Water

With the help of Frankfurt Bridges, Frankfurt can become the "water-sensitive city" of the future.

Up to two million cubic meters of construction pit water and 1.6 million cubic meters of rainwater from rooftops can be professionally treated and, with the help of the cisterns under the bridges and the ring main at the bridges, transported from their places of origin to huge reservoirs

Reservoirs can be to bathing lakes near the city or to infiltration areas under green spaces in the city and the surrounding area. There, water is stored in the unsaturated soil layer above the groundwater. The water can then be drawn from the reservoirs as needed for irrigation and cooling of the city.

Another source of water in Frankfurt will be treated waste water, which will can be conducted by the Frankfurt Bridges‘ main to water the city‘s greenery, once pending investments into the current wastewater treatment plant of Frankfurt have been made.

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The goal: Preparing the City for Challenges

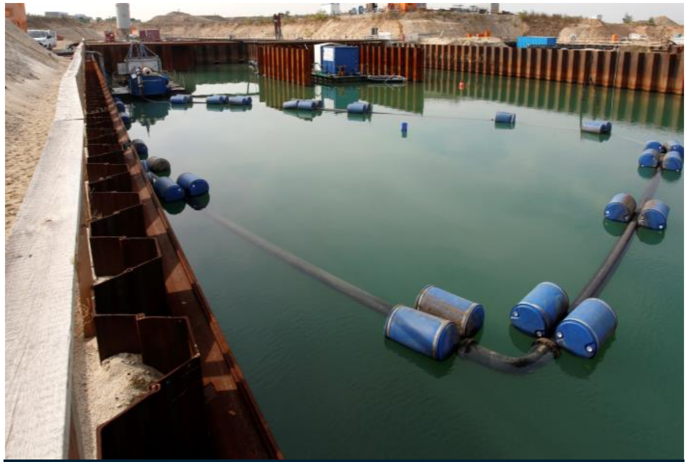
Conserve drinking water resources instead of using them to irrigate greenery

The water distribution with the Bridges Ring Line

Water transport, finely distributed throughout the city, can be done via the bridges

Harvesting Rainwater instead of Discharging it into the Canal

Roofs of buildings along the bridges can be connected to the water system of the bridges

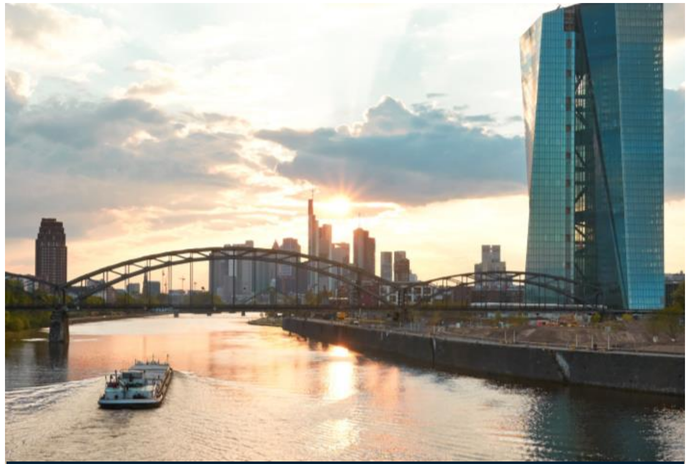


Groundwater from Excavation Pits to be used for Watering Greenery

Up to 2 million m^3 of groundwater p.a. can be transported to storage facilities via the bridges instead of being dumped into the Main River

Storing Water in the Soil through Infiltration

Groundwater supplies are enriched by infiltration of the collected water and thus can be used as natural reservoirs



The City of the Future does not Waste any Water

Only a city that is capable of collecting and storing water is armed against dry periods and heavy rain events

Preparing the City for Challenges

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The goal: large-scale vital urban greening, protection against flooding and healthy urban climate

The bridges will make Frankfurt an (even) greener city: 1 million m^2 of green space will be brought into being on the bridges, 100,000 square meters of vitalized and 40,000 square meters of unsealed green space will be created in Frankfurt's inner city area, while at the same time the aim is to plant over 1,000 new trees. All of this needs to be irrigated. The Frankfurt Bridges provide the necessary irrigation water for this.

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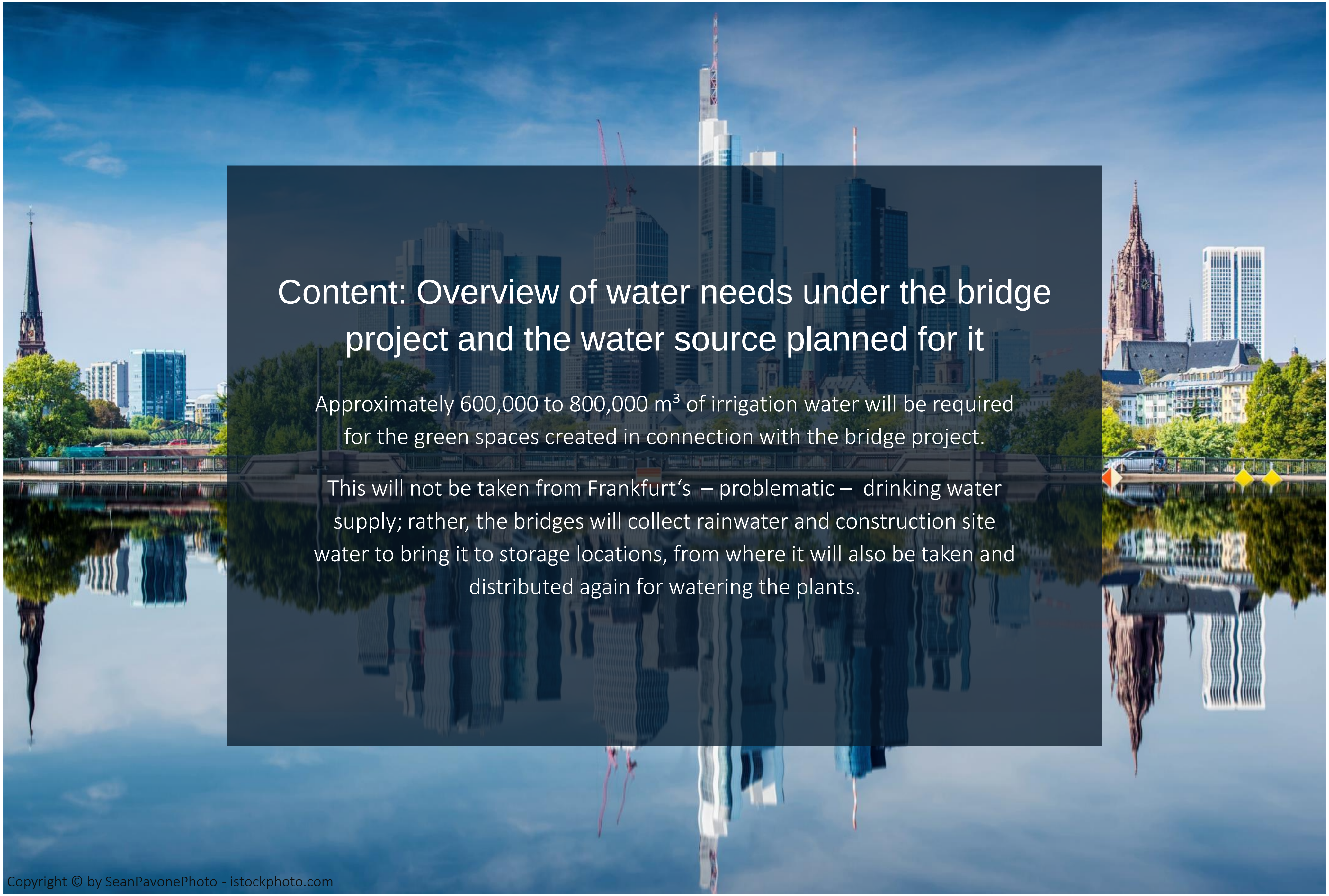
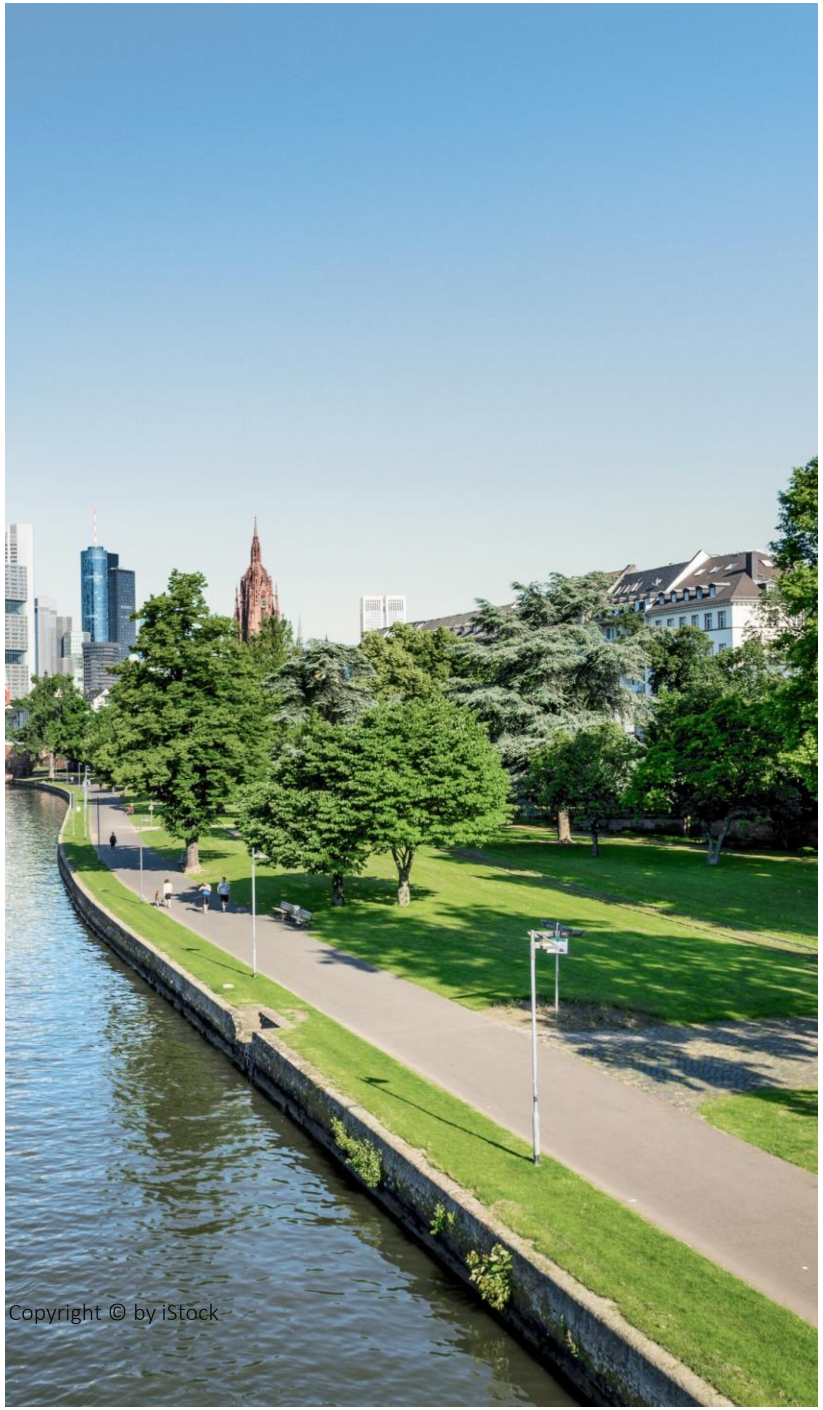


Content: Overview of water needs under the bridge project and the water source planned for it

Approximately 600,000 to 800,000 m³ of irrigation water will be required for the green spaces created in connection with the bridge project.

This will not be taken from Frankfurt‘s – problematic – drinking water supply; rather, the bridges will collect rainwater and construction site water to bring it to storage locations, from where it will also be taken and distributed again for watering the plants.



Frankfurt becomes an even greener city thanks to the bridges

More than 1,000,000 square meters of green space will be created by the flower beds and meadows on the bridges alone. In addition, an unsealing plan provides for the creation of new green spaces on 40,000 square meters in the city: Where asphalt previously covered Frankfurt's ground, flower beds and meadows are to be created. In addition, around 1,000 new trees are to be planted in the city center. The challenge here is that all of this needs to be watered.

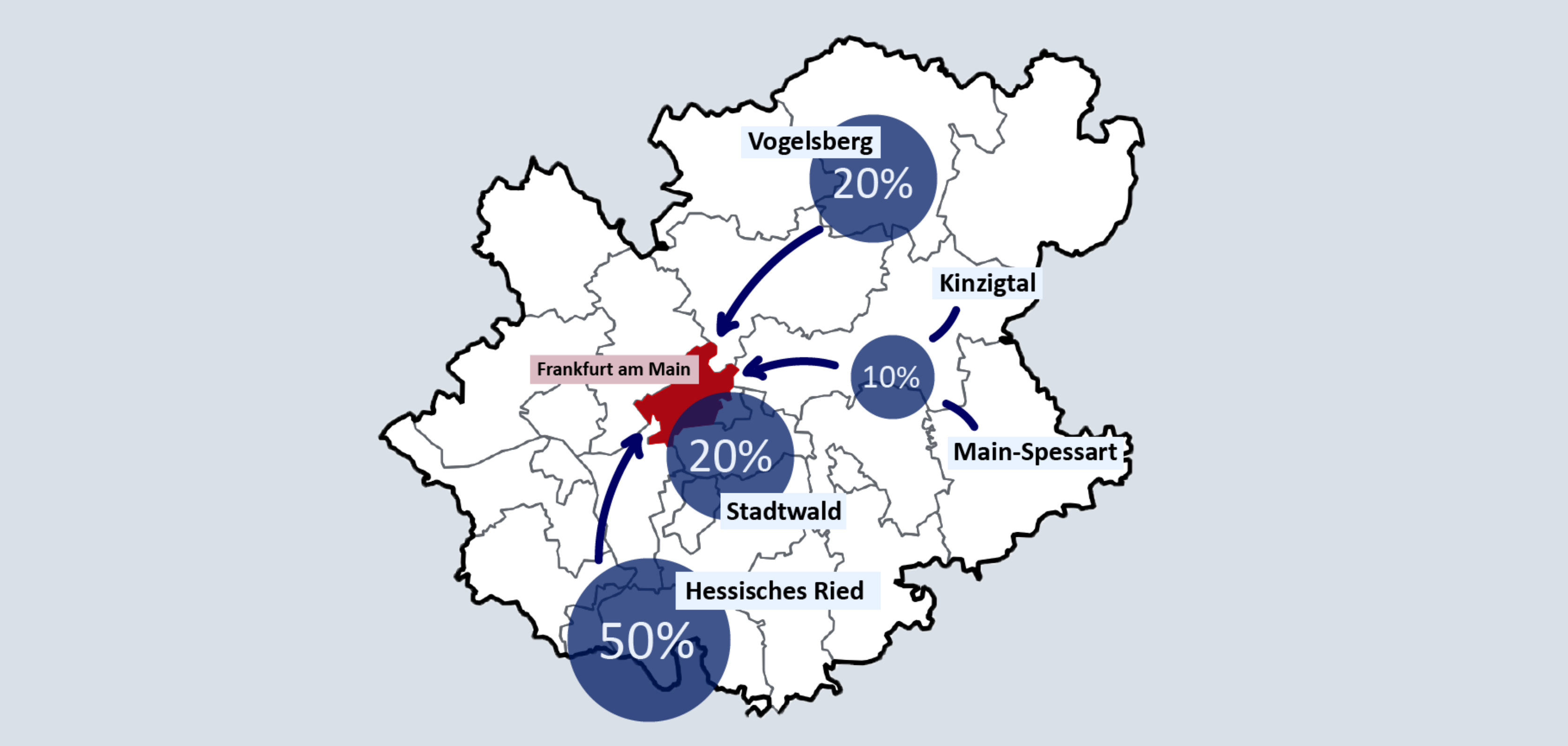
Approximately 600,000 - 800,000 cubic meters of irrigation water are estimated to be needed for this purpose, depending on the dryness of a year. Groundwater and rainwater should therefore be kept in the city so that it is available for watering the plants.

For this purpose, a pipe system for irrigation water separate from the city‘s sewage system must be created. Rainwater as well as groundwater from excavation pits, which is currently pumped into the Main River, should be collected in it or transferred.

In addition, all of this must be stored for the drier periods of the year when it is needed.

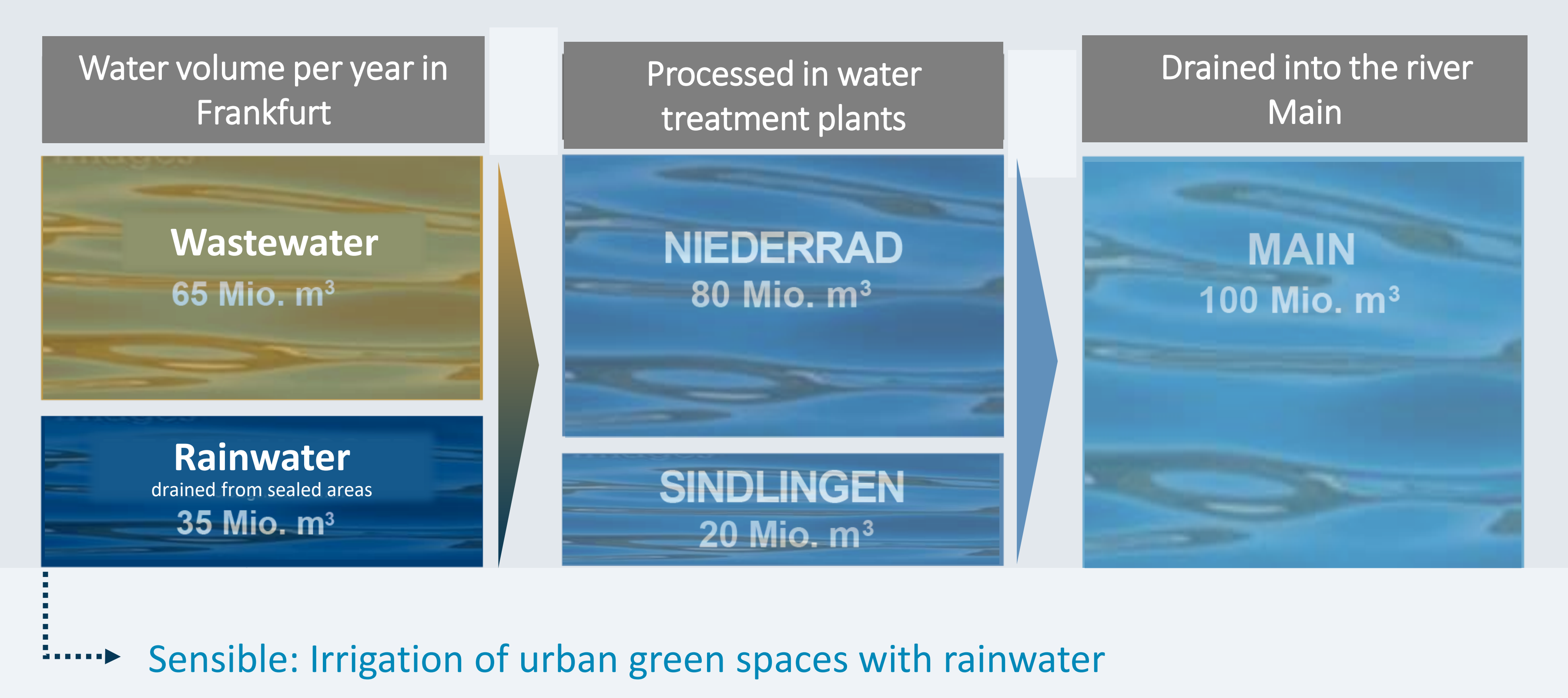
More than 50 million cubic meters of drinking water are currently "imported" from Frankfurt's surrounding area - the additional 600,000 - 800,000 m³ of irrigation water required should therefore be generated in the city area

Frankfurt needs about 65 million cubic meters of drinking water per year: about 20 % of this is obtained in Frankfurt, the remaining share is imported from the Vogelsberg, the Kinzigtal, the Main-Spessart and the Hessian Ried, which increasingly leads to groundwater depletion there.



Potential irrigation water from precipitation cannot currently be used on a large scale, as it is mixed with wastewater in the sewer system

The wastewater from the buildings, together with rainwater from the street sewers, is treated in Frankfurt's wastewater treatment plants and then discharged back into the Main River. In order to be able to use it as irrigation water instead, it would have to be treated even further. Therefore, it cannot currently be used to irrigate the new green spaces to be created.



But where does the 600,000 to 800,000 cubic meters of irrigation water should come from, where is it stored and how is it distributed?

Where would you get 800,000 cubic meters of water? And even if you had it: Where do you want to store this volume? And could you store these rough volumes of water - how can the water from those reservoirs be re-distributed to the green spaces?

Unfortunately, the water does not always arrive at the places where it is needed and usually not at the times when it is urgently needed.

The Frankfurt Bridges offer the solution: water is "collected" when it occurs, i.e. when it rains or the river water level is higher, or when groundwater is being pumped out at major construction sites to enable civil engineering work: The bridges pass by everywhere and can collect up to 1.6 million cubic meters of rainwater and up to 2 million cubic meters of construction site groundwater as pipeline carriers.

The next step is to store the water until it is needed during dry periods. The bridges reach possible storage locations in all directions - this solves the problem of storing huge amounts of water, which would be difficult in the middle of the city.

And last but not least, the irrigation water must then be delivered to where the plants need it. Here, too, the bridges with their ring structure and arms offer an extensive network of lines and taps.

Over the next 100 years, less and less rain could fall, especially in the summer - this trend has been noticeable for years already

A look back at the past reveals a clear picture for Frankfurt: Compared with the period from 1981 to 2010, rainfall has fallen by around 12 percent over the past 10 years. In the course of climate change, the average amount of rain will probably continue to decrease. In addition, gradually increasing temperatures and sunshine intensity lead to longer vegetation phases and more evaporation. In addition to the amount, the distribution of precipitation has also changed - heavy rainfall events and dry periods have tended to increase.

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Total Summer	Total Winter
2011	37,2	23,1	14,5	16,0	24,8	82,8	59,9	79,7	33,5	25,7	1,1	107,4	505,7	296,7	209,0
2012	57,8	6,8	16,4	38,5	46,6	104,0	66,0	78,5	40,8	58,0	45,1	71,0	629,5	374,4	255,1
2013	33,1	33,0	27,4	63,1	103,3	78,2	17,8	47,9	58,5	93,7	64,6	21,9	642,5	368,8	273,7
2014	38,8	45,6	10,9	30,7	64,9	36,5	128,7	101,6	35,2	53,9	46,8	56,2	649,8	397,6	252,2
2015	62,8	20,9	17,7	19,7	15,4	57,5	26,1	43,3	57,0	16,4	65,9	28,1	430,8	219,0	211,8
2016	66,8	81,9	57,0	47,1	88,7	110,6	47,3	41,9	24,4	47,7	39,4	9,3	662,1	360,0	302,1
2017	24,4	16,7	42,6	10,4	85,0	25,4	94,4	103,3	62,5	33,1	83,1	81,8	662,7	381,0	281,7
2018	71,3	10,6	40,4	54,1	33,0	19,4	17,1	20,3	26,3	7,0	25,9	75,3	400,7	170,2	230,5
2019	42,3	10,8	41,7	34,5	72,5	43,6	43,5	53,3	51,4	78,8	48,0	65,2	585,6	298,8	286,8
2020	36,9	78,9	47,9	21,8	31,1	44,4	15,5	76,0	32,0	60,7	16,2	81,1	542,5	220,8	321,7
2021	66,7	55,3	26,0	33,4	66,8	120,8	60,0	53,5	45,7	42,7	22,8	48,3	642	380,2	261,8
Average	**48,9**	**34,9**	**31,1**	**33,6**	**57,5**	**65,7**	**52,4**	**63,6**	**42,5**	**47,1**	**41,7**	**58,7**	**571,2**	**308,7**	**262,5**
1981-2010	*44,8*	*41,3*	*48,3*	*42,0*	*63,5*	*57,9*	*65,1*	*56,9*	*53,2*	*54,7*	*55,0*	*54,0*	*636,7*	338,6	298,1
Deviation	9,2%	-15,5%	-35,5%	-20,1%	-9,5%	13,6%	-19,5%	11,7%	-20,1%	-14,0%	-24,1%	8,7%	-10,3%	-8,8%	-11,9%
Max month	71,3	81,9	57,0	63,1	103,3	110,6	128,7	103,3	62,5	93,7	83,1	107,4	662,7	397,6	321,7
Min month	24,4	6,8	10,9	10,4	15,4	19,4	15,5	20,3	24,4	7,0	1,1	9,3	400,7	170,2	209,0
85-Perzentil Monat	68,4	80,0	51,1	57,3	93,8	106,3	106,4	102,2	59,9	84,0	71,9	90,8	662,3	386,8	309,0

A solution contributed by the Frankfurt Bridges: Where rainwater previously hit asphalt directly, the bridges and their cisterns catch some of it during heavy rain events

When rain falls on the bridge surface, it is collected by the plants, the substrate and the retention layer. In this way, up to 250,000 m³ of water can be released with a time delay to the cisterns in the roadway floor under the bridges and - again with a time delay - to the sewage system.

The cisterns will be laid under the roadway area in the course of bridge construction. With a storage capacity of approx. 90,000 m³, you can temporarily store a very heavy rain event over all connected areas.

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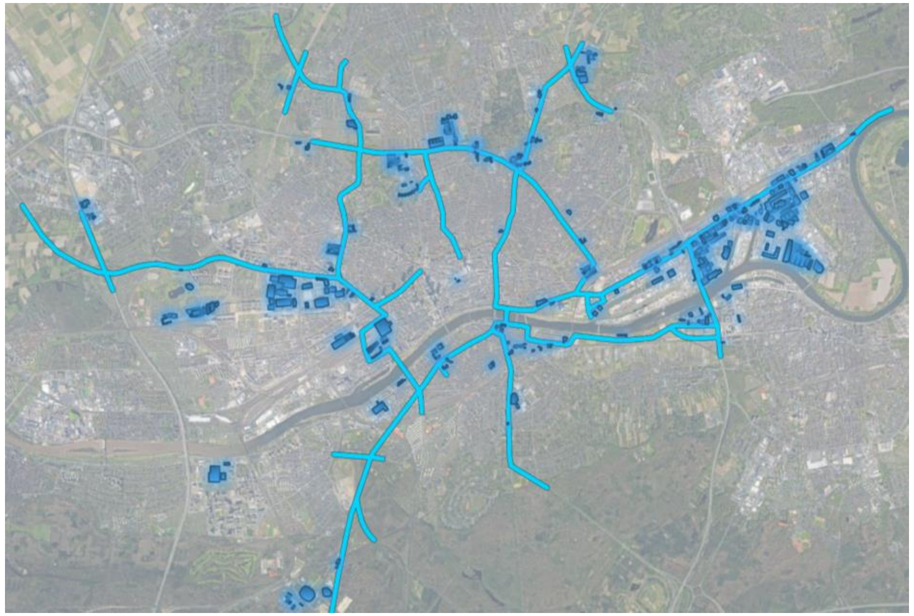
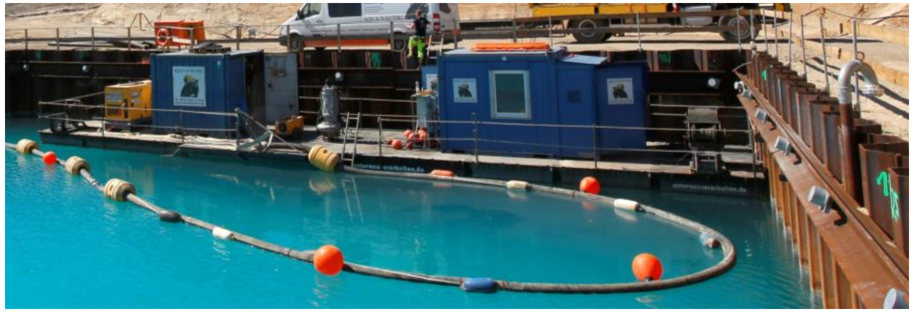
Other solution contributions of the Frankfurt Bridges: They serve as a network for water sources and storage within the project area

The Frankfurt Bridges will create a network throughout the city. In this way, the various water sources and storage facilities can be connected with each other: the new swimming lake to be created in Niddapark, a wide variety of infiltration areas, rainwater from roofs and parking lot canopies, and groundwater from construction sites - they will all be linked by the bridges.





Overall, the Frankfurt Bridges are an important step on the way to becoming the „Water-Sensitive City of the Future"

One often reads the demand that modern cities should become "sponge cities". That sounds like wet basements and dry rot. Another term for the same goal is much nicer: the "water-sensitive city. What is really meant by this?

The "water-sensitive city" braces itself against longer periods of drought and, at the same time, more frequent and extreme rainfall events, by no longer draining accumulating water out of the city as quickly as possible, but instead keeping it in the city's water balance and reusing it.

In the medium term, this could be collected rainwater and water from construction pits. In the long term, however, German cities will also have to treat their wastewater to a greater extent than in the past and at least use it as irrigation or service water. In Frankfurt, the prerequisites are currently being created by the introduction of the fourth treatment stage in the city's wastewater treatment plants.

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Frankfurt

Conclusion: With the bridges as a water infrastructure, a more intensive urban greening becomes possible - true to the motto of the "water-sensitive city" with the help of a water cycle concept

Frankfurt must continue to work on using less of the surrounding area for its water needs.

The Frankfurt Bridges can collect the required 600,000 to 800,000 cubic meters of water from various sources as part of the bridge project, transport it to storage locations, and make it available again for irrigation when needed.

They also represent an urban infrastructure that can add millions more cubic meters of water to Frankfurt's water balance in the distant future: by also being able to transport even larger volumes of groundwater and rainwater, as well as further treated wastewater, to storage locations.

