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Urban Waters and the Development of Vienna between 1683 and 1910

Abstract

The development of cities and their rivers is closely intertwined. Urban environmental histories have explored river-city interactions in detail, but none has focused on an entire waterscape and the ways its different hydro-morphological features have influenced river uses and urban development. Our research on Vienna's aquatic environment examined how the nature of rivers co-determined urban residents' utilization of them. We combined an in-depth reconstruction of rivers, streams, and canals with urban development over time. Based on three cases, we studied how natural

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Gertrud Haidvogel, Verena Winiwarter, Gert Dressel, Sylvia Gierlinger, Friedrich Hauer, Severin Hohensinner, Gudrun Pollack, Christina Spitzbart-Glasl, and Erich Raith, "Urban Waters and the Development of Vienna between 1683 and 1910," *Environmental History* 0 (2018): 1–27

doi: 10.1093/envhis/emy058

features and a large metropolis co-evolved between the late seventeenth century and the beginning of the twentieth century. Our research shows how the diverse hydro-morphological conditions of the Viennese waters had a bearing on potential uses, and on the kind, of newly built material arrangements and practices. Studying the surface waters and their groundwater aquifers in their entirety makes visible how they were used in complementary ways to satisfy urban demand for a multitude of water services. This article reveals the full spectrum of human–river interactions in Vienna by exploring the various functions that different types of waters had, the means of intervention implemented by a variety of actors in the city’s urban industrial transformation, and how these functions and their mix changed over time.

INTRODUCTION

Karl Weiss (1826–95), director of the Vienna Archive and Library, described Vienna’s waterscape in his *Topographie der Stadt Wien* (*Topography of the City of Vienna*), published in 1876.¹ Weiss first focused on the Danube and referred to the links between this main urban river and the spatial development of the city. The large alluvial floodplain with its unstable islands had directed urban growth to the right bank of the Danube and towards the terraces of the surrounding hilly terrain, the Vienna Woods. Weiss highlighted the significant role of the southernmost river arm for urban trade and reported that urban authorities had fought for many years to prevent the main arm of the Danube from moving away from the city center. Frequent floods, which Weiss summarized, were the bane of those using the river for commerce and trading. Weiss also provided a chronicle of the recurring devastating floods that occurred along the Wien River, which was Vienna’s most important river commercially. He reported various problems—such as those encountered by the millers during periods of low flow—and he elaborated on the increasing health threat posed by the refuse deposited by urbanites. By the 1870s, this combination of issues prompted the creation of local engineering measures to prevent flood damage, improve hygiene, and to contend with rapid and extensive urban growth.

To describe Vienna’s topography fully, Weiss included the smaller Danube tributaries rising in the Vienna Woods and passing through the city from west to east. One of the most remarkable was the Ottakringer Bach. By the 1870s, engineers had buried the entire stream beneath the suburbs. Thereafter, it flowed below ground

towards the sewage canals that ran along the Wien River's left bank. Although Weiss's brief description of Vienna's urban water supply also included a discussion of the first Viennese Alpine Water Pipeline, which opened in 1873, it did not incorporate the early network of water pipelines, which the imperial court and aristocrats erected as a unique feature of the Viennese water topography. Nevertheless, by paying attention to the small urban Danube tributaries that had been mostly neglected in previous topographies of the city, he highlighted the diverse nature of the urban waters as well as the variety of uses and the consecutive human changes of hydro-morphology. Weiss did not systematically link the societal functions and human practices to the diverse natures of the urban waters, but he showed the close ties between the water, urban topography, and urban development. His topography was an early example of conceptualizing an intertwined history of Vienna and its rivers during a dynamic period when urbanization and industrialization intensified human modifications of urban waters. Before fossil fuel-based technologies allowed for the spatial separation of water supply and consumption, for example, or of hydropower production and use, such functions had to be provided for locally. Growing population and technological progress, combined with the use of fossil energy, put pressure on urban waters to satisfy an increasing need for hydropower, industrial water supply, waterborne transport, wastewater discharge, and aquatic wildlife and fishery resources.²

We studied Vienna and its waterscape, investigating how socioeconomic demand for river functions and water was met and enhanced in a pre-industrial city and how various uses, technologies, and practices of risk reduction developed on different river types. The specific combination of size, discharge, seasonal patterns, slope, and morphological dynamics were decisive for a river's role in urban development and vice versa. For example, during the summer, the small urban tributaries of the Danube exhibited very low flow or fell dry, but sudden flash floods happened regularly. Despite the large gradient, the efficiency of milling on such brooks was limited and often rendered impossible, for example, as soon as a landowner or an artisan abstracted water for other purposes. Large rivers such as the Viennese Danube facilitated many water uses, but the vast floodplains were too unstable for settlement and proved a barrier for urban growth well into the nineteenth century. Our interdisciplinary team combined an in-depth reconstruction of the rivers, streams, and canals in comparison with the urban development of the region. We conjoined historical sources and literature, spatially explicit data derived from a wealth of historical maps analyzed by new digital tools such as a geographic information system, and expertise in river morphology.³

In 1683, the starting point of our study, the Viennese successfully defeated an Ottoman siege. This definitive victory against a

century-long threat gave new impetus for Vienna's rise to an imperial residence. By 1910, Viennese waters and water uses had been modernized with few exceptions. We conceive the city and its waters as socio-natural sites.⁴ The concept of socio-natural sites stresses the hybrid character of what is often considered mere "technical" arrangements that are the material precipitates of human practices. Arrangements and practices depend on time-specific knowledge, technology, ideologies, and convictions. Rivers are transformed as they become socio-natural sites, but, at the same time, they determine the possible arrangements and practices and co-determine what can be considered successful (that is, functional for the desired purpose without major side effects). Our research into the diversity of Vienna's aquatic environment reveals how a large metropolis and its waterscape co-evolved and demonstrates that rivers are not immutable environmental determinants but, instead, co-determine how urban residents utilize them.

