

How water and its use shaped the spatial development of Vienna

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Abstract Telling an environmental history of Vienna’s urban waters, this paper advocates the compound study of the evolution of fluvial and urban form. It traces the structural permanence of diverse types of running waters in a period of massive urban transformation from early modern times to present. The focus on the material effects, side-effects and afterlives of socio-natural processes offers novel perspectives to the reconstruction of city development. The featured cases show that long-term studies are vital in understanding the genesis of urban water bodies and urban form as a product of socio-natural processes. They inform us about the inertia of arrangements and the unforeseen perpetuation of site-specific effects of interventions. Societal interaction with natural elements such as Vienna’s waters, we conclude, reverberates in the material and immaterial realm alike.

Keywords Urban Development · River Dynamics · Industrialisation · Persistence · Structural Permanence · Mills

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Introduction

Water had and has a huge impact on the built environment. Spatial characteristics influence the transformation of urban entities and their waters and are vice versa influenced by them. As Terje Tvedt and Eva Jakobsson (2006, p. ix) point out, “no city and no country has been able to exist or develop without subjugating water in one form or another to the demands of human society”. The physical presence of water has always been crucial in the siting and spatial disposition of human settlements. Urbanites use water for its material properties, water bodies also serve as important transportation lines and did so even more in the past (Sieferle 2004). Inscribed into the urban fabric, human interaction with water generates a variety of persistent physical forms and patterns. Water and its uses mould the urban layout in general (visible in e.g. Chicago, Bern or Bangkok) but also on the micro-level of building practices. Not least, the presence of water decisively bears on “softer” factors like a city’s visual character and the quality of its ambience.

This paper tackles the question how water and its use shaped the spatial development of the city. It results from the URBWATER project, a study of the environmental history of Vienna’s urban waterscape 1683–1918¹ and draws on an interdisciplinary approach rooted in fluvial and urban morphology. While fluvial morphology deals with the evolution of water bodies and related human interventions such as channelisation and flow regulation, urban morphology is the study of “the city as human habitat. Urban morphologists [...] analyse a city’s evolution from its formative years to its subsequent transformations, identifying and dissecting its various components” (Moudon 1997, p. 3). It seeks to understand physical structures of human habitats, land use and land control at different scales.

This study rests on the premise that physical (urban) form as such is worth studying because it may be viewed as “the most tangible and persistent of all the aspects” that make up the processes of the development of settlements (Kropf 2009, p. 117). Taking Vienna as an example, we trace the transformation of selected sites closely linked to an urban water body on meso- and micro-scales.² We combine detailed, spatially explicit reconstructions of the co-evolution of waters and built urban structures as basis of an urban environmental history. This allows us to identify the ‘structural permanence’, i.e. material and immaterial afterlife of waters that have mostly disappeared from the surface during the study period. With this study, we demonstrate the possibilities of such interdisciplinary approaches in urban (environmental) history and finally address their wider potential regarding the present and future scope of urban planning.

Research status, concepts and approaches

Winiwarter et al. (this issue) have compiled a short overview of the state of research in urban environmental history. Main themes of this field are the interactions between rivers and society, with a tendency in the scholarly treatment to grant rivers more and more agency, and hence, narratives becoming increasingly co-evolutionary. Historiography has

¹ URBWATER—Vienna’s Urban Waterscape 1683–1918. An environmental history. FWF Austrian Science Fund grant no. P25796-G18.

² Therefore we focus on water uses which materialise in more or less complex arrangements such as mills and their infrastructure. Ephemeral practices such as washing or bathing are excluded from this investigation despite their practical relevance, because they do not materialise in the same way.

not often been concerned with the long-term interdependency between aquatic systems, technological change and urban development, nor with the spatial distribution of river functions and uses. Notable exceptions are André Guillerme's seminal work about eighteen cities of northern France (1988), Isabelle Backouche's work on the Seine in Paris (2000, 2008), Stuart Oliver's work on River Thames (2000, 2013) and Jim Clifford's work on River Lea (2012) in London. Some spatially explicit studies have been conducted in historical geography (Frank and Gandy 2006; Gandy 2014), highlighting water as a central element in the fabric of urban space. The importance of the material evidence of rivers and water infrastructure in cities has been emphasised by archaeologist Matt Edgeworth (2011).

In fluvial morphology, numerous studies highlight the historical changes of rivers and their floodplains in rural areas. Some of them focus on the persistence of riverine structures and the role of fluvial disturbances (e.g. Ward 1998; Arscott et al. 2002; Hohensinner et al. 2011). In that context, human transformation of urban water systems has received far less attention. Recent studies on urban rivers mostly focus on human altered hydrology/flood regimes and on the potential for river restoration (Booth et al. 2004; Walsh et al. 2005; Gurnell et al. 2007).

The permanence of physical and social urban structures, i.e. their resistance to redesign and innovation is central to this paper. This links well to 'technological frames', a central concept of science, technology and society (STS) studies. The 'obduracy' such frames create in urban sociotechnical change has been discussed by Anique Hommels (2000, 2005a, b). Obduracy is an actor-centred approach that features in a number of recent studies on urban development (Hodson 2008; Kirkman 2009; Dotson 2015). As such it emphasises the immaterial factors of permanence such as "fixed ways of thinking and interacting" or the "long-term cultural contexts" of acting (Hommels 2005a, pp. 331, 339). The approach of urban morphology, in contrast, focuses on the importance of forms and emphasises the "ubiquity and persistence of physical form" which makes it "most suited to act as the point of reference for co-ordinating and comparing aspects" of the study of urban development (Kropf 2009, p. 117). It can provide an explanation of obduracy³ by the long-term persistence of built structures. But actors as central to practices—of urban transformation—use, control, emergence vs. intentional design etc. are by no means neglected.

