided to build a thermal sludge dewatering line. This was on account of the low energy costs, as the price of one litre of fuel was less than 10 Pfennig (0,05 €)

1977 First biological treatment stage

Meanwhile, the state of waterbodies became so poor that biological treatment was required. After four years of construction, the first stage of biological wastewater treatment was put into practice in 1977. This consisted of 18 activated sludge chambers (22,000 m³) and 6 final clarification tanks (18,000 m³).

1978 Construction of waste air cleaning plants

Residents bitterly complain about the emissions from the open sludge activation chambers and the thermal sludge dewatering line. In just a short amount of time the activated sludge chambers are covered. The malodorous air is brought by suction to a 3-step air cleaning plant which uses chemicals. In a second air cleaning plant, the odorous air from the thermal sludge dewatering line is treated.

1981 Commissioning the first sludge incinerator

According to regulations, the 120 tons of sewage sludge which are produced each day can no longer be disposed of at the city's landfill. There are problems of malodour during warm seasons and the stability of the landfill when mixed with domestic waste during rainy seasons. The only technical solution is to incinerate the waste.

1984 Four trickling filters: the second stage of biological treatment

After commissioning the second stage of biological treatment, four trickling filters, as well as two additional sedimentation tanks for the first stage, outflow concentrations can be considerably reduced. In addition, this technical solution provides nitrification, thus reducing ammonium, which is poisonous to fish at higher pH-levels.

Karlsruhe wastewater treatment plant, 2009

1990 **Phosphorus reduction**

After extensive large scale tests, phosphate has been precipitated by means of "green salt" (Fe-II-sulphate) since 1990.

1992 **Construction of a second sludge incinerator**

To ensure a reliable operation for sludge combustion, a second fluidised bed incinerator is built in 1992.

1998 **Nitrogen elimination**

After a six year period of construction, which included extensive reconstruction, denitrification is put into operation. Over a period of four years before the reconstruction is started, experts assist staff in finding an ideal solution. Several alternatives are tested for suitability in pilot plants. A very economic solution is found as it becomes possible to largely incorporate the existing basic structures into the new construction step.