Our study builds on previous environmental histories of cities. Over the last years, authors have focused increasingly on urban waters, their transformation, and their changing roles for society.⁵ Major research themes have included floods and the threat they have posed for urban life and economies, the practices of flood protection, the effects of industrialization on urban development and waters, urbanization and different modes of drinking water supply, and waste and wastewater removal.⁶ Researchers have also analyzed the significance of urban rivers for mills and other technical facilities as well as for the transportation of goods and people.⁷ For the late nineteenth and the early twentieth centuries, the fight of urban governments against water pollution and the role of new experts in hygiene, medicine, or engineering was an important topic.⁸ But the nature of urban waters, their diversity, and their varying and complementary potential for urbanites has not yet been sufficiently explored.⁹

To investigate this interplay, we describe three distinct parts of the Viennese river system that are different in size, natural characteristics, and location within the city: the Ottakringer Bach, the Wien River, and the urban section of the Danube. Vienna controlled only a very small fraction of the Danube, which, approximately 930 kilometers downstream of its source in the German Black Forest, was already a sizeable river with a floodplain almost six kilometers wide when it entered the city. About a third of the Wien River's basin is situated in the city's present area, while Ottakringer Bach's entire basin is located within the present city limits. Drawing together these three cases, we show how, over the course of 230 years, Viennese burghers, urban authorities, and the imperial court transformed the three rivers. Over time, new socio-natural sites as specific nexuses of arrangements and human practices arose from different means and solutions customized to the nature and desired functions of the streams.

VIENNA'S WATERS AND THEIR SOCIETAL ROLE

Vienna was built on the Upper Danube. Upstream of the city, the river receives the water of alpine tributaries, which influence the water temperature and hydrological regime. Major floods occur especially in late spring and summer (see [figure 1](#); see also [online supplementary material](#)). Before 1875, when the Great Danube Regulation (GrDR) was completed, several laterally shifting river arms had crisscrossed the broad alluvial floodplain. Floodplain waters and islands formed a large part of today's built-up area.¹⁰ The Danube and the Donaukanal, which was called Wiener Arm before the channelization of the upper section was completed in 1704, were the main sources of transportation to and from the city.¹¹ Floodplain forests and surface waters provided wood, fish, and a variety of other resources (see [online supplementary material](#) for Supplement 2). Until the GrDR, the intensive fluvial dynamics made building in the floodplain difficult, due to recurring floods and the erosion of islands.¹²

Apart from its main river, the city encompassed only rather small streams rising from the Viennese Woods that discharged into the Donaukanal. Catchments and, consequently, flows were small, but fluctuations between low and high flow were remarkable. Impermeable sandstone and marl layers ("Flysch") in the upper stream sections contributed to sudden and severe floods with each heavy rainfall, a common weather pattern especially in the thunderstorm-prone summer months.¹³ Geology in the catchment determined the availability of groundwater. It abounded in the small alluvium of the Wien River, was moderate in the Pleistocene terraces, and scarce everywhere else. The highlands of the Vienna Woods (rising up to about 900 meters above sea level) on the western fringe of the city formed a defining part of the urban environment and constrained urban growth. The city's development depended not only on the Danube but also on the small streams that originated in the Vienna Woods. They could be used for hydropower and as drinking and industrial water, and they served as receptacles for waste and wastewater. Until 1754, wood was transported on the Wien River.¹⁴ Tapping into resources of the aquatic environment, millers, tanners, dyers, or fishermen modified the hydromorphology of streams and their biota.

The valley of the Wien River, Vienna's largest tributary of the Danube, cuts through the terraced landscape. The thirty-four-kilometer-long course drains an area of about 230 square kilometers, of which sixty square kilometers fall within the present city limits. Before its systematic channelization between 1895 and 1906, the river flowed in a sinuous channel with several braided sections in the Viennese suburbs. The mean discharge amounted to two cubic meters per second before parts were abstracted into the Viennese sewage

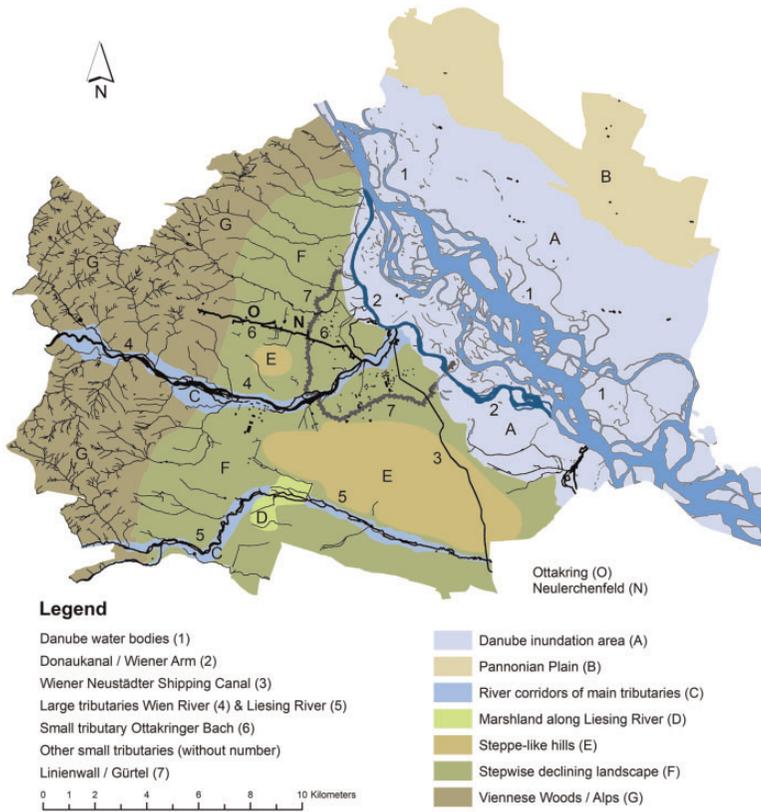


Figure 1. Overview of Vienna's waterscape: geomorphological zones and aquatic network around 1800. Credit: Reproduced with permission from Severin Hohensinner, 2016.

system. Seasonal fluctuations were typical, with both floods and very low flow in the summer. Next to the Danube, the Wien River was the main urban source of hydropower.