Urban morphological theory uses the notion of 'structural permanence'. We chose it because it clearly articulates the physical, structural side of urban change and hence proves compatible to the long-term studies central to (environmental) history. Structural permanence is part of the conceptual framework of the 'process typological approach' in urban morphology (Caniggia and Maffei 2001), denoting forms that retain their old attributes despite their components being renewed (Malfroy and Caniggia 1986). This is an important phenomenon we encounter when e.g. vanished meanders or filled mill creeks shape urban layout for centuries. Structural permanence hence describes phenomena of inertia in urban transformation. As do the waters, the built city, today and in any historical state, carries structural remnants of anterior conditions. This makes it a source for our work, because it contains residues of earlier states of society-nature relations, too. An analysis of urban

³ Hommels (2005a, p. 342) lists three models which highlight different yet equally relevant interpretations of the phenomenon of obduracy: 'frames', 'embeddedness' and 'persistent traditions'. Based on the persistence of physical form, an urban morphological approach to obduracy might well add a fourth category to this. Likewise, fluvial morphology can contribute a focus on the persistence and malleability of geomorphological features (Nanson and Croke 1992; Ward 1998; Tockner et al. 2010). However, in this paper we are limited to only hinting at the possible synergies between STS and urban and river morphology respectively.

forms, understood as hybrids formed both naturally and socially, contributes to the analysis of the transformation of socio-natural sites (Winiwarter et al. 2013).

The next sections lay out why Vienna is particularly suited for this study, which methods were used and what places were selected for case studies.

Vienna and its water network

Vienna is situated at a remarkable place at the confluence of three large European landforms. At the eastern foothills of the Alps the Danube corridor enters the Pannonian Plain (Fig. 1). Due to the geographical and geomorphological situation they created, Vienna's climate ranges between a temperate, Atlantic climate in the west and a more continental one in the east. Vienna's western mountainous region on average receives 15 % more precipitation than its eastern ranges (Fürst et al. 2007). Both the different landforms and the complex climatic and hydrological conditions are reflected in the variety of Vienna's urban waters.

Large parts of today's urban area were formed by the Danube River. Passing the *Viennese Gate* (*Wiener Pforte*) just upstream of the city, the Danube developed a broad alluvial floodplain with numerous laterally shifting river arms. The Viennese Danube in its natural state is characterised by a highly variable alpine flow regime with high loads of coarse bed material and suspended load. Summer and autumn floods after heavy rainfalls in the upper catchment, thaw floods in spring and the very typical ice jam floods in winter repeatedly caused sudden channel changes (Hohensinner et al. 2013a). All other Viennese watercourses adapted their channel gradients to the deposition level of the dominant main stem. Besides the large Danube system, numerous mountainous rivers and streams with flashy regimes but also less turbulent lowland waters fundamentally influenced urban development. Until the early 19th century, numerous streams originating in the Viennese Woods flowed eastward over the stepwise declining landscape to the Danube. Owing to soils with low infiltration capacity, water levels of these tributaries respond to precipitation

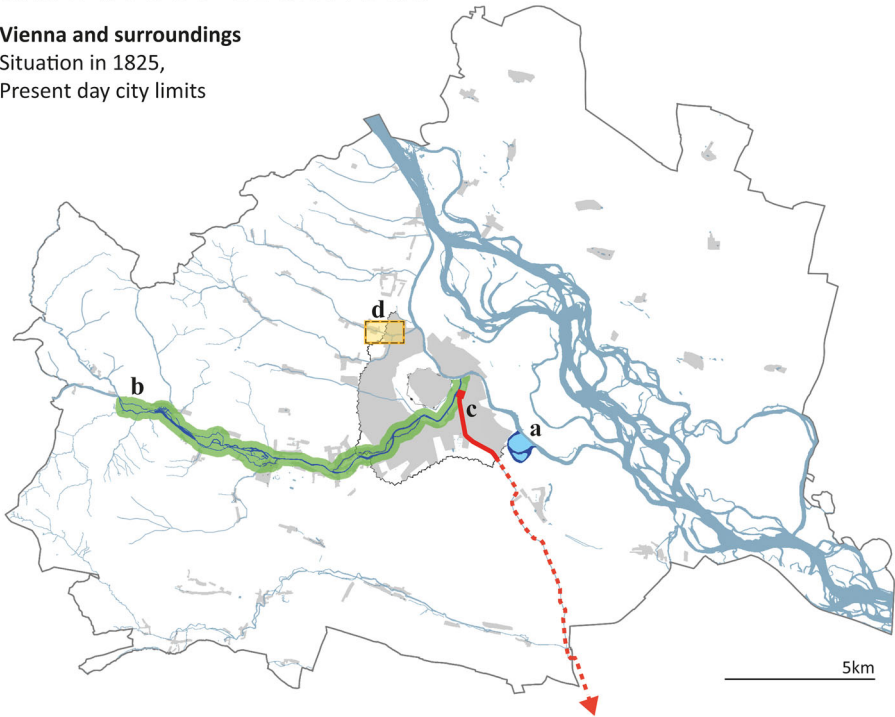


Fig. 1 Vienna (red dot) and its geographical location in the western Danube River basin. *a* Alpine arch, *b* Danube corridor, *c* Pannonian Plain (based on www.naturalearthdata.com, modified)

CASE STUDY LOCATIONS

Vienna and surroundings

Situation in 1825,
Present day city limits



CASE STUDY TIMELINE

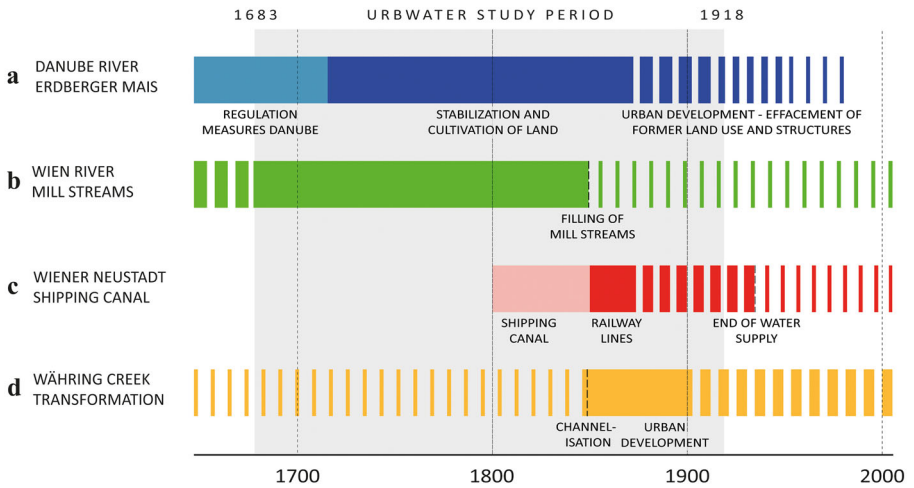


Fig. 2 Case study sites and periodisation. The dashed red line in the map marks the part of Wiener Neustadt Shipping Canal outside the city in 1825 which is not covered in this study

immediately. Short, but heavy floods of a kind typically found in alpine torrents are a consequence of this natural endowment. The tributaries anastomose to several major streams which either discharged into the *Donaukanal*, a major side arm of the Danube River, or directly into the main stem (see Fig. 2, top). *Wien River* is the largest tributary. It collects the discharge of several smaller streams. In large part Vienna's urban streams have disappeared from the aboveground cityscape, only their headwaters have been preserved in many cases.