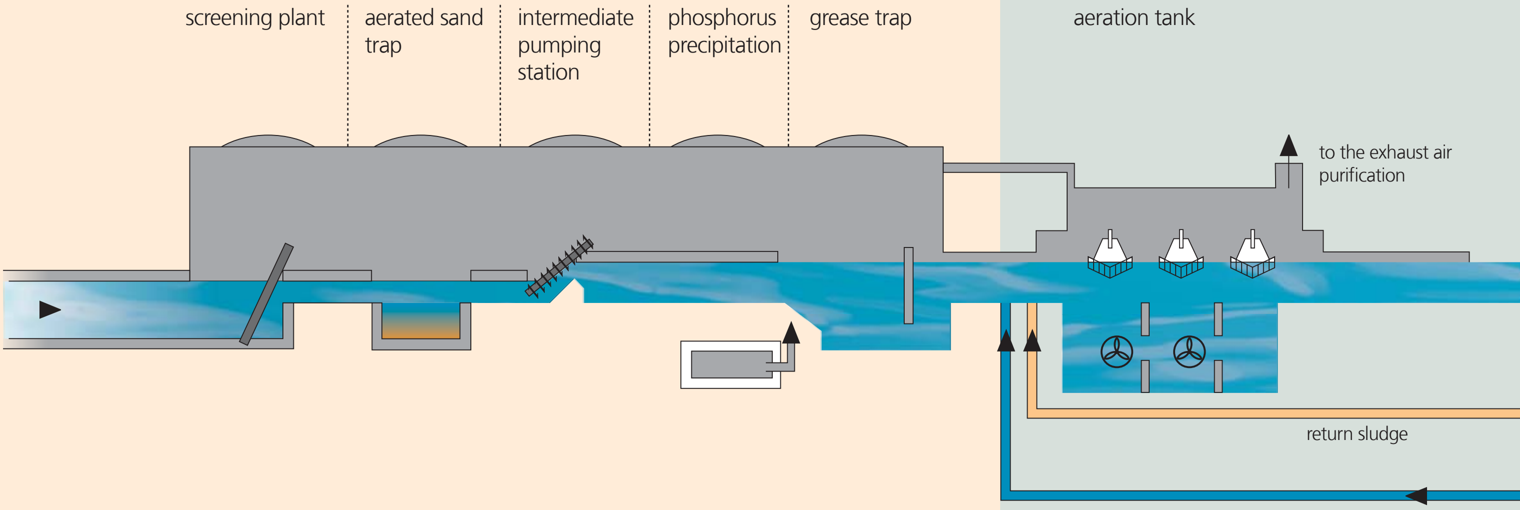
2002 **Advanced nitrogen elimination**

The effluent concentration for total nitrogen was once again reduced by legislation from 18 to 13 mg/L in 2002. Another four trickling filters were planned and commissioned by the end of 2007. Two of these trickling filters can also be converted for a downstream denitrification.

Bacteria purify the wastewater

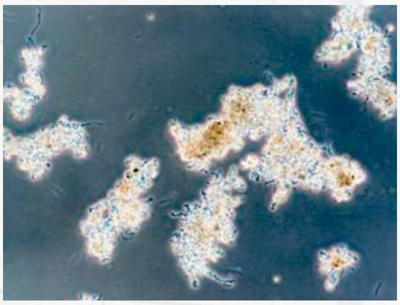
Mechanical purification stage

First biological purification stage *with denitrification*



An **automatic screening** system retains all rough waste materials. This is subsequently followed by an aerated **grit chamber** where the flow velocity decreases so that all mineral particles, such as sand and gravel, settle.

By means of an **intermediate pumping station** (Archimedean Screw), the wastewater is lifted and then Fe-II-sulphate is added for simultaneous **phosphate precipitation**. Grease and suspended particles floating on the surface are separated in the **grease trap**.

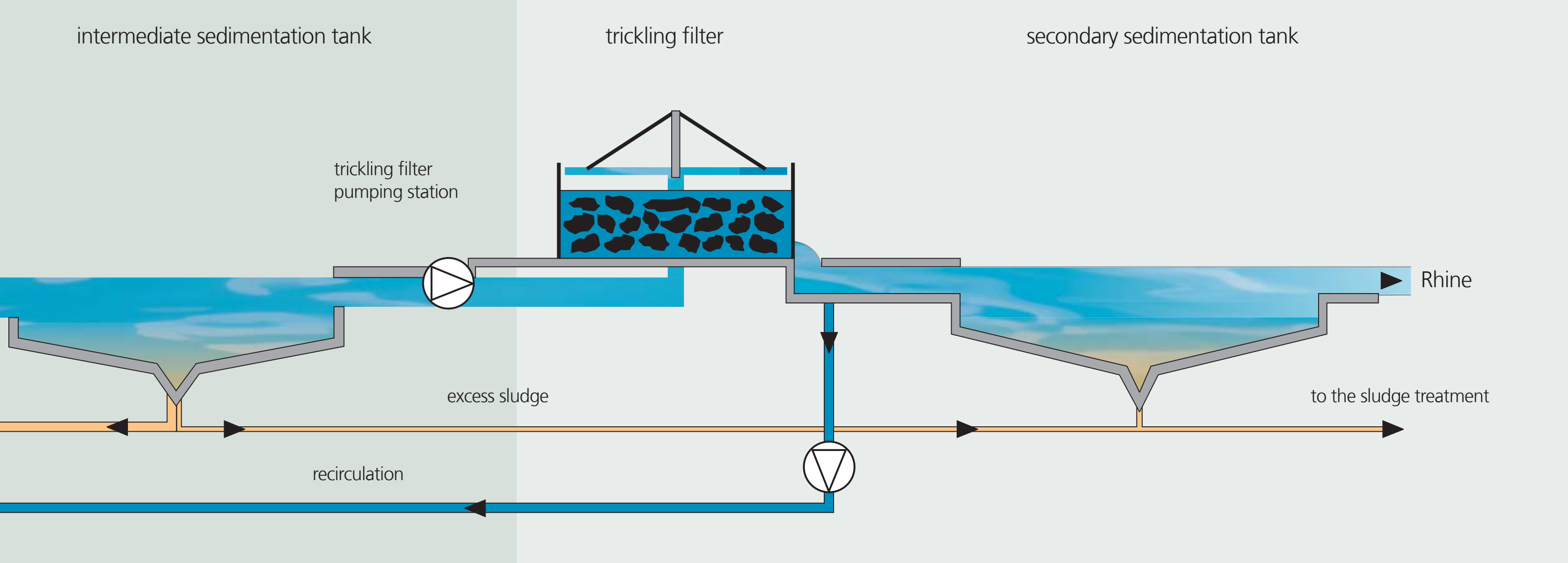


Sludge particles (enlarged)