All other Viennese Danube tributaries are much smaller and flow entirely within the present city limits, with one exception. Similar to the Wien River, the Liesing River, which is located south of a dry, loamy ridge—the Wienerberg—runs from west to east. Situated outside the old city limits, its mills still served the city. Catchments and discharges of the other brooks were small most of the year, but all of them exhibited sudden and large floods. Periods of low flow or even periodical droughts limited the use of these urban rivers. Operating mills on these rivers was even more difficult than on the Wien River. Although technologies to tap the hydropower of very small rivers existed, the competition of different water users usually favored the supply of water over the generation of hydropower. In addition, the demand for flour in urban areas generally exceeded the potential of

small mills. The Ottakringer Bach has a mean discharge of only forty to sixty liters per second, but during floods it could swell up to thirteen cubic meters per second. Before channelization, it flowed mostly in a straight bed but split into several arms in some sections. In 1803, the artificial Wiener Neustädter Shipping Canal opened, connecting Vienna to various coal mines and to the large and hitherto unexploited forests south of Vienna. The canal discharged into the Wien River just upstream from its mouth to the Donaukanal. Hydropower use and water supply soon complemented the initial transport function of the canal. From 1905, it also flushed the main sewer along the right side of the Wien River.¹⁵

MILESTONES OF VIENNA'S URBAN DEVELOPMENT

In the 1680s, when Vienna's aquatic environment began to appear in the sources, fewer than 50,000 people inhabited the center of the metropolis, which was then a small, walled area of approximately three square kilometers. Around 20,000 to 30,000 additional people lived in the scattered peri-urban villages surrounding the city.¹⁶ Feudal lords had founded most of these villages in the twelfth and thirteenth centuries along the smaller creeks that discharged into the Danube. Settlement axes to the west and northwest followed the tributaries, while flood-prone areas closer to the Danube were expanding more slowly. The Vienna city council, the imperial military council, and the emperor and his household had initiated regulations governing the Danube, which had been undertaken in a piecemeal fashion since the fifteenth century.¹⁷ In the Danube floodplains, fishers harvested the biomass of the larger and smaller Danube arms; landlords exploited the fast-growing softwood forests for firewood and animal pastures; and the emperors used large areas for hunting.

After the failed Ottoman siege of 1683, the city grew, slowly at first but, from the 1850s onwards, with unprecedented velocity. Socio-economic drivers such as the vicinity to the city center, the availability of space, and the connection to the transportation infrastructure became significant in establishing new urban areas. The Linienwall, the outer fortification wall, was converted into a tax boundary soon after its erection in 1704. Less wealthy persons and small workshops were attracted by the lower prices of foods and consumables in the villages outside the wall.¹⁸ Landlords, among them religious orders, the court, the city, the Burghers' Hospital, and aristocrats also played an important role in the urban development. By the eighteenth century, entrepreneurial landowners had erected new quarters even in areas with an unfavorable water supply. A case in

point is the suburb of Schottenfeld, which was founded in 1719 upon the initiative of a long-established Benedictine order, the Schottenstift, on a ridge relatively far from surface waters and groundwater.

The growing demand for water and energy led to a patchwork of technical structures for supply and discharge as well as to growing water scarcity combined with severe pollution.¹⁹ Ever-growing amounts of refuse and wastewater and new diseases challenged city authorities. In 1831–32, Vienna was hit by a cholera epidemic, which fueled the hygiene debate. Urbanization close to the Danube increased potential flood damage. Navigation with steam ships had started on the Austrian Danube in 1830, and this mode of transportation necessitated a technically shaped, homogenous riverbed. Due to these factors, a new main riverbed was built between 1870 and 1875 after almost seven decades of planning.

Around 1910, more than 2 million people inhabited the city. About 20 percent of the population, or 420,000 people, lived in the Danube floodplains, which were protected at that time by inundation dikes.²⁰ All of the small creeks within the built-up area had become invisible. Their former uses had been abandoned, and they had become a necessary part of the citywide waterborne sewage network. Coal and steam-driven machinery in large factories and steam mills had taken over the function of streams as energy sources. The ‘first’ and ‘second’ Alpine Water Pipeline opened in 1873 and 1910, respectively, providing Vienna with clean water in abundance for drinking and for the waterborne sewage system. Water was then affordable and abundant, becoming a valuable asset for the quality of metropolitan life.

CONTESTED RESOURCE: THE OTTAKRINGER BACH

The Ottakringer Bach is representative of the small Viennese Danube tributaries, which were intensively intertwined with urban development. However, the creek’s history makes it unique among Vienna’s rivers. It was the only river to traverse the historical center before it was deflected at the outer side of the defense wall.²¹ In the centuries to come, the Ottakringer Bach supplied the necessary water for the moat that formed an integral part of the city’s defensive arrangements. When they were rebuilt between the two Ottoman sieges of 1529 and 1683, the new fortifications still used the moat.²² The Ottakringer Bach, which had meanwhile been diverted towards the Wien River, was again used to fill the moat after 1683 when the Ottoman threat diminished. Eventually, the city’s fortifications lost their importance, and, in 1733, the Ottakringer Bach was finally connected to the Wien River.²³ The creek crossed the Linienwall through

a short tunnel, which fixed the stream's location at this spot for the following 150 years. The diameter of the inlet was too small for higher floods, causing backwater to flood the surroundings.

Springs and the groundwater in the vicinity of the Ottakringer Bach were more important than its surface flow. They supplied several water pipelines built in the eighteenth century for the court and aristocratic palaces. Between 1710 and 1712, the famous baroque architect Johann Fischer von Erlach constructed a prestigious palace for Johann Leopold Trautson, the former educator and intimate of Emperor Josef II, just outside the fortification wall. In 1711, Emperor Josef II ennobled Count Trautson as prince of the Holy Roman Empire, which was an additional stimulus to build his new palace as a sign of wealth and dignity. Irrigating the large gardens, cooking, washing, and cleaning led to a sizeable demand for water. While most urban residents extracted their domestic and industrial water from wells, the demands of wealthy aristocrats who successfully claimed the available water resources were too great for such sources. For Palais Trautson, a pipeline was built, tapping the sources of the Ottakringer Bach downstream of the village of Ottakring (see figures 1 and 2). Four well houses collected the water before cast-iron pipes transported it towards the palace.²⁴

These pipelines reduced the water that was supplied to local residents. This is documented for the facility that provided water from the Ottakringer Bach basin for the Schönborn Palace after 1707.²⁵ Christian Gundl, whose property was traversed by the pipeline, received compensation; Baron Yppen received 350 guilders for his permission for a similar concession; and Anton Schwach, burgher of Ottakring, received three guilders per year upon the premise that he would not extract water.²⁶ The basin of the Ottakringer Bach supplied two further pipelines, both mainly serving the imperial court and the aristocratic and monastic buildings as well as large public wells in the city. One originated from springs in the hilly area of the Vienna Woods, from where cast-iron pipes led to four well houses further downstream. Soon after its completion, residents near the tapped springs complained about the decreasing water flow of their wells. The Viennese magistrate finally paid 500 guilders to the commune of Ottakring as compensation, for which the commune abandoned any right of further complaints.²⁷

No information about the water quantities delivered by the pipelines is available. Considering the Ottakringer Bach's mean flow of fifty liters per second at the mouth as an indicator for the potential amount of water from the entire basin, the average volume was likely around 4,000 cubic meters per day. During low flow, the supply was certainly much smaller. Increasing population and commercial needs intensified water scarcity, especially in summer. City authorities planned a reservoir with a capacity of 410,000 cubic meters in the

1790s to increase water availability, but it was not built. The deteriorating water quality of the Ottakringer Bach amplified the adverse effects of decreased quantities due to low flow and abstraction by pipelines.