The longer the distance from the steep slopes of the Viennese Woods to the Danube River, the smaller was the channel gradient of the respective tributary. The hydromorphological configuration of the tributaries was an important factor for human uses and urban development, since flow velocity and sediment transport capacity are directly tied to the gradient. Different types of urban water bodies associated with distinct patterns of fluvial dynamics stimulated or restricted human practices and arrangements (Winiwarter et al. 2013). Over centuries, the diversity of the water bodies led to different forms and processes of urban development.

Sources and methods

While to some extent the sources and methods of this study draw on the findings of the ENVIEDAN project ("Environmental History of the Viennese Danube 1500–1890") presented in a thematic issue of this journal (2013, Vol. 5.2), its spatial focus as well as its conceptual and interdisciplinary setting are new. A GIS-based reconstruction of Vienna's historical waters and its hydraulic constructions for several points in time between 1663 and 2010 is fundamental to our analysis. Its basis are historical maps and plans, written sources and technical reports. Together with current geomorphological and hydrological data, and reports about archaeological findings these sources provide excellent data for the study of changes in historical landforms and the urban fabric. In addition, geological and land use data from the river catchment help identify pressures originating outside the study site that affect urban water bodies. The reconstruction of the long-term transformation of the Viennese waters has been conducted using the regressive-iterative GIS-method according to Hohensinner et al. (2013b). Methodically analogous, the reconstruction of the city's built-up area and its building patterns can draw on very detailed sets of maps provided by the city archive⁴ and the Federal Office for Metrology and Surveying (*BEV*). Moreover, it builds on studies about different spatial aspects of urban development (Mayer 1972; Bobek and Lichtenberger 1978; Eigner and Schneider 2005), morphological analyses of specific areas (Raith 2000) and processed cartographical data published in Vienna's historical atlas (*Historischer Atlas Wien 1981–2010*). Urban reconstructions yield GIS-compatible CAD-based analytical models of the study areas, which are combined with hydromorphological reconstructions.

Mill registers and administrative documents such as petitions, reports and correspondence of the *Wassergrafenamt*⁵ dating back to the 17th century complement spatial reconstructions. Moreover, we used cartographic and written descriptions of specific water bodies (e.g. Stummer 1847–1857,⁶ Riebe 1936) and juridical sources such as land title

⁴ In its cartographical collection (*Kartographische Sammlung*, 16th century onwards) and in the *Plan- und Schriftenkammer* (18th century onwards).

⁵ The *Wassergrafenamt* was an institution in charge of administrating water rights.

⁶ WStLA, Kartographische Sammlung, Wienfluss, Pl.253: Prof. Josef Stummer, Wienflussaufnahmen, 1847–1852 and 1857.

registers. Information from several local museums was used in addition.⁷ Specific information about certain sites and practices of water usage and users (e.g. specific mills, trades, landlords and leaseholders) were then combined with more general information from technical literature and urban history. This allowed for an analysis of the cases as part of the development of the urban fabric and the larger waterscape.

Selection of case studies

To engage with the interdependency of urban form and water (use), we will look at the transformation of four different sites—each of which features a particular case of structural permanence:

- (a) Semi-permanent patterns: *Erdberger Mais* is a by-product of regulating measures undertaken at a main arm of the Danube in the 17th and early 18th centuries. Since then, land use patterns first stabilised and later underwent major changes—conserving and finally erasing the traces of the area's aquatic past.
- (b) Material and immaterial structural permanence: *Wien River's (Wienfluss)* extensive mill streams date back to medieval times. These human-made arrangements aimed at stabilising water flow and fall in order to harvest hydraulic energy. After their abandonment around 1850 both their forms and commercial sites induced by them persisted.
- (c) Legal permanence and functional shifts: *Wiener Neustadt Shipping Canal (Wiener Neustädter Kanal)* is an artificial water body built as transport infrastructure around 1800. However, within the city's ambit it functioned only a few decades for its original purpose. Between 1848 and 1879 its bed was remodelled to take railway lines—by that time the much more powerful alternative for transportation.
- (d) The large impact of small water bodies: *Währing Creek (Währingerbach)* is one of the minor tributaries flowing through what used to be Vienna's northern suburbs. Like most of the other urban brooks, it was integrated into the emerging waterborne sewage system network in the mid-1800 s. Several decades later, the structural permanence of the creek resulted in a very special pattern of urban transformation.

To tell an environmental history of Vienna's urban waters, we try to cover a range of transformation phenomena with diverse types of water bodies. In doing so we trace prototypical aspects and atypical developments alike. As Fig. 2 shows spatial and chronological aspects have also been considered for the choice of cases.

Semi-permanent patterns: *Erdberger Mais* as an unstable by-product of river regulation

Around 1632, a main arm of the Danube River located almost two kilometres north of *Erdberger Mais* started to shift southward. In the following years, the river arm developed a bend, thereby eroding large parts of the imperial hunting ground called *Prater*. To prevent further erosion, massive bank protections and two cut-offs were constructed

⁷ Vienna has local museums for each of its 23 districts. For our case studies we used material from the district museums *Landstraße*, *Wieden*, *Mariahilf*, *Alsergrund*, *Meidling* and *Simmering*.

between 1645 and 1649⁸ (Fig. 3a).⁹ However, 60 years later, around 1716, the Danube broke through the *Prater* and reached *Donaukanal*, the side arm of the Danube which had served as a supply line for the provisioning of the city probably since Roman times. Large parts of the channel network directly downstream of the city were now under threat of being affected by substantially altered flow conditions. As a reaction, a massive 140 m long closure dam was constructed to separate the main stem from *Donaukanal*.