After such mechanical treatment, the wastewater flows into the **activated sludge chambers**. A part of the outflow is refluxed from the trickling filters to the first chambers of the biological treatment where **denitrification** occurs. There is no aeration and therefore the carbon degrading bacteria (denitrifying bacteria) take up the oxygen from the nitrate for their survival. Nitrogen gas is formed and emitted into the atmosphere.

In the following tanks, micro-organisms – in particular bacteria – consume the dissolved organic pollutants in the wastewater. Agitators and technical aeration devices keep the activated sludge in suspension and also supply the oxygen that is necessary for these bacteria's survival.

Second biological purification stage *with nitrification*



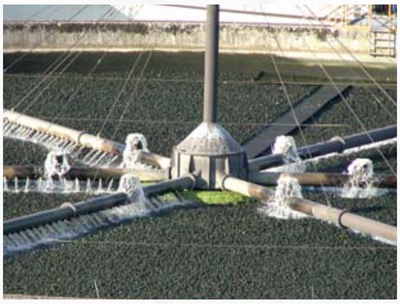
The sludge and purified water are separated in the **intermediate sedimentation basins**. Due to the slow velocity of flow, the sludge settles at the bottom of the basin.

In order to ensure high bacteria density and thus achieve good purification, the sludge from the sedimentation basins is recycled into the activated sludge chamber.

The second stage enhances biological purification. The wastewater is equally distributed over the **trickling filters** which are cylinders of concrete filled with lava rocks. A thin, viscous layer of nitrifying bacteria forms on the surface of the lava rocks, which causes the ammonium nitrogen to be oxidised to nitrate **(nitrification)**.

The purified water is separated from the remaining sludge in four clarifiers **(secondary sedimentation basins)**. After two biological treatment steps, the purified wastewater is discharged into the river **Rhine** through a large open channel.