Degrading water quality was mainly due to yet another of the many functions of urban watercourses. Just like other small urban brooks, the Ottakringer Bach was a preferred place to deposit private and commercial refuse. In May 1753, Empress Maria Theresa ordered sewers to be built for individual buildings, thereby mitigating the pollution of house wells, which were usually situated close to private cesspits. Progress was slow in the suburbs, but, by 1830, 1,080 houses inside Linienwall had sewers, which discharged directly into the Ottakringer Bach. This did not alleviate the pollution of small streams but, rather, exacerbated it, turning them progressively into open sewers. When the first citywide projects to improve the hygienic situation were developed after the cholera epidemic in 1831–32, the Ottakringer Bach was already flowing below ground within the Linienwall.²⁸ As a result of construction work that took place from 1837 to 1840, the river became part of the urban sewage system. In the 1840s, burying the stream also started in the villages outside the Linienwall (Neulerchenfeld and Ottakring). After two cholera epidemics had hit Ottakring in 1865 and 1866, work was sped up, and, by the end of the 1870s, the stream was buried in the outer districts. The systematic integration of the creek into the urban sewage system was completed after the second city enlargement in 1891–92.²⁹ During large floods, however, the capacity of the buried channel was too small, as became clear after a flood in 1862 when the bed was undercut by water, and some areas were flooded.³⁰ The necessity of recurring repair work was a usual side effect of burying small brooks.

WIEN RIVER: SERVING THE CITY'S NEEDS

Similar to the Ottakringer Bach, the Wien River's groundwater was intensively exploited for wells and water pipelines. Due to its comparably large flow and gradient, the Wien River was a main source of urban hydropower and, in the nineteenth century, the most important stream for water-dependent crafts. Over the centuries, distinctions between the sections developed: an upstream section in the more rural area west of the city center; a peri-urban section with intensive commercial use; and an astonishingly open downstream section, which passed the center of the city close to the "Glacis," an open space that fronted the city walls before their demolition after 1857.³¹

Millstreams and weirs built since the eleventh century diverted water from the main course. They made the mills less dependent on the seasonally fluctuating discharge, as it was easier to concentrate the

low discharge that usually prevailed in the summer while the broad main riverbed fell dry. Floods often damaged the weirs, but at least the mills were less prone to destruction. The river gradient of 4.4 per thousand meters enabled substantial drop heights with short inflow channels. Nevertheless, the slope of the mill creeks was smaller than that of the Wien River, so they silted up, necessitating regular sediment removal.³² By the beginning of the nineteenth century, more than ten kilometers of millstreams paralleled the river's course. They were located mostly in the peri-urban suburbs, but some were also built in the villages outside the Linienwall. Five weirs fed the canals, which supplied nine grain mills, one brewery, one polishing mill, and three tanneries (see online [supplementary material](#) for Supplement 3).³³ Artisans using the millstreams were obliged to participate in their maintenance and neighbors had to provide access to the stream in case of maintenance work.³⁴ Other crafts and businesses clustered around mills. The number of technical structures built in and along the river rose, as did the incidence of conflicts.³⁵ Tanners and dyers erected wooden platforms for rinsing fabrics or animal hides, which were then hung out to dry on stakes and laundry racks on the riverbank (figure 3).

In the peri-urban river section, the number of slaughterhouses, tanners, dyers, brewers, and chemical factories increased from fifty-four in 1780 to 219 in 1875. In the nineteenth century, craft workshops had spread also to the most upstream rural section, and the number of crafts rose from twenty-one in 1825 to 162 in 1875.³⁶ Complaints against rinsing and drying hides cited hygienic concerns. In 1823, a governmental decree ordered an evaluation of the potential health risks. Such risks were a reason to relocate a workshop to outside the built-up area. Spatial separation was considered an option to enable water uses that adversely affected each other, although in the case of the Wien River effluents were washed downstream towards the city. The release and deposition of increasing amounts of waste from workshops and private households polluted the river and transformed it into a foul-smelling sludge. During low flow in the summers, the situation became almost unbearable. Urban authorities needed to find ways to improve the hygienic situation. The construction of sewers along the Wien River had already been proposed in 1792 and again in 1822, but these plans did not lead to action.³⁷ The cholera epidemic of 1831–32 triggered their quick realization. They were completed by 1839, and the polluted Wien River was partially buried within the Linienwall. But each solution remained local at best. Adjacent houses were connected to the sewers, which discharged into the Donaukanal, aggravating water pollution there.

Restricting the slaughter of cattle to two new central slaughterhouses reduced the water pollution of the small urban streams. In these facilities, the city administration could control food quality