Meanwhile, extensive meander bends had developed at the *Donaukanal*. The largest meander loop formed the *Erdberger Mais*.¹⁰ Such loops tended to shift laterally and break through the *Prater* towards the Danube. To prevent future channel dynamics, around 1715, a minor meander was cut off, the large meander of the *Mais* followed in 1726 (Fig. 3b).¹¹ In addition, a court commission for the improvement of Vienna's waterways set up by Emperor Karl VI ordered the construction of a closure dam to separate the former meander loop from the straightened *Donaukanal*. This measure marks the starting point of the settlement history of the *Erdberger Mais*, for it had now become part of the urbanised right bank of *Donaukanal*. The construction of the closure dam and the embankments of the *Mais* aimed at enhancing the deposition of fine sediments and terrestrialisation in the oxbow lake.

In the 1740 s, after some legal disputes and transactions with royal forest wardens and hunters regarding land-use rights (Kretschmer 1982; Ziak 1975), the land was opened to the close-by village of *Erdberg* and its population of mainly vegetable farmers.¹² As a map of 1748 shows, the villagers soon converted parts of the area into kitchen gardens—small arable plots of land used for urban supply (Figs. 3c, 4). Such gardens were often located in floodplain areas close to Vienna,¹³ where nutrient-rich and sandy soils favoured plant growth, plenty of water was available, and markets were close (Wrbka 2011).

Vienna's population tripled between 1700 and the early 19th century, reaching around 360,000 in the mid-1820 s (Weigl 2000). The green belt of horticultural land surrounding the city shifted outwards and downstream (Aschenbrenner 1974). In 1820, roughly 100 years after its creation, *Erdberger Mais* constituted an important area for the city's food supply: it accounted for about 20 % of acreage for vegetable production in the city and its close environs.¹⁴ It was this specific kind of land-use that preserved the contours of the former river bend and a small island in the configuration of its parcels and topography (Fig. 5). River morphology, history of technical interventions and shifts in land use let the *Mais* stand out as an example for the structural permanence of a vanished natural element in a suburban context.

⁸ OeStA, AVA–FHKA, Kartensammlung, F 244: Thomas Claußnitz, “Wasser gebeus Abriß in der Donau zum brater gehörig. Ad acta“ c. 1652.

⁹ Three further cut-offs together with new embankments were planned, but it seems that they were never built.

¹⁰ The term *Mais* refers to a young forest, in this case covering the extensive scroll-bar inside the bend.

¹¹ OeStA, AVA–FHKA, Kartensammlung, F 528: F Kollmann “Grundh Rieß Von den durckh den Erthbergischen grundh durckh geschnidene Canal...“, 1716. OeNB, Kartensammlung, K I 98.480: J J Marinoni “Neuer Atlas des KayserLen Wildban in Österreich unter der Ens“, 1726–1729.

¹² OeStA, FHKA SUS KS, F-225: “Erdberger Mais an der Donau in Wien“— this 1740 s map documents the enclosure of arable land plots.

¹³ Mainly in the floodplain areas of the Danube and *Wien River*.

¹⁴ By that time, *Erdberger Mais* accounted for 0.58 of approx. 2.5 square kilometres in the city and its close environs. Calculation based on the maps of the cadastral land survey of 1817–1829 (Franziszischer Kataster), counting the surface of land use category “vegetable gardens” (“Gemüseärten”).

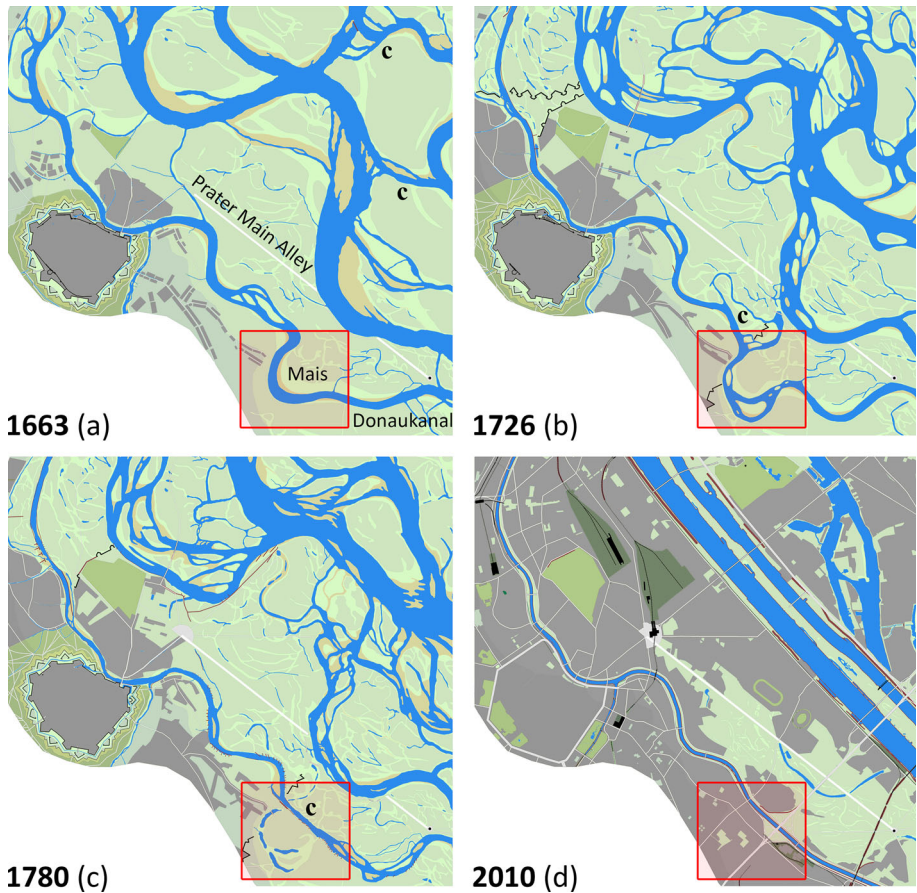


Fig. 3 The emergence of *Erdberger Mais*. **a** Situation in 1663 after partial erosion of the *Prater Main Alley* (c = Cut-off), **b** 1726 after breakthrough and construction of the first cut-off at the *Donaukanal*, **c** 1780 after cut-off of the meander loop of the *Erdberger Mais*, **d** current situation (after Lager 2012 and Hohensinner et al. 2013a)