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The Bridge Ring Line


Harvesting" rainwater instead of discharging it into the canal


Groundwater from excavation pits should be used


Store water in the soil through infiltration


The city of the future wastes no water


Unsealing of the city center


Vitalization of the urban green


The green metropolis of the future

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The Bridge Ring Line

Water distribution with the help of the bridge ring main

The bridges stretch along the main „traffic arteries“ through the city, not only creating an additional level of living and mobility for people, but also helping Frankfurt's water system to achieve an additional level: the ring main. This main collects water along the course of the bridges, transports it to storage locations, and when it is taken from there again as needed, the ring main distributes it again for the irrigation of Frankfurt's plant life - on and next to the Frankfurt Bridges.

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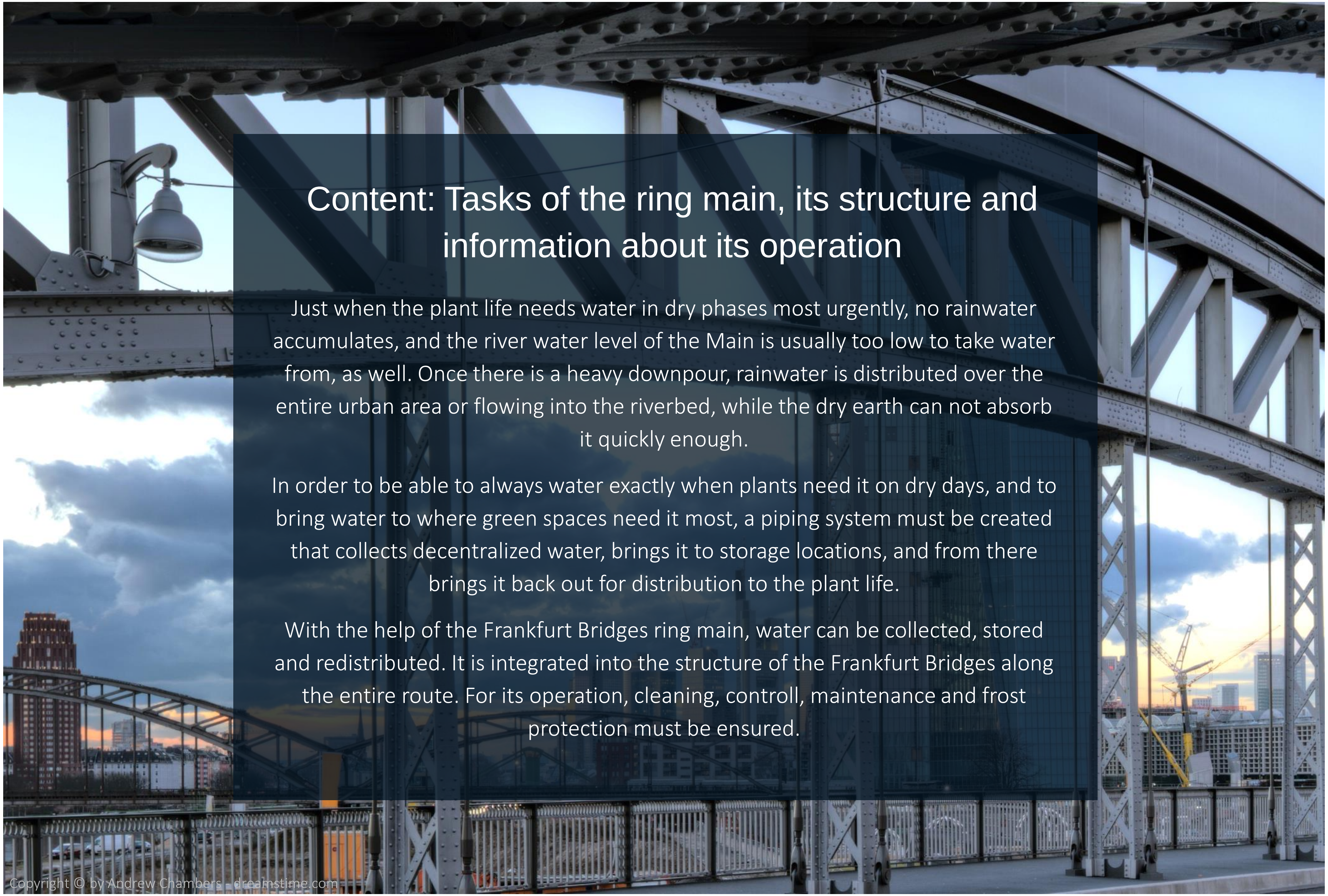

Content: Tasks of the ring main, its structure and information about its operation

Just when the plant life needs water in dry phases most urgently, no rainwater accumulates, and the river water level of the Main is usually too low to take water from, as well. Once there is a heavy downpour, rainwater is distributed over the entire urban area or flowing into the riverbed, while the dry earth can not absorb it quickly enough.

In order to be able to always water exactly when plants need it on dry days, and to bring water to where green spaces need it most, a piping system must be created that collects decentralized water, brings it to storage locations, and from there brings it back out for distribution to the plant life.

With the help of the Frankfurt Bridges ring main, water can be collected, stored and redistributed. It is integrated into the structure of the Frankfurt Bridges along the entire route. For its operation, cleaning, controll, maintenance and frost protection must be ensured.

The conventional wastewater and sewer system in Frankfurt does not allow rainwater to be used as irrigation water on a large scale

As in the vast majority of cities, most surfaces in Frankfurt are sealed. This means that rainwater cannot seep away, but flows into the sewage system. Since Frankfurt has a mixed system in the inner city area, in which wastewater and rainwater are discharged together, this water is lost for the irrigation of green spaces. An incredible waste.

Frankfurt's canal system was built in the 19th century, at a time when no one could have imagined that rainwater could one day become precious. The main goal at the time was to channel rainwater and sewage out of the city as quickly as possible to prevent flooding and epidemics. Once constructed, however, sewer systems can be difficult to adapt to changing conditions. Separating wastewater and stormwater would require major construction work. Gradually, all streets would have to be broken up and a parallel pipe system built: one pipe for wastewater, the other for rainwater. Nowadays, this so-called separation system is mostly used in new housing estates, but it is hardly ever used in existing housing estates.

The Frankfurt bridges offer the possibility to solve this problem in a different way: Independent of the existing sewer system, a water ring main runs in the bridges for the collection of potential irrigation water, across the entire rout.

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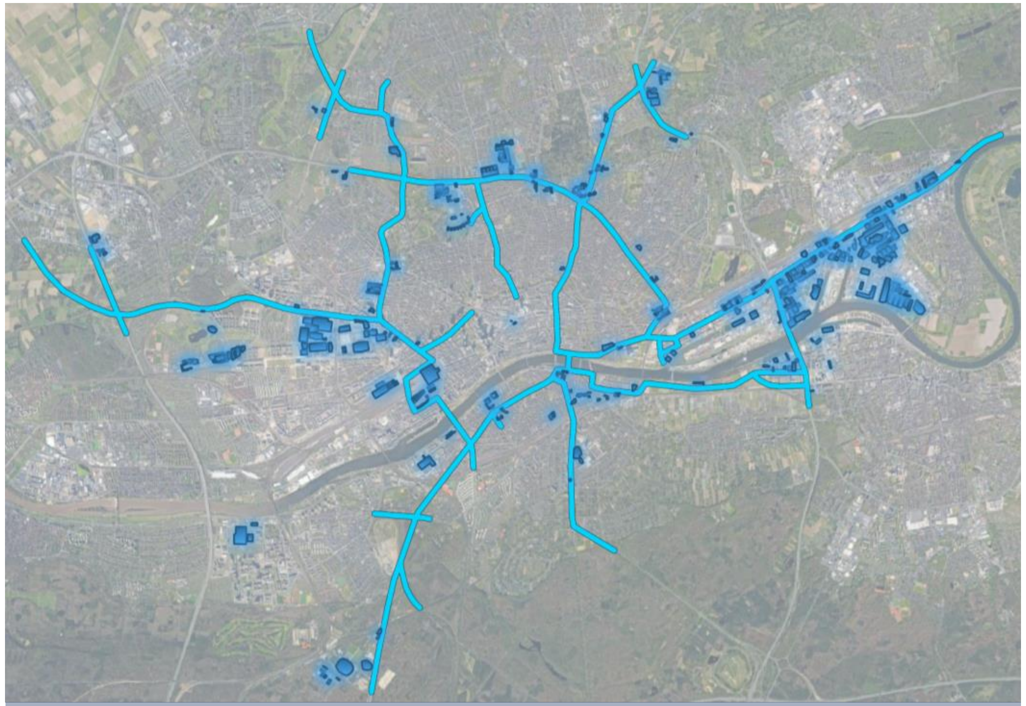
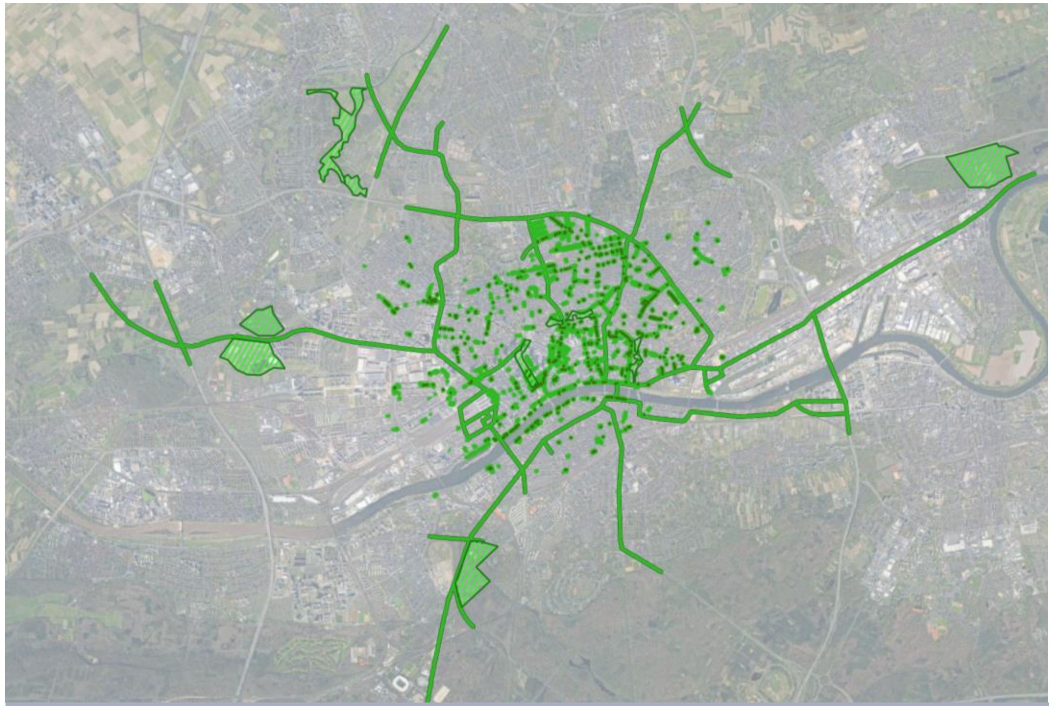
Collecting, storing, distributing water independently of the existing sewer system: the Frankfurt Bridges ring main makes it possible

Rainwater can be collected and stored over the entire course of the bridge and on adjacent roofs. In subsequent dry phases, it can be made available again to the plant life on and next to the bridges.



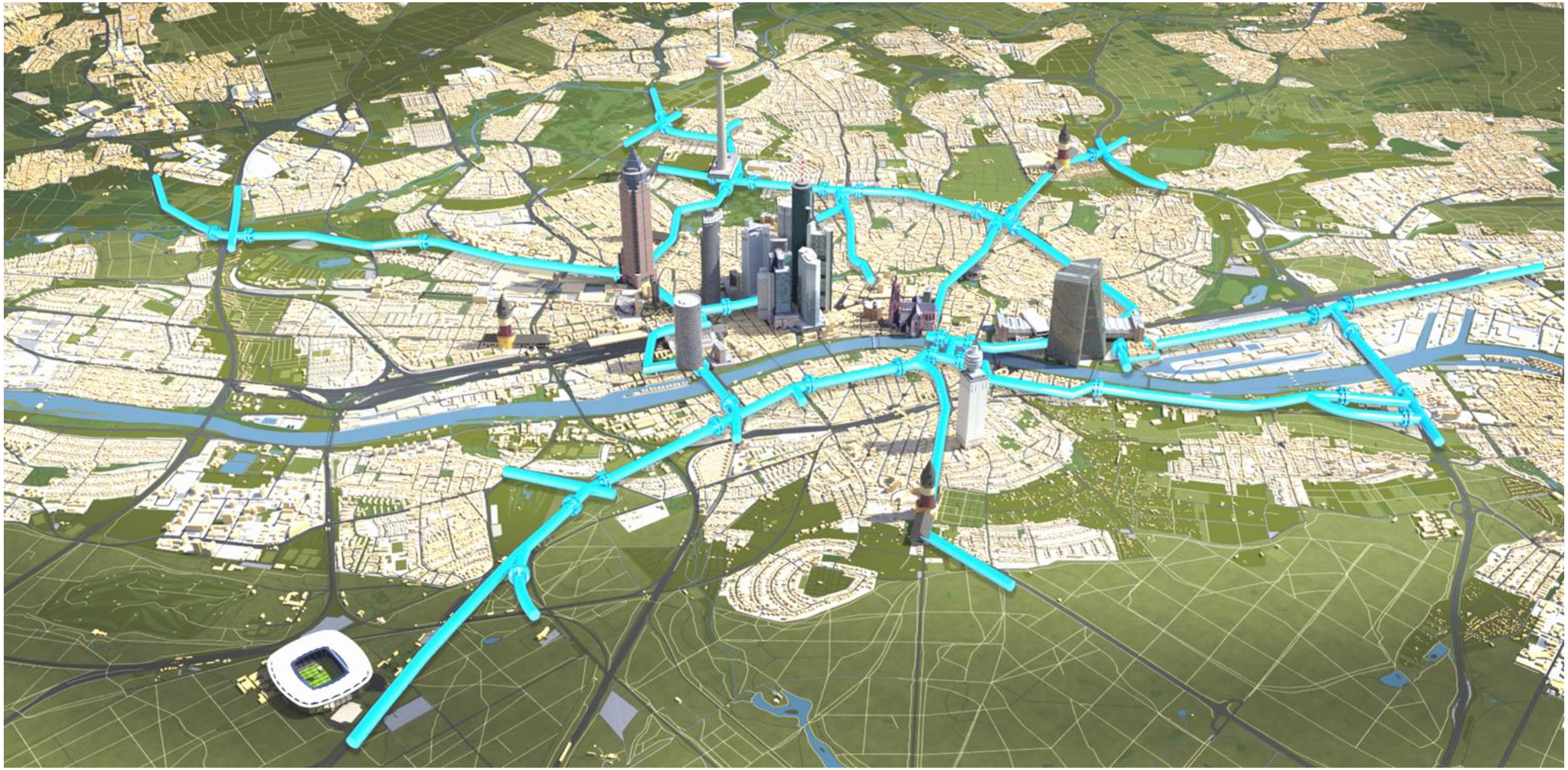
The bridges collect water and transport it to storage locations . . .



. . . later they take it from there and distribute it again

The bridge ring main is an additional layer for the transport of water through the city

The bridges stretch along the main arteries through the city, not only creating an additional level of housing and mobility for people, but also helping Frankfurt's water system to achieve an additional level: the ring main.



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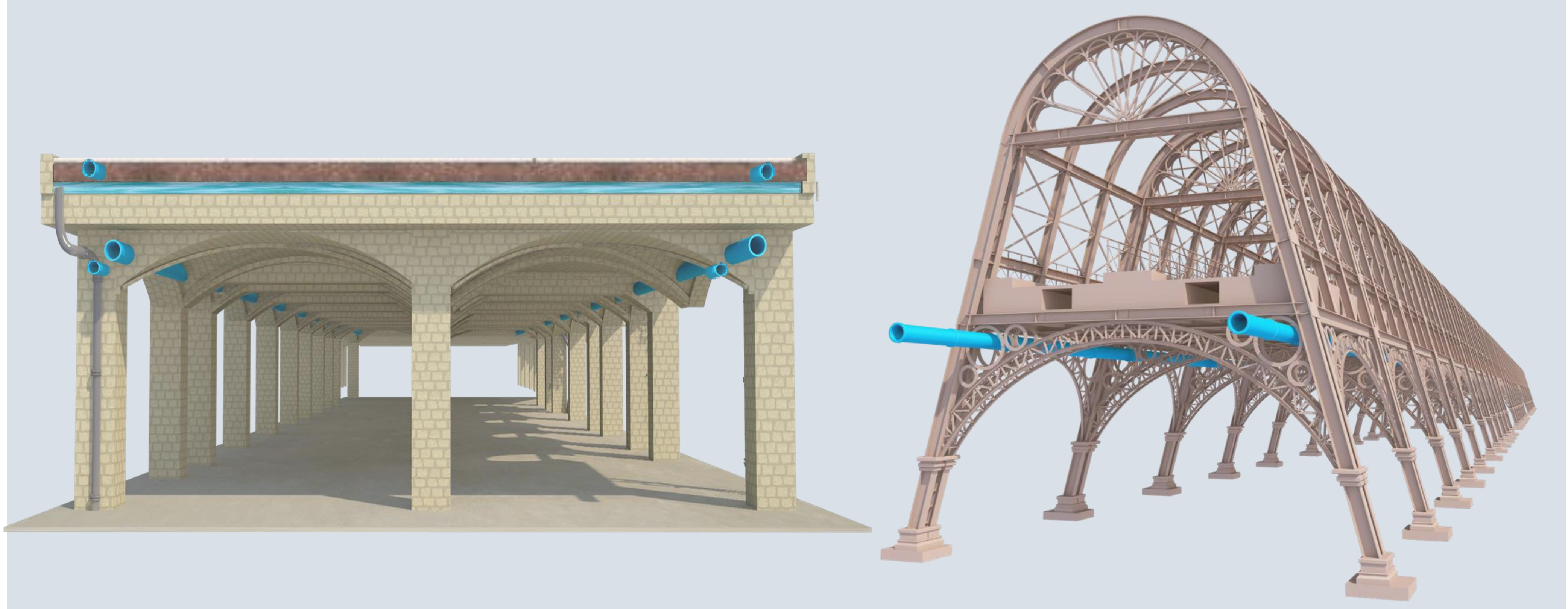
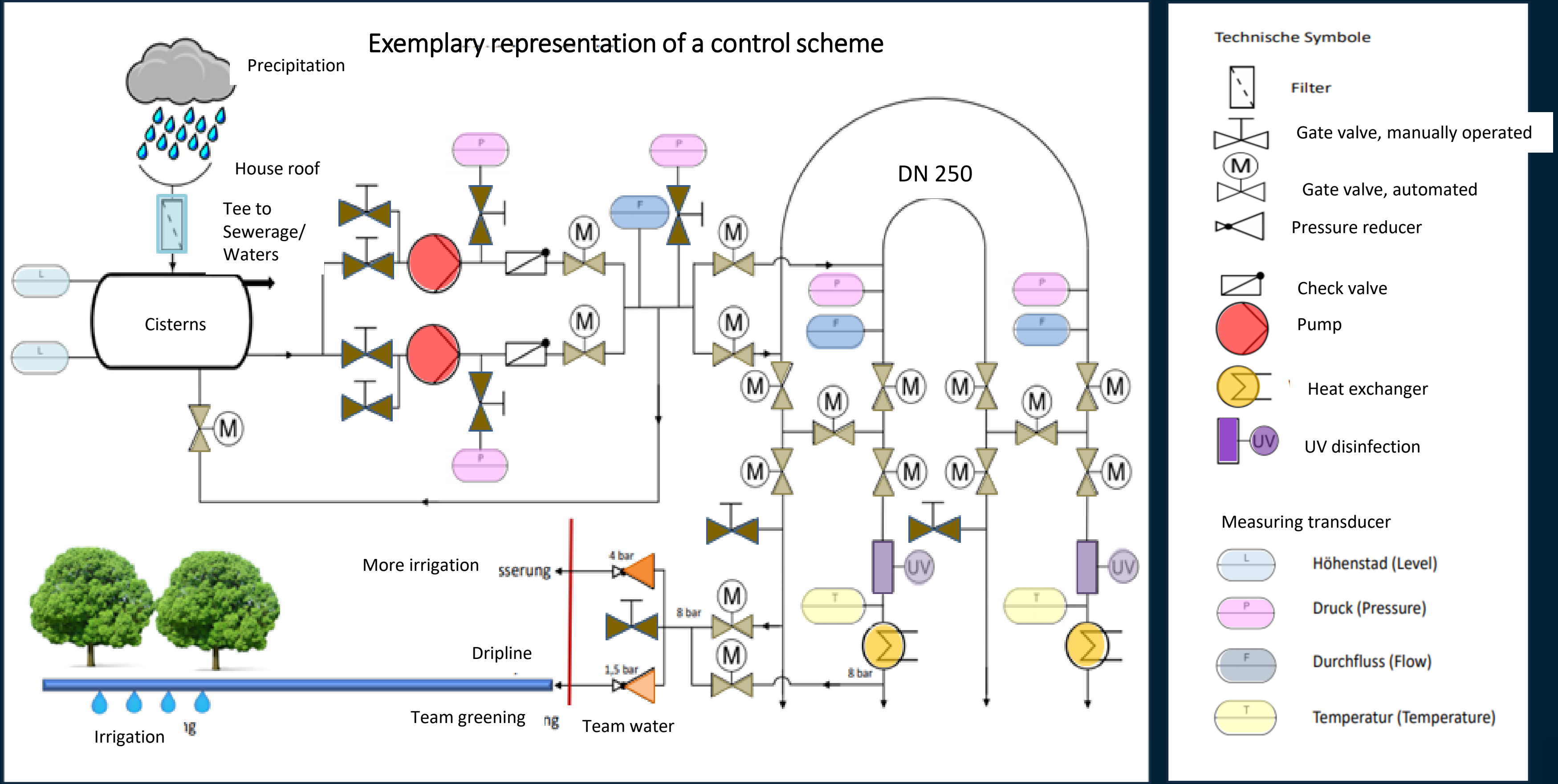
The ring line will be integrated - almost invisibly - into the structure of the Frankfurt Bridges over the entire course of the line

In the case of bridge sections of concrete construction, the ring main can be installed in the body of the bridge. In metal structures, it is integrated into the structure of the bridges and visually disguised like a dark cast-iron pipe. And in some places it is also hidden in the plant substrate on top of the bridges.



For the irrigation of the green areas through the ring main, a sophisticated control system is required

You can't just pour water on the plants to the right and left of the bridges: In addition to pumps and fittings, various measuring points and variables are required to control the water system. The main measured variables are pressure, filling level, degree of moisture in the soil, flow rate and temperature.



Erläuterung der UV-Behandlung

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This system with its numerous valves and interfaces must be kept continuously clean

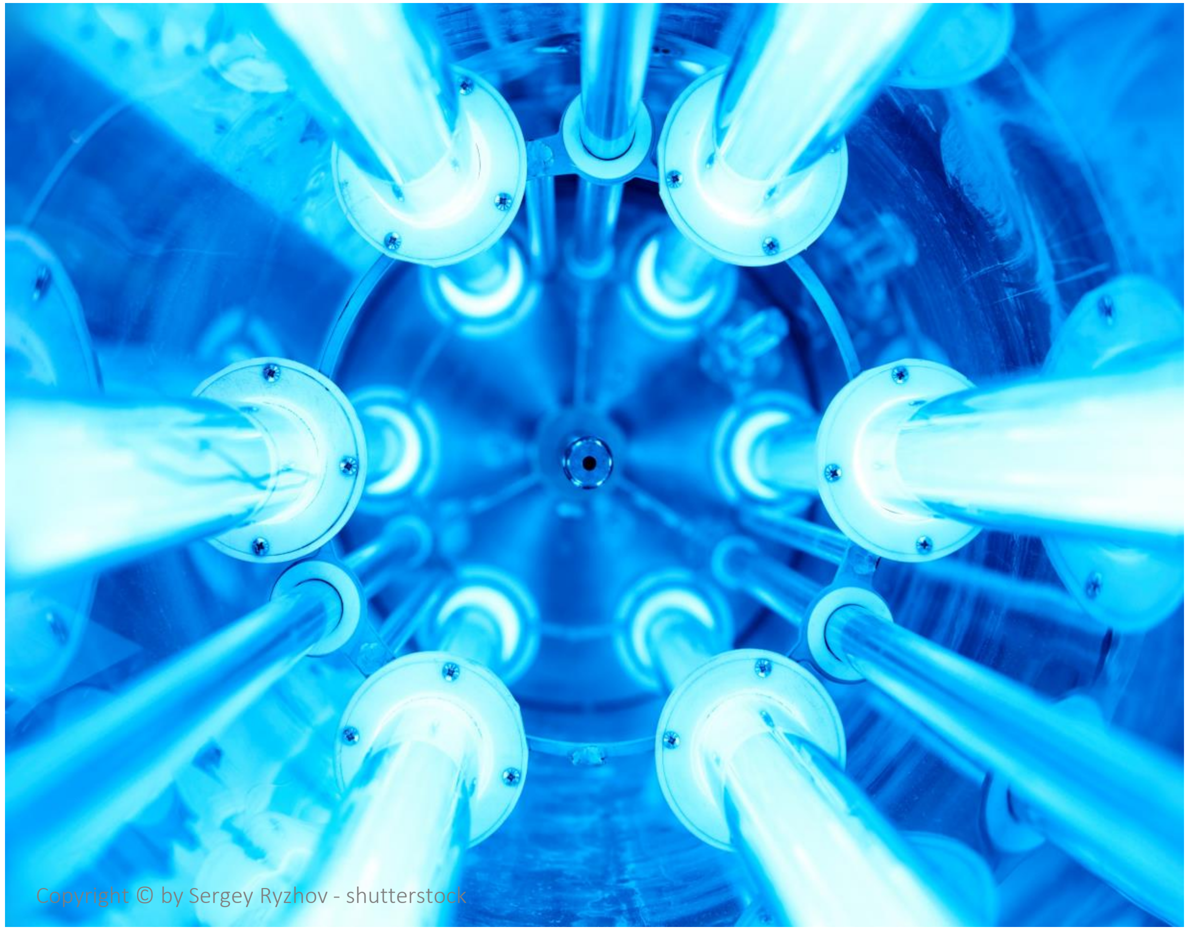
As with any complex piping system, it must be ensured that there is no contamination from solids, pollutants or germs. While there are filter systems for solids and pollutants, germs can be effectively rendered harmless with UV treatment.

Explanation of UV treatment

The modules are designed so that the water flows along the UV lamps at a small distance.
In addition, a turbulent water flow is created so that every water particle receives UV treatment.
The UV radiation thus destroys the genetic material of the microorganisms, making reproduction impossible.

The UV light is emitted by low-pressure mercury vapor lamps located in transparent protective tubes.

Radiation wavelength: circa 254 nm
Power consumption: circa 50 Wh/m³



Heat exchangers and heating tapes together with waste heat from bridge cable ducts ensure frost protection

During the coldest weeks of winter, the ring main usually does not carry water. However, if surprising frost events should occur in the fall or spring, frost protection for the ring main is provided differently depending on the bridge section:

Sections that pass by data centers can be protected with a heat exchanger system using the year-round waste heat from these building complexes.

On some sections, the ring main can run under the sidewalks next to the cable shafts under the bridges. The cable shafts also release sufficient thermal energy in their ducts in winter that even rather thick waterproof protective walls can protect an adjacent ring main from freezing.

Solar heat stored in storage probe fields under the Frankfurt Bridges is also conducted through the body of the bridge in winter to keep the roadways frost-free, which, depending on the constellation, can also help keep the ring main free of frost.

On sections of the line where it is not possible to use waste heat from data centers or cable ducts, frost protection of the ring main is provided by demand-controlled heating strips.

The design and structure of the ring main system, as well as the control of its operation, pose a challenge even at the planning stage

Ring circuit fact sheet

Inner diameter of the pipe: 25 cm (DN 250)

Length: 2 x 50 km

Average operating pressure: 4 bar

Laying: In the bridge body

Redundant design for more operational reliability

Year-round operation (frost-free conditions are guaranteed)

But the effort is worth it: With the help of the ring line, areas further away from the bridges can also be planted and revitalized

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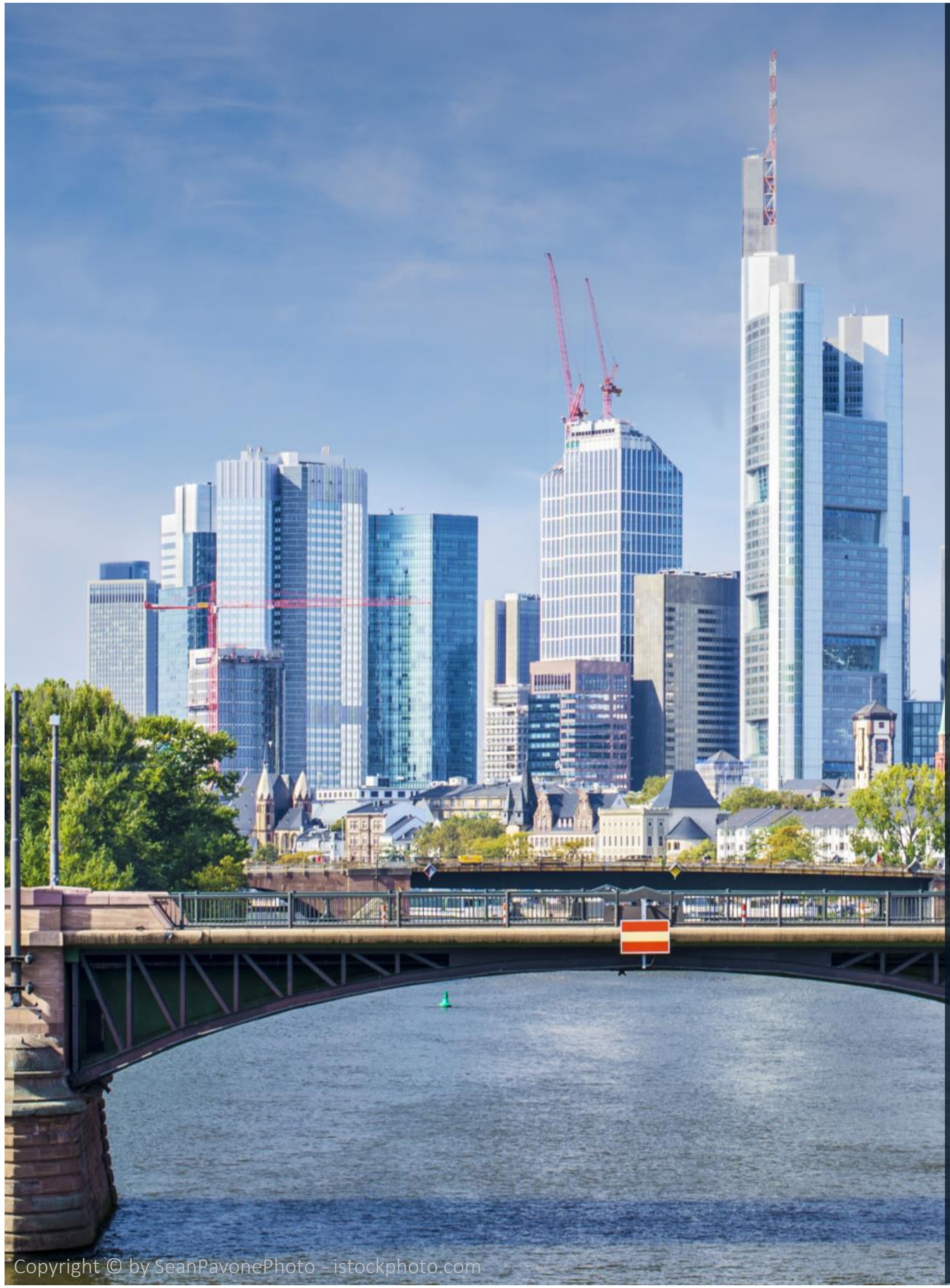

Conclusion: The Frankfurt Bridges ring main is a useful addition to the city's existing water system

With its network-like route, the Frankfurt Bridges‘ structure is a suitable support for a complementary water infrastructure: the ring main.