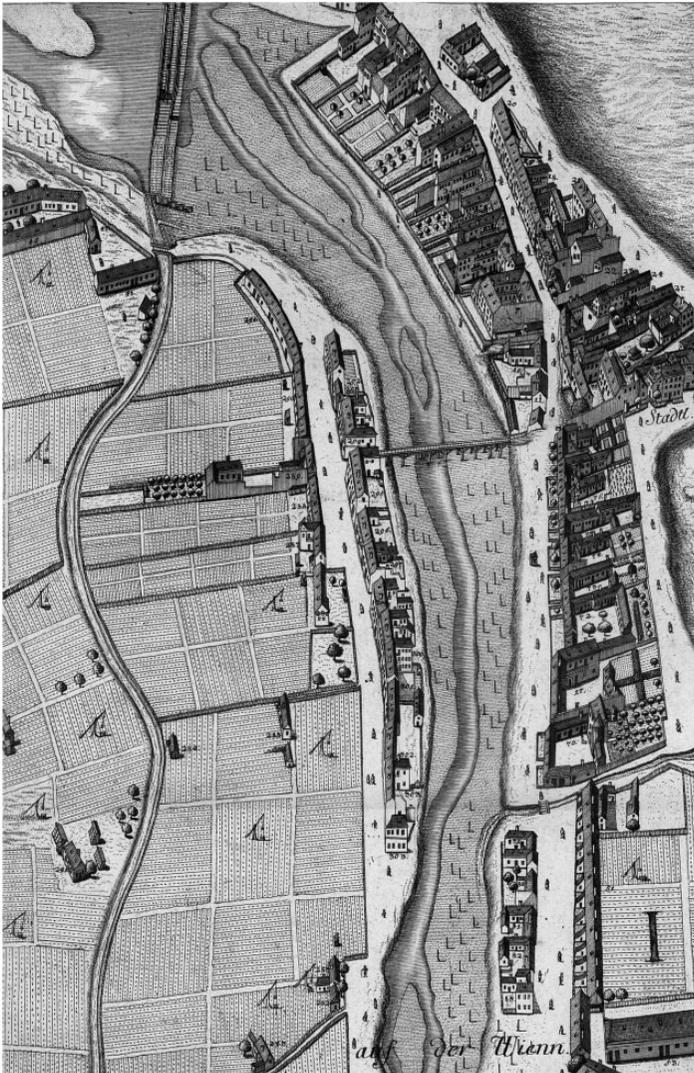


Figure 3. A section of the Wien River as depicted by J. Huber in 1769–74; flow direction top to bottom. A mill weir is visible in the upper part of the picture, as is the mill canal diversion on the right riverbank; stakes for drying clothes can be seen on the riverbanks, and wells for vegetable gardens also can be discerned. Buildings situated directly on the riverbanks suffered from high flood risk. Several islands are depicted. Credit: Vogelschauplan Wiens von Josef Huber 1769–1774, P1. 11, Kartographische Sammlung, Pläne und Karten—Sammelbestand, reproduced with permission from Wiener Stadt- und Landesarchiv.

effectively and secure a sufficient meat supply. One of the slaughterhouses was built in 1851 on the banks of the Wien River near the outer fortification (see [figure 4](#)). In the beginning, it discharged



Figure 4. A slaughterhouse in Gumpendorf on the left bank of the Wien River during the period of regulation in 1894–98. Credit: Reproduced with permission from Bezirksmuseum Meidling.

wastewater directly into the Wien River, but, by 1860, it was connected to the intercepting sewer.³⁸ Cadavers and other animal wastes were buried between the slaughterhouse and the Wien River. Apparently, this practice was considered acceptable.

In the late nineteenth century, the heyday of the mills was over, and millstreams had become the object of sanitary concern. During low water, waste accumulated and remained on the banks until the next flood moved it downstream. The city of Vienna abandoned two millstreams and had them filled in in 1847 and 1856, respectively.³⁹ Only one creek, which was further upstream in a less inhabited area and, thus, less prone to pollution, remained partially in use until the twentieth century. The beneficial conditions for commerce and mill operations came at a cost. Apart from low water, the major threat to riparian residents was regular flooding, which damaged mill creeks, infrastructure, and buildings close to the river and frequently killed livestock and even people. Newspapers regularly reported such events. The particularly devastating flood of July 29, 1785, was even mentioned in English newspapers as one of the most deplorable incidents of the season.⁴⁰ Ignaz de Luca (1746–99), author and retired professor of Staatskunde (a precursor to political science), published a booklet on the catastrophe in the immediate aftermath.⁴¹ De Luca listed material damage and fatalities, but, more importantly, he identified some of the human arrangements built in the river and on the banks as amplifiers of flood damage. The flood had destroyed all

thirty-nine houses of Magdalenengrund, a village west of the Wien River. De Luca pinpointed its location and river engineering as the reasons for this tragedy. The village was situated directly opposite the Gumpendorf weir with its considerable drop height. The weir pressed the water to the right bank, which added to the danger and enhanced the risk of flooding. The city and riparian land owners regularly had to rebuild the regulating infrastructures along the river, especially during the phase of intensified floods between 1768 and 1789, when inundations occurred almost every year, repeatedly damaging nearby settlements, bridges, and streets.⁴²

Stream regulation, which occurred at a number of points in the city's history, aimed at stabilizing the riverbed and mitigating the effects of flood dynamics. It can be safely assumed that the first stream regulation measures on the section of the Wien River close to the city date back to the late Middle Ages. Historical depictions also suggest that the Wien River was already regulated upstream of the fortification wall before 1683. Between 1726 and 1736, a meander across the inner city walls was straightened. During the 1770s and 1780s, several local measures were implemented, such as raising the banks or deepening the riverbed. The situation outside the Linienwall was different compared to the other small tributaries because of the adjacent imperial palace of Schönbrunn, which demanded the riverbanks to be fixed. Two comprehensive regulation plans along the Wien River were drawn up but not implemented in the eighteenth century.⁴³

Early in the nineteenth century, the city of Vienna systematically regulated the Wien River in the city center and in the peri-urban section, upon imperial decree. Outside the Linienwall, either the court or the riparian communities initiated piecemeal activities, which resulted in a regulated riverbed along and downstream of the Schönbrunn Palace by the 1870s.⁴⁴ Upstream, railway construction required a considerable narrowing of the stream. The comprehensive regulation between 1895 and 1906 erased all previous measures (figure 5), capturing the stream in a paved, U-shaped channel, burying several sections, and disconnecting the floodplains to make room for a new city railway built between 1895 and 1899.⁴⁵ By 1910, parts of the Wien River flowed below ground. One of these covered sections, a centrally located space close to downtown, became the site of the largest market of the city. This was not the only future envisaged for the river, though. Some planners had bolder visions for the river, advocating the addition of water from nearby streams or the river's diversion, turning it into a shipping channel.⁴⁶ None of these ideas came to pass, as local and regional transportation services were less and less dependent on ships, increasingly served instead by the new city railway that had been built in the former floodplain.