Intermediate sedimentation tank

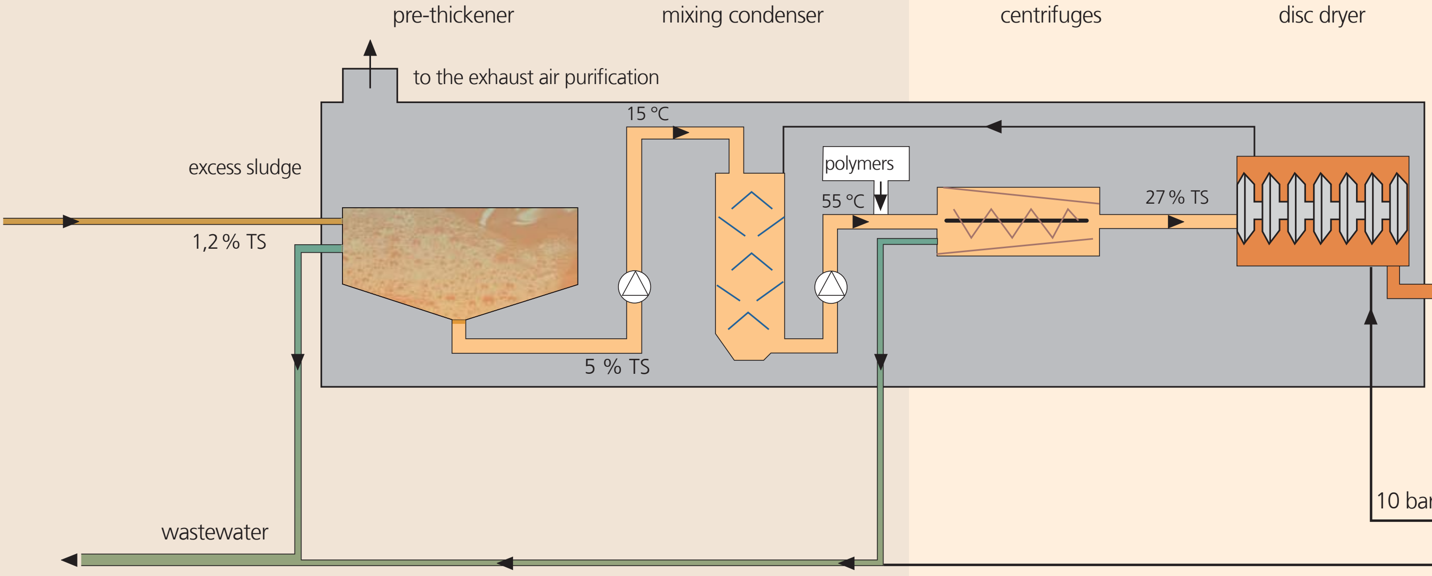


Trickling filter irrigation

What about the sludge?

Sludge dewatering

Thermal sludge drying



About 1.2 % of the sludge from the secondary and final clarification basins is solid and the rest is water. The aim of the sludge dewatering is to reduce this high proportion of water. In the **pre-thickeners**, a solid content of about 5 % is attained by static thickening, i.e. by simply letting it stand.

The sludge is subsequently preheated in a **mixing condenser** to attain a temperature of about 55 °C.

To further drain the sludge mechanically, chemical conditioning materials **(polymers)** must be added beforehand. This conditioning causes the small particles of sludge to form together to create larger particles from which water can be easily drained.

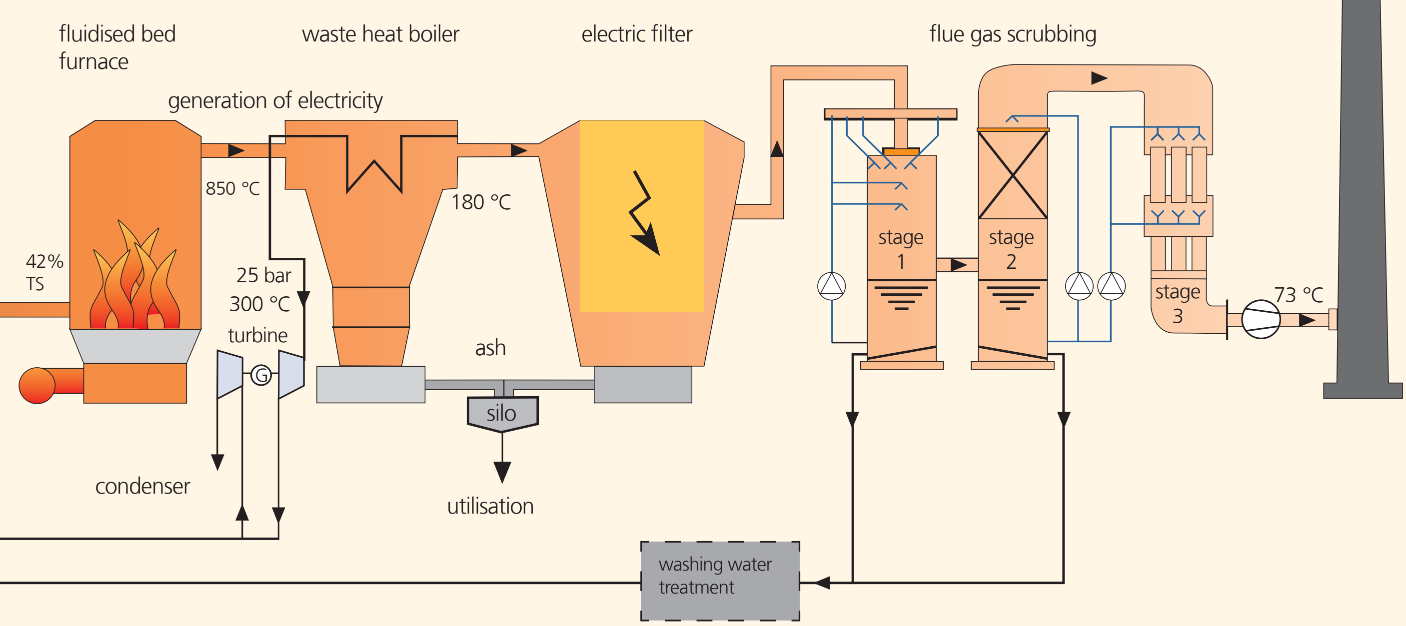
Three **centrifuges** each with a maximum capacity of 45 m³ per hour drain the sludge.