The following century was characterised by industrial urban development and the biggest growth phase in the history of Vienna. The city underwent massive transformation, and *Erdberger Mais* was transformed with it. By late 19th century, perimeter block structures with privately owned, low standard residential buildings were erected at its northern rim and substituted earlier allotment and land use. In the southwest, buildings of the ever-expanding municipal abattoir and livestock market replaced older structures.¹⁵ By the end of the Habsburg Empire, however, this transformation process had only progressed half way (Fig. 6). In the first decades of the 20th century, there was still an important market for the products of horticultural businesses in the closer ambit of the city (Greif 1967) and economic succession in the area was proceeding slowly. After WWII, from the 1950 s to the 1980 s, the area was completely transformed, partly following the rectangular

¹⁵ This vast municipal complex had been opened in 1851 at the location where the road to Hungary, an important supply line, entered the city.

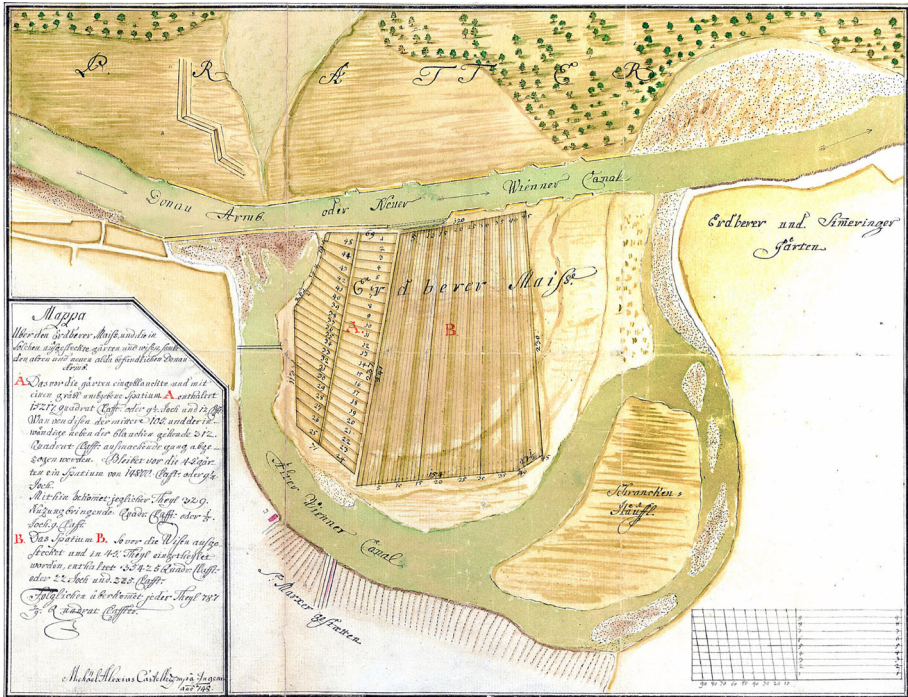


Fig. 4 Delineating the recently conquered land and making it arable: section A marks horticultural plots, section B marks meadows. The closure dam and the course of the former meander loop are clearly visible. Source: WStLA, Kartographische Sammlung, P1.42: “Mappa über den Erdberger Mais und die in Solchen ausgesteckte gärten und wisen, sambt den alten und neuen alda befindlichen Donau Arms”, 1748

block grid stipulated in earlier zoning plans.¹⁶ This recent development erased the visible remains of the area’s aquatic past which had so clearly structured all earlier developments (Fig. 7).

Material and immaterial structural permanence: Wien River’s mill creeks

Using a river’s kinetic and potential energy¹⁷ was an important means of supporting crafts and industries dependent on mechanical energy. Mills were therefore key elements for the supply of a city and its economic development, which also holds true for Vienna. Mostly they required a complex set of infrastructure far beyond the sole building with its wheels and machinery (Edgeworth 2011). It was necessary to concentrate water flow and fall through weirs and mill creeks depending on the hydromorphological and fluvial characteristics of a river. In Vienna, mills utilizing the energy of *Wien River* were connected to an

¹⁶ See for example, WStLA, Kartographische Sammlung, 1701a: Generalstadtplan 1912.

¹⁷ The kinetic energy of a river is the energy it possesses due to its motion, while its potential energy is the energy stored in the water due to gravitational forces acting on it (Reynolds 1983).



1825 **Fig. 5** Situation in 1825, vegetable and fruit garden plots highlighted in green. *a* former scroll bar, *b* former meander, *c* former *Schrankenhäufel* island, *d* village of *Erdberg*, *e* *Donaukanal*. Based on digitalisations of Franziszeischer Kataster by Stadtarchäologie Wien

ample and long-lasting infrastructure¹⁸ (Fig. 8). In the first half of the 19th century, more than 10 km of mill creeks paralleled almost the entire course of the river in Vienna's metropolitan area. Five weirs diverted water from the river's bed and supplied nine grain mills, one brewery, one food factory, one polishing mill and three tanning factories.

There is evidence for many of them dating back to the Middle Ages (Lohrmann 1980). Since all of the mill creeks are located within *Wien River's* recent alluvium, they

¹⁸ Mills were located on several smaller tributaries, but *Wien River* was the largest and closest to the city centre. Along Danube arms stable mills never have been constructed. This may be due to high fluvial dynamics and a very low channel slope of 0,4 ‰. Mill creeks would have required extensive construction and maintenance efforts and weirs would have caused conflicts with river transport. Instead, there were boat mills on some Danube arms. The number and importance of these small businesses using basic milling technology directly on the river increased strongly between 1750 and 1870 (Bergauer and Hrauda 2011).



