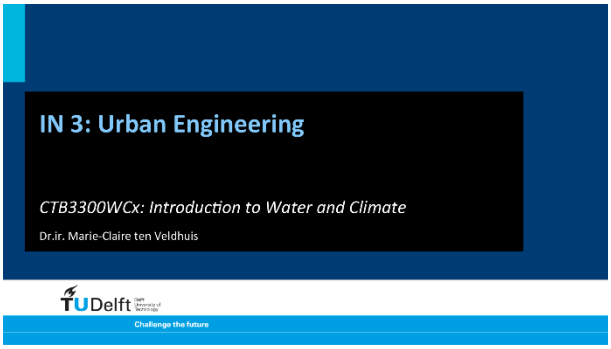
CTB3300WCx – Introduction to Water and Climate

IN4 – Urban Engineering

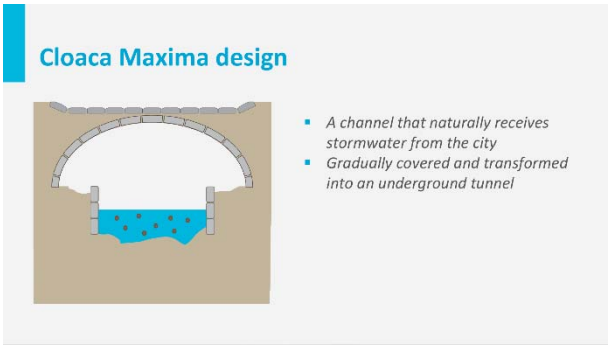
Marie-Claire ten Veldhuis



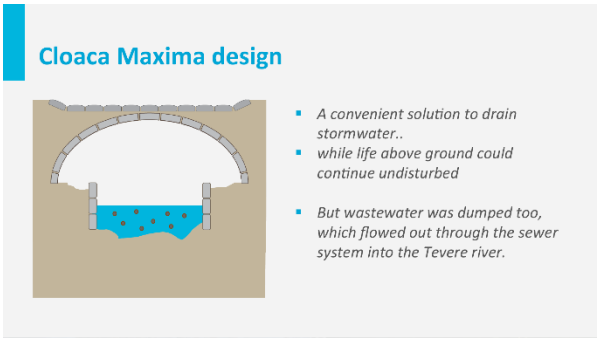
Welcome to urban engineering. My name is Marie-Claire ten Veldhuis, and I work as an assistant professor for urban watersystems at Delft University of Technology. In this submodule we will see what interventions have been developed to protect cities from flooding and dirty waters.

The Romans were great engineers: they built impressive structures strong enough so we can still see the remains of some of them today.

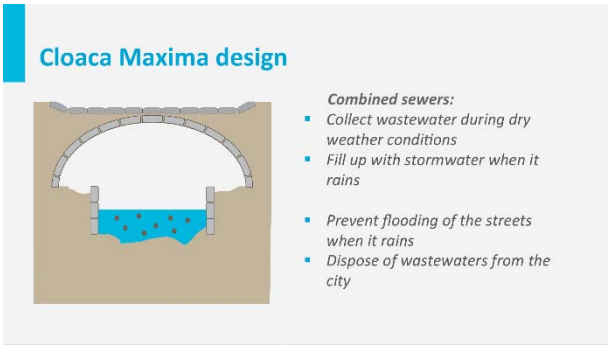
One of their great works started around 600 BC: they built a gigantic underground tunnel to collect stormwater from the streets of Rome, to protect Roman citizens from stormwater flooding. The so-called Cloaca Maxima, or “Greatest Sewer”, is still in place and its sewer mouth can be seen on the borders of the Tevere River. The design principle of the Cloaca Maxima was simple:



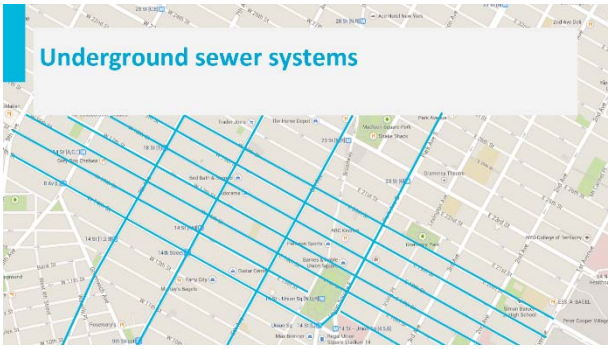
a channel that naturally received much of the stormwater from the city was gradually covered and transformed into an underground tunnel, a gigantic sewer.