With the appropriate control and cleaning system, the ring main can make a contribution to the sustainable water management of the city of Frankfurt - similar to the existing sewer system.

In addition, the waste heat from the cable ducts integrated in the bridge body can be used as frost protection.

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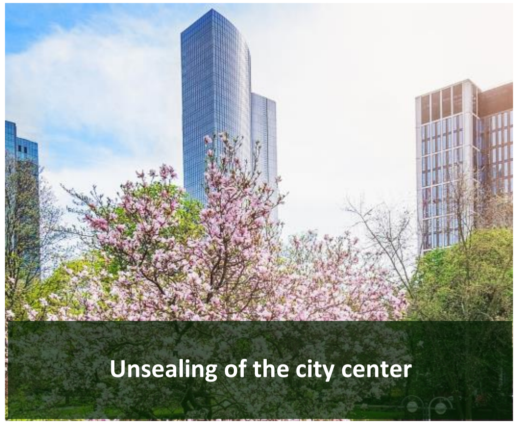
The water distribution with Bridge ring line


Harvesting" rainwater instead of discharging it into the canal


Water Storage near the City


Store water in the soil through infiltration


The city of the future wastes no water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Vitalization of the urban green


The green metropolis of the future

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Harvest Rainwater

„Harvesting" rainwater instead of discharging it into the canal

With efficient stormwater management, precious rainwater is not discharged directly into the existing combined sewer system: Through the approximately 60-kilometer-long bridges, up to 90,000 m^3 of rainwater can be collected and temporarily stored on site in cisterns under the roadway. The total volume of water that can be stored in selected infiltration areas close to the city is 600,000 to 800,000 m^3 . On dry days, this water can then be redistributed via the ring main to irrigate the city's green spaces as needed.

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Content: Which rainwater is suitable and where are potential areas for rainwater harvesting as well as temporary storage?

Rainwater from the street is usually contaminated with pollutants and tire abratson (microplastics). If one wants to avoid costly cleaning processes, it is recommended to collect roof rainwater for irrigation of green areas: both from the surfaces of the Frankfurt Bridges and from roofs of adjacent buildings and parking lot canopies.

The collection and use of rainwater in Frankfurt is currently hampered by the problem that rainwater is discharged directly at the buildings together with the wastewater into the so-called "combined sewer system". The Frankfurt Bridges solve this by temporarily storing intermittent precipitation in cisterns under the roadway along the bridge route. From these, the collected rainwater is transported via the ring main to the final storage locations (infiltration areas).

The bridges' ring main in combination with the bridges' cisterns below the roadway thus represents a "bypass" to the combined sewer system. With the comparatively clean water from the roof and bridge drainage, all of Frankfurt's green spaces can be irrigated in this way without hesitation.

Collecting and storing rainwater for the irrigation of urban greenery would be a sensible solution

Frankfurt "imports" more than 50 million cubic meters of drinking water per year, mainly from the Vogelsberg and Hessian Ried regions, to meet its total demand of around 65 million cubic meters. However, 100 million cubic meters of wastewater are discharged into the Main each year - after treatment in the wastewater treatment plants in Niederrad and Sindlingen.
The difference of 35 million cubic meters is rainwater that is currently discharged into the combined sewer system along with dirty wastewater and transported to the treatment plant instead of being used for irrigation.

"Disposal" of precious rainwater must be reduced through intelligent water management: Rainwater must be collected and infiltrated in a targeted manner so that the city's groundwater reservoirs can be filled up with it - then it can be taken back from there for irrigation as needed.

But it is only the Frankfurt Bridges that make such a cycle possible: They can "harvest" rainwater, as experts call the collection of rainwater, store it temporarily and ultimately also bring it to a "harvesting reservoir" at the end of the bridge arms.

Not all rainwater is equally usable

Rainwater from the roof is usually the cleanest, while that from the streets is usually contaminated with tire wear and harmful fluids.

Much of the rainwater that falls annually in Frankfurt should therefore not simply be used directly to water plants.

Rainwater from roofs is most suitable

Rainwater can also be contaminated with pollutants on properties: by fertilizers for the garden, by parking lots or by other pollution. Rainwater from roofs, on the other hand, is much better, with a few exceptions: slate or tiles drain the rainwater cleanly, and even flat roofs hardly emit any pollutants if no adhesive materials containing pollutants have been used.

This roof rainwater has to be collected - but there is a small hurdle: rainwater and wastewater from the buildings are mixed in most parts of Frankfurt before they enter the sewer system.

Treatment of rainwater

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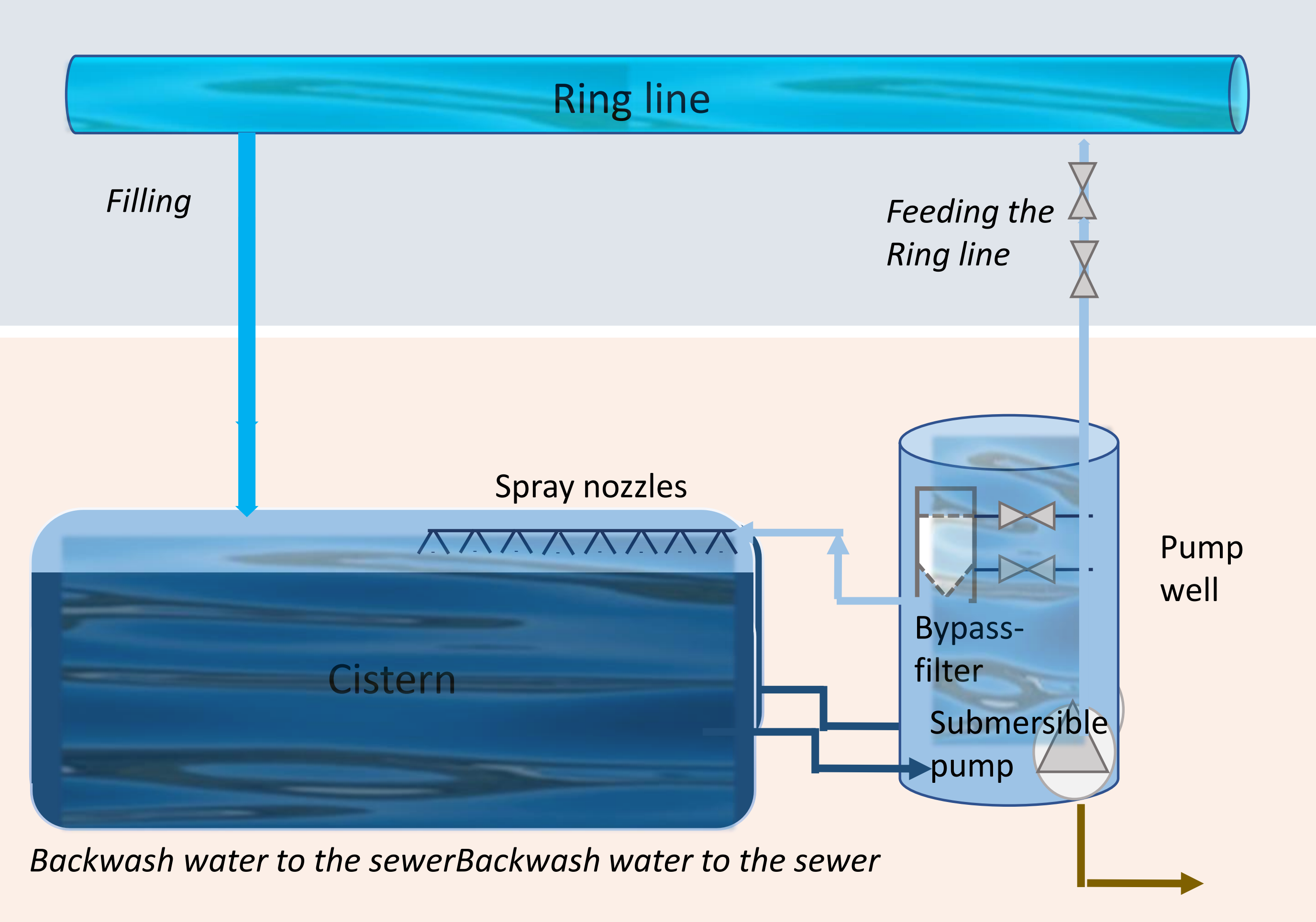
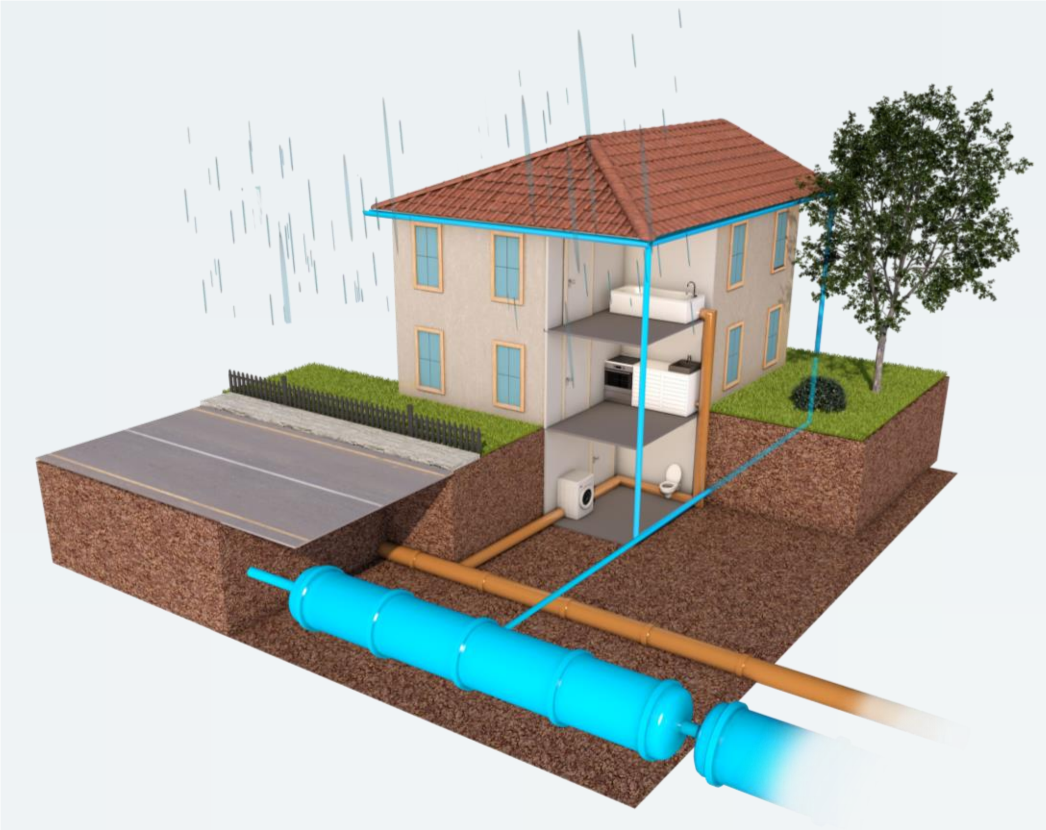
Rainwater from roofs must also be treated before use

A coarse filter is installed in the inlet pipe(s), which is installed as standard on downpipes and collects larger components such as leaves and branches. The cisterns are equipped with a bypass filter, which acts as a fine filter.



Harvesting" rainwater from roofs is easier said than done

The key is: to capture the rainwater before it mixes with the building's contaminated wastewater.
Because at present, in most parts of Frankfurt, rainwater runs into the sewage pipe together with the contaminated wastewater of the building's residents - and then from the property into the city's combined sewer system. If you want to "harvest" it, you have to tap it beforehand. And even if you have separated it from the dirty water on the property, the next problem presents itself: In front of the front door there is only the combined sewer, where the rainwater should not be discharged together with the dirty water. The construction of the Frankfurt Bridges brings the solution: The rainwater can be stored in the newly built cisterns below the road over which the bridges pass.



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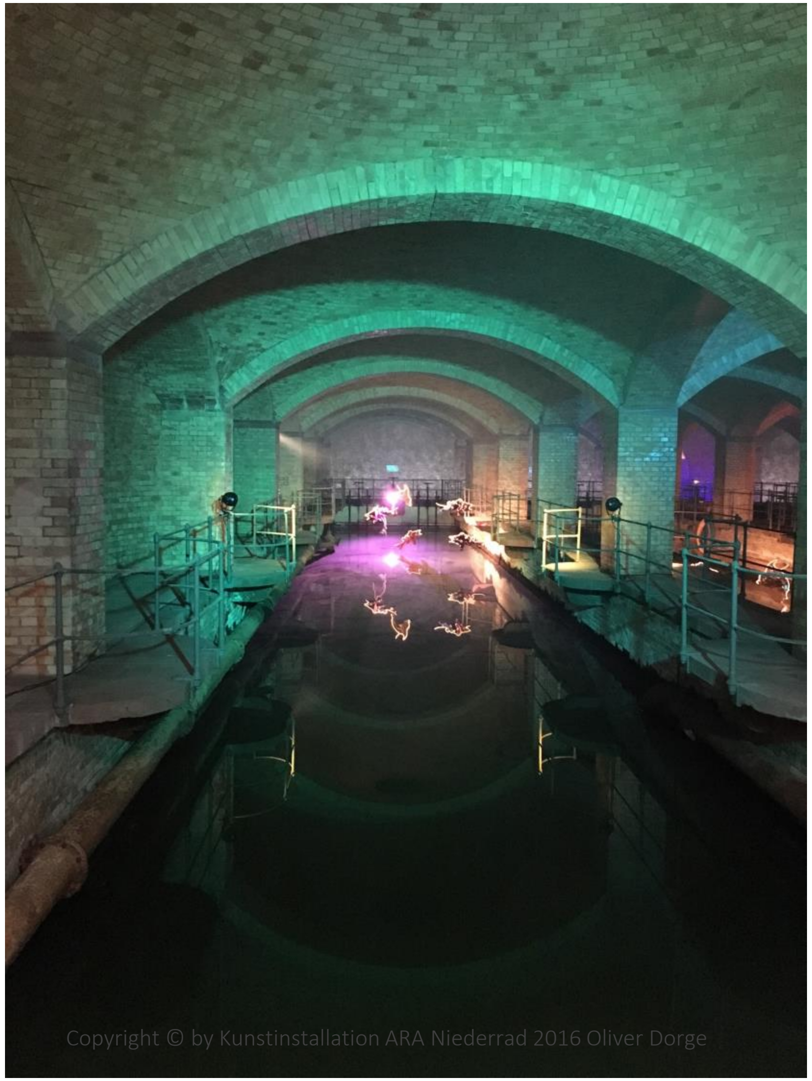
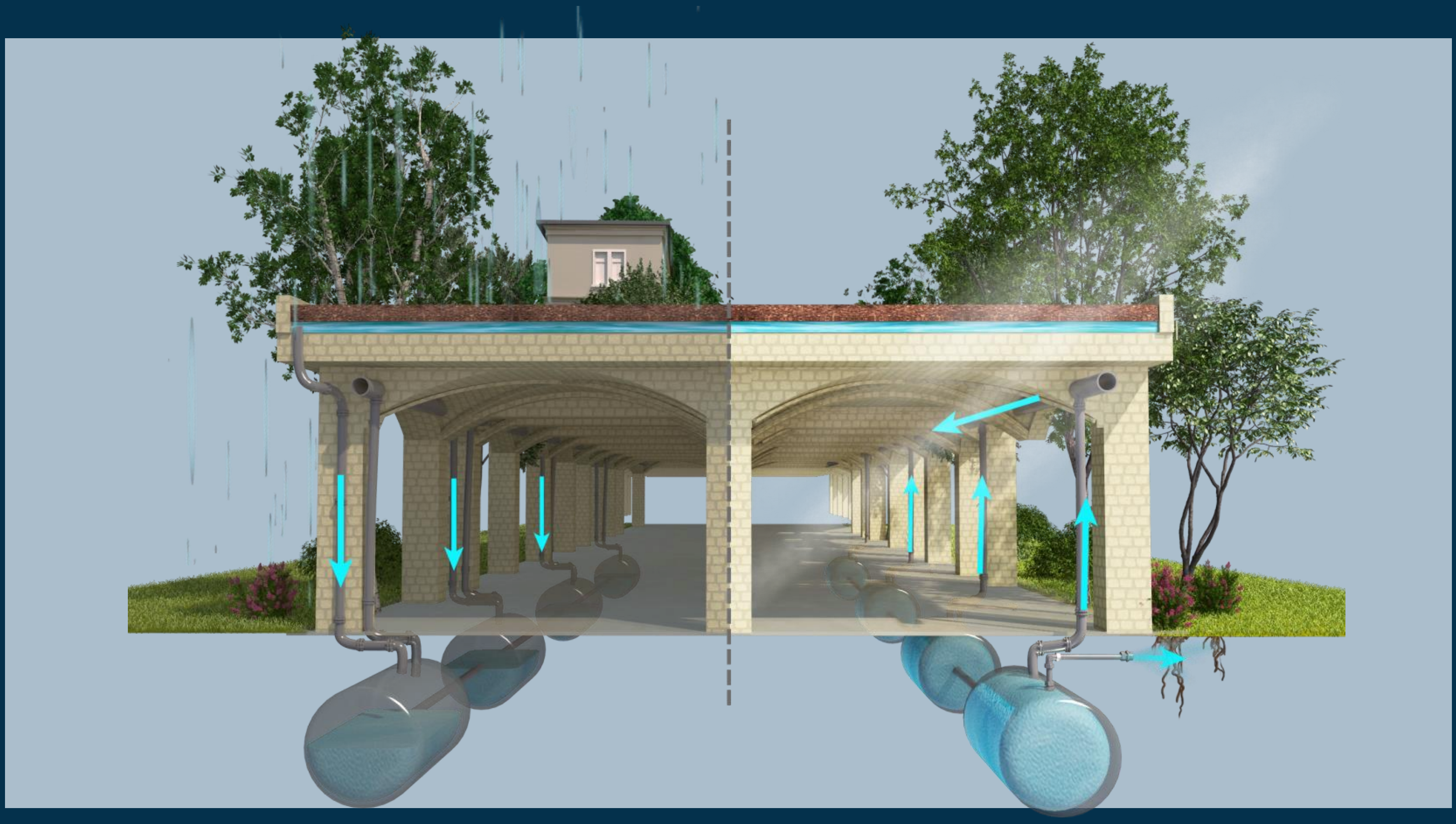
Frankfurt has a sewer network of around 1,700 km in length: some of it beautifully built, but most of it designed as combined sewers



This is where the Frankfurt Bridges come into play

For the construction of the bridges, the road will be torn up anyway, which facilitates the installation of cisterns. Roof rainwater from the adjacent houses and the bridge flows into the cisterns for temporary storage - to be later either released to the plant life directly to the left and right of the bridges as needed or to be transported to larger storage facilities via the bridge ring main. In order to be able to collect a 100-year heavy rainfall event from all areas to be considered, approx. 90,000 m³ of cistern volume must be provided.



Space Requirement

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Do large water storage tanks even fit in the bottom of the road?

Since ancient times, cisterns have been used to store water - especially in areas where rainfall is irregular. So it makes sense to store rainwater in cisterns.

But laying underground cisterns in a city like Frankfurt is a challenge, because a wide variety of supply lines for water, gas, electricity, communications and much more already run under the sidewalks.

There is, however, an unused space: the space under the roadways. There are usually no longitudinal pipelines underneath the roadways, only the sewer, if any, and this is usually several meters deep underground.

Lines are rarely laid under roadways for good reason: Otherwise, traffic would have to be closed in the event of malfunctions or maintenance work on the lines. The low-maintenance cisterns, on the other hand, can be accommodated here in the course of the construction work for the Frankfurt Bridges and can be accessed by connecting to maintenance shafts in the pedestrian area.

Planned are cisterns with a diameter of 2 to 2.5 meters

Accordingly, at least two of these water tanks can usually be placed next to each other underneath multi-lane roadways if no other pipes are laid there or run across the road.

The cisterns, however, are merely a temporary storage facility

The length of the cisternsrows varies - depending on the space available - and can be between 20 and 200 meters. Several cisterns can also be connected to each other via pipelines if desired.

The planned capacity of the cisterns under the course of the bridge is about 90,000 cubic meters over the entire length of the bridge, because it is not possible to put cisterns in the ground everywhere.

While this storage capacity is not enough for the 600,000 cubic meters of rain harvesting planned, they serve as the closest temporary storage after heavy rain events. For safety, cisterns can be equipped with an emergency overflow into the existing sewer or into the ground.

As soon as a certain filling of a cistern is reached, it conveys its water to the ring main, which brings it to the storage locations, and is thus emptied again for new rainwater.

However, each road section is different - so the cisterns cannot simply be placed schematically in the ground everywhere the bridges run

Depending on the course of the road and the existing infrastructure in the ground (intersection sections, for example, are often very full of pipes), cisterns with a diameter of 2 m or 2.50 m can be installed. To store the annual precipitation volume of an example section (max scenario for 4-lane roadway), the following dimensions are required mathematically: If a cistern diameter of only two meters is chosen, the length of the cistern row-string must be 72 meters; if a diameter of 2.50 meters is chosen, the same volume can be stored with a cistern string of only 46 meters in length.

In the example on Kennedyallee, nine long and four shorter cistern row-strings with different diameters but a uniform capacity of 225 m each^3 can be installed in a section of road approximately 600 meters long, taking into account the location of pipes. This corresponds to a total cistern row-string length of 832 meters and a storage volume of around 3000 m^3 of water.

Other potential areas for the installation of cisterns are to be defined in the course of further planning.

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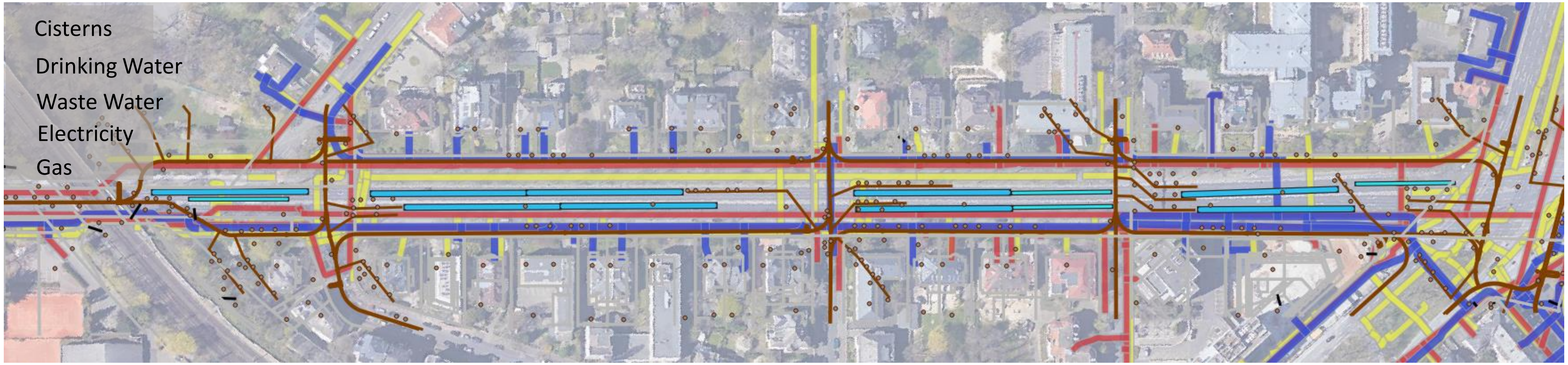
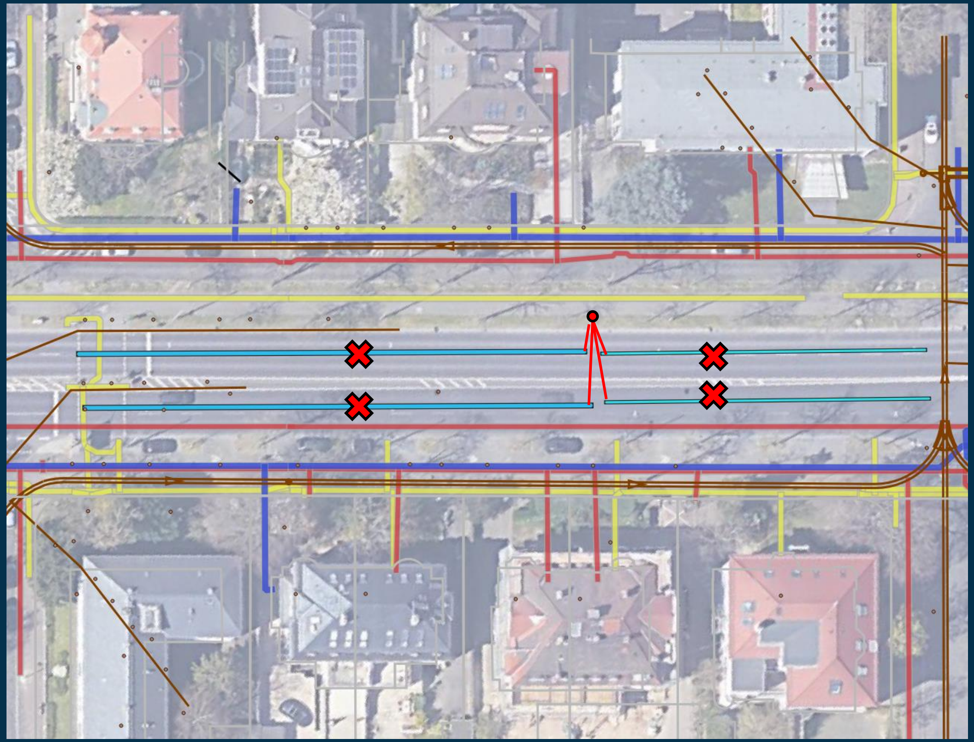


Repairs and maintenance are carried out via inspection shafts

Each cistern requires an access for revisions. This is located above the road surface. The exact location along the cistern string is freely selectable.

In addition, each cistern requires connection to a pump to pump water into the ring main. This is located together with a filter in a pump shaft, which should be placed outside the roadway if possible, in order to be better accessible. The shaft diameter for the pump connection is 1.50 m, and depending on the situation, up to four cistern row-strings can be connected to such a shaft.

For the inlet pipes from the bridges as well as from other roof areas along the bridges, the connection points to the cisterns can be freely selected or adapted to the local conditions.



Drainage of buildings and sealed areas plays a major role in Frankfurt: For building owners with large areas, connection to the rainwater cisterns of the Frankfurt Bridges is attractive

Currently, the monetary incentive to unseal one's property or to green one's roof in order to save precipitation water charges is rather low: only 50 cents per square meter per year cost the owner of a property sealed land areas.

For example, for a DIY store with a roof area of 6,000 m^2 , this means a payment of € 3,000 per year for the rainwater on the roof. No problem for a DIY store. They would rather pay that than invest in a much more costly green roof.

To drain the roof rainwater into a cistern in the street, on the other hand, is much more attractive, especially if the costs for the only important investment for this are borne by the bridge operating company: the separation of the wastewater pipe and the rainwater pipes on the property or at the building.

Once you have endured this construction measure as an owner and/or tenant, you can save thousands of euros and at the same time you have done something good for the city as a company - a marketing effect for free!

Example calculation for building owners

A 6,000-square-meter DIY store with a corresponding parking lot can save around 70,000 euros over ten years - and offer its customers significantly more convenience in parking

For the example DIY store with a 6,000 m^2 roof area, the possibility of connecting to the bridge cisterns not only means €30,000 saved over 10 years: Rather, there is also the offer from the bridge company to equip the DIY store parking lot with photovoltaic roofing, the rainwater from which can also flow into the cisterns.

For a parking lot of, say, 8,000 square meters, that's savings of another €40,000 over 10 years. This means that it is slowly starting to become attractive even for a large DIY store.

What's more, the parking lot canopies protect DIY store customers with cars from rain and snow or mean they no longer have to climb into blazing hot vehicles in the summer - a real customer loyalty campaign for all companies that take part.