Fig. 6 Situation in 1920, garden plots highlighted in green. *a* Donaukanal, *b* abattoir and animal market complex, *c* advancing perimeter block development. Based on Historischer Atlas Wien 2003: 2.7.1/1920/3 and 2009: 2.7.1/1920/11

potentially originate from natural side arms (Hofmann et al. 2003). The morphology of *Wien River* was suitable for mills due to a channel gradient of 4–5 % which allowed substantial fall with comparably short inflow channels. Nevertheless side arms might have been extended and their beds raised over time to achieve more fall. These beneficial conditions were directly tied to challenges connected to the dynamic flow regime of a torrential alpine river that implied flash floods and periods of water scarcity. Maintenance of mill creeks and weirs required continuous effort.¹⁹ Some sections of the mill creeks located directly along the active fluvial channel of *Wien River* as well as inflow sections

¹⁹ OeStA, FHKA AHK VDA Mühlen: A 12, B 2, G 8, H 9, K 4, M 3, R 11, S 4, V 2, W 7, W 9, W 10 (1554–1780).

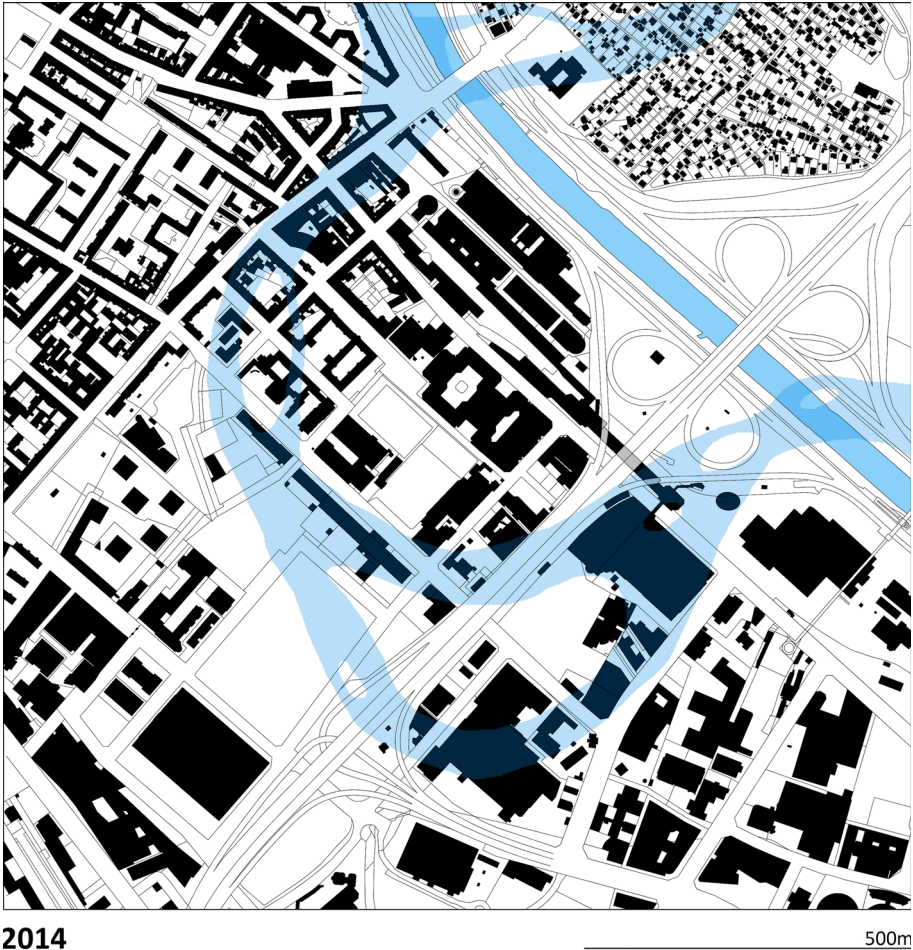


Fig. 7 Urban transformation of a former river bend: the state of the *Mais* in 2014 shows that roughly two centuries of accelerated change and physical turnover wiped out all the traces of the Danube arm, which had been conserved for over 200 years. Meander of 1726 superimposed. Based on information from: <http://www.wien.gv.at/kulturportal/public/>

were eroded and weirs were regularly damaged during floods.²⁰ Often new design approaches for milling infrastructure were first tried on the occasion of rebuilding after a flood in order to maximise available water and to minimise risk for the surrounding areas (Atzinger and Grave 1874; Lohrmann 1980).

The soil's poor potential for subsurface water storage in the catchment is also reflected in comparably low mean annual flows (today c. 0.3 m³/s, in the past potentially

²⁰ Torrential floods with flow rates of up to 450 m³ per second are the consequence of surface with low infiltration capacity. (City of Vienna, MA 45, <https://www.wien.gv.at/umwelt/wasserbau/hochwasserschutz/wienfluss/>).