The sewer proved to be a convenient solution to drain stormwater from the city's roofs and streets, while life above ground could continue undisturbed. Perhaps too convenient, because not only stormwater flowed into the underground sewer. Wastewater from public toilets, bathhouses and workshops was dumped into the underground tunnel, too, and a smelly mixture flowed out through the sewer system into the Tevere river.

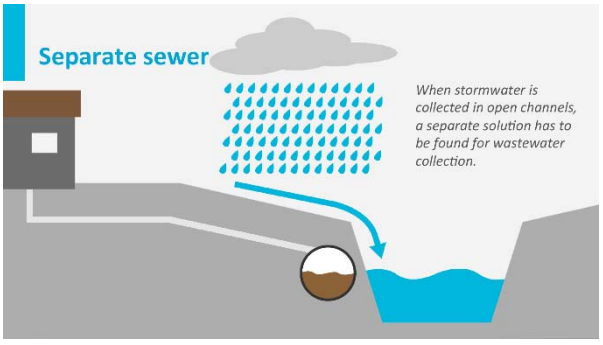


We call sewers like the Cloaca Maxima combined sewers. They collect wastewater during dry weather and fill up with stormwater when it rains. Combined sewer systems have been constructed in many cities worldwide as a robust engineering solution: they prevent flooding of the streets and dispose of dirty, smelly wastewaters from the city's households and businesses.

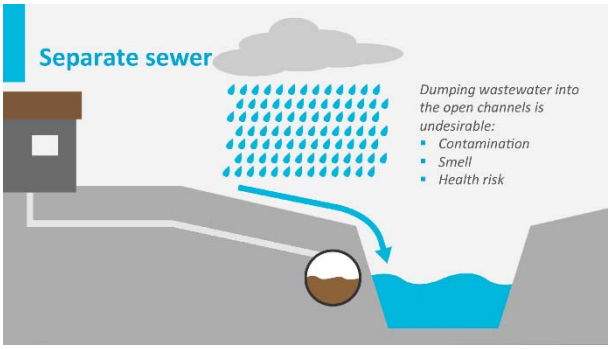


In many cities including large cities like Paris, London, New York and Tokyo, sewers have been constructed under almost street connecting every house and every road to the sewer system. This amounts to thousands of kilometres of sewers underlying our city's streets.

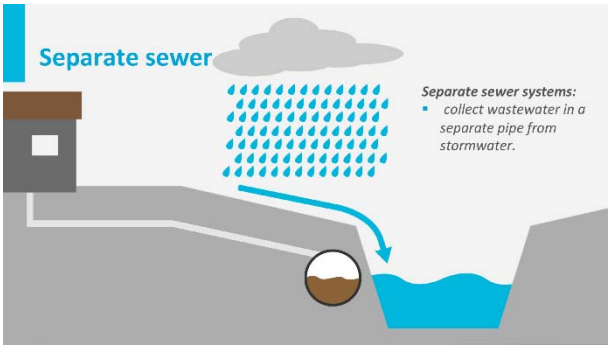
But large combined sewer systems are not always the most convenient solution. In some areas of the world, stormwater is collected by open channels instead of underground sewers. In areas where rainfall can be really intense, think for instance of heavy storms in the tropics, very large amounts of stormwater need to be transported. In that case, building underground pipes of such large sizes is simply too expensive and open channels are often a more feasible solution.