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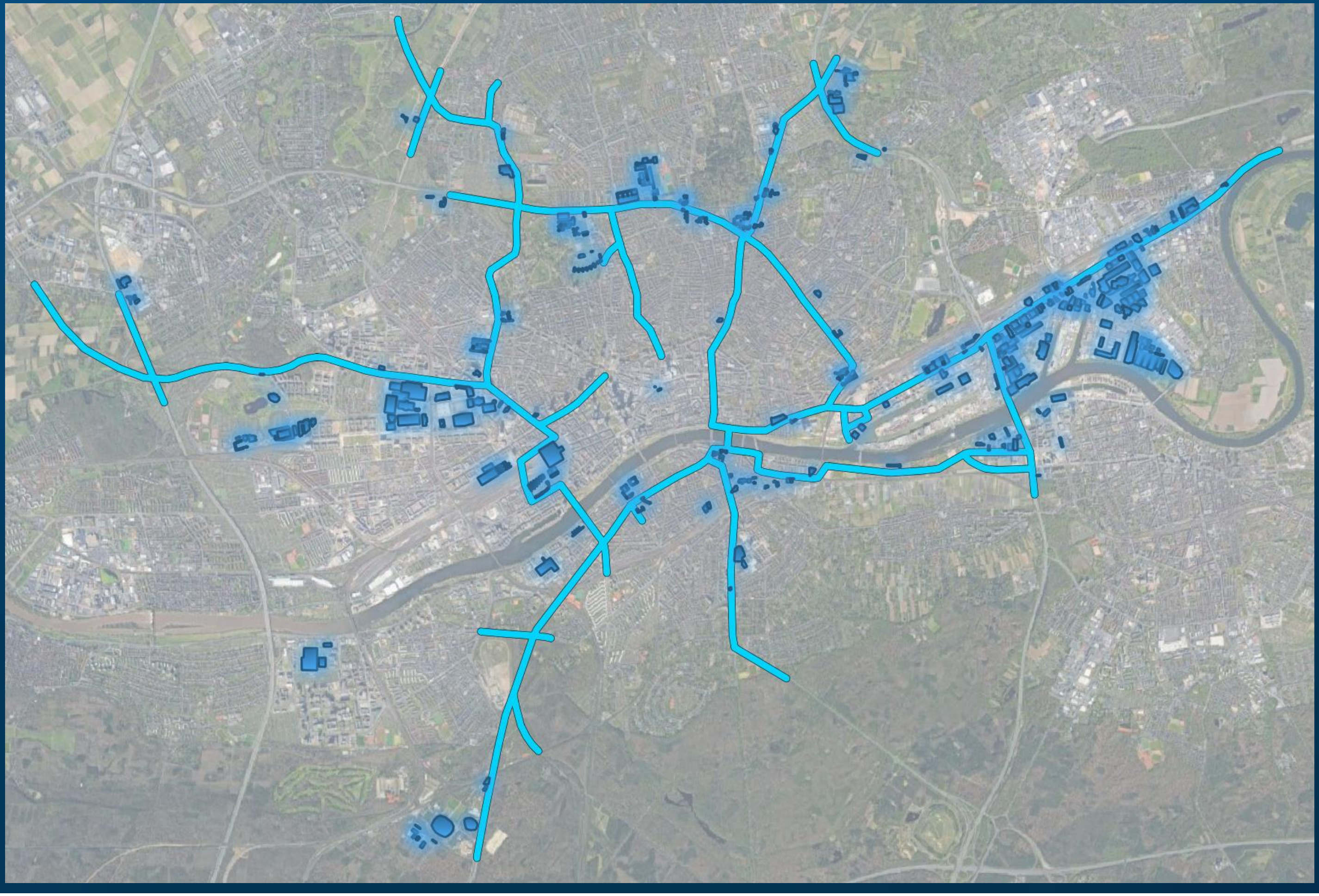
Along the bridges, roof areas and covered parking areas of about 1.2 million m^2 in Frankfurt are eligible for rainwater harvesting

Publicly or semi-publicly owned buildings and company buildings with more than 1000 square meters of roof space along the bridge route were considered for rainwater harvesting. Where possible, parking lot areas were also identified to be covered to collect rainwater and install photovoltaic systems on them.



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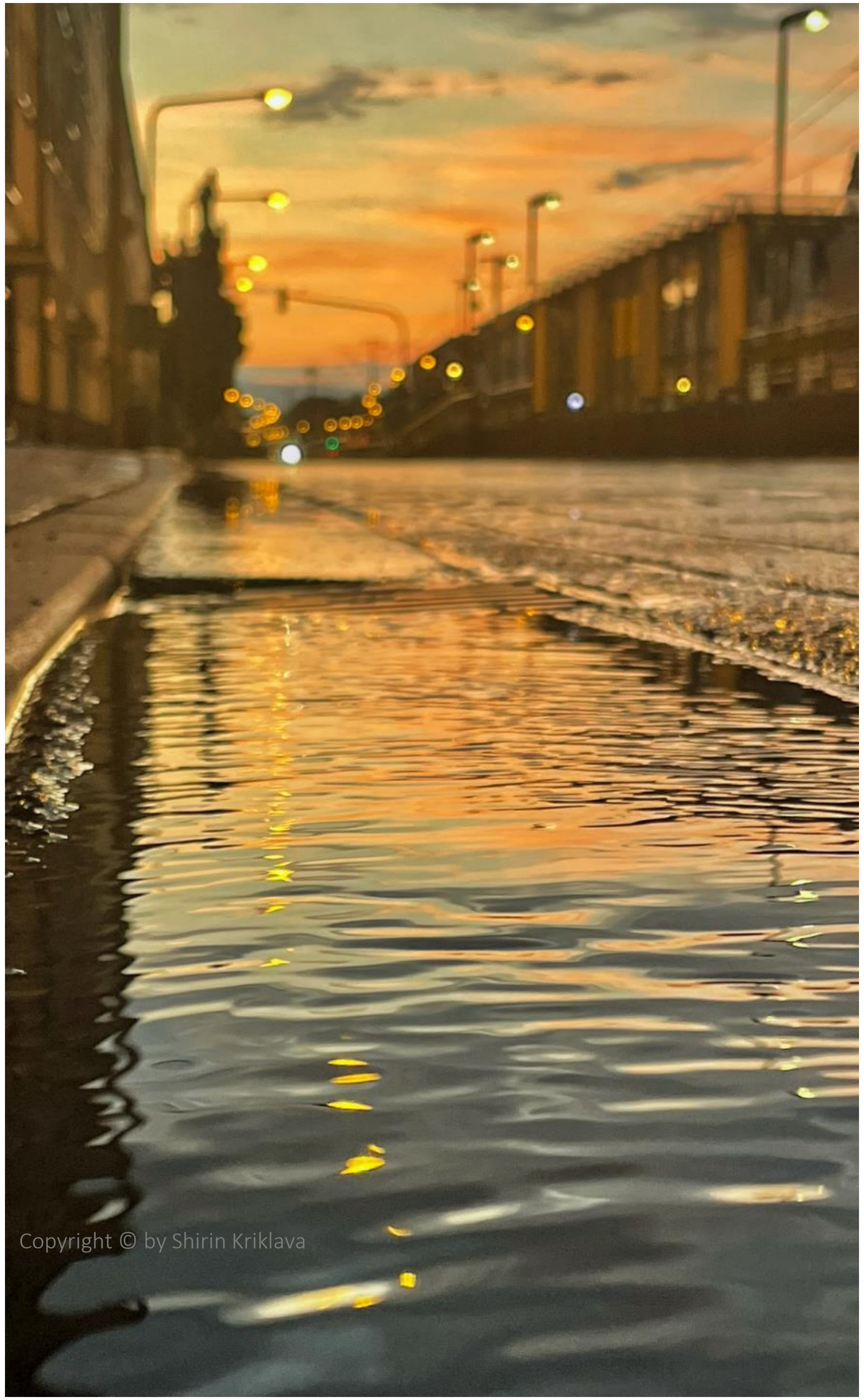


These roof areas along the bridge can collect about 625,000 m3 of rainwater per year

Based on an average rainfall of 650 l/(m² x a) in Frankfurt, the potential rain harvest can be estimated at 520 l/(m² x a). Consequently, up to about 625,000 m³/a of rainwater can be captured.

Some of the roof and parking areas are likely to be not suitable for rainwater harvesting for a variety of reasons, for example because the owners do not consent or because there are substances on the roofs that are harmful to irrigation water - adhesives on bitumen roofs in particular are a common source of pollutants.

Accordingly, the theoretically available roof area is likely to be reduced. However, even with a reduction from around 1.2 million to around 1 million m², the irrigation requirement of 600,000 m³ of water for the new green spaces being created and revitalized in Frankfurt would be covered by the rainwater from these remaining roof areas alone.

The principle of rainwater harvesting with storage in cisterns can also be applied independently of bridges to buildings with large roof areas - for example, at Frankfurt's main train station: its forecourt could be lushly planted with the rainwater from its ample roof.

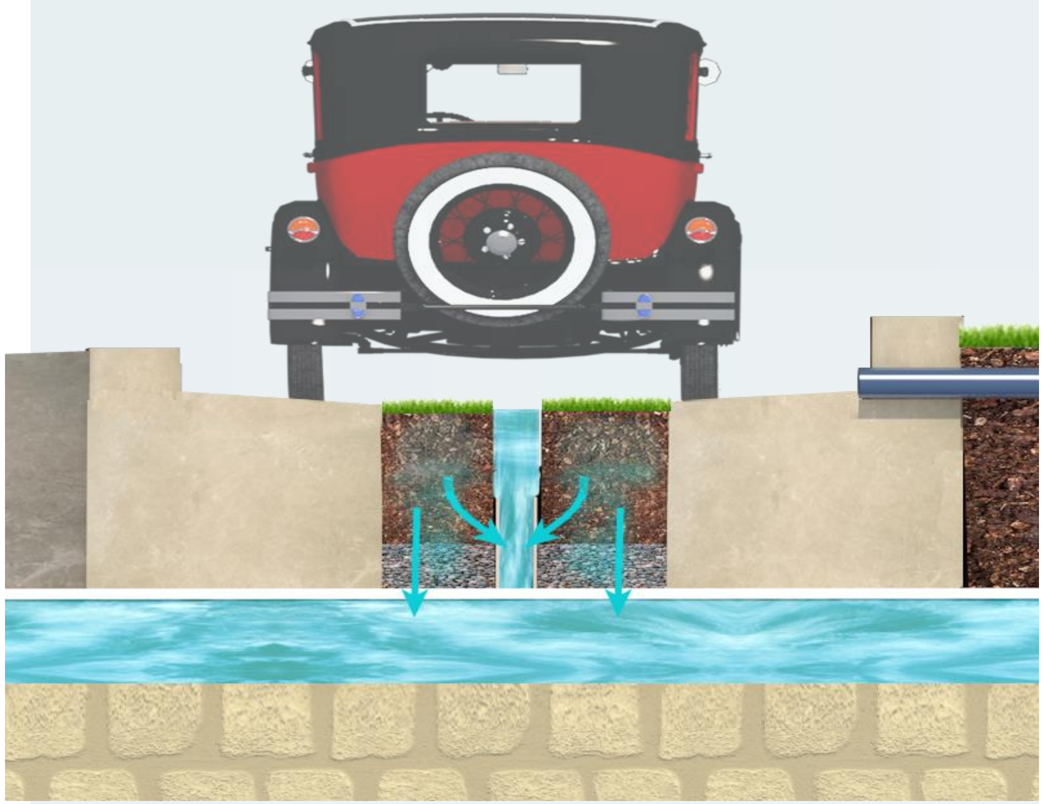
The bridge area must also be drained: Less evaporation, approx. 500,000 m^3 of rainwater can be harvested there and partly used directly

When it rains, the water-bearing layer under the bridge beds, known as the retention layer, is used for drainage. A large part of the roadway as well as all non-green roofs of buildings on the Frankfurt Bridges can be considered sealed surfaces. From these surfaces, much of the precipitation flows over said retention layer through downspouts on the bridge columns toward the ground. The rainwater that falls on the footpaths of the bridges is drained into the green areas on the bridges. Thus, part of the rainwater remains in the beds and is available to the plants there.

Streets covered by the bridges are no longer directly sprinkled. In the event of downpouring rain, this reduces the load on the municipal sewer system. If the precipitation load on the bridges is extremely high, however, the rainwater is also discharged from there directly onto the road on the right and left via the bridges‘ shoulder and still reaches the sewer system in parts during such extreme weather events.

Drainage of the bridge deck takes place via center green strips planted in the middle of the bridges‘s driving roads

Rain that falls on the roadways of the bridges is diverted toward the center, where it infiltrates into the green median strip that can be found in all roadways on the bridges; or else, the rainwater is also diverted into the retention layer in the center.



In part, the rain diverted from the bridges is used directly on site for the irrigation of greenery

Precipitation water is discharged from the retention layer directly into the cisterns under the streets when fully saturated. The cisterns, in turn, irrigate the greenery directly along the bridges, on the one hand, when needed; but as soon as they are full, they also release their water to the ring main, which then transports it to larger storage locations.

In areas with sufficient space next to the roads - mostly outside the city center - infiltration can also be carried out directly in swales at the roadside. Where neither a cistern is available on site nor infiltration is possible, discharge into the sewer system continues.

Conclusion: The Frankfurt Bridges make rainwater harvesting possible on a larger scale in the city

Around 35 million cubic meters of rainwater are discharged annually through the combined sewer system into the Main River via the wastewater treatment plant.

The aim is to capture as much of this as possible and reuse it. The Frankfurt Bridges are like a bypass parallel to the combined sewer system: Rainwater can be collected from adjacent roofs, temporarily stored in cisterns and transported to the final storage locations.

Such a "bypass" could also be installed in other parts of the city with numerous large roof areas.

The Frankfurt Bridges infrastructure model for rainwater harvesting is an important step towards making Frankfurt less dependent on water imports from the surrounding area.

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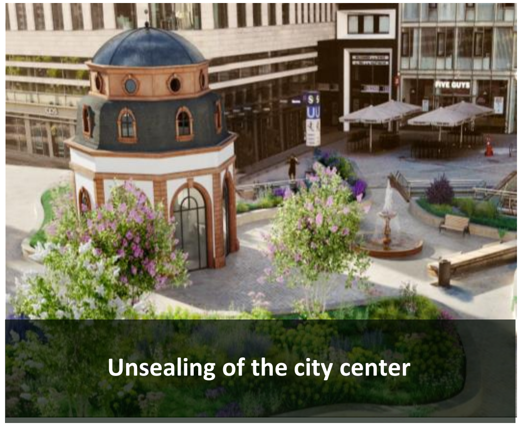
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Using Construction Site Groundwater

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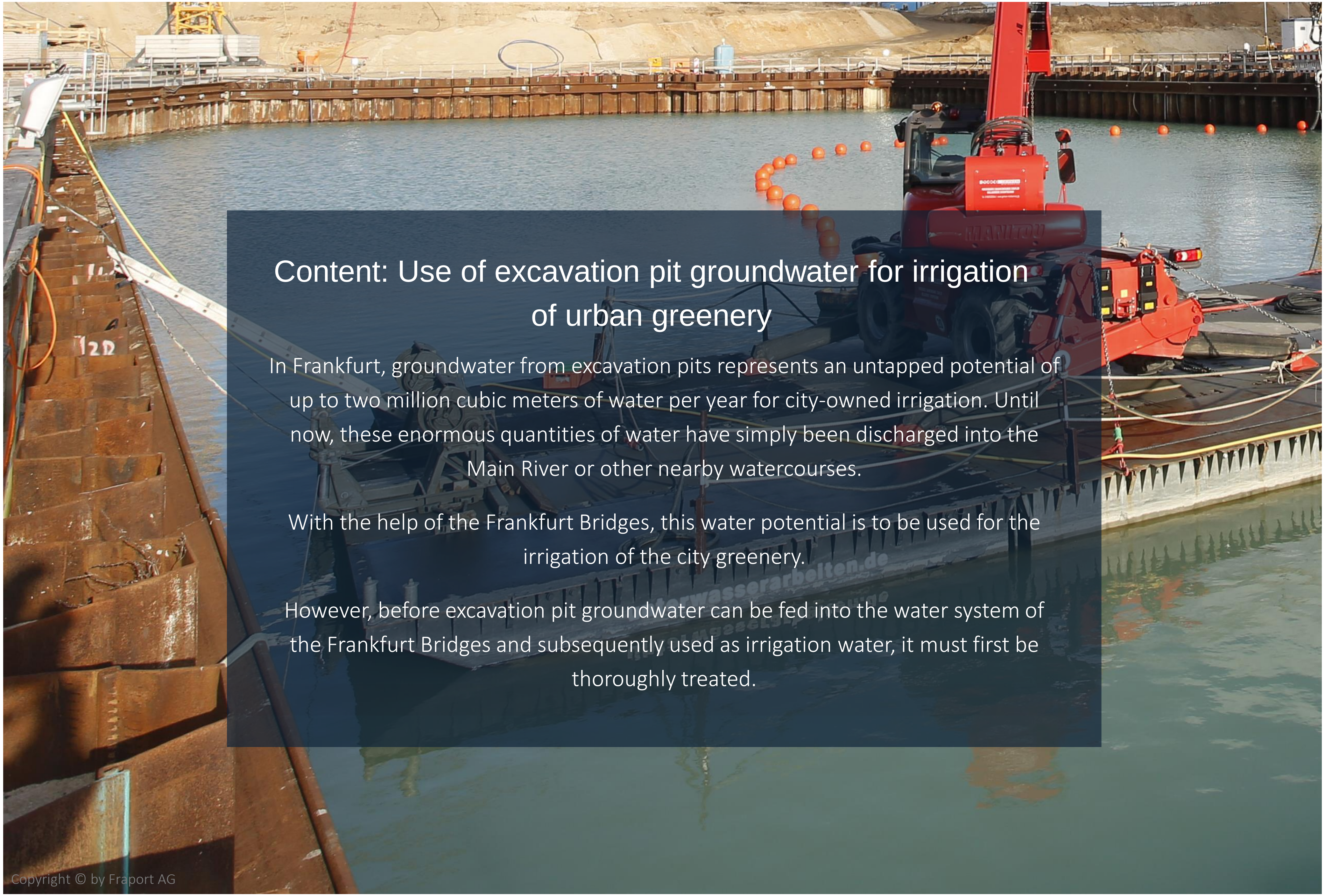
It is sensible to make use of groundwater from excavation pits in urban areas

Like most German cities, Frankfurt is blessed with sufficient quantities of groundwater and rainwater. For this reason, construction projects in the inner-city area of Frankfurt come up against the groundwater relatively quickly. This is currently fed into the Main River through specially laid pipes across the city: at times up to two million cubic meters per year. Using comparatively simple treatment methods, however, this water can be purified into irrigation water and fed into the ring main at the nearest point, so that it can be made available to green areas in need of water.



Content: Use of excavation pit groundwater for irrigation of urban greenery

In Frankfurt, groundwater from excavation pits represents an untapped potential of up to two million cubic meters of water per year for city-owned irrigation. Until now, these enormous quantities of water have simply been discharged into the Main River or other nearby watercourses.

With the help of the Frankfurt Bridges, this water potential is to be used for the irrigation of the city greenery.

However, before excavation pit groundwater can be fed into the water system of the Frankfurt Bridges and subsequently used as irrigation water, it must first be thoroughly treated.

Groundwater from large excavation pits: an untapped potential for city-owned irrigation

Anyone driving through Frankfurt can see it: There is a lot of construction going on here. Apartment buildings, high-rises, underground parking garages and even subway shafts. Construction projects of this magnitude require digging deep into the ground. Groundwater often collects in the resulting excavation pits, because in Frankfurt it is usually found at a depth of only 3 to 7 meters, depending on the location.

This groundwater must be pumped out during a construction project to keep the excavation pit dry. In Frankfurt, experience shows that this involves 400,000 to two million cubic meters of excavation pit groundwater per year. Currently, this water is discharged unused into the Main River. In view of falling groundwater levels, this is a waste that a city like Frankfurt will no longer be able to afford in the future.

Since most of the larger construction projects are located in the inner city area of Frankfurt, these construction sites can be connected to the Frankfurt Bridges' ring line with relatively little effort.

The colorful pipes transport groundwater from construction sites to the Main River

For drinking water treatment, the excavation groundwater is too heavily polluted and, above all, often contaminated with pollutants. This is the legacy of a time when pollutants were handled much more thoughtlessly than today and some pollutants were released into the soil. As irrigation water, however, excavation groundwater can be used with little effort.

Discharging groundwater from large construction sites so that it can be stored as irrigation water involves some effort on the part of real estate builders

Large construction sites are a real challenge - watering flowerbeds is understandably not usually high on the agenda for real estate builders.

Regulatory requirements and complexity of large construction sites are already hard to manage- yet another requirement from the municipality about groundwater treatment will therefore not meet with great approval - but it is possible in principle.

Groundwater from construction sites usually has to be treated before it can be used as irrigation water - or even be discharged into the Main River

The quality of groundwater varies greatly: in some areas of Frankfurt it is heavily polluted by former industry, while in other places it is relatively clean.

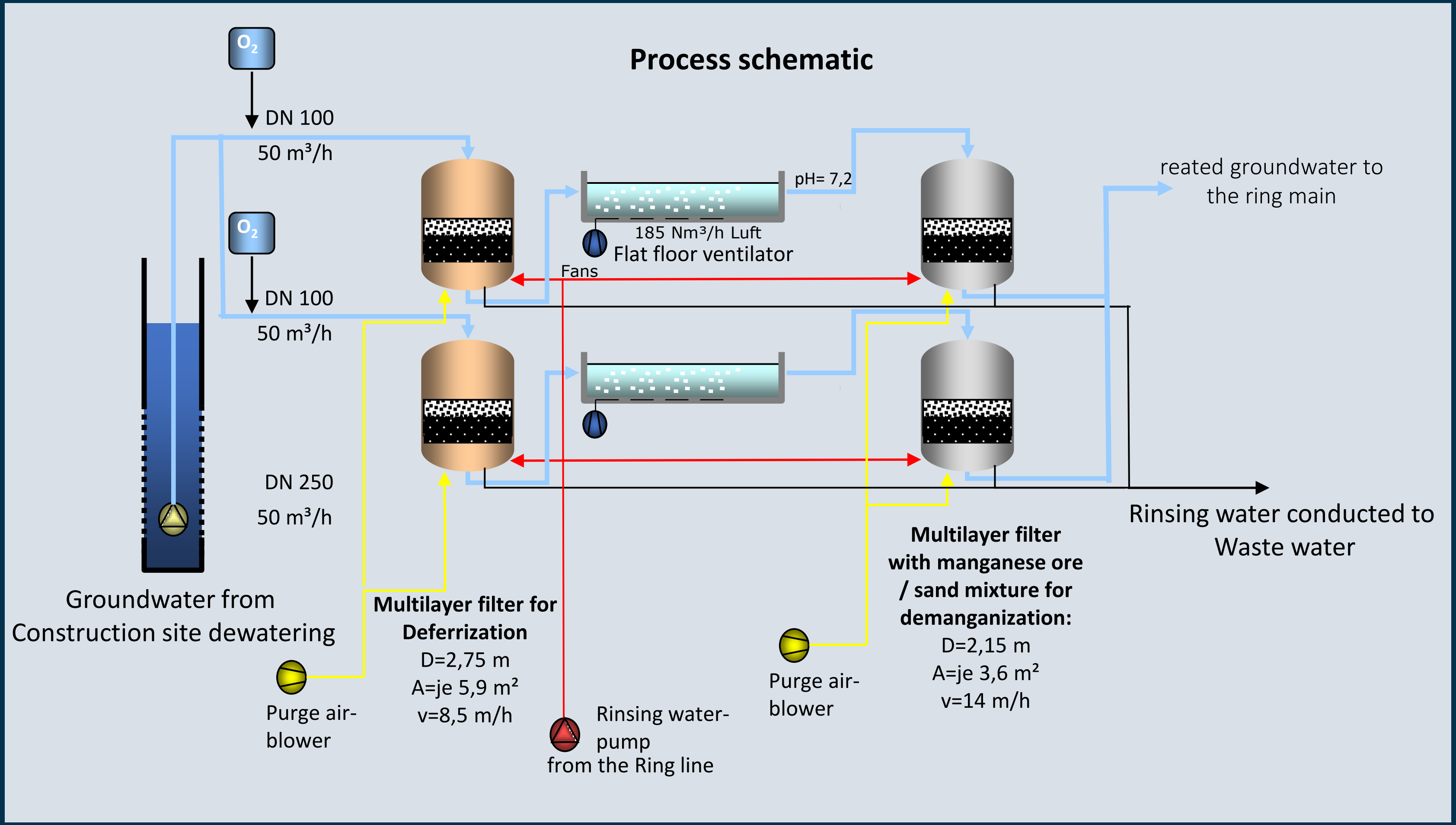
The groundwater does not rest like a lake under Frankfurt, but flows in so-called aquifers.

Some of these aquifers are interconnected, but some are not, so there may be differences in quality at different locations.

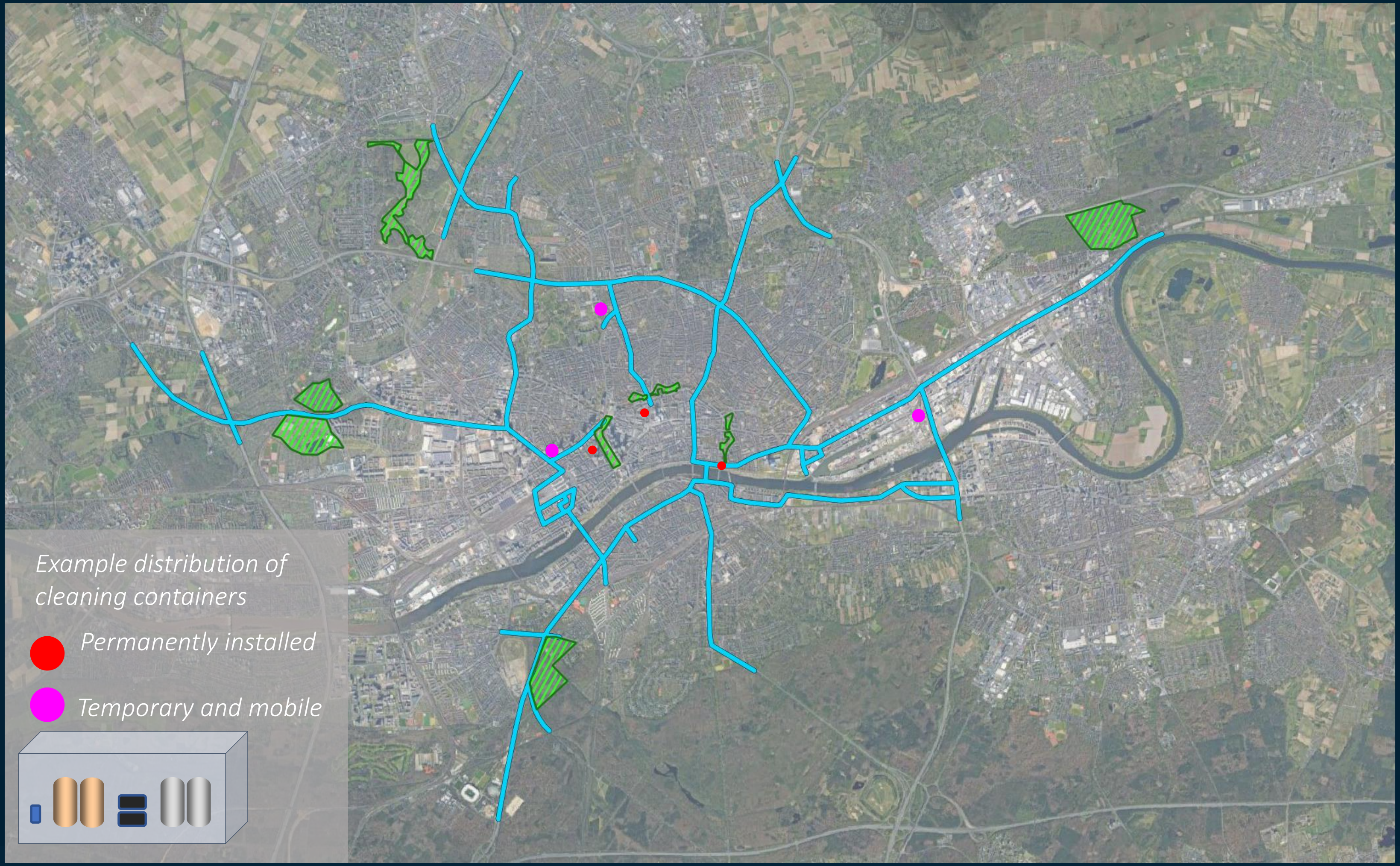
In addition, if groundwater is pumped at a construction site, there is often contamination from site operations.

Groundwater from excavation pits must be thoroughly treated - including with flat-bottom aerators

The plant for deferrization and demanganization for $50m^3$ /h is shown below as an example. These plants can be supplemented as required, i.e. their performance can be scaled. The filter dimensioning and the selection of the filter material can only be made for each construction site after a detailed water analysis. The filter systems are installed in a container.



Along the bridges, there are special purification containers for excavation groundwater: This allows the water to be treated, transferred and stored directly after extraction at the construction site



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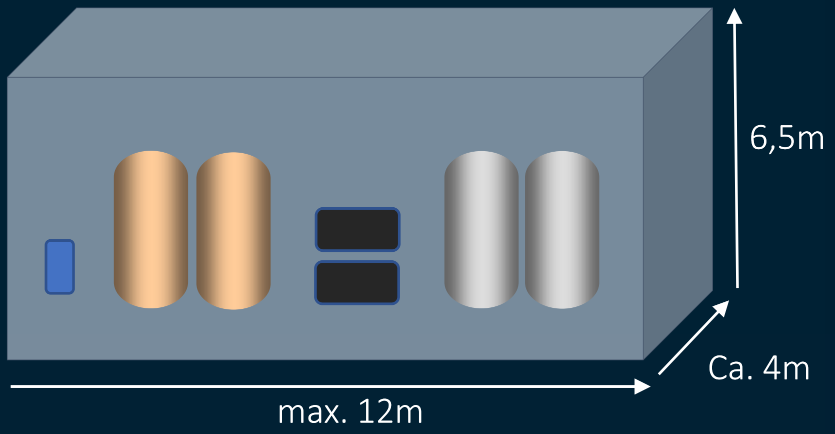
For large construction sites in the extended urban area, mobile "tailor-made" cleaning containers are installed - whereas in inner city locations, which are always characterized by construction activity, they can be permanently installed

The permanently installed cleaning containers for water treatment are all planted with greenery



Containers can also be sunken into the ground, so that they are hardly noticeable in the respective landscape.