27 % of solid content is obtained after centrifuge. It is necessary to have 42 % solid content for self-combustion and this is obtained using **disc dryers** which are heated by steam.

Sludge pumping station

Disc dryer

Sludge incineration with generation of electricity



Fluidised bed furnace

The sewage sludge, which includes properties of fat and debris, is burned at a temperature of approximately 850 °C in a **fluidised bed furnace** which today is the most environmentally friendly form of incineration. The heat energy contained in the exhaust gas is used in the **waste heat boiler** for steam generation. 60 % of this energy is needed for drying the sludge and the remaining 40 % is used to generate **electricity** via a turbine and generator.

The heavy dust particles of the flue gas settle in the waste heat boiler.

An **electro-filter** with a cleaning degree of 99.8 % holds back the lighter dust particles.

The remaining pollutants are subsequently eliminated from the flue gas in a three step wet flue gas scrubber according to state-of-the-art technology (17. BImSchV).

Of the daily 2,500 m³ of fresh sludge, about 10 m³ of ash remains. The ashes are used as aggregate for the filling of mineshafts.

Sludge incinerator

Flue gas scrubbing

Around the clock operation

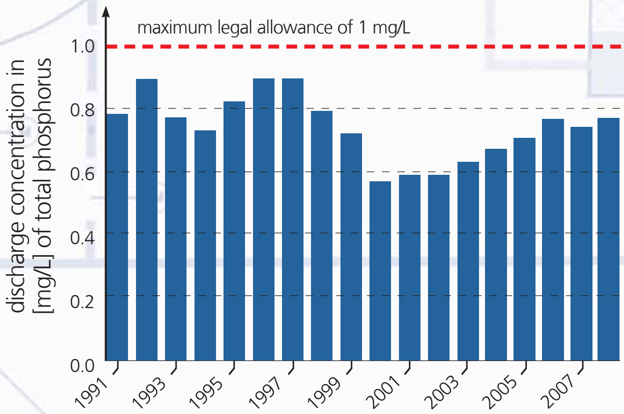
Nowadays **wastewater treatment plants** are similar to modern factories. Only instead of product treatment it is all about incremental water treatment. In this case, the »production process« aims to obtain clean water. However, there is one difference between wastewater treatment plants and normal factories: a waste water treatment plant must not be switched off and legislation requires a special cleaning performance during continuous operation.

The requirement to remain **permanently operational** imposes high demands on the cleaning operations. Sufficient resources must be kept for all important installations, above all the machines, which are permanently in operation. Staff must be able to quickly identify and eliminate upcoming malfunctions.

With each further upgrade, the aim is to construct low-maintenance and reliable plant components. All parts of the system are automatic as long as it is both technically possible and economically sound. Regulation and supervision are carried out in an operating control room.

Wastewater treatment plant operations centre

Employees of the wastewater treatment plant



Success in phosphorus removal

Outside of normal working hours, 3 specialists are required to run and monitor the sewage plant. A total of 65 people are employed at the plant.

The wastewater technology has since become highly developed and requires a skilled and responsible workforce. The good results of recent years owe credit to this dedicated team.

Constant internal and external control

The wastewater flowing to the plant is subject to strong variations in quantity, pollution load and composition. Samples of the sewage are routinely collected and examined from specific sites in the plant. The chemical analyses provide important data for the plant's operations, such as the pollution loads of the wastewater and the level of treatment, which indicates the efficiency of the plant. These analyses are carried out at the central laboratory on a daily basis as part of the plant's **selfmonitoring** process. Only with the help of these measurements is it possible to ensure optimised treatment and improvements at the plant. The laboratory analyses as well as the constant measuring devices ("online devices") provide continuous information about the level of pollution in the wastewater as well as the current purification performance of the plant.