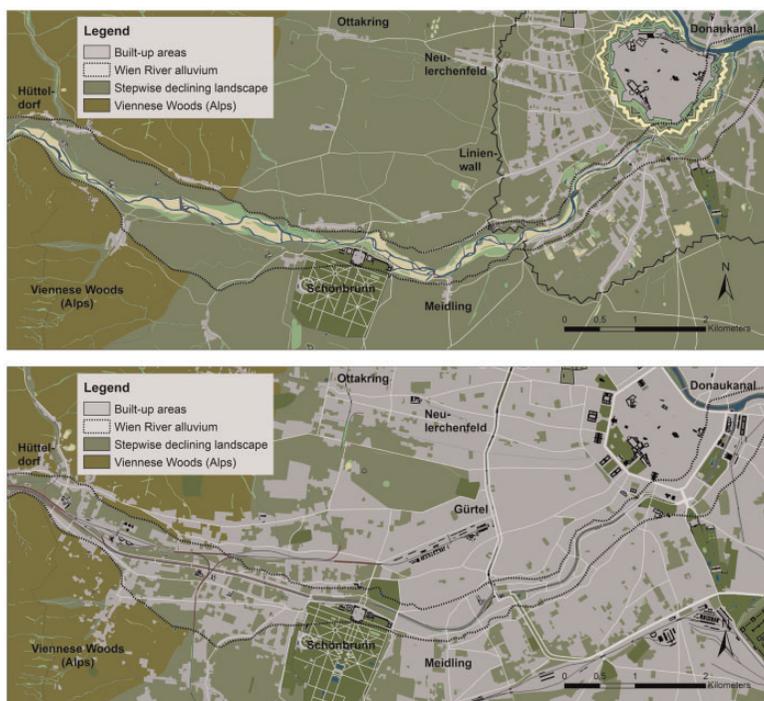


Figure 5. Wien River and the urbanized area of Vienna in 1755 (above) and 1912 (below). Credit: Reproduced with permission from Julian Reichstein and Severin Hohensinner, 2016.

THE DANUBE AND THE DONAUKANAL

The Danube and its floodplain were the major aquatic resources of Vienna. They provided surface and groundwater, washed away waste, and powered mills. Fishermen exploited the waters and stocked the Viennese fish market. But the shipping of food and commercial goods was the major concern and focus of urban authorities. Fuel and construction wood, delivered on the river from upstream areas, were indispensable for the urban economy and development. In the beginning of the 1830s, about 250,000 tons of fire and construction wood, food, and consumables came by ship to the city every year. Soon thereafter, steamships augmented transport capacities. Before the GrDR, approximately 600,000 tons of goods and food were unloaded on the banks of the Donaukanal annually.⁴⁷

The Donaukanal was the major place for traffic and trading. Food and consumables were mostly dispatched to the city center and sold directly on the banks or brought to markets in the city and in the suburbs. Wood was unloaded upstream of the center. Water-bound commerce benefited from the large and relatively stable flow of the canal throughout the year. Around 1780, Viennese dyers and tanners

concentrated on the left bank opposite to the city or nearby. Butchers clustered on the right bank downstream of the city center, following late medieval regulations, which required slaughtering downstream of the city center.⁴⁸ In the nineteenth century, these types of commerce would concentrate on the Wien River instead, but the Donaukanal never completely lost its importance.

The Danube powered ship mills. In contrast to the Wien River, where the number of mills remained rather stable, the number of ship mills increased in the eighteenth and nineteenth centuries from thirty-eight to sixty-eight sites, milling almost all of the rye that came to the city. Hydropower on the Danube made it possible to meet the growing urban demand for rye flour.⁴⁹ Ship mills were particularly flexible as they could be adapted to varying water levels or removed from the river—for instance, in the winter before the ice would encase them. When floods caused the erosion of the riverbanks, ship mills could be fixed at a new position, as occurred in the early spring of 1830 when a large ice jam created a new site with especially favorable velocity conditions.

In 1841 and 1846, respectively, the government of Lower Austria and the Viennese magistrate intensified an urban function of the Donaukanal that had previously only been used in a minor way. Water scarcity had become critical when the population in the city and the suburbs inside the Linienwall rose from 230,000 inhabitants in 1800 to 360,000 in 1840, and further growth was expected. Deteriorating water quality and hygienic concerns amplified the pressure. On the occasion of his coronation on March 2, 1835, Emperor Ferdinand I endowed the Viennese population with a new drinking water pipeline. It abstracted water filtrated naturally by seeping through the gravel from the Donaukanal towards the aquifer at the northern border of Vienna, upstream of the polluting inlets, and was the first area-wide water supply for the suburbs inside the Linienwall. But water quantity and quality remained problematic until the opening of the first Alpine Water Pipeline in 1873. It tapped springs some 100 kilometers south of Vienna and secured ample and clean drinking water for the city, which meanwhile housed more than 600,000 inhabitants in the city center and the surrounding suburbs. Subsequently, the Viennese used the Kaiser Ferdinand Water Pipeline only during maintenance of the Alpine Water Pipeline.

Attempts to control the fluvial dynamics of the mighty alpine river for navigation required considerable human and financial resources for centuries. Beginning in the sixteenth century, urban and imperial administrations implemented numerous measures to halt the north-easterly shift of the main Danube arm at the inflow of the Wiener arm; such efforts were intended to forestall further problems with the already difficult issue of shipping to the city center. After 1610, the Viennese had to accept that their efforts had been in vain. The main

arm of the Danube flowed further north. From then on, the city council and the concerned imperial authorities dedicated financial resources to maintaining a minimum flow for shipping in the Wiener arm and to preventing the new main Danube arm from moving further downstream towards the city and towards Prater, the imperial hunting grounds in the south (figure 6).⁵⁰ Here, two sizeable cut-off channels dug around 1649 could not stabilize the situation. At the inflow of the Wiener arm, a spur dike built from 1671 to 1680 should have increased the current, but sediment deposited at the river bottom and along the banks soon impeded the flow once again.⁵¹ Twenty years later, a new, one-kilometer-long channel was excavated, and another guiding wall was constructed to improve the water flow. The old inflow was dammed in 1704, and the Wiener arm became the Donaukanal.⁵² Around 1715, the new main arm of the Danube broke through a large meander it had formed in Prater and reached the Donaukanal. A massive closure dam was constructed, and two large meander bends of the Donaukanal were cut off in 1715 and 1726. One of them would later be called the Erdberger Mais, which has been completely transformed more recently into a mixed suburban development bearing no traces of its hydraulic history.⁵³

At the end of the eighteenth century, the magnitude and frequency of the floods intensified, and flood protection along the Donaukanal gained importance, with several comprehensive river-engineering projects proposed after 1810.⁵⁴ None of these projects was undertaken and local flood protection arrangements remained in use even after the catastrophic ice jam flood of 1830. Throughout the centuries, different municipal authorities, together with riparian landowners, developed a variety of practices to mitigate the adverse effects of floods. Provisions were stockpiled, including, among others, food, drinking water, and firewood, and wooden planks for boardwalks were gathered.⁵⁵ Such measures allowed urban development in the floodplain. Recurring smaller floods could successfully be dealt with using these measures, minimizing the health risks and the economic damage. They were less successful with large floods, however, which, although less frequent, would often lead to human and capital losses.