Conclusion: Groundwater that accumulates at construction sites can be returned to the natural water balance in Frankfurt

Up to two million cubic meters of groundwater have to be pumped out every year for major construction sites in Frankfurt.

Instead of discharging it into the Main River as before, the infrastructure of the Frankfurt Bridges makes it possible to treat this groundwater and infiltrate it back into the groundwater near the city.

The groundwater reserves thus obtained can be used for intensive irrigation of the urban greenery: Valuable water is thus preserved in Frankfurt's natural water cycle.

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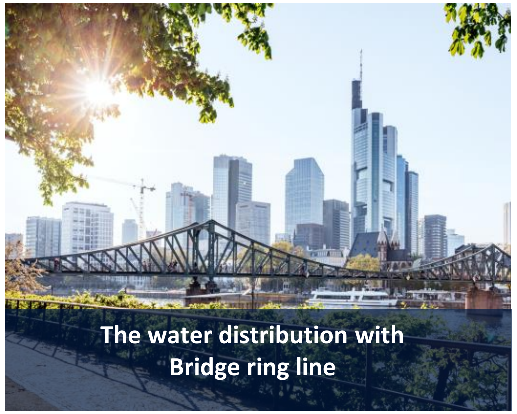
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Vitalization of the urban green


The green metropolis of the future

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Water Storage near the City

Water storage through targeted infiltration in the soil

With the help of the Frankfurt Bridges, up to 2 million cubic meters of water can be collected. Since near-surface storage capacities are exhausted relatively quickly, the project aims to infiltrate this water into the groundwater body. In this way, large volumes of water from precipitation or from excavation pits can be collected, selectively infiltrated, and withdrawn as needed. The present groundwater modeling has been done for areas close to the city and has been limited to the absolutely necessary 600,000 cubic meters of water. By adding more seepage areas slightly further away that are reached by the bridge arms, initial estimates suggest that the full 2 million cubic meters of collected water could also be infiltrated or stored in the area of Frankfurt or close by.

Content: 600,000 cubic meters of water can be stored in groundwater close to the city

Under certain conditions, these enormous quantities can be infiltrated into the groundwater close to the city and enrich the groundwater body to such an extent that it is permissible to withdraw water from it again.

The following explains which soil quality standards must be met in order to be allowed to infiltrate into groundwater.

Potential infiltration areas close to the city were selected for the Frankfurt Bridges. Taking into account the existing groundwater level, a groundwater model was used to simulate by how many centimeters the groundwater level would rise with certain amounts of infiltration.

A prerequisite for any groundwater recharge is thorough special water treatment. The timing and location of extraction is also subject to strict regulation by the relevant authorities.

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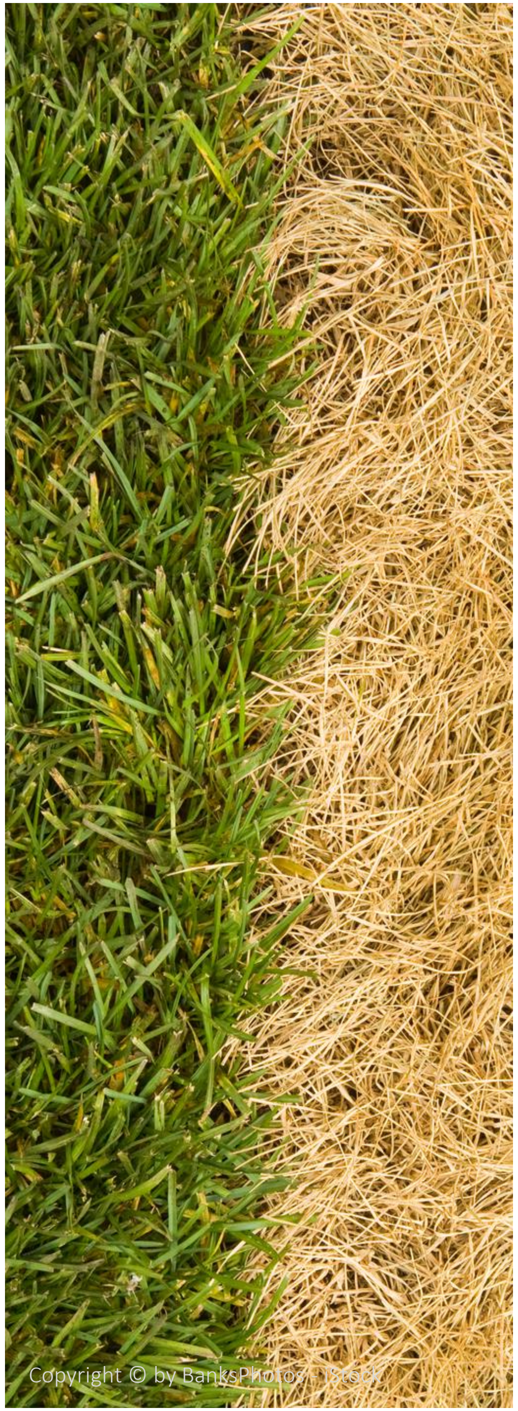


With the help of the bridges, more than two million cubic meters of water can be collected - storing such volumes is a major challenge

To have enough water for irrigation, several water sources can be used: Rainwater can be collected, groundwater can be pumped from excavations, and water can be taken from the Main River when it carries a lot of water.

This means that even theoretically more than the 600,000 to 800,000 cubic meters of water needed for irrigation can be collected over the year. But when exactly is it needed? How long do you have to store it?

The planned storage capacity was designed within the framework of the Frankfurt Bridges to be able to irrigate all green areas in question from April to September. This already takes into account the fact that the growing seasons in Germany have been extended by two weeks forward and two weeks backwards in recent years. This means that plants begin to sprout earlier in the spring and have longer foliage in the fall. This trend is likely to continue.

Consequently, sufficient water must be available at the end of March to ensure that green spaces and trees that are precious to the city's climate are protected against potential long dry spells: a Herculean task.

For such quantities of irrigation water, storage in the aquifer is more sustainable than the creation of huge artificial water reservoirs

In principle, several types of storage are possible: for example, large underground structures (similar to the 11 rainwater retention basins in Frankfurt) in which water is collected; or surface waters such as lakes near the city. The end section of a harbor basin on the Main River could also be considered.

But all of these reservoirs would require a great deal of construction. Moreover, due to the lack of space, it is not easy to provide large water storage facilities in Frankfurt's urban area. However, there is a large existing storage facility located directly underground: groundwater.

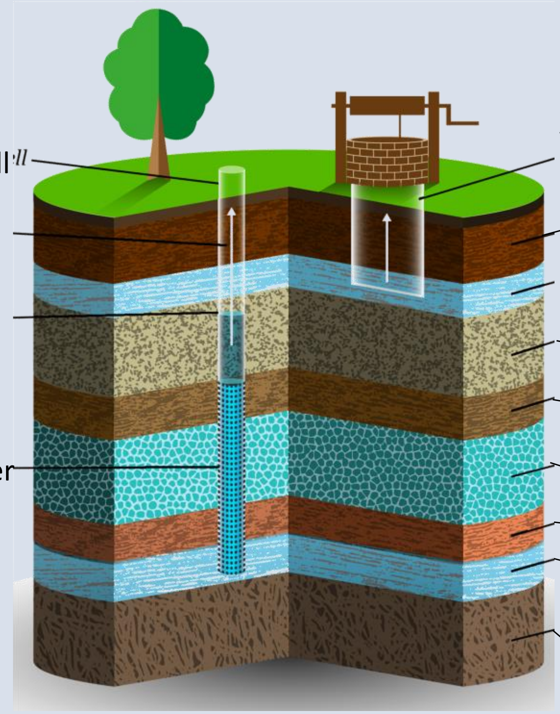
The principle is simple: the water is infiltrated into the groundwater. With regard to the quality of the discharged water, the legally stipulated prohibition of deterioration must be observed, i.e. the quality of the groundwater must not deteriorate as a result of the infiltration of water into it.

Subject to compliance with all conditions, the "groundwater body" can be enriched by infiltration, and water can be drawn again from nearby wells as needed without lowering the groundwater level - a storage principle that is otherwise only permitted in Germany if it can be ensured that the groundwater level is not endangered.

This is also how drinking water extraction works for Frankfurt in the Hessisches Ried region, and similar to that there, infiltration pits and infiltration shafts can also be installed close to the city in Frankfurt, for example in municipal parks.

Infiltration of the irrigation water enriches the groundwater body

Infiltration can best take place where an unsaturated layer still exists in the soil above the current groundwater level. Infiltration gradually fills the free spaces (pores) between the individual earth and rock particles in the unsaturated layer. The groundwater level rises. Once the layer is completely saturated, it cannot absorb any more water. If seepage were to continue, the soil there would soon be under water.



Here, the soil properties determine the infiltration potential

The decisive factor for the suitability of an area for groundwater storage is thus the "thickness" of the water-permeable soil layer above the groundwater; the experts speak of the "thickness" of the "unsaturated zone". This varies within the Frankfurt urban area: In Oberrad, the unsaturated zone is rather low in thickness; the groundwater lies more densely below the surface. In Eschersheim, on the other hand, the zone is thicker and the groundwater lies deeper.

Soil composition also varies greatly within Frankfurt: In the south of the city, the soil is sandy, while in the north it tends to be loamy. Accordingly, the percolating water takes different lengths of time to reach the groundwater.

The soil must not be contaminated with contaminating sites

This is because these contaminations would otherwise enter the groundwater through the infiltration processes. This means that some areas that used to be commercial areas (such as the Riederwald) are no longer potential infiltration areas, even though they appear to be completely clean.

The area must have space for water treatment devices and containers

Water may only be infiltrated if its quality is not worse than that of the underlying groundwater. But even if it is taken from the nearest wells, it may have to be treated again before it is allowed back into the ring main. And any kind of water treatment needs certain space.

The soil must be permeable to water

Traditionally, water seepage takes place in the city forest in the south of Frankfurt, where the soil is very permeable. North of the Main River, on the other hand, one quickly encounters the clay layer that lies beneath Frankfurt in large parts and makes seepage difficult.

The soil must have sufficient storage capacity

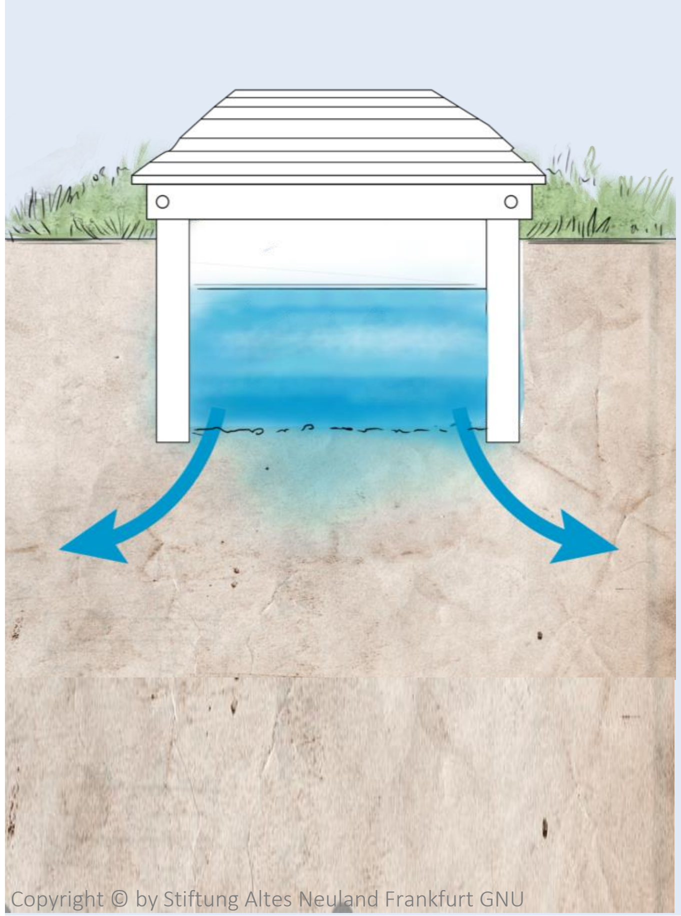
The unsaturated layer in the soil must be thick enough to absorb sufficient groundwater without allowing the water table to rise to such an extent that existing buildings or trees are endangered.

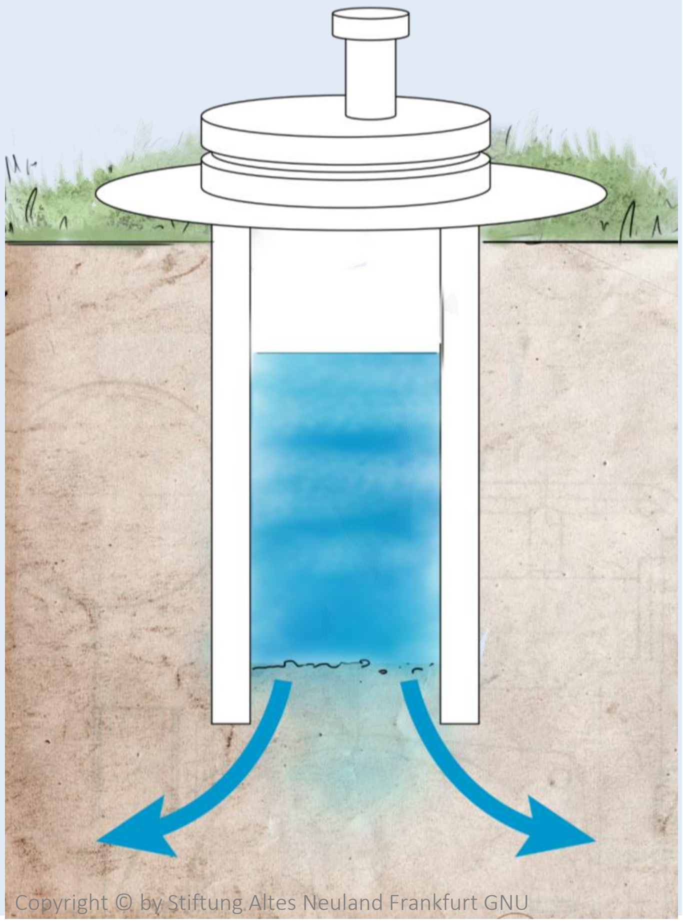
There are basically two different options for infiltration: Trench or shaft

For percolation close to the city, no parks or meadows within the city are flooded, but special percolation facilities are created: For one, infiltration trenches can be constructed. These can be easily hidden under walking paths.

On the other hand, there is the possibility of building deeper infiltration shafts at specific points.

The choice depends on the location: If you have enough space, you choose infiltration trenches, while in confined spaces the usually deeper infiltration shafts are more suitable.





If the infiltration takes place via coverable trenches into the groundwater reservoirs these trenches appear from the outside like ordinary walkways

Infiltration trenches make it possible to slowly channel large quantities of water into the ground while taking up as little space as possible. To do this, they are excavated a few meters deep and then filled with gravel. The water is introduced and fills the voids between the pebbles. While it stands in the pit, it gradually penetrates the soil.

To avoid people trampling over the gravel and also to prevent contamination, the infiltration trenches are covered. Thus, they become almost invisible and can serve as walking paths.

So while Frankfurt's population strolls along walkways in parks and enjoys the greenery, their city's aquifers are gradually filling up under their feet.

Risks and issues related to infiltration of water into groundwater must be clarified during the preliminary planning phase of the Frankfurt Bridges and examined by the authorities

Before infiltration into groundwater can take place, important prerequisites must be clarified:

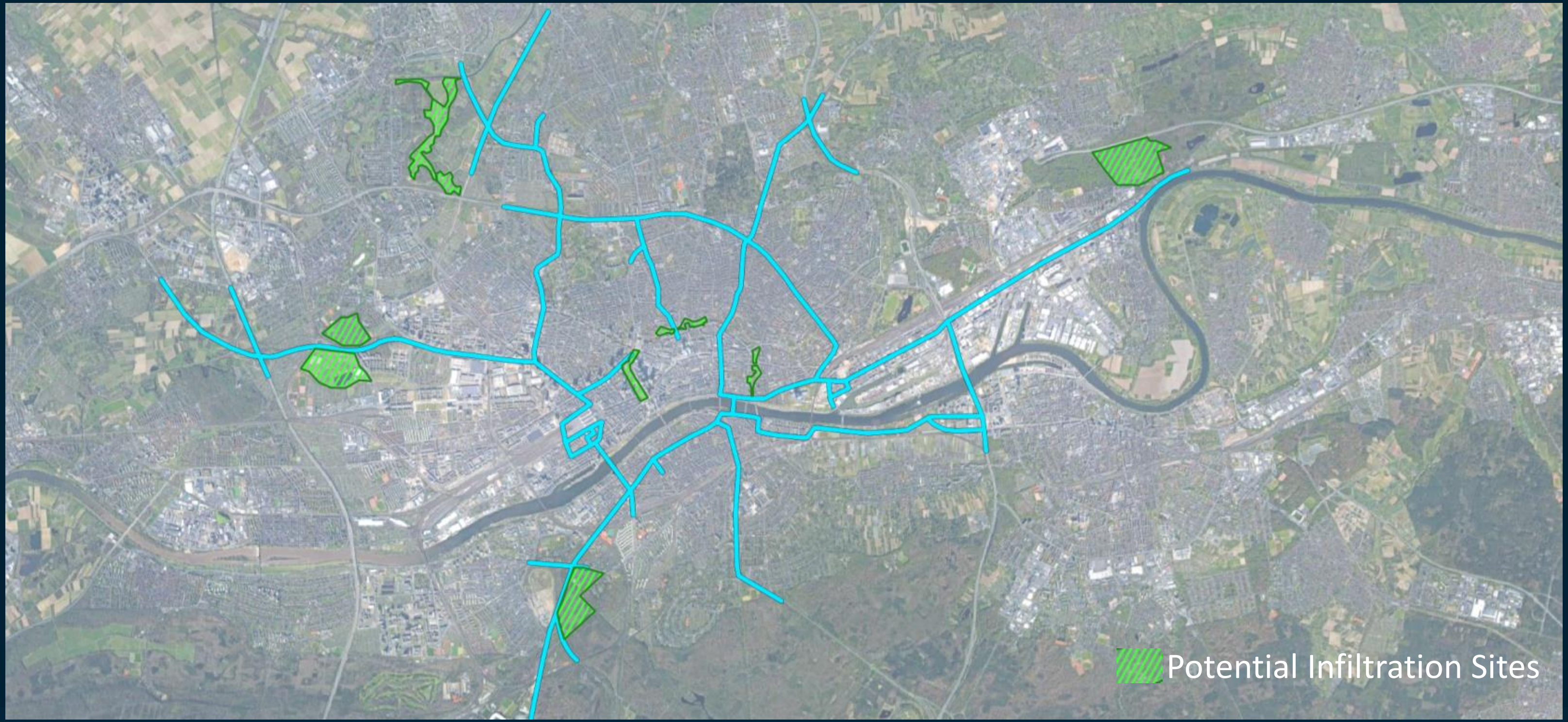
Where can seepage take place in Frankfurt's urban area or close to the city? What is the soil quality and composition there?

What degree of treatment is required? Purification to drinking water quality or less?

At what local distance from the infiltration source may water be extracted?

At what temporal distance from the infiltration source may water be extracted?

Taking into account the local soil conditions and with the help of a simplified groundwater model, the areas in Frankfurt were identified in which water can probably be infiltrated without hesitation



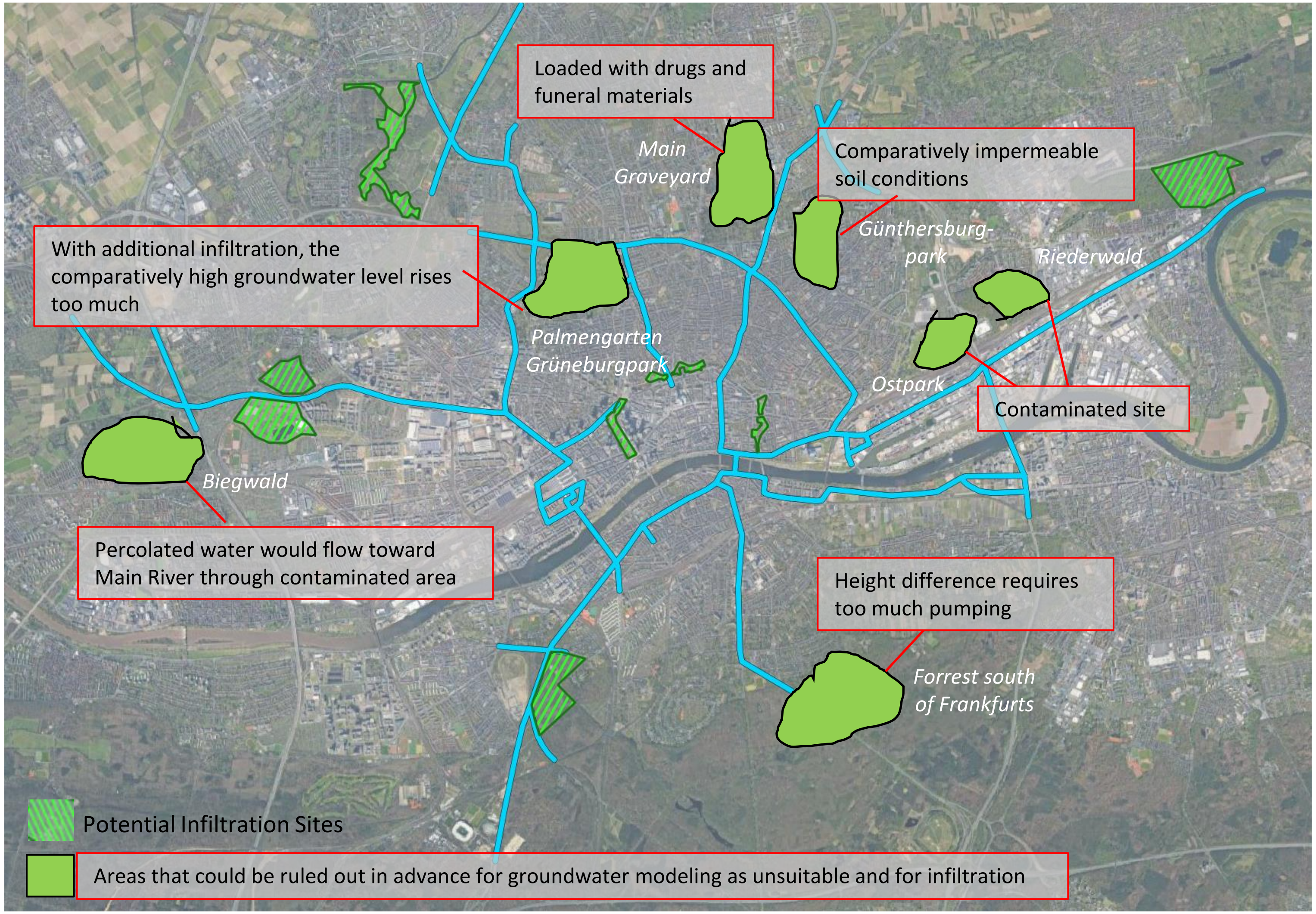
In the present groundwater model, potential infiltration sites for large amounts of water were identified: The geology and groundwater situation of an area are decisive for the effects of infiltration there. Significant amounts of water can only be infiltrated in an area if the level of the aquifer affected there is not yet too high and therefore only rises to a certain extent. Otherwise, there is a risk that an excessively high groundwater level will cause damage to structural elements or plants.

In a first step, suitable areas were selected from all potential infiltration areas and unsuitable areas were excluded

Potential parks and green areas where infiltration could take place under walking paths certainly exist throughout the city. But not all of them are suitable for the infiltration of large quantities of water.

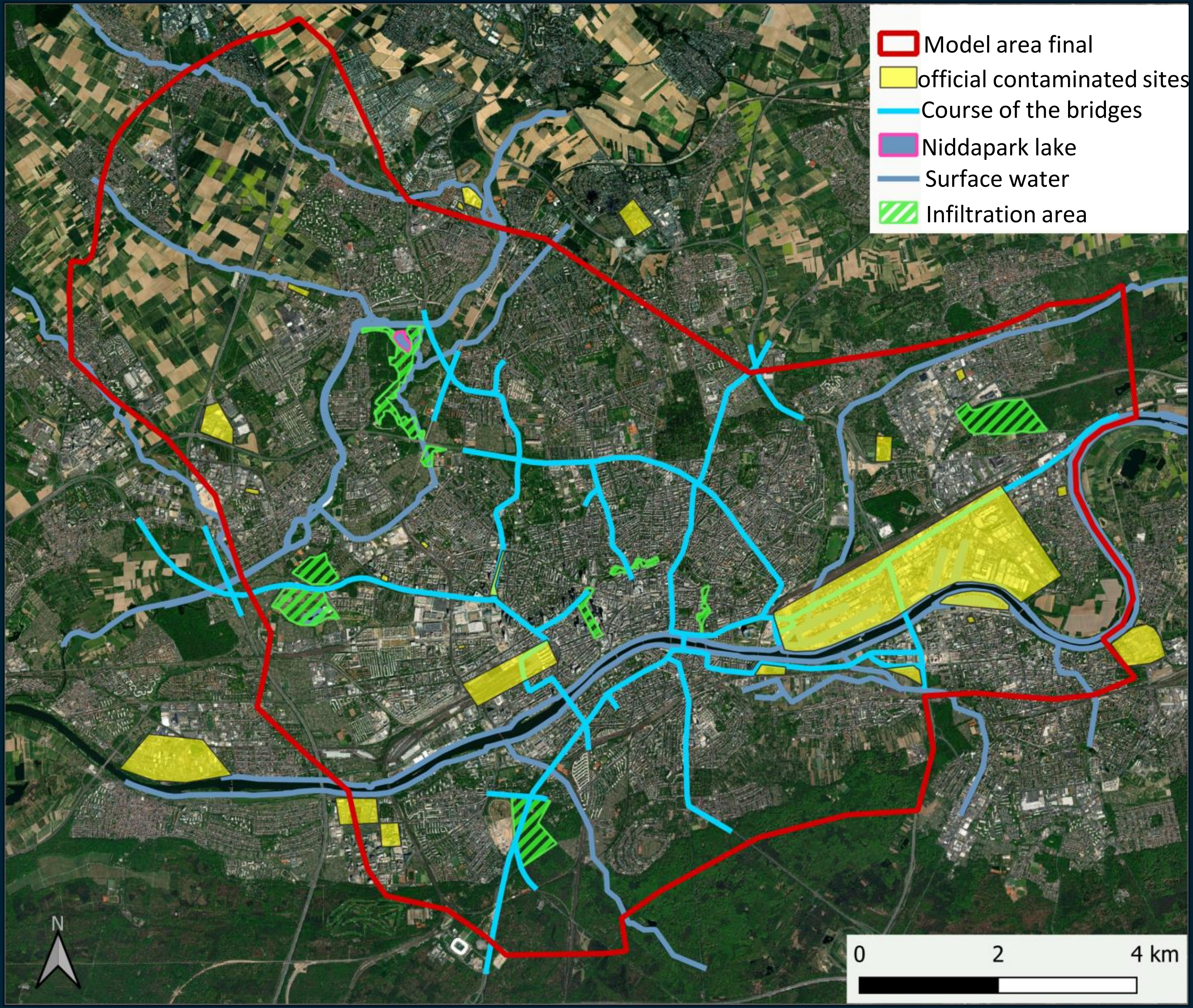
Selection parameters

1. Information about soil contamination
2. Relief of the project area (elevation profiles)
3. Geological conditions (clay, sand, rock, etc.), i.e. water permeability and storage capacity of the soil.
4. Current level of groundwater and corresponding increase in case of infiltration - only identifiable with the help of the groundwater model



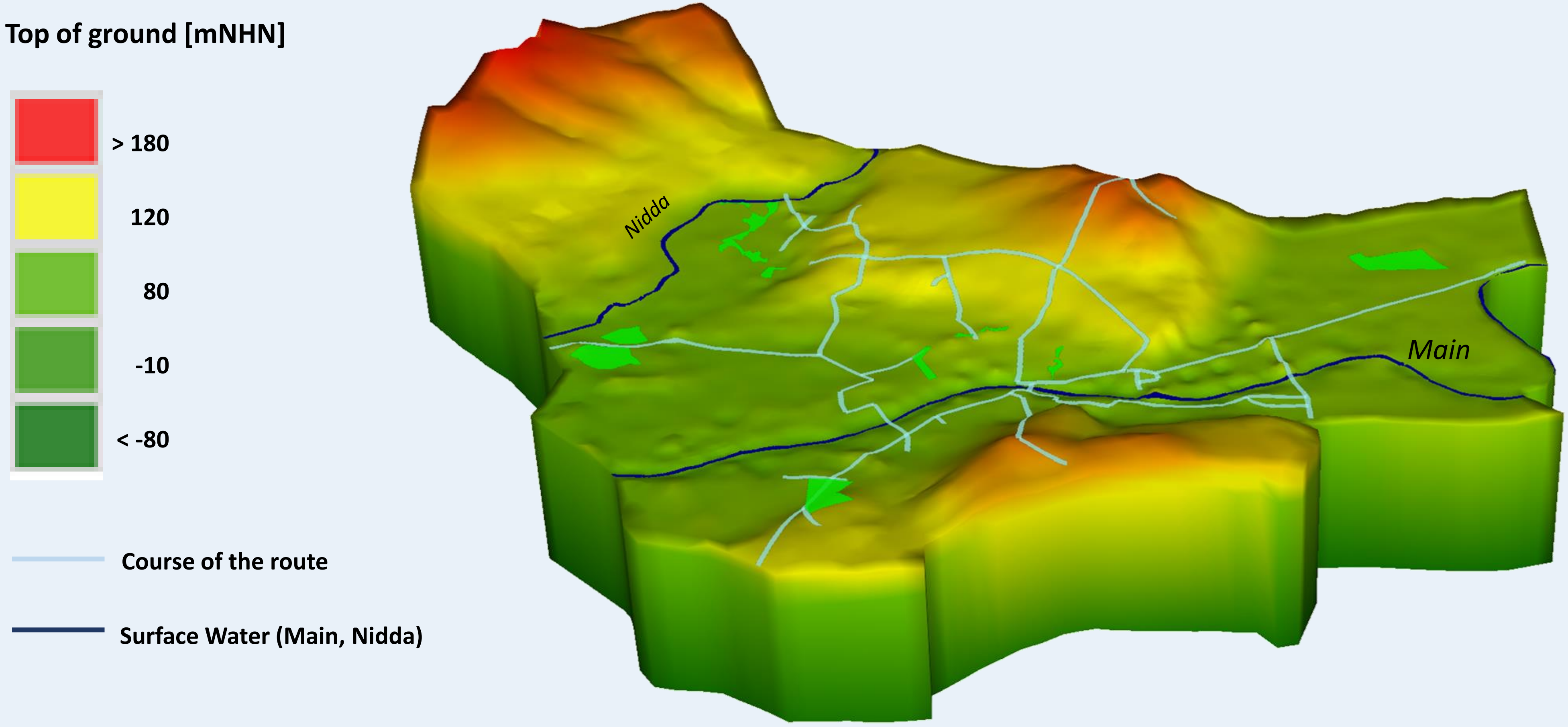
(1) Contaminated sites in the model area

The identified contaminated sites preclude their use as infiltration areas, as this would impair the quality of the groundwater.