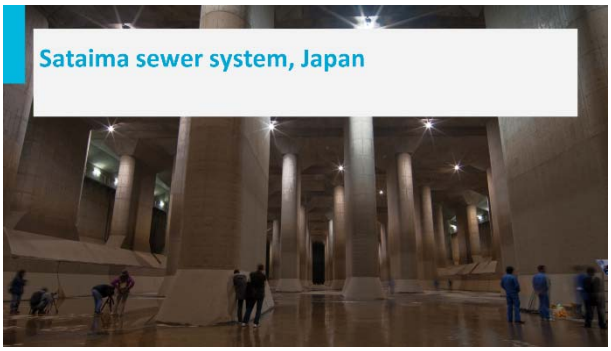
When stormwater is collected in open channels, a separate solution needs to be found for wastewater collection.



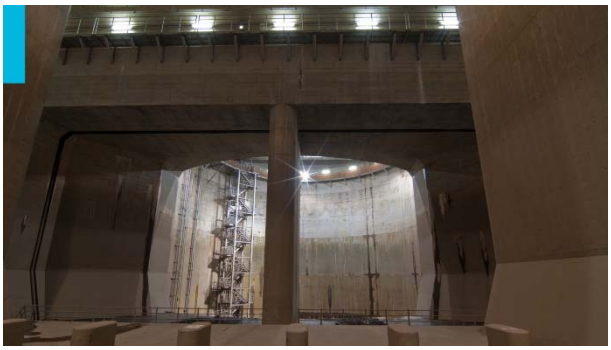
Dumping wastewater into the open channels is undesirable because the channels would get contaminated and foul-smelling and pose a health risk to the citizens.



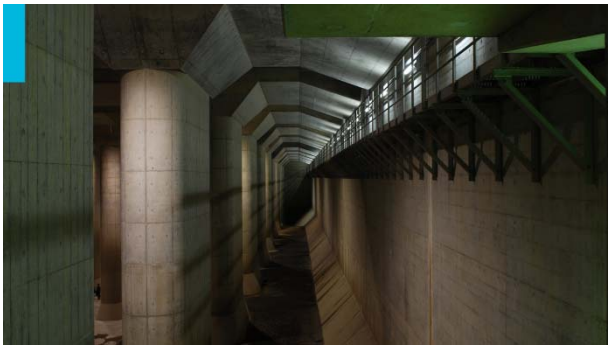
We call such systems separate sewer systems: they collect wastewater in a pipe, separate from stormwater. Stormwater can easily be collected in open channels. But channels take up a lot of space, and this is why in large, densely built cities, underground stormwater pipes are still preferred instead of open channels.



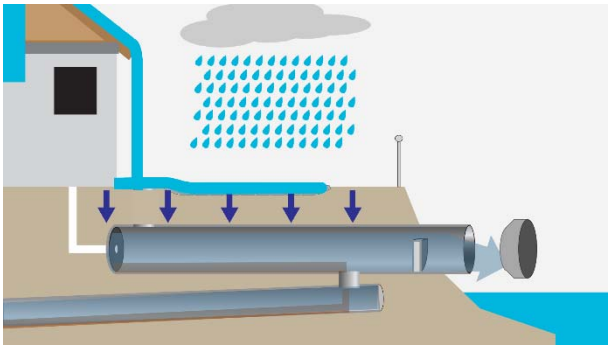
Japan is a typical example where high amounts of rainfall coincide with very high population density. It would be a lot easier and cheaper to collect large amounts of rainfall in open channels, but many Japanese cities are so densely populated that there is not enough space and large stormwater pipes are built instead.



For instance in Sataima, a city in Japan, a gigantic underground stormwater system has been built that consists of five large storage basins connected by 6km of tunnels, 50 m beneath the surface.



Eventually, stormwater is pumped into the Edo river by a series of 10 MW pumps that can pump up to 200 tons of water, the approximate volume of a standard 25 meter pool, per second.



In most cities in moderate climates such as in Europe and the US, underground, combined sewer systems have been the rule for decades. Gradually, this is changing and cities are converting their combined systems to separate systems. Now the question is, why? When it rains really hard, the capacity of combined sewers is not sufficient to cope with all stormwater. When a combined sewer fills up and it continues to rain, the sewer gets overloaded and a mixture of wastewater and stormwater spills from the combined sewer. To prevent the water from spilling onto the street, combined sewer overflow locations are created where water from the combined sewer flows out to rivers, streams or lakes. Combined sewer overflows cause pollution of our surface waters. They may harm natural water ecosystems and even pose a threat to citizens' health. Nowadays, we prefer to prevent such pollution and get rid of combined sewer overflows. One way to do this, is by changing combined sewers into separate systems by taking stormwater apart, creating alternative solutions for stormwater collection. Instead of leading stormwater flowing from streets and roofs towards a combined sewer, stormwater can be collected in separate channels, gutters, infiltration beds and swales. In these facilities, stormwater is stored and filtered.