The GrDR from 1870 to 1875 radically changed flood protection practices. It was one of the biggest engineering efforts initiated by urban authorities and the imperial court in the nineteenth century, rivaled only by the building of the centralized water supply. The solution chosen after consultation with international experts maintained the river as near as possible to the city, but it cut off the growing villages north of the Danube, which would eventually be incorporated into the city in 1904. Along the left bank of the new main channel, a 470-meter-wide inundation area was excavated to enhance the discharge capacity during larger floods (figure 6).

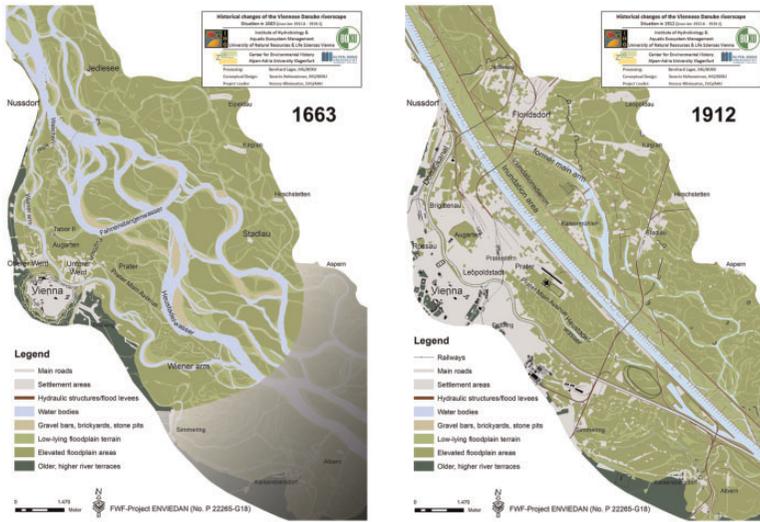


Figure 6. The Viennese Danube in 1663 (left) and 1912 (right). Credit: Severin Hohensinner, 2016, based on Lager (2012); Severin Hohensinner, Bernhard Lager, Christoph Sonnlechner, Gertrud Haidvogel, Sylvia Gierlinger, Martin Schmid, Fridolin Krausmann, and Verena Winiwarter, "Changes in Water and Land: The Reconstructed Viennese Riverscape from 1500 to the Present," *Water History* 5 (2013): 145–72.

Remains of the existing river arms were filled with digging material. Large parts of the Viennese districts situated between the Donaukanal and the main channel would later be erected on these areas, which would create compaction problems in the medium and long term.⁵⁶ Ships transporting food to Vienna continued to use the Donaukanal after 1875, but the main part of navigation was now directed to the new channel, on which large trading and storage buildings were erected. The GrDR relieved residents in the floodplains from long-performed practices of flood mitigation; it created a set of arrangements, which were as decisive for the later development of the city as the burying of the small urban tributaries had been.

Pollution problems were common on all waters but particularly problematic for the Donaukanal, which received increasing amounts of wastewater after the citywide sewage canals had been constructed in the late nineteenth century. Deteriorated water quality was a source of debate between an urban expert group installed in 1862 to solve the question of water supply and the urban health authority (*Stadtphysikat*) established in 1864.⁵⁷ In the 1890s, the emerging scientific knowledge of monitoring and improving water quality led to comprehensive surveys in the Donaukanal.⁵⁸ Just like the Wien River, the Donaukanal exhibited recurring periods of low discharge, which posed serious problems for the city. This affected urbanites' use of the canal, especially the traders at the Viennese fish market who kept

their fish alive in the canal until they were sold. The large overall discharge of the Danube prevented severe pollution of the river downstream of Vienna, as a study reported in 1906.⁵⁹

THE TRANSFORMATION OF VIENNA'S WATERSCAPE

As we have shown, the diverse hydro-morphological conditions of the Viennese waters shaped potential uses and had an important bearing on newly built material arrangements and practices. Geology, catchment size, discharge, and slope were decisive factors delineating the spectrum of possible interventions. Studying the surface waters in their entirety shows how they complemented each other to satisfy urban demand for a multitude of water uses. Such research also makes visible the full spectrum of human–nature interactions and the various functions performed by different bodies of water. Furthermore, it demonstrates the ways in which various actors changed these functions and their mix over time (see online [supplementary material](#) for Supplement 4).

Water use practices adapted to hydrology and fluvial dynamics and changed in the eighteenth and nineteenth centuries with new technologies, industrialization, the growing population, and urbanization. This is particularly obvious for domestic and industrial water as well as for wastewater discharge, all of which were closely intertwined. Domestic water used by the urban and peri-urban dwellers mainly originated from the aquifers of the smallest urban Danube tributaries and the Wien River. The Ottakringer Bach is a case in point, as the court and the aristocrats could afford to tap its resources using technical arrangements such as water pipelines, well houses, or reservoirs, whereas the less wealthy depended on house wells, which often had poor water quality as a result of being close to private cesspools. Urbanites faced growing competition for water and utilized the courts for redress, often receiving monetary compensation but rarely achieving better access to clean and abundant water. By the second quarter of the nineteenth century, per capita water quantity, which was small compared to other European metropolises, dropped steadily in Vienna due to increasing population, making bank filtrate from the Donaukanal a main source of domestic and industrial water.⁶⁰ Steam engines pumped water into a network of pipelines and distributed it to the suburbs. For water-bound crafts, all types of surface waters were used for washing and cleaning, but the intensity of use depended on the discharge and on the various agreements with other water users.