(2) The digital terrain model illustrates the elevation profile of the study area

The digital terrain model of the study area with the entire route of the bridge and the Main River gives an impression of the relief of the city and serves as a data basis for the creation of the 3D groundwater model. The considered infiltration areas are additionally shown in neon green.



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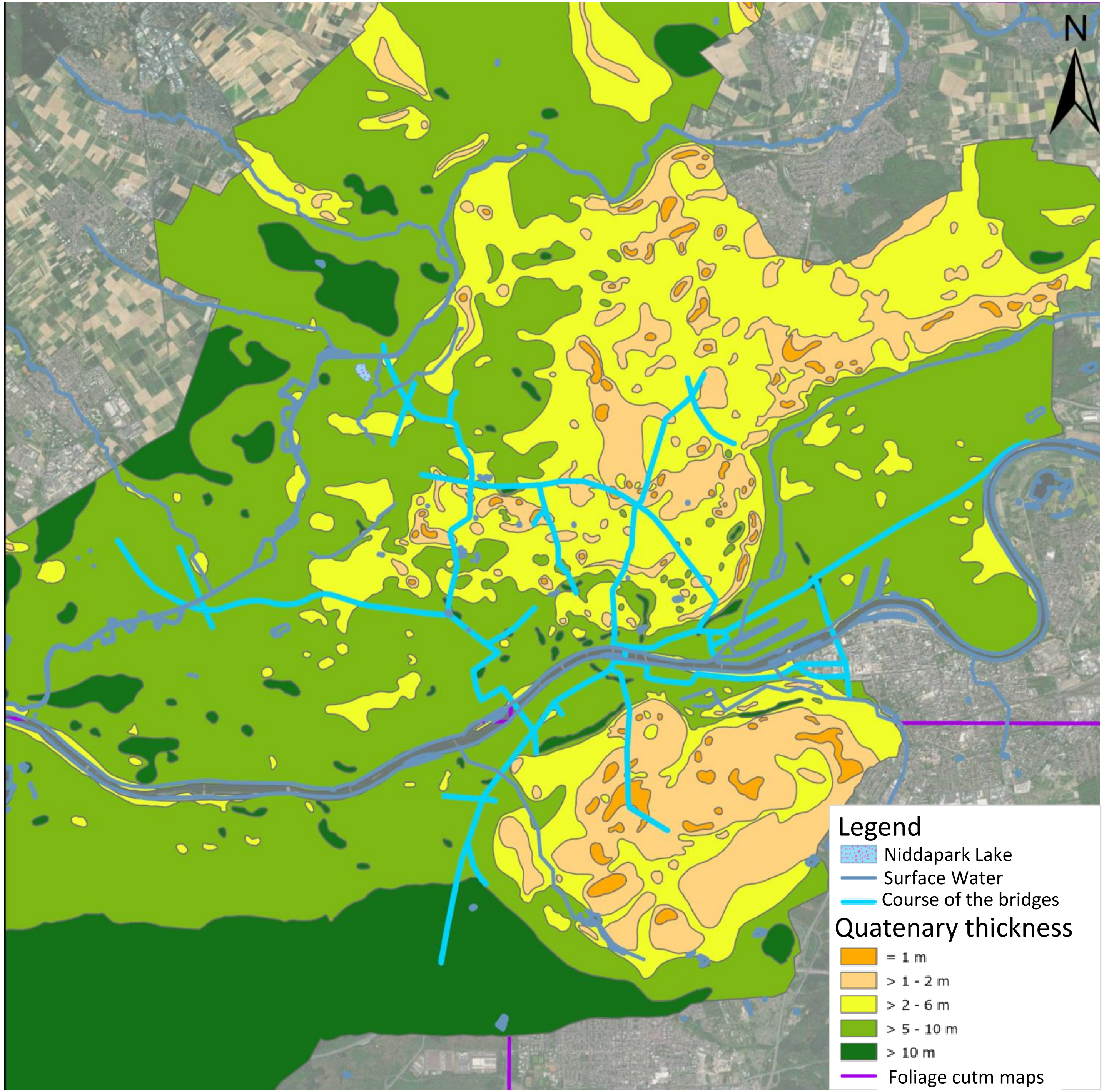
(3) Quaternary thickness (in the model structure) indicates the water permeability and storage capacity of the soil

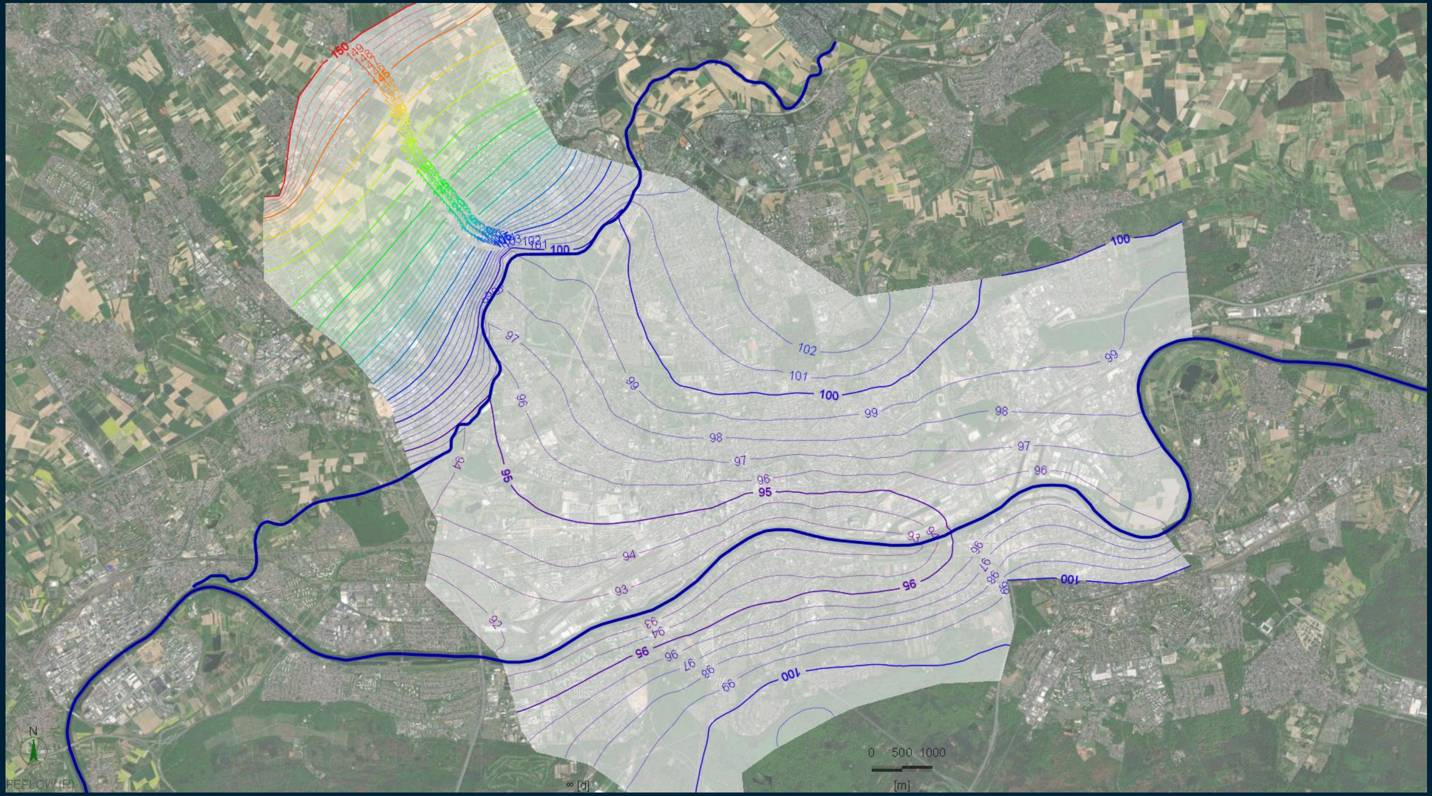
The so-called "Quaternary thickness" describes how thick the layer in the soil is that is capable of holding groundwater.

Put simply: The lower the Quaternary thickness of a site, the "thinner" the aquifer there



(4) Current groundwater levels are important input parameters for the groundwater model

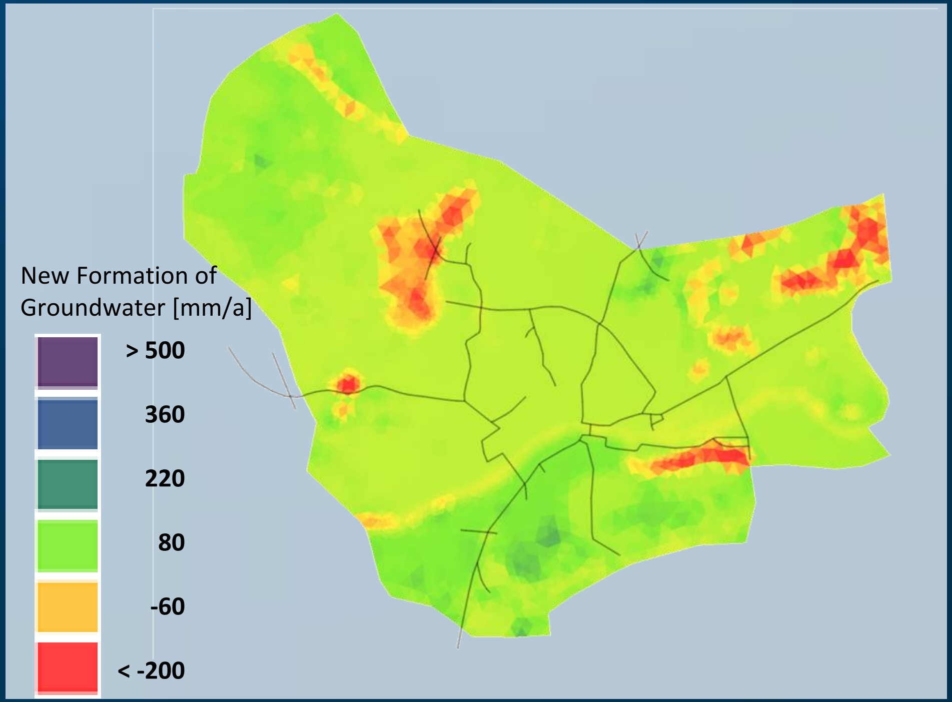
In the 2D groundwater model, the current groundwater elevations can be read out in a very differentiated manner. This is an important basis for simulating the infiltration of additional water.



Procedure: In the groundwater model, groundwater levels were calculated for the entire model area before and after infiltration through the main of the Frankfurt Bridges. Even though the modeling results are only an initial estimate, they provide an important basis before simulating the influence of infiltration of additional water.

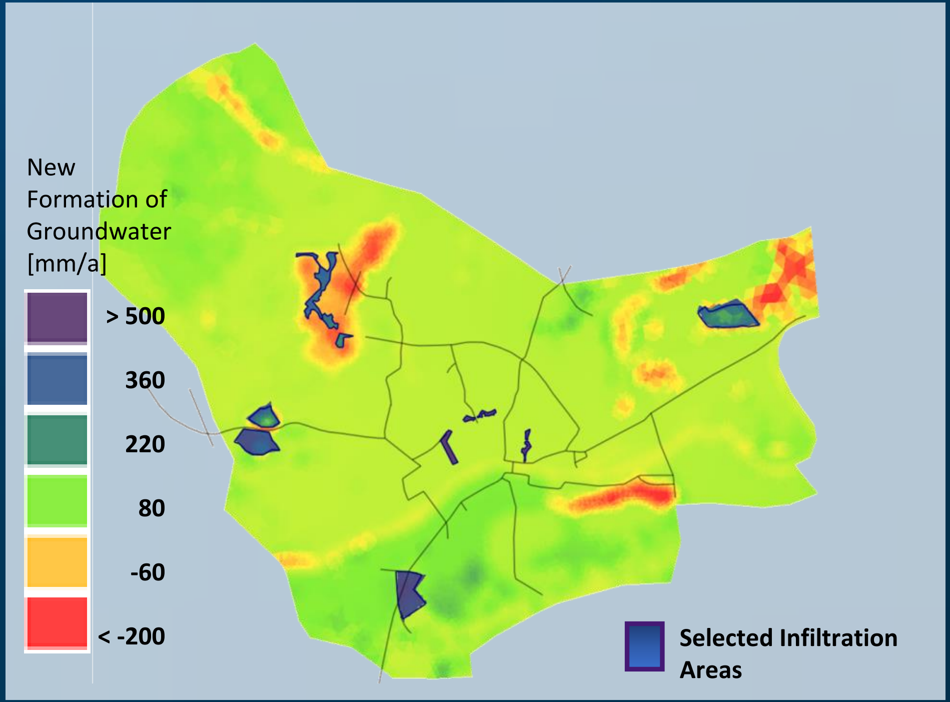
The initial situation of groundwater recharge in the model area

Groundwater recharge is defined as "access of infiltrated water to groundwater" (DIN 4049-3). Low or negative groundwater recharge rates can tend to be associated with a lot of evaporation, whereas high groundwater recharge rates indicate increased groundwater recharge. Suitable infiltration areas depend primarily on the particular subsoil structure and terrain sealing.



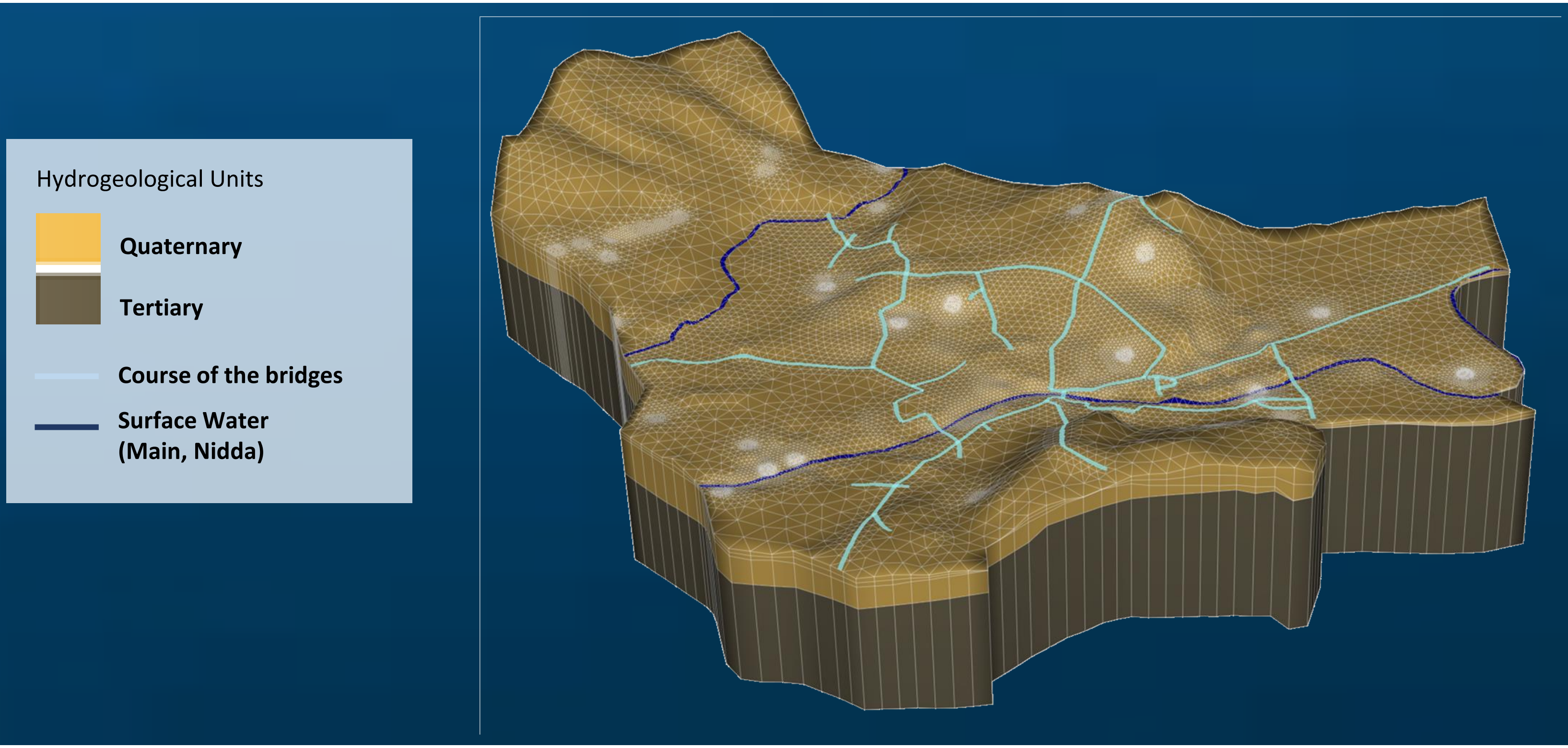
Infiltration areas for the Frankfurt Bridge World additionally contribute to groundwater recharge

In the groundwater model, existing groundwater recharge is combined with recharge from the infiltration areas. The areas that are particularly suitable for infiltration are: the Niddapark, parts of the Anlagenring, the Rebstockpark, the Heinrich-Kraft-Park and the Stadtwald.



A hydrogeological structure model is used for the - highly simplified - analysis of groundwater dynamics

With the help of the - publicly available - borehole points of the digital terrain model, a hydrogeological structure model was spatially (3D) interpolated. It represents the essential hydrostratigraphic formations of the Quaternary and Tertiary in a highly simplified way.



The figure also shows the discretized mesh of finite elements at whose transitions the differential equations of groundwater flow are solved. At known extraction wells, the model mesh is more finely discretized in order to represent the groundwater dynamics there in greater local detail.

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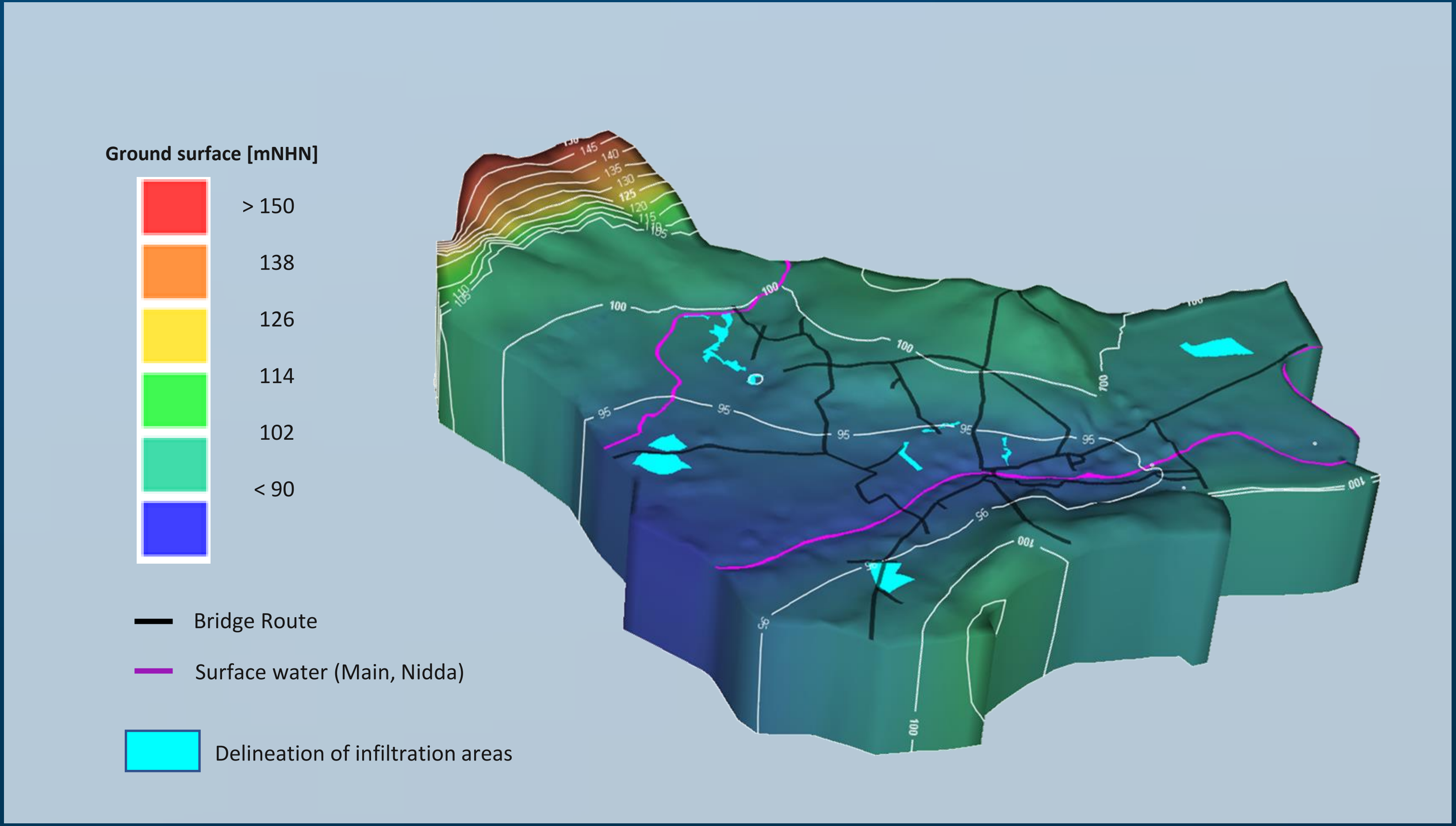
The 3D groundwater model shows the current calculated groundwater levels (contour lines of groundwater levels) in the shallow Quaternary aquifer



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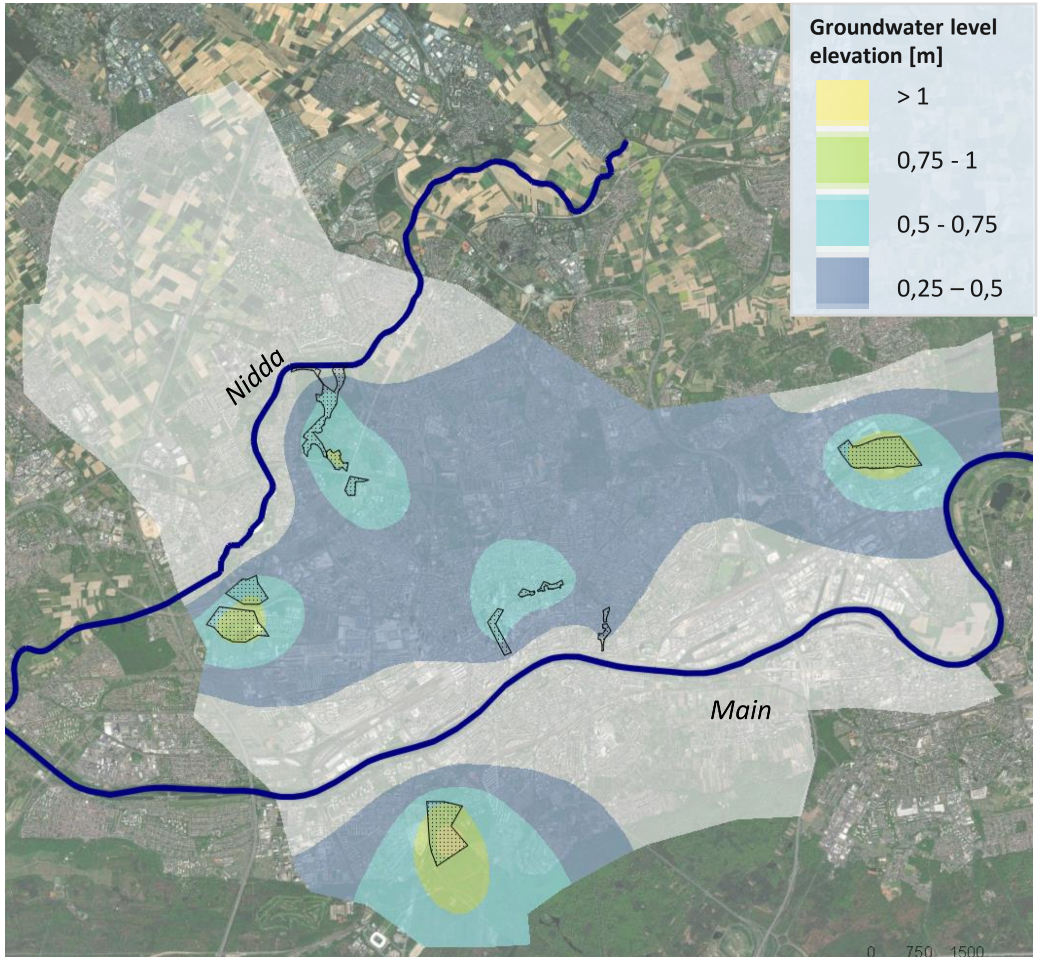
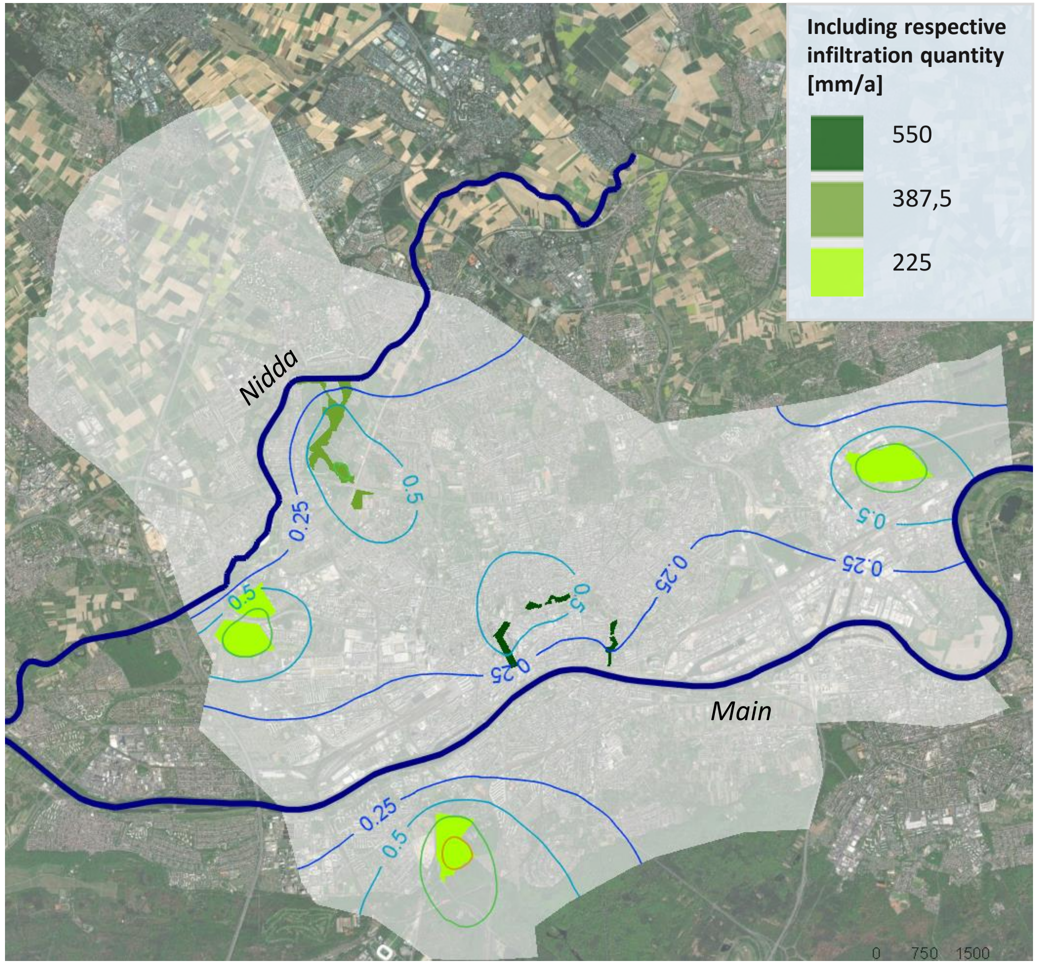
The groundwater model shows the increases in groundwater levels after infiltration of an additional 600,000 m³ of water per year

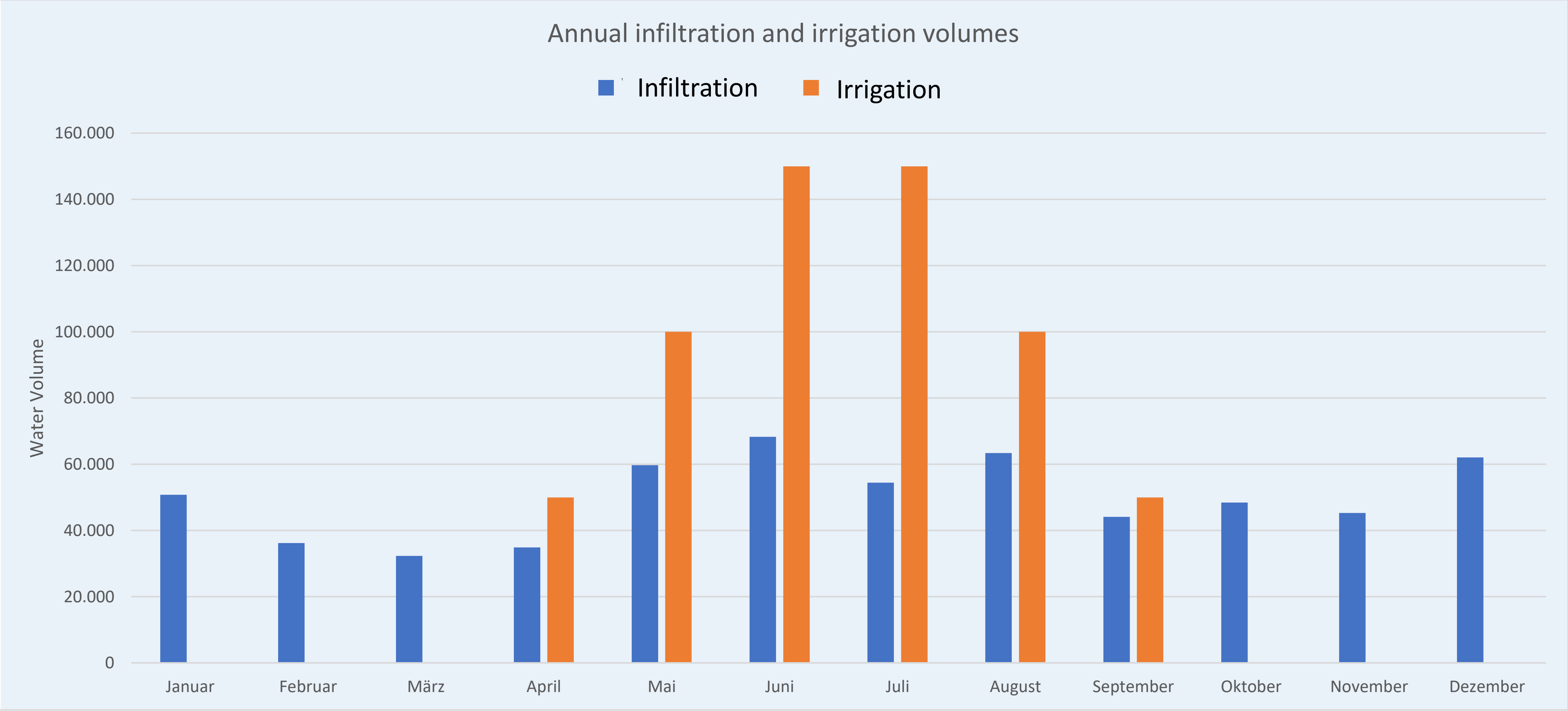
The additional infiltration is expected to raise groundwater levels by only 25 to 50 centimeters over a large area. This means that up to 600,000 cubic meters of water can be infiltrated close to the city without affecting existing buildings or plants. If the model areas are expanded, up to two million cubic meters of water can be stored by infiltration in the immediate vicinity of Frankfurt.