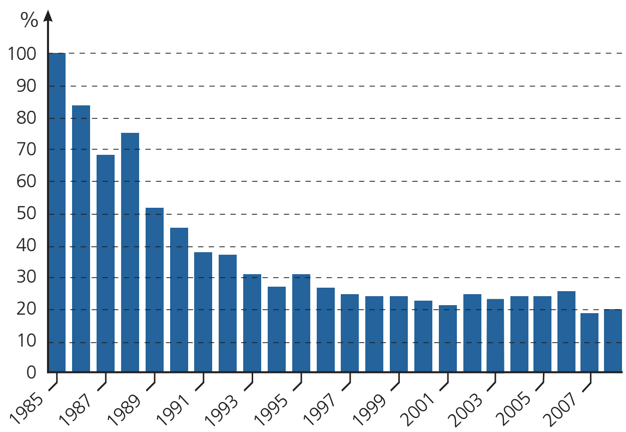
Analysis in the central laboratory

Another area of responsibility of the central laboratory is the guidance and control of industries in terms of **indirect influent monitoring**. Commercial and industrial companies may only discharge their wastewater into public sewers if the concentration or contents of pollutants does not exceed a certain level. These levels are legally fixed for different industries. Companies that have an industrial wastewater treatment plant or are strong polluters are regularly examined. Samples are currently (as of 2009) taken from approximately 110 companies in the city area and in Ettlingen on a regular basis. All information are managed with a modern computer-based EDP-supported wastewater register. The data collected are provided to the respective water authorities.

On-site sampling

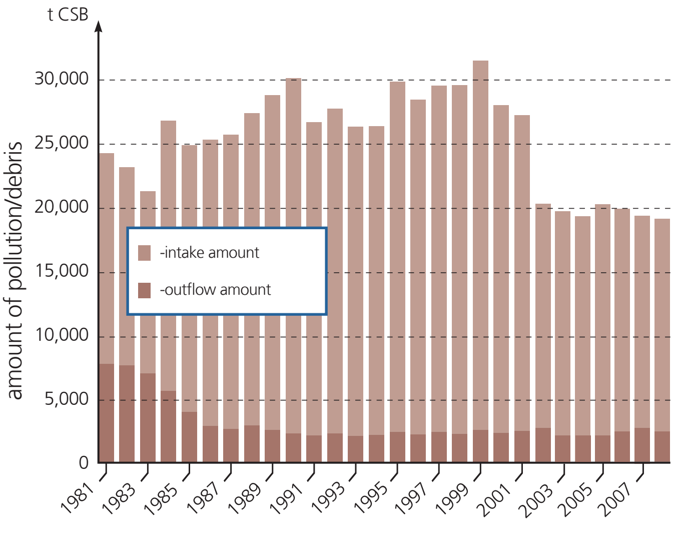
The advantage of these periodic examinations is evident from the improvement in the amount of heavy metal content, which has been reduced to less than a third since 1985 (see chart). The heavy metal concentrations in the influent of the treatment plant are actually below the limit values required for the effluent. Therefore, the City of Karlsruhe does not pay for these pollutant emissions.

The city's wastewater treatment plant also cleans wastewater from Ettlingen, the Beierbach sanitary federation, as well as from Malsch and Rheinstetten-Forchheim. These **communities** as a whole make up a proportion of about twenty percent (as of 2008). The annual accounts of these communities are calculated by charges which are ascertained monthly.



Development of heavy metal content (lead, chrome, copper and nickel)

What is the cost of wastewater?



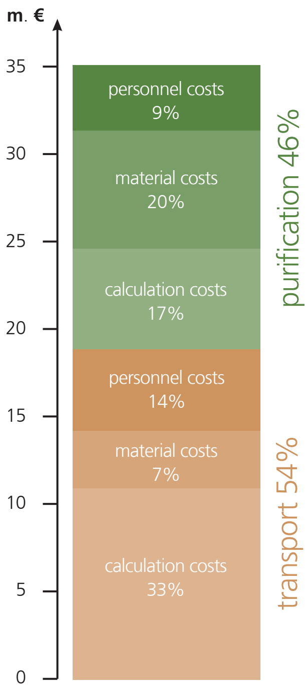
Wastewater purification/treatment by example of COD

Wastewater treatment is an official municipal task. The occurring costs are financed by usage fees. The cost of treatment inevitably rises as the level of treatment increases, as shown in the diagram below. After the turn of the millennium, when the wastewater treatment plant's extensions for the further elimination of phosphorus and nitrogen were completed, the financial situation stabilised to some extent. The usage fees could even be reduced with a few small steps.