Many of the practices amplified pollution, which originated primarily from local waste and wastewater. By 1831, when the first

cholera epidemic hit Vienna, the small tributaries and the Wien River had turned progressively into open sewers. Growing hygienic problems triggered the construction of sewage canals and the burying of riverbeds within the built-up area. By 1850, all of the small tributaries inside the Linienwall had disappeared below ground and had become part of the urban sewer system. Nevertheless, they have had a lasting effect on the urban layout as the main streets connecting the suburbs with the center of the city largely follow the former watercourses. As the main sewers expanded in length and the number of buildings that were connected grew, point source pollution in the Donaukanal increased, especially during the low flow in the summer months. Finally, sewers along the Donaukanal became necessary and were built between 1893 and 1902. They would eventually carry the wastewater out of the city, polluting the river downstream of the populated area. The sewage system benefited from the first Alpine Water Pipeline, which had liberated urban dwellers from their dependence on local drinking and industrial water sources.

The kinetic energy of the Wien River and the Danube supported hydropower production and transport, but the rivers required specifically-adapted arrangements such as millstreams. In the late seventeenth and eighteenth centuries, water abstraction on the Wien River competed with water needed for log driving. When the accessible woodlands had been exhausted in 1754, log driving was no longer necessary, and, from 1803, the Wiener Neustädter Shipping Canal provided part of the urban wood supply. On the Wien River, mills, in combination with mill canals, dominated the socio-natural site until the 1850s.

Arrangements and practices on the Viennese Danube were determined, in particular, by the size and the dynamics of this alpine river. The hydrological forces of the Danube recurrently destroyed local bank-protecting structures, which were mostly made of wood, resulting in a great deal of maintenance and reconstruction. On the Danube and the Donaukanal, ice jams exacerbated the situation, and measures had to be taken to combat the piling up of ice; long saws were employed to deal with the ice, making the area one of the most dangerous, but transitory, work places involving a socio-natural waterway. The GrDR fundamentally transformed this socio-natural site. The operation of ship mills, which had contributed substantially to the local supply of flour, almost vanished with the GrDR. At this time, coal-powered steam mills already offered an alternative to water-powered mills. One important asset was that they could be sited almost anywhere, at least in terms of kinetic power.

At the turn of the twentieth century, pre-industrial water uses and the spatial patterns initiated by the diversity of urban waters were fundamentally altered. New technologies allowed for water sources to be tapped a considerable distance from the city, which therefore replaced the use of local water sources. High dikes constructed as

flood protection disconnected the Wien River from the former floodplains. An urban railway line was built along the left bank, rather than turning the river into a shipping canal, as Karl Weiss had imagined in as late as 1876.⁶¹ Upstream of the populated areas, large retention reservoirs secured the supply of water until buildings were connected to the new Alpine Water Pipelines.

With respect to the Danube, engineers believed that the GrDR would rid the city of floods forever. But this imaginary freedom came at a cost. The regulations were responsible for decisions that influenced the further development of the city in material, organizational, and financial terms. Flood-protection dikes required constant and costly maintenance work that continues to this very day. In the 1890s, it turned out that the dikes were too low, forcing them to be augmented. The enlargement of urban flood protection arrangements occupied water engineers throughout the twentieth century. The dikes disconnected the new and growing populated areas from the river, which rarely was accessed anymore except for shipping.

The experience with river engineering gained through the small-scale projects of the seventeenth and eighteenth centuries could be implemented on a large scale only when fossil fuel became available. Early on, surface waters were used for many conflicting purposes. The various uses of watercourses had to be adapted to the particular nature of the rivers and the river basins. The energy transformation to fossil fuel, with its connected transportation, manufacturing, and construction revolutions, brought all urban surface waters onto the same trajectory; they were regulated, buried, or cast in artificial beds. This went along with a change in the pattern of segregated uses, which went from local segregation to functional segregation. During the period of industrialization, in all likelihood, one of the waterway's many functions became dominant, usually its function as a connector. Water's role in the rise of the networked city should also be noted. Water prefigured many of the urban networks or became a material part of them, as in the case of sewage. While a lot of watercourses have been buried, and surface water seems to be technologically transformed in the networked, industrial city, water networks are still important, even if they have been extensively transformed.

The dynamics of the original rivers, however, still need to be taken into account. The necessary respect for the particular dynamics of each different water body is embodied in the reservoirs and the underground retention rooms of the water and sewage network, in the layout of the urban roads, in the protective weirs, and, not least, in a twenty-one-kilometer-long artificial island in the Viennese Danube, which was the primary measure constructed for flood protection by the city in the 1970s. Vienna's waters in their diversity have enabled and constrained urban development and continue to influence the city's trajectory. As we have shown in a

long-term perspective, taming the waters came at an enormous cost through the maintenance of regulation infrastructures and will continue to demand resources from city authorities. Using Vienna's small rivers as part of the sewage system has remade them into an organic machine, one that cannot be undone as long as the city continues to require a sewage network.⁶² And while the maintenance work is largely out of sight, it also continues to burden city finances. The socio-natural sites of the aquatic network of Vienna extend far out to the alpine springs from where the fresh tap water originates. They also extend far out into the future, building a framework of constraints for city development that are usually not seen in their entirety. A long view back, as we have presented here, might be useful in bringing the buried waters and their nature to the surface of the city's political discourse.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Environmental History* online.

Gertrud Haidvogel works on the environmental history of rivers as a senior scientist in the Institute of Hydrobiology and Aquatic Ecosystem Management at the University of Natural Resources and Life Sciences, Vienna.

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Notes

This article is a product of the research projects Vienna's Urban Waterscape 1683–1918: An Environmental History (URBWATER), which was funded by Austrian Science Fund Grant no. P25796-G18, and Environmental History of the Viennese Danube 1500–1890, funded by Austrian Science Fund Grant no. P22265-G18. The authors wish to thank Magdalena Fink, Anna Hagen, Julia Leineweber, Julian Reichstein, Elias Schnee, Dagmar Slavicek, Alexander Streitberger, and Julia Tanzer, who contributed as master students to the URBWATER project. We also would like to acknowledge Anna Wögerbauer's untiring work in the administration of the project, the members of the international advisory board for their helpful input, and the editor of *Environmental History* and the two anonymous reviewers for their comments and advice.

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