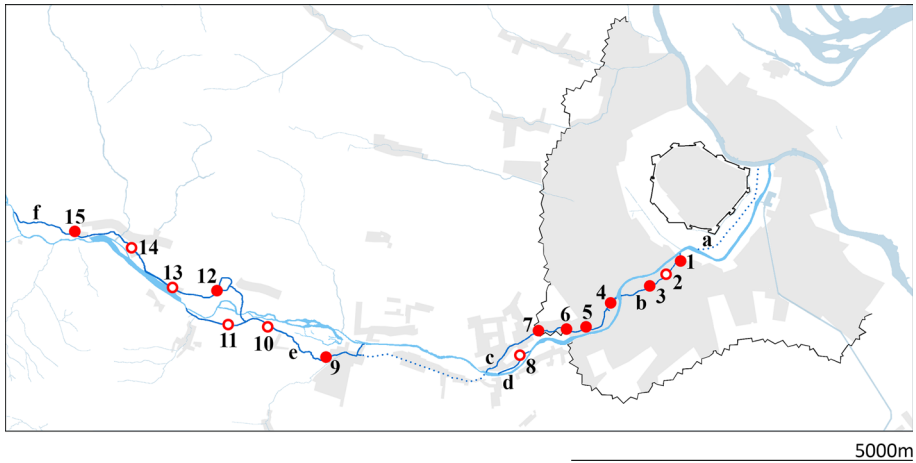


Fig. 8 *Wien River* from *Mariabrunn* to the *Donaukanal* in 1825. Mill creeks are highlighted in dark blue, grain mills with a full red dot and other mills with a blank dot. Asterisk marks the terminus post quem, the date of the oldest written evidence for the mill. As the names of mills and mill streams frequently changed, we are giving the youngest name under which a mill was known. *a* Mill creek on the location of the later *Glacis* (abandoned at the beginning of the 17th century in the course of enhancing the fortification of the city), *b* Mill creek from *Gumpendorf* weir (abandoned in 1856/57), *c* Mill creek from *Meidling* weir (abandoned in 1847), *d* *Pfeiffer* mill creek (abandoned in 1875), *e* Mill creek from *Hacking* (dotted part abandoned in 18th century due to a military barrack, rest abandoned at the turn of the 19th century), *f* Mill creek from *Mariabrunn* weir (connected with mill creek from *Hacking* by an open wooden race that most likely bridged *Wien River* in the 18th century, abandoned at the turn of the 19th century, remains still visible in the urban fabric), 1 *Bärenmühle*: grain mill, 1705–1857, 2 *Schleifmühle*: grain and polishing mill, 12th century–1857, 3 *Heumühle*: grain mill, 1326(*)–1857, 4 *Hofmühle*: grain mill, 1433(*)–1848, 5 *Kirchenmühle*: grain and stamper mill, 1357(*)–1848, 6 *Dominikanermühle*: grain mill, 1357(*)–1848, 7 *Mollardmühle*: grain, spice and precious metal treatment mill, 1331(*)–1848, 8 *Pfeiffer* factory: tannery, 9 *Feistmühle*: grain mill -ca.1880, 10 *Feldmühle*: tannery, 11 *Neumühle*: food factory, 1803-ca. 1860, 12 *Sina* mill: grain mill, 13 *Hacking* mill: tannery, 14 *Hütteldorf* brewery, 15 *Glutmühle*: grain mill. Based on digitalisations of *Franzsiszeischer Kataster* by *Stadtarchäologie Wien*. Information on mills from *WSLA*, P1.253, *Atzinger and Grave* (1874), *Lohrmann* (1980)

0.4 m³/s).²¹ During low flow situations, the operation of mills was significantly constricted as they had to shut down one or more gears. At such times almost all available water was diverted into the mill creeks leaving the river bed virtually dry. This could cause serious sanitary problems, as commercial and private sewage water was disposed into the river.

Nevertheless, the general layout of the *Wien River* milling landscape by and large remained stable between 1660 and 1850.²² Mills were likely to remain at the same place, since their locations were bound by water rights and infrastructure. At the same time, the permanence of mills on *Wien River* was a consequence of the manorial system and the miller's guild (*Schlottau* 1985). The landlords of most mills rarely changed, neither did mill numbers, location and trade. But the persons running the mills did change frequently (*Lohrmann* 1980).

²¹ Historical discharge rates at low flow were probably a little higher than today because the extensive sewage system did not yet exist (*Pollack* 2013).

²² *NOeLA*, *HS StA 1005/1*: *Mühlenbuch VOWW*, *VUWW* “Endtwurff der Mühlen, Gäng, Bestandtgelts vnd Malters nach der Herrschafft vndt Müllerzunfften eingerichteten Attestationen” 1661; *Handels- und Gewerbekammer* (1855).

Besides being important parts of Vienna's economy and long-lasting elements of the built city, mills also contributed to the commercial character of the emerging surrounding quarters. Crafts depending on the material use of water, e.g. tanning and washing, settled along the mill creeks as they were filled even when the water level in the river was very low.²³

In 1847 and 1851, the milling infrastructure was once again severely damaged by flooding. But the circumstances differed from earlier days, as new means of transport and milling techniques, including coal-driven milling factories, constituted a major challenge even to long-established water mills. Businesses along the mill creeks became less dependent on water supply and discharge as their demands were increasingly met by newly established water pipelines and sewage networks. Moreover, mill creeks in the densely populated urban areas were incrementally perceived as health hazards contributing to Cholera epidemics, which finally caused city authorities to dispose of several centuries-old mills and their creeks in the 1850 s.²⁴ In the less densely populated urban periphery outside of Vienna's outer fortification lines (*Linienwall*) some mills operated until the turn of the 19th century. Today, the buildings of *Heumühle* and *Feistmühle* are the only remnants.

Along *Wien River*, new sanitary paradigms and technologies as well as a shift in administrative competence resulted in ending a once complex waterborne network and important urban industry. Although massive urban transformation completely changed the face of the river and adjacent city districts in the decades up to WWI, the course of the mill creeks remains largely visible in the layout of the road network and parcelling of land (Figs. 9, 10). Besides, mill- (and more generally, water-) induced commercial development along *Wien River* left a strong imprint on the socioeconomic character of adjacent city districts.²⁵ A concentration of textile and timber workshops (Eigner and Resch 2003) and chemical industries persisted beyond WWI (Historischer Atlas Wien 1990: 2.3.2/5). Only slowly did the main axis of production areas change from west–east, following *Wien River*, to north–south, following major new transportation routes (Banik-Schweitzer 1983).

Legal permanence and functional shifts: *Wiener Neustadt Shipping Canal*

Wiener Neustadt Shipping Canal was built 1797–1803 following the example of British „Narrow Canals“ for horse-drawn ships. It connected Vienna with the city of *Wiener Neustadt*, about 50 km to the south. Its purpose was to decrease transportation costs for coal from mining areas in *Ödenburg/Sopron* (Hungary) to Vienna. Started as a private venture with only 25 % public financing, the shipping canal became state-owned property in 1802 after a major increase in building costs due to war and unforeseen constructive problems (Hradecky and Chmelar 2014). Besides coal, the most important goods transported were wood, bricks and other building materials. From 1822 the canal was leased to private investors, from 1847 onwards to brick manufacturers who owned factories in the surroundings of the canal south of Vienna.

Water came from the rivers *Leitha*, *Schwarza* and *Piesting* with catchment areas in the eastern alpine regions of Lower Austria. In Vienna, the canal opened to a port basin close

²³ WStLA, Kartographische Sammlung, Wienfluss, P1.253: Prof. Josef Stummer, Wienflussaufnahmen, 1847–1852 and 1857.

²⁴ WStLA, Hauptregistratur, Politika, Q-Bau 1856, B1.652 and B1.653.

²⁵ See the study of Pollack et al. in this issue.