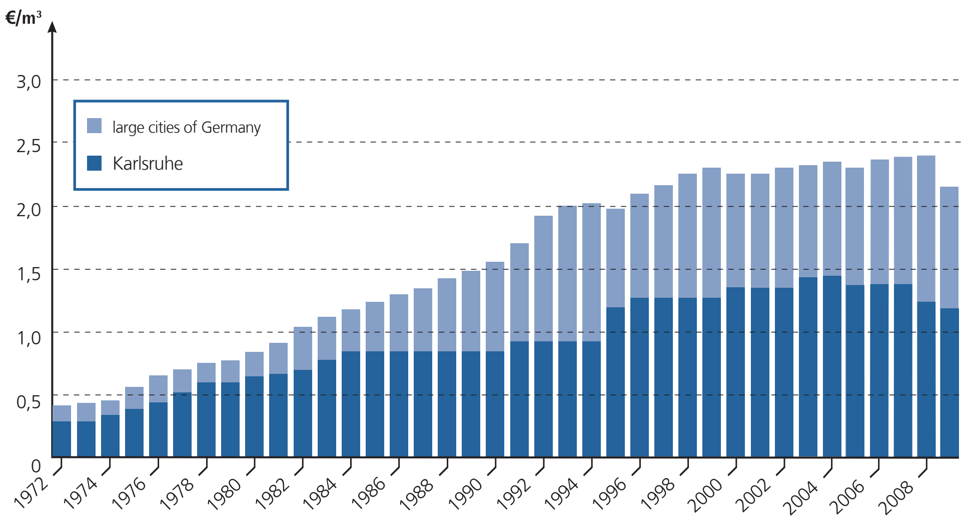
The wastewater treatment will also have to face tighter requirements in the future. Extensive, long-term tasks for the sanitation of the sewers are also on the agenda. Therefore a moderate rise in charges in the future cannot be ruled out.

In order to fairly distribute the charges according to the actual use of the public sewerage system, the split wastewater fee was introduced in 2008, which is the separate billing of wastewater and rainwater for pieces of land with a sealed surface of 1,000 m² or larger that is subject to fees. Plots with smaller sealed surface can be converted to the split-system on request.

In comparison to other large German cities, Karlsruhe has had some of the most cost effective drainage fees for years.



Spreading of costs of the sewage disposal 2008



Comparison of the sewage charges (standard charges for fresh water consumption)

Prospects of wastewater treatment

An interconnected network of sewers

Large main sewers with an internal diameter of 1.6 to 2.5 m are the backbone for a fast discharge of wastewater from the different districts. Most main sewers were built between 1883 and 1922, i.e. they are over 90 years old. The main sewers network has, for the most part, a radial layout. At the present time, many main sewers cannot be left to dry out to be reconstructed because it is not possible to bypass them. The Stadtentwässerung intends to develop the sewer system step by step into an interconnected system within the next 30 to 50 years. With this interconnected system, the performance of the sewer system will be significantly improved and will thus enable the maintenance and reconstruction of damaged parts of the sewers.

Outflow of secondary sedimentation tank

Pollution reduction at source

Current wastewater treatment techniques can only break down dangerous or less degradable substances, such as organic halogen compounds, pharmaceutics and many other chemical substances, to a small extent. Passing these pollutants into the sewage is not the right way to discharge them. It is essential that these pollutants are more effectively held back at their place of origin.

In the longer term it is imperative that the technical-industrial production is altered, so that only substances that can be disposed of safely are developed. Only through these precautions dangerous accumulation of pollutants in the air, ground and water can be avoided. Only in this way will the wastewater purification close the water cycle loop and thus contribute to providing clean water to mankind on a long-term basis.

Sustainable water management

The technique of using water carriage system of waste disposal was developed in the 19 th century. From an ecological point of view, this technique – the transportation of excreta with the help of drinking water – is currently critically questioned. For developing countries in particular, this technique is rarely suitable due to high costs and because many agglomeration areas lack infrastructure and sufficient water supply. Today discussions on sustainable water-management favour many new alternative discharge techniques. In developing areas in several cities of Germany, the separation of wastewater (grey, yellow and black water) and decentralised treatment is currently being tested. Real performance and the costs involved will decide which technology will remain in the wastewater market in the future. Despite of this, the central wastewater treatment needs further improvement on a continuous basis.