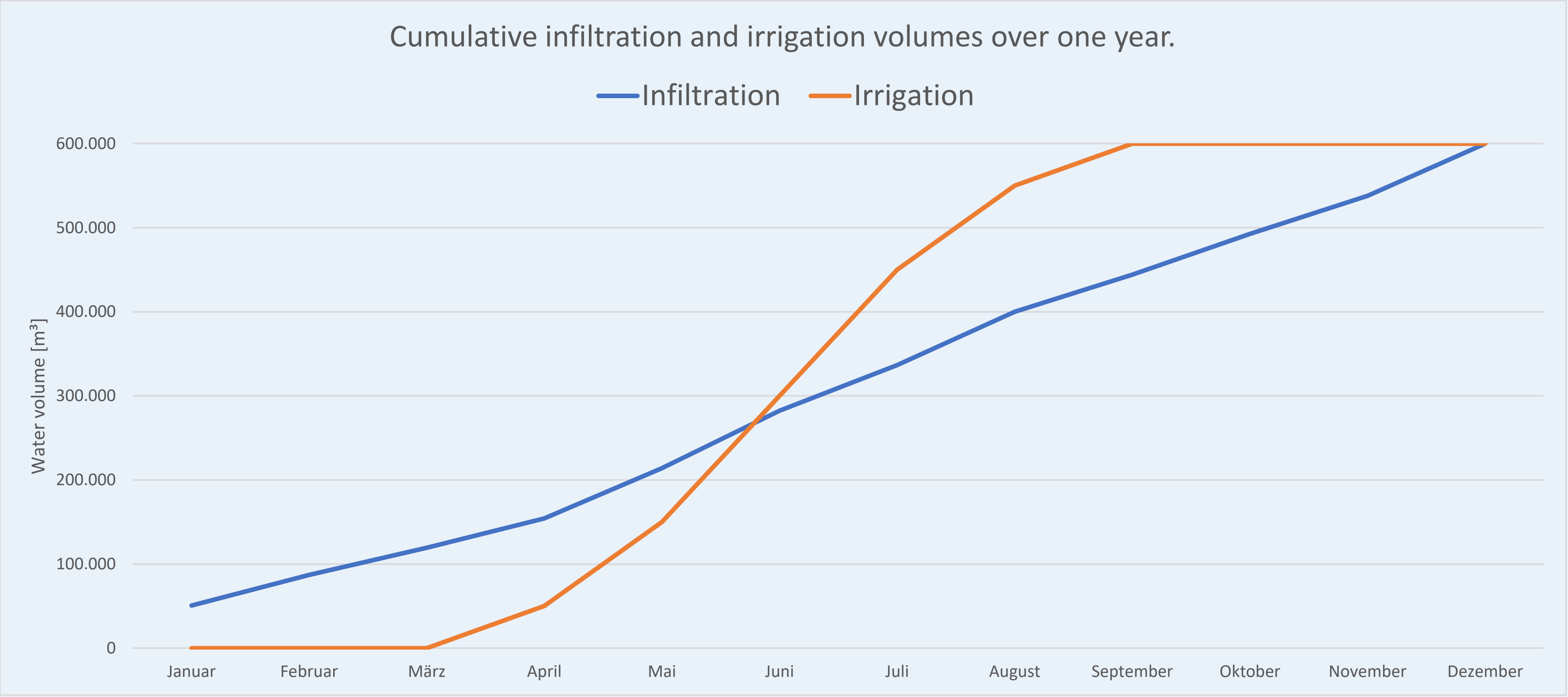




Model annual balance infiltration and irrigation

The figure below shows an example of the annual cycle of infiltration and irrigation in an idealized year based on an irrigation demand of 600,000 m³/yr. Irrigation takes place over 6 months in summer and increases in quantity with daytime temperature. Infiltration occurs year-round and was estimated here proportionally from long-term monthly precipitation. The total balance is zero, accordingly.





Infiltration and withdrawal in the seasonal course

If the infiltration and irrigation values are plotted cumulatively over the year, the maximum required storage, in this case groundwater volume, can be determined from the largest difference between the two curves at a given period. In this example (irrigation volume 600,000 m^3), the maximum in August and September is about 150,000 m^3. For an irrigation volume of 1,000,000 m^3/a, the required storage is about 250,000 m^3. It can be concluded that even with a very high degree of certainty, for extreme years, the 600,000 m^3 storage capacity of the groundwater is sufficient for the irrigation needs of the bridges, greenery and parks in Frankfurt.

One challenge: determining withdrawal locations and times in relation to infiltration locations and times.

In addition, the model can be used to calculate the flow and velocity of the groundwater. In this way, not only the best infiltration locations, but also the best extraction locations for the groundwater are determined.

Ideally, you should promptly withdraw as much water as you previously percolated - so in July, for example, you withdraw the water you allowed to percolate in February.

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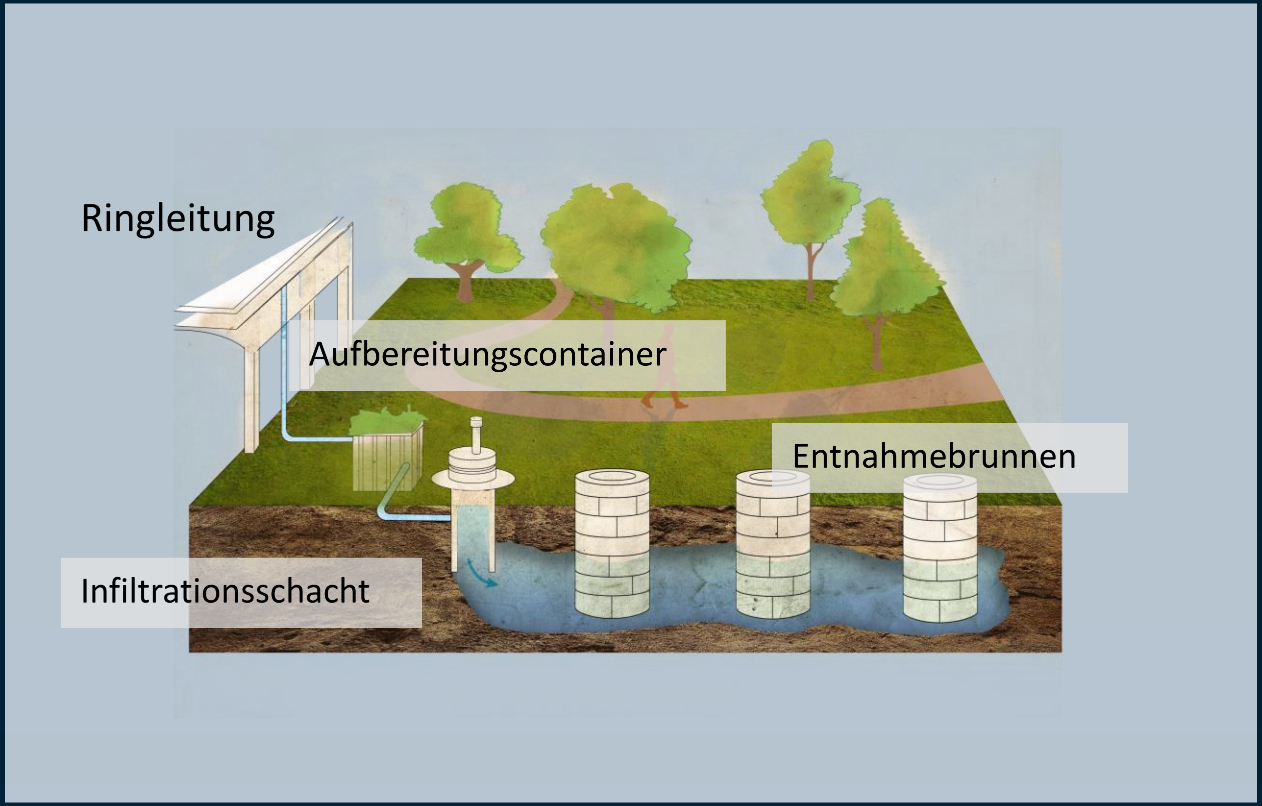

Dimensioning of Filtration Container

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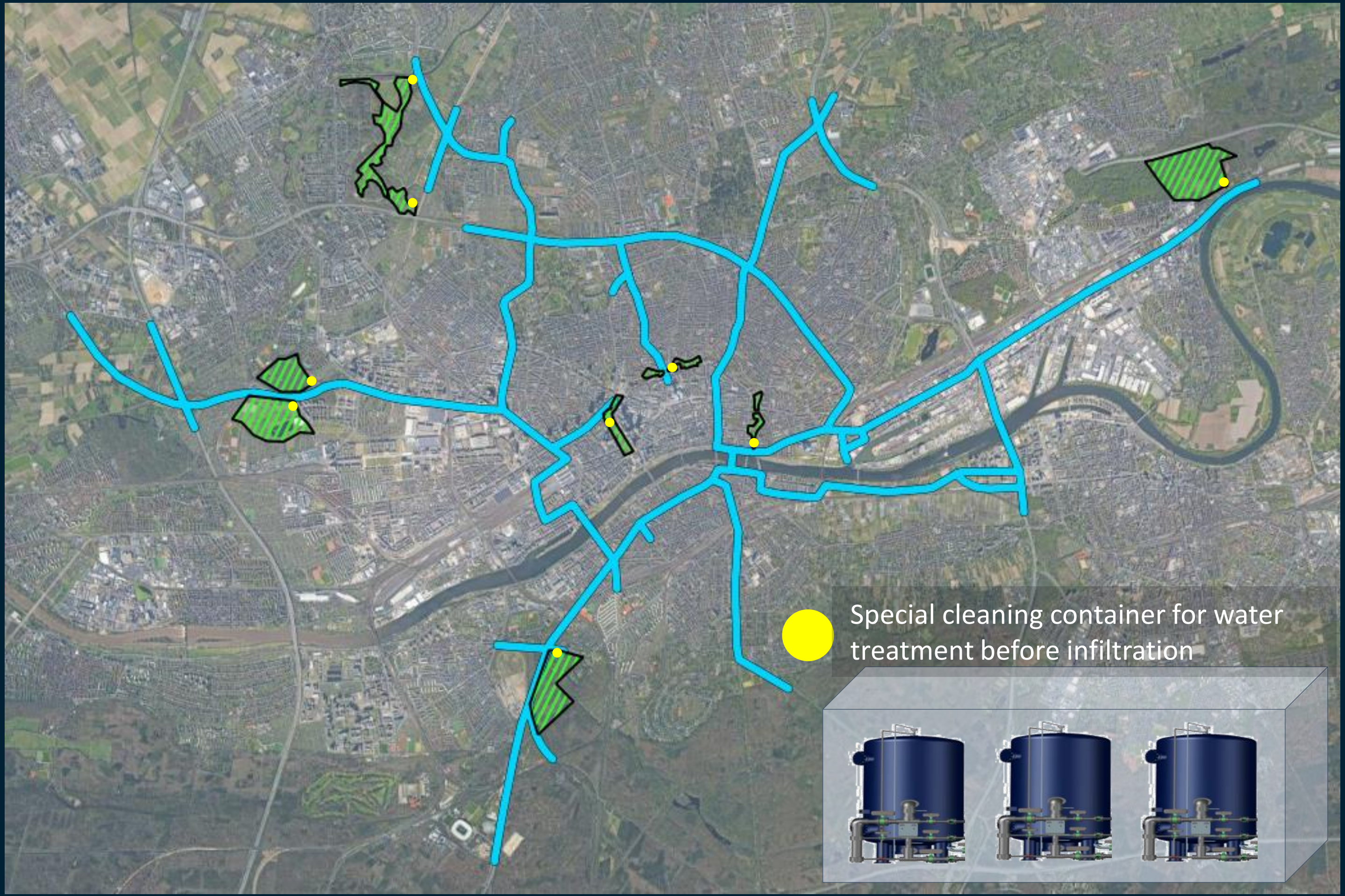
Before infiltration into the groundwater, the water from the ring main may have to be treated a second time. This is to be done in purification containers (probably by means of activated carbon filters)



Conclusion: In the area close to the city center, at least 600,000 m^3 can be stored by infiltration

With the help of an initial rough groundwater model, it was possible to estimate the feasibility of storing larger volumes of water by infiltration in the Frankfurt urban area. The model showed that in selected infiltration areas located along Frankfurt's bridges, at least 600,000 m^3 can be easily infiltrated without raising the groundwater level by more than 25 cm to 50 cm. This storage is sufficient for irrigation needs.

As irrigation needs increase due to climate changes or more extensive unsealing with planting, additional infiltration areas can be identified in the vicinity of the city.

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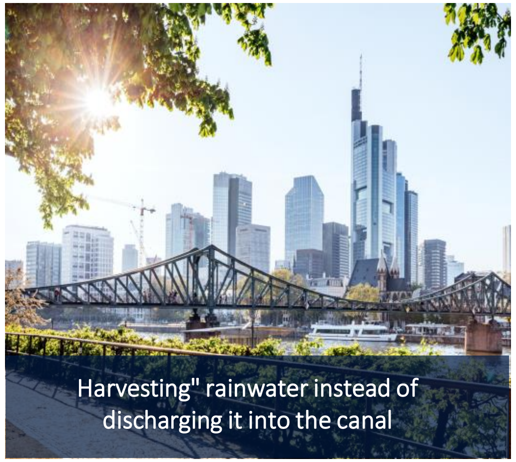
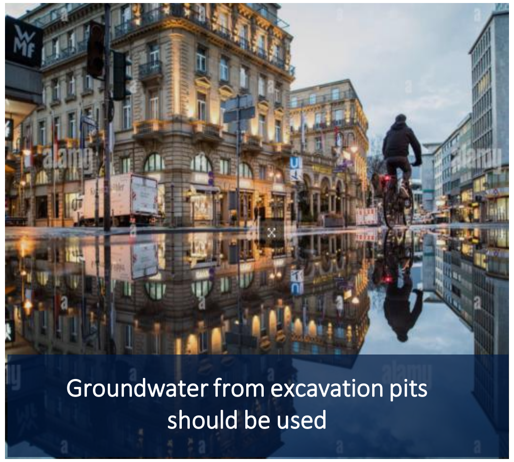
The water distribution with Bridge ring line


Harvesting" rainwater instead of discharging it into the canal


Groundwater from excavation pits should be used


Store water in the soil through infiltration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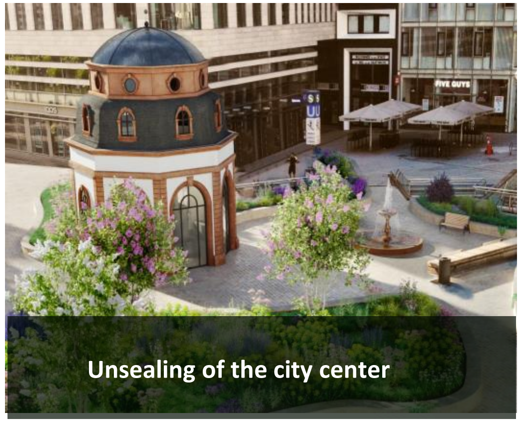
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The water-sensitive Frankfurt

The city of the future wastes no water

Only a water-sensitive city is armed against periods of drought, heavy rain, tree death or flooding. For a long time, the goal of cities was to dispose of accumulating water as quickly as possible to avoid potential damage. In the future, however, the goal must be to keep any water in the city and use it as efficiently as possible. Infiltration, treatment and intra-urban storage are some important elements along the way.

Content: The following packages of measures are described for Frankfurt on its way to becoming a water-sensitive city

Surface waters in the city represent reserve and intermediate storage for the watering of plants. Like rainwater and groundwater from construction sites, water from the Main River or from stillwaters must be treated before it is fed into the ring main and before it seeps into the groundwater reservoirs.

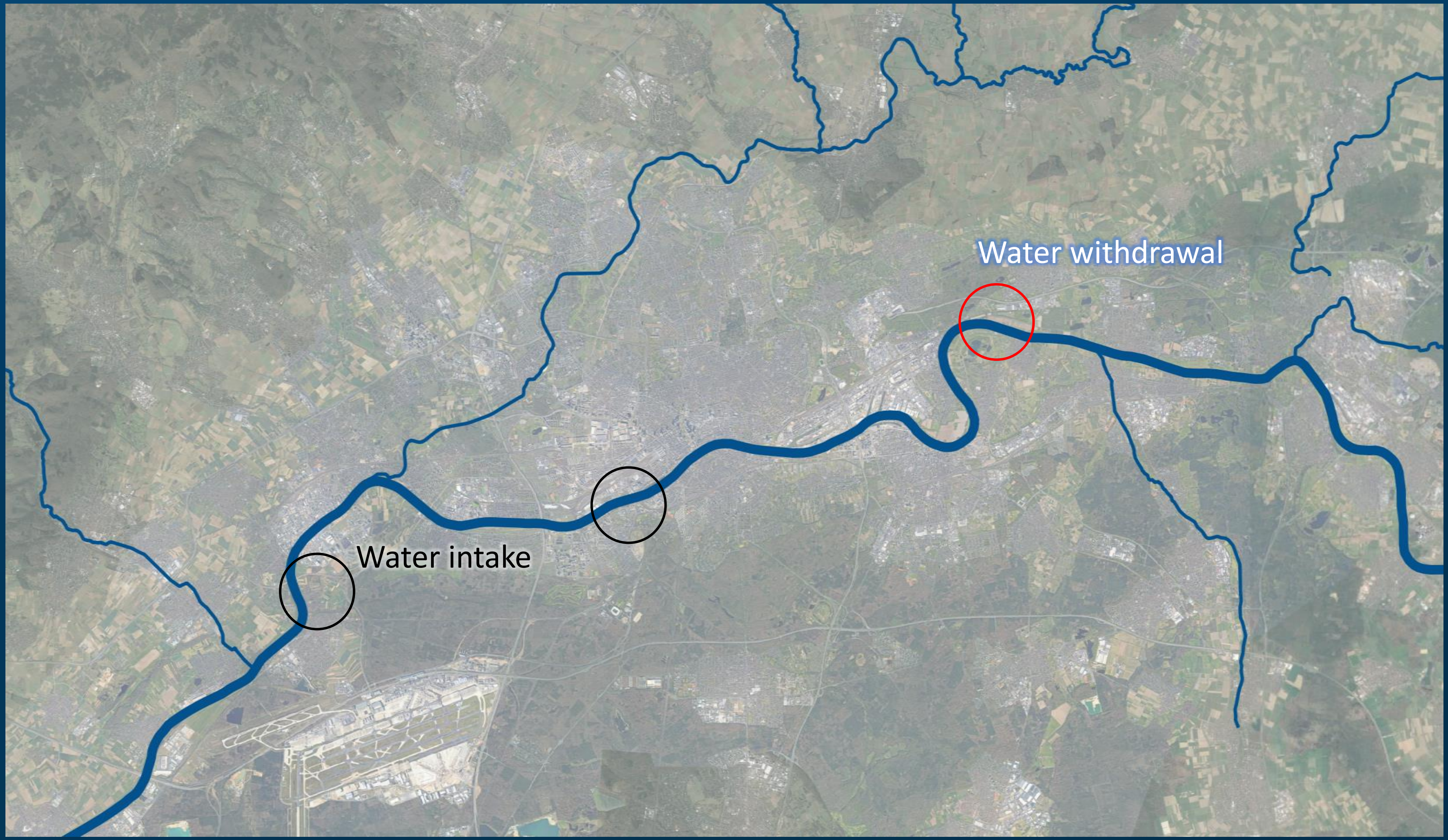
Another important untapped source of water is wastewater: Similar to most other major cities in the world, the greatest reserve potential for the city of Frankfurt lies in the reuse of wastewater. The need for this could arise in the context of climate change.

In Frankfurt, there are also numerous additional smaller measures to irrigate urban greenery and thus improve the urban climate, such as the creation of swales or the installation of cisterns or infiltration trenches - all milestones on the way to becoming a water-sensitive city.

River water from the Main can be used as a reserve to replenish the reservoirs

If the rain and groundwater volumes are not sufficient, there is a safety net: the Main River. However, water can only be taken from the Main at high levels and must then be stored for later.

In Frankfurt, it makes sense to have the extraction point upstream in the direction of Fechenheim, since further south the municipal wastewater treatment plants (ARA) Niederrad and Sindlingen discharge the (multi-stage treated) wastewater into the Main.



At the northern end of the bridge, a bathing lake can be newly created close to the city as a further reservoir

Frankfurt does not have its own bathing lake that is easily accessible by public transport. Such a bathing lake is being created in the Niddapark on the former Federal Garden Show site on the northern spur of the Frankfurt Bridges.

The bathing lake is not only an ideal reservoir for irrigation water, it also increases the value of this local recreation area and provides an important habitat for various animal and plant species.

The lake is easily accessible by local bridge passenger transport and drop-offs lead directly from the bridge down to the lake. For families without a car, senior citizens and children, who until now could only get to a bathing lake with a lot of effort or in the company of adults, this is a new leisure attraction in Frankfurt.

The bathing lake also has a positive influence on the city climate: due to the evaporation of the water - at least in some weather conditions - the air near the lake is cooled down and can move into the city center.

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The bathing lake on the Nidda - water reservoir, climate cooler and recreational area

Scope: 820 m

Surface area: 45.000 m^2

Storage capacity: around 120,000 m^3

Extraction capacity: 13.500 m^3

Accessible via autonomous traffic on the bridges - every minute as needed

Replacement for dog run: The complete area south of the lake

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The people of Frankfurt have always appreciated natural open-air swimming pools in the city, as shown in this historic photograph of the Main-Swimmingplace at the Eisernen Steg from 1930

The bathing lake is created in a nature-friendly and sustainable way

During the planning phase, hydrogeological investigations must be carried out to determine the extent to which the lake can be fed by groundwater. The remaining water enters the lake through collected and treated rainwater via the bridges‘ ring main.

The lake has a large storage volume; depending on the depth selected, it can hold up to 120,000 cubic meters of water.

Not all the lake water is discharged for irrigating of Frankfurt‘s greenery, but the so-called "water usability" in dry periods is limited to 30 cm of the water level (circa 13,500 m^3 of water): This ensures that the bathing lake acts as a natural air conditioner for the city even in dry periods – and as a great recreational swimming place for Frankfurt‘s citizens.

The Frankfurt Bridges Society is responsible for the water quality of the lake, the cleanliness of the overall area and the safety and care of bathers.

Explanation of the bathing lake facility

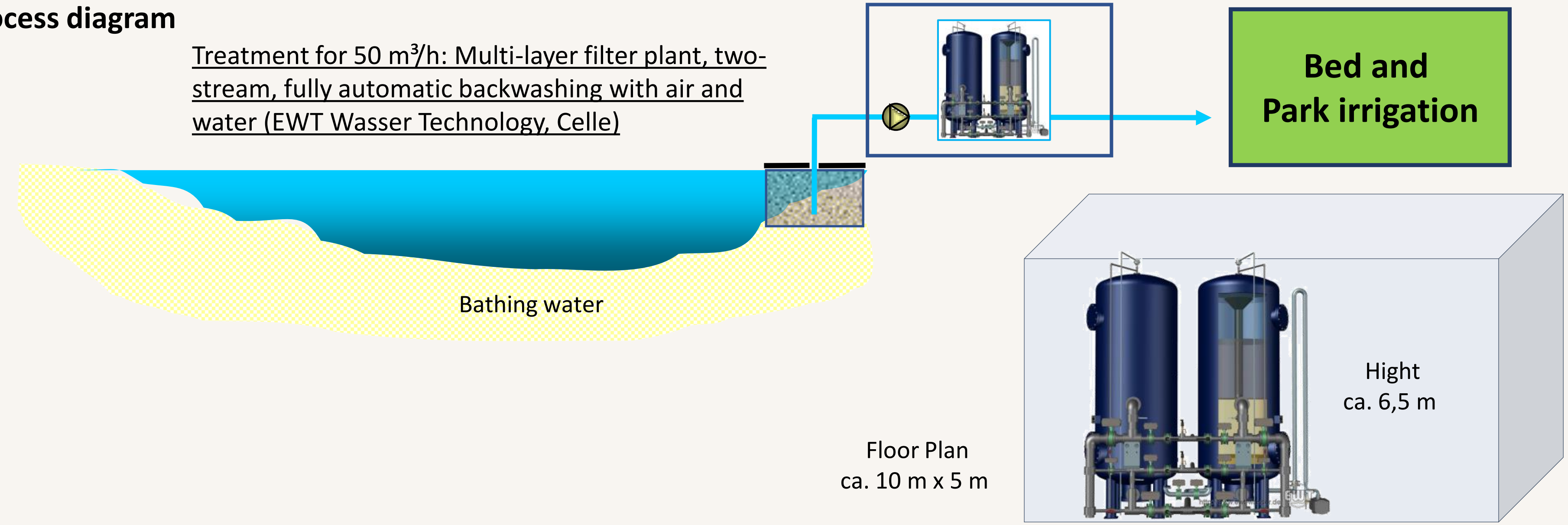
The withdrawal of water from bathing lake waters

Due to the quality of bathing water, the extraction can be done directly by a dry installed self-priming pump in the shore areas. A submersible pump should not be installed because of the risk of electric shock.
To prevent coarse material from being sucked in, the suction lance should be surrounded by a coarse to medium gravel pack. A cover can minimize algae growth and a subsequent fully automatic filtration system ensures extensive reduction of undissolved contaminants.

The pipe for bed and park irrigation should be installed so that when the pump is switched off, it is automatically drained. The plant can be equipped with a hygienization stage (UV irradiation or chlorination and/or an activated carbon filter).

All components of the plant can be installed in a simple functional building/container. During operation, as-needed checks and annual cleaning of the water intake are required.