Channels and Gutters

It can infiltrate to groundwater or, in case of high ground water tables, slowly flow towards a natural stream or river. Stormwater is then no longer mixed with wastewater, creating dirty spills; instead it becomes an attractive part of the urban landscape. Many creative solutions have been invented in the past decades, often referred to as Sustainable Urban Drainage Solutions.

Permeable pavement

Most have been implemented in newly built areas, where they have become an integrated part of urban design. More and more solutions are created for existing urban areas as well. Examples of such solutions are permeable pavements, green roofs and water squares. Surely, examples of sustainable urban drainage can be found in your city as well. Try and locate some examples and next time when it rains, go out to take a photo or movie of sustainable urban drainage and upload it.

Movie sewer Breda city

Here, we are in Breda city, under one of its main roads. We are about 5 meters below street level in the cities oldest sewer. It was constructed in 1863 and still functions today. And originally this was not a sewer, but a moat, running along the city walls. The moat collected water from many creeks running through the city center. These creeks collect not only storm water, but were also used to dump waste water from the cities households and factories. Gradually, these creeks became so polluted and smelly, that they were filled up or covered over,

and so was this cities moat, creating this brickwork tunnel, we can still see today. It's a combined sewer system collecting waste water from the cities households, shops and restaurants as well as storm water from the streets, the roofs and the central market place. This shows that the sewer is popular with rats. Citizens used these bowls to feed the rats, in order to make sure that the rats would stay inside the sewer. Nowadays the sewer is closed, and the rats will stay inside anyway. Here we see a really greasy household connection, probably one of the restaurants that throws its kitchen oil into the sewer. This is not supposed to happen, the grease will stick on to pipes and pumps and eventually clog the system. Imagine what would happen if this wastewater is no longer transported, and flows back onto the streets. The wastewater is full of pathogens, and the citizens could easily pick up water born deceases, like happened frequently in the Middle Ages. Back then, sewers for waste water collection were rare. Look at these lines on the sewer walls. This shows us we are in a combined sewer.
Right now the water level is really low, because the sewer only transports wastewater. But when it rains, the water level quickly rises, and from these deposits on the wall we can tell that during recent rainfall, the water must have been at this level. In case of very heavy rainfall, the water level might even rise up to the ceiling. In that case we need a solution to prevent the water level from rising onto the streets. Especially because then, the stormwater is mixed with the wastewater from the sewer. Causing the citizens not only to get their feet wet, but it would also pose a threat to their health. This is a combined sewer overflow weir. To prevent combined sewer water from flowing out onto the streets, combined sewer overflows are constructed to release the system from excess water. This means that a mixture of stormwater and wastewater flows out of the system. Therefore, combined sewer overflows need to be constructed in non-vulnerable areas. Preferably, at large surface waters or away from the people. However, in densely populated areas, such locations are hard to find. And therefore, if you live in a city with a combined sewer system, it is probably not a good idea to go fishing, or take a boat trip after a heavy storm.

Fortunately, this happens only sporadically. Under normal conditions, waste water and storm water flow through the sewer to a pumping station. Here we see sewer pumps, that pump the waste water and storm water to a sewer treatment plant several kilometers away. The capacity of one pump is enough to transport the wastewater flow. Additional pumps are available when it rains. In total, these pumps can transport four times the average wastewater flow from the city center. That is about the volume of a swimming pool pumped away, every hour. Altogether, twelve hundred kilometers of sewers in combination with the pumping station and overflow weirs, make sure the citizens of Breda can go about their business without being bothered by dirty smells or flooded roads. Thanks to an invisible but indispensable feat of urban engineering.