Contact

If you have any questions please contact the Stadtentwässerung Karlsruhe via:

- phone: 0049 721 133-7412
- fax: 0049 721 133-7439
- e-mail: stadtentwaesserung@tba.karlsruhe.de

You will find Karlsruhe's Stadtentwässerung online on the Tiefbauamt website at:
www.karlsruhe.de/b3/bauen/tiefbau/entwaesserung.de

Here you will find further information especially concerning drainage charges.

In addition, the following documents are available in German language:

- Satzung der Stadt Karlsruhe über die öffentliche Abwasserbeseitigung (Entwässerungssatzung)
  (Statute of the City of Karlsruhe concerning public wastewater drainage)

- Satzung der Stadt Karlsruhe über Gebühren für die öffentliche Abwasserbeseitigung (Entwässerungsgebührensatzung)
  (Statute of the City of Karlsruhe concerning the charges on public wastewater drainage)

- Broschüre »Schutz vor Rückstau - Wie schütze ich mich gegen Rückstau aus der Kanalisation und gegen Eindringen von Oberflächenwasser«
  (Brochure "Backflow protection – How can I safeguard against backflow of canalisation and intrusion of surface waters")

- Broschüre »Regen bringt Segen - Versickern statt Ableiten« des städt. Umwelt- und Arbeitsschutzes
  ("Rain brings blessing – Infiltration instead of discharge" Brochure of municipal Department of Environment Protection and Health and Safety)

Technical data

Discharge of sewage

Canal system (drainage area)

discharging area	4,586 ha
mixed system (57 %)	2,596 ha
separate system (43 %)	1,990 ha
net length (Status 31.12.2009)	1,108 km
maximum distance to the treatment plant	20 km
maximum difference in altitude to the treatment plant	288 m
maximum flowtime (to the plant)	ca. 11 Stunden

Pumping stations

15	wastewater pumping stations
29	rainwater pumping stations
8	mixed water pumping stations
12	pumping stations for pressure sewage systems
8	rinsing wells

Connected towns and communities

Abwasserverband Beierbach, Ettlingen, Rheinstetten-Forchheim, Malsch

Measuring devices

145	groundwater observation wells 113 operate automatically
10	rainfall recorder

Rainwater treatment

13	rain overflow basins
13	rain overflow
8	rainwater settling tanks
27	open rainwater retention basins
12	closed mixed water retention basins
4	wastewater switches

Wastewater purification (average values 2004 - 2009)

Quantity of wastewater	
afflux per year	34,000,000 m^3/a
mean afflux per day (rainy weather and dry weather)	93,000 m^3/d
mean afflux per day in dry weather	64,000 m^3/d

Quantities for plant		
afflux Q_{TW} (dry weather)	=	2.1 m^3/s
afflux Q_{RW} (rainy weather)	=	4.0 m^3/s
treatment cap. is equivalent to	=	105 t/d CO 875,000 PT

Consumption of operating resources per year	
electricity	21,700,000 KWh/a
fuel	317 m^3/a
polymer (active ingredient)	57 t/a

Quantities (of sludge)	
sewage sludge (dry solid matter)	10,240 t/a
ashes for utilisation	3,560 t/a

Purification efficiency	COD	Nitrogen	Phosphorus
inflow concentration [mg/L]	617	45.2	8.1
inflow load [kg/d]	53,700	4,060	710
outflow concentration [mg/L]	52	11.8	0.73
maximum permissible value [mg/L]	75	13	1
purification efficiency [%]	91.6	73.9	91

Explication of technical terms

PT = total number of inhabitants und population equivalents (Value for one inhabitant, in terms of COD it amounts to 0.12 kg/d)

COD: Chemical **O**xygen **D**emand
Amount of oxygen which is needed for total chemical oxidation of organic compounds in the wastewater

a = year, **d** = day

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Entrance to the underworld of Karlsruhe

Interested groups of visitors may arrange an appointment on telephone number 0049 721 133-7441 (Kanalbetrieb)

und viel darunter.