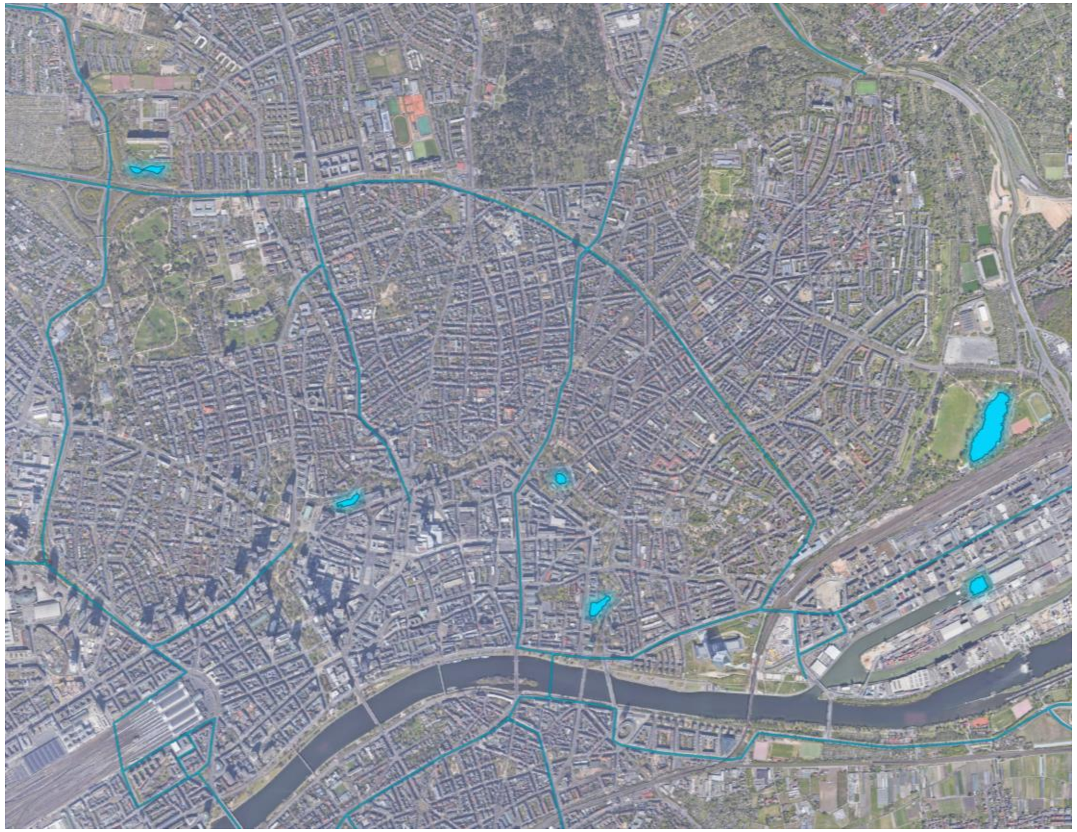
Process diagram



In addition, other still waters in the Frankfurt urban area can be integrated into the water system of the Frankfurt Bridges

In addition to the bathing lake described, other surface waters can be integrated into the system. Depending on the location, it would be conceivable for these so-called still waters to function in a similar way to the cisterns, i.e. to collect and temporarily store rainwater from roof surfaces and then release it into the ring main; or, like the groundwater and the bathing lake, they can serve as storage until the supplied water is withdrawn for irrigation needs.

In the case of the stillwaters, as with the bathing lake in Niddapark, the level fluctuation is also limited to 30 cm: Accordingly, a total of up to 12,775 m^3 of water can be temporarily withdrawn.



Still waters	Area	Volume (rise 30 cm)
East Park Pond	34.985 m^2	10.496 m^3
Federal Bank Pond	4.195 m^2	1.259 m^3
Albert-Mangelsdorff pond (plant ring)	3.403 m^2	1.021 m^3
Lake Schwedler	6.139 m^2	1.842 m^3
Bethmannweiher	2.325 m^2	698 m^3
Rechneigrabenweiher	4.951 m^2	1.485 m^3
Total	**42.583 m^2**	**12.775 m^3**

Thoroughly treated wastewater will provide another irrigation water reserve in Frankfurt in the future

Currently, water generated in the city, whether stormwater, groundwater or wastewater, is primarily disposed of.

The Frankfurt Bridges can offer the solutions already described for the use of rainwater and groundwater. That leaves wastewater: from households and commercial units.

Around 65 million cubic meters of treated wastewater are discharged annually into the Main River from Frankfurt's wastewater treatment plants in Niederrad and Sindlingen.

The treatment of this wastewater is already very thorough: In a three-stage process, coarse solids are first removed in mechanical treatment. Biological and chemical treatment then primarily removes carbon and the nutrients nitrogen and phosphorus. Only then is the water disposed of into the Main River.

In order to be able to use it without hesitation as irrigation water over a wide area, the so-called "4th purification stage" is still required.

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The fourth treatment stage includes more extensive elimination of phosphorus and removal of micropollutants.

More and more cities are implementing this treatment stage in their water management.

The implementation of this advanced wastewater treatment is also already being planned in Frankfurt.

In the 4th purification stage, sand and activated carbon filters, ozonation and membrane systems as well as combinations thereof are used.

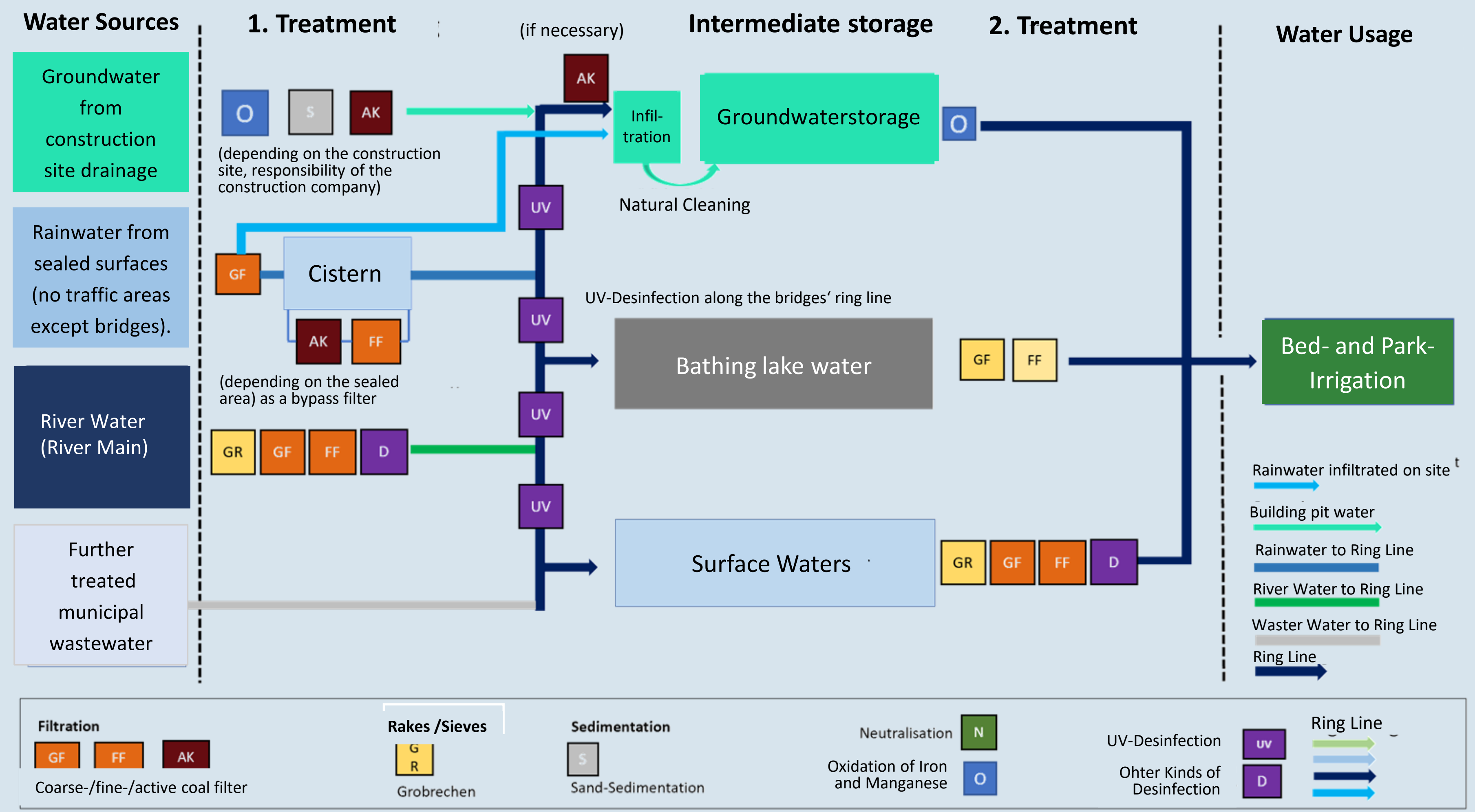
Currently, there are no binding legal requirements for the "4th purification stage". However, it can be assumed that this circumstance will change in the near future.

After the first large-scale implementations of such plants in Switzerland, Germany has followed suit, especially in Baden-Württemberg and North Rhine-Westphalia.

The first experimental plant in Hesse was realized with the support of Darmstadt Technical University at the Langen wastewater treatment plant. The first industrial-scale plant on Hessian soil is currently being built in Bickenbach.

Different treatment processes are necessary for the different water sources and stations of the bridge water system

The ring main serves as the central distribution organ. All water from the sources to the reservoirs and from there to the plant beds and trees flows through the ring main, for which any water must be of minimum quality, so as not to damage them. There are no fixed limits for irrigation water itself. The decisive factor is that it is largely free of solids and germs. Depending on the initial water quality to be expected, different treatment processes are required.



The water-sensitive city of the future uses every drop of water

Due to climate change, water shortages are now increasing in some years even in the previously water-rich countries of Central Europe, especially in the summer months.

Accordingly, the reuse of treated wastewater has been defined at EU level as an additional source of water - and is now to be further promoted in the member states.

Germany is also working on this: an expert committee of the German Association for Water, Wastewater and Waste (DWA) is currently drawing up a set of rules for the German region, which is to be published in 2023. It explicitly states that the treated wastewater should not only be used in agriculture, but also for irrigating urban green spaces.

This is already the case in other industrialized countries with water shortages, such as the USA, Australia or Israel, and is likely to become inexorably widespread in Germany as well.

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Reuse of more extensively treated wastewater will become a future component of the bridge project

The plan is for the wastewater to be used specifically for groundwater recharge, i.e. to travel the same route via the ring main to the infiltration facilities as the collected rainwater, excavation pit water or river water.

For this purpose, a connection will be created from the outflow of the Niederrad wastewater treatment plant to the nearest bridge section. Since sewage treatment plant drains are a permanent source of water compared to the other water sources in the bridge project, water can be transported from the sewage treatment plant via the ring main to the beds only when there is a need for irrigation, depending on the weather. Thus, if necessary, the "detour" via groundwater can be avoided, shortening the water transport and reducing the energy demand of the irrigation system.

The prerequisite for such an application is the realization of the 4th purification stage at the Niederrad wastewater treatment plant on a large technical scale. This has not yet been done at present, with the lack of space on the site posing a challenge in addition to the necessary investment. Furthermore, there are no binding specifications as to how much of the water produced must be further treated to be used as irrigation water.

However, it is expected that by the time the Frankfurt Bridges are completed, the 4th treatment stage will also be implemented in Frankfurt and the distribution function of the bridges will bring the treated wastewater to storage locations and, after removal, make it directly usable as irrigation water for the city.

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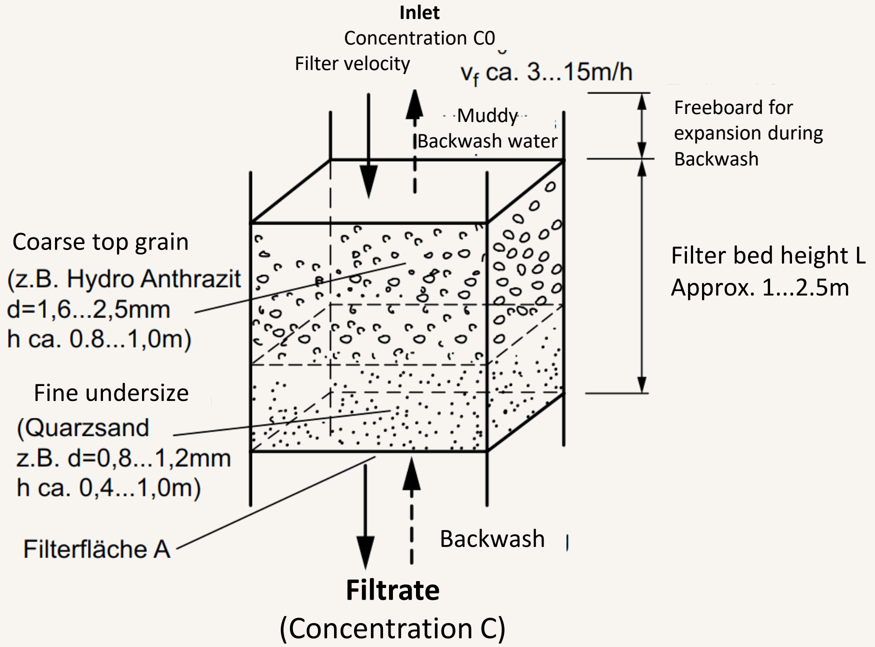
Dimensioning of the filtration containers

Basic dimensioning of a rapid filtration system (two-layer rapid filter



Dimensioning of activated carbon filter with GAK (granulated activated carbon) as optional treatment before infiltration

Empty bed contact time: 5 to 30 min (20 min selected!)
Filter bed velocity from 5 - 15 m/h (10 m/h selected!)
Flow rate selected: 25 m³/h
Redundancy concept: always at least +1, so-called police filter

Bemessung	Kontaktzeit	20	min
	Filterbettgeschwindigkeit	10	m/h
	Durchsatzleistung	25	m³/h
	Erf. Querschnittsfläche	2,5	m²
	Erf. Filterdurchmesser	1,8	m
	Erf. Filtervolumen	8,3	m³
	Filterhöhe gesamt	3,3	m
	Gewählt	3 Filter mit 2m Höhe	

Cross section and floor plan (rough dimensioning)

Height approx. 3 m

Floor plan approx. 8 m x 4 m

The package of measures on the way to becoming a water-sensitive city also includes small-scale decentralized measures such as the creation of swales

The design of green areas in a swale character with a maximum height difference of 30 centimeters to the surrounding surface allows for decentralized collection and infiltration of rainwater, especially during heavy rain events.

If the water from sidewalks or other sealed areas is directed to such swales, this relieves the burden on the sewage system. At the same time, the water is available to the plants, which must be specially selected for swales. In this way, rainwater is returned to the natural water balance on site.

Especially in summer, increased heavy rainfall events can be better absorbed, and the evaporation effect provides a pleasant microclimate afterwards.

When the permanently vegetated swales are professionally installed, the water seeps away within 24 hours, preventing waterlogging, damage to plants, insect breeding grounds, or other unpleasant side effects.

The swale concept can be implemented not only along the bridges, but throughout Frankfurt's urban area

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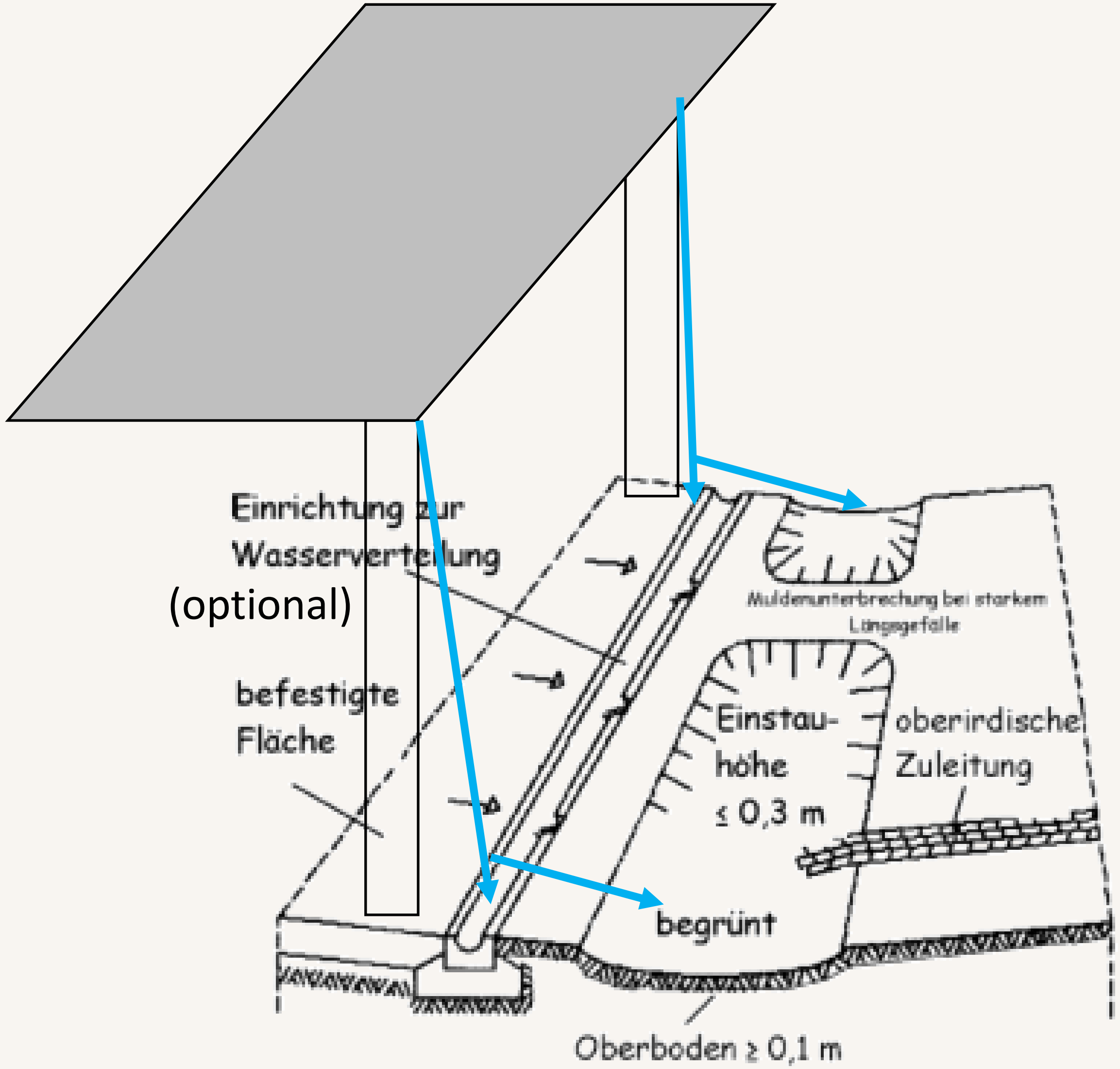
The installation and dimensioning of swales must be professionally planned and calculated in advance

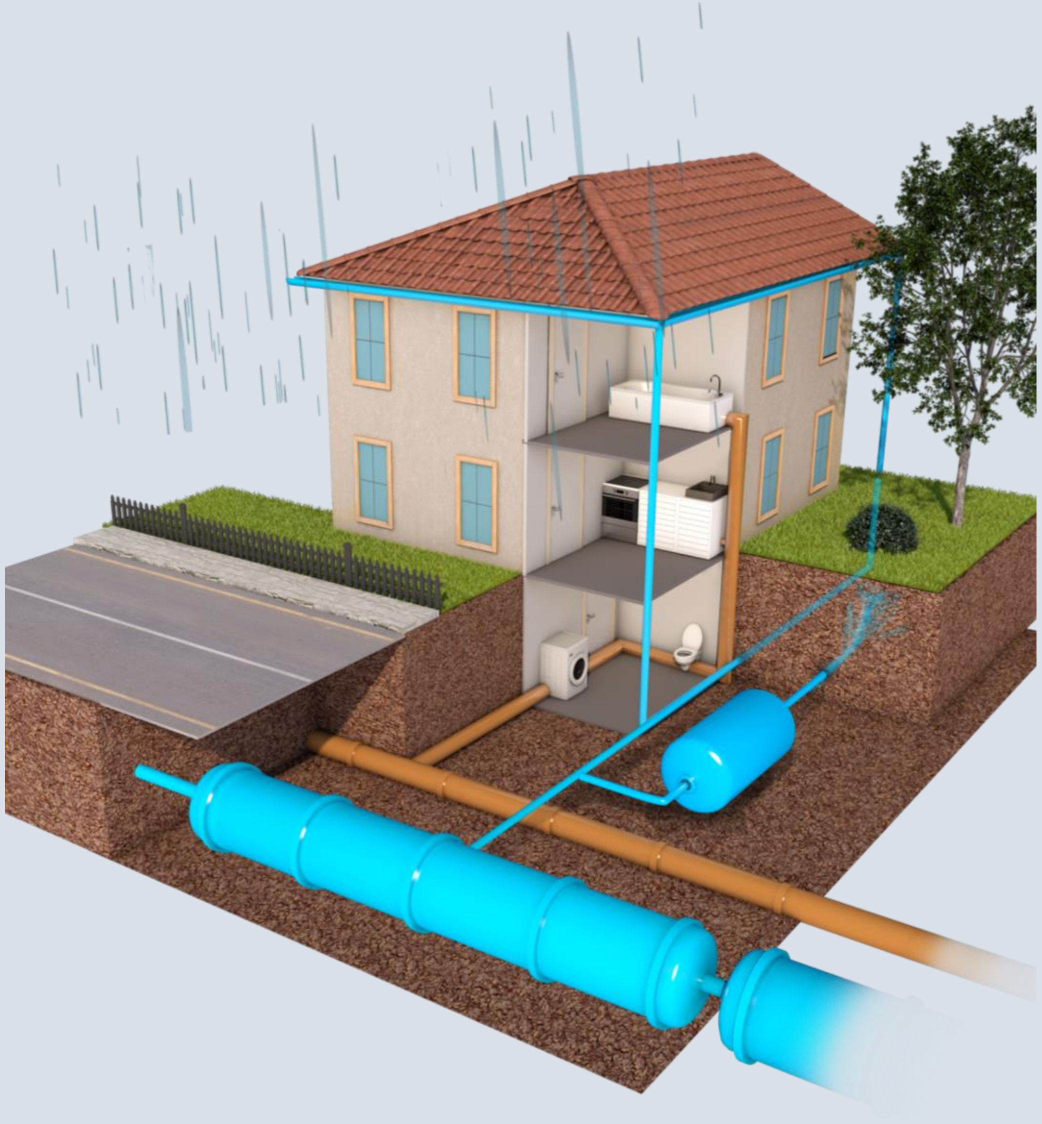


A cistern statute should be introduced in Frankfurt

Wherever the bridges pass large blocks of houses whose facades are suitable for greenery, a cistern should be installed on the property of the blocks of houses to irrigate the facade greenery.

The bridge cisterns under the roadway "in front of the front door" serve as a backup: If the property's own cistern is completely full, it can empty excess rainwater toward the bridge cistern. And if the in-house cistern does not carry enough water, it can draw this from the bridge cistern.

The installation of a cistern on plots of land with a certain minimum size could also be made mandatory in Frankfurt (similar to other municipalities), especially for new buildings, in the form of a "cistern statute".



As a water-sensitive city, Frankfurt can contribute to the sustainable development goals of the United Nations

Today's standard wastewater treatment will be expanded in Frankfurt in the future to include the 4th treatment stage, which eliminates micro-pollutants:

Microplastics such as tire abrasion, hormonally active substances and pharmaceutical residues or antibiotic-resistant germs are removed in the process.

Accompanying measures such as the creation of infiltration troughs or the standardized installation of cisterns and infiltration trenches on courtyards and open spaces are further building blocks on the way to a water-sensitive city.

In this way, Frankfurt can keep not only the rainwater and groundwater that accumulates in the city, but also the wastewater in a municipal water cycle and no longer has to deprive other communities of drinking water for water imports to Frankfurt.

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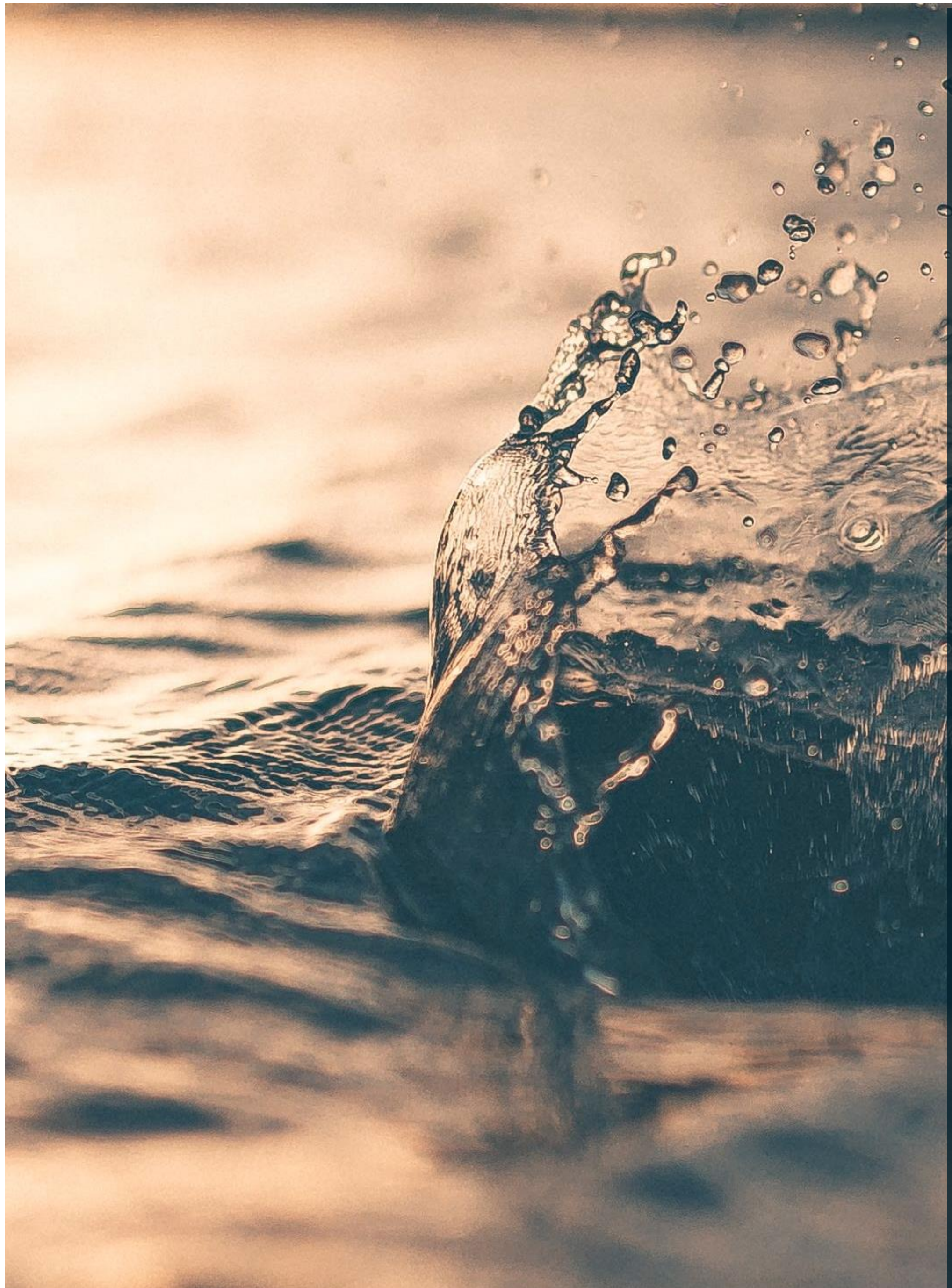

Conclusion: The Frankfurt Bridges are an important milestone on the way to becoming a water-sensitive city

The Frankfurt Bridges will create a system to collect, store and redistribute previously unused water.

Not only rainwater or construction pit water can be used as water sources for the unsealing and greening of Frankfurt, which is important for the city's climate; in the future, it will also be possible to transfer further treated wastewater from the bridges to storage locations or green areas.

With the help of the Frankfurt Bridges, a wide variety of water flows, which historically has always been transported out of the city, can then be used to irrigate urban greenery and thus be returned to the city's natural water cycle.

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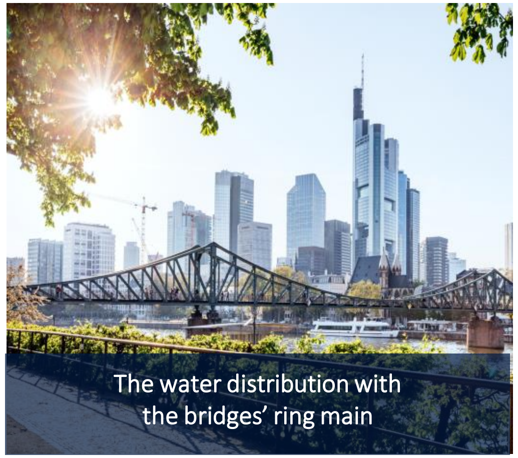
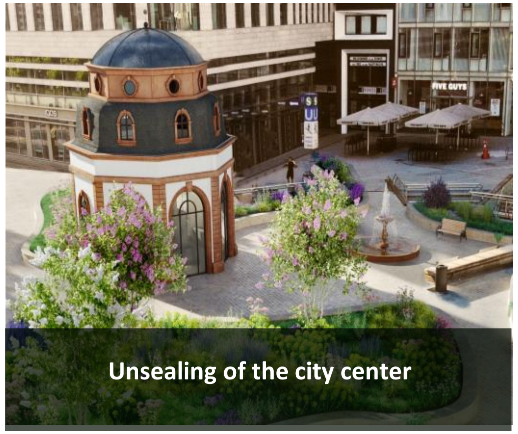
The goal: to arm the city against drought and heavy rainfall events


The water distribution with the bridges' ring main

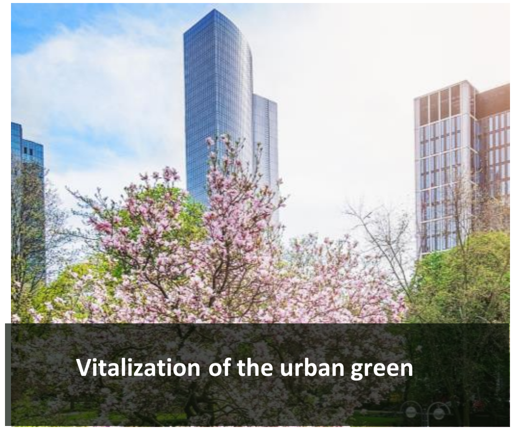

Harvesting" rainwater instead of discharging it into the canal


Groundwater from excavation pits should be used


Store water in the soil through infiltration



Unsealing of the city center


Vitalization of the urban green


Measures next to the bridges

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