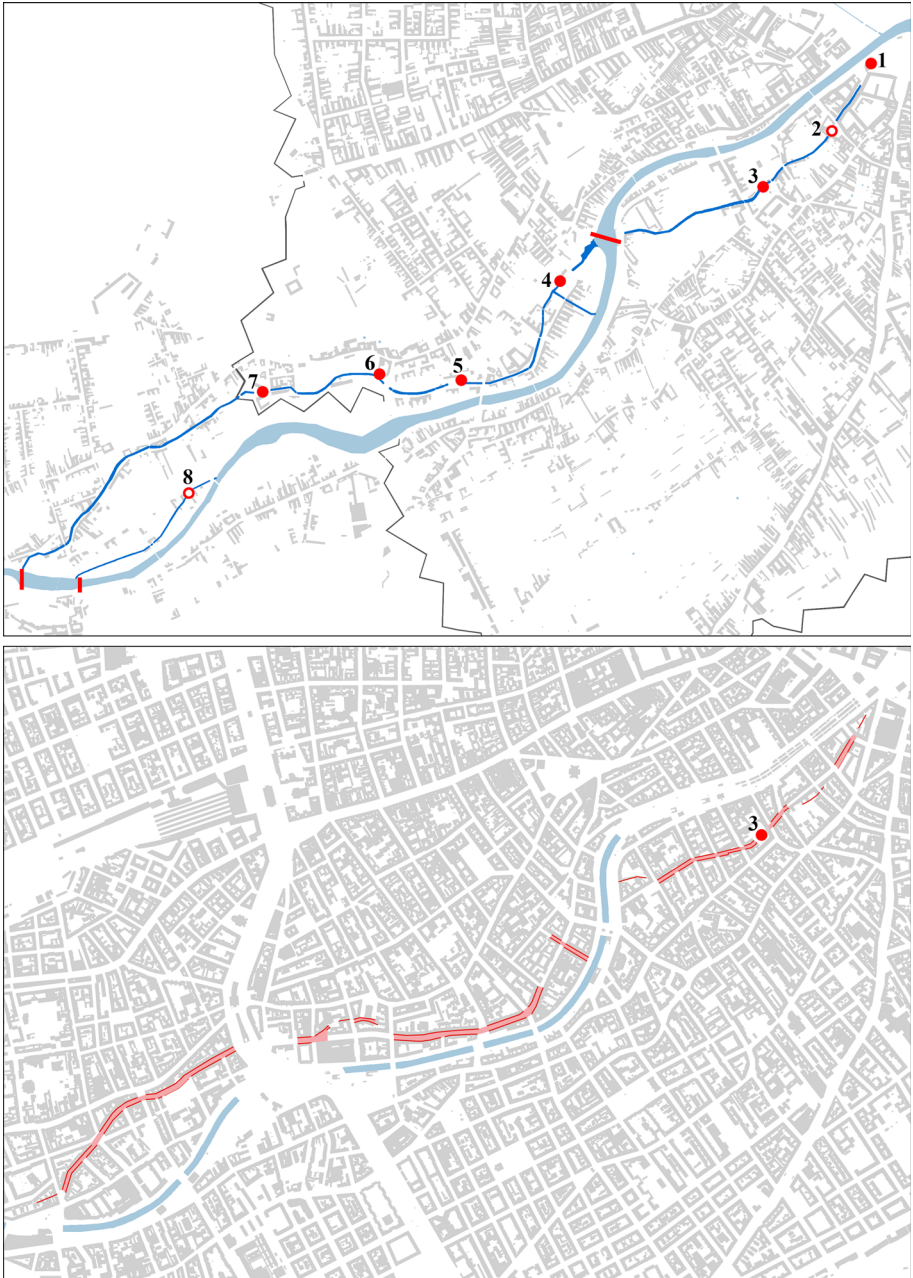


Fig. 9&10 The lower section of *Wien River* in 1825 and 2014. Mill creeks are marked in *dark blue*, weirs and mills in *red* in the 1825 plan (see Fig. 8 for detailed legend). Streets and edges of buildings following the course of the former mill creeks are highlighted *red* in the 2014 plan. Based on digitalisations of *Franziszeischer Kataster* by *Stadtarchäologie Wien* and data from www.openstreetmap.at

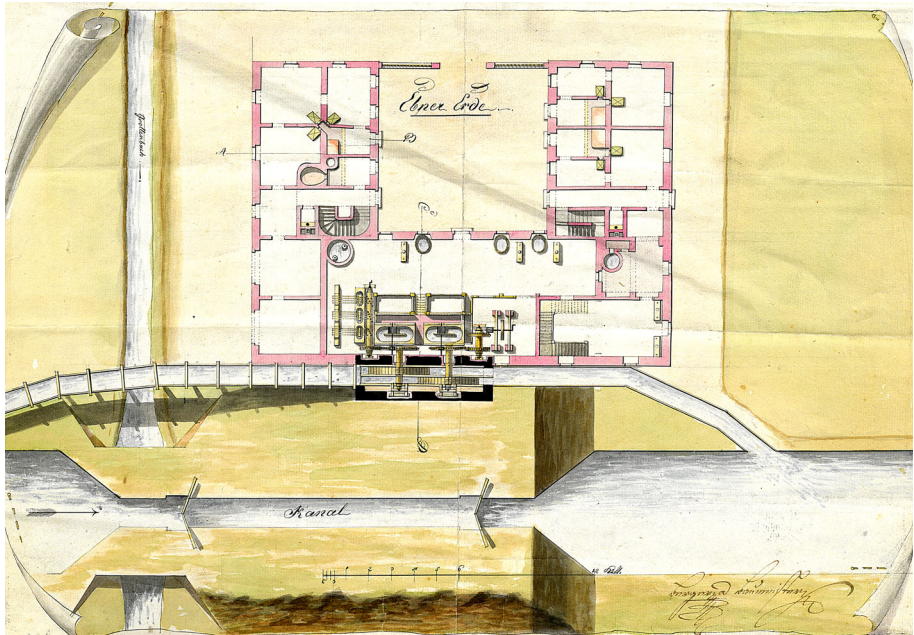


Fig. 11 Paper mill at *Grottenbach* lock (1812): The drawing shows how the fall of approximately two metres at one of the canal's 50 locks was used energetically. Water was diverted upstream of the lock and directed onto one or more water wheels. In this case the arrangement's complexity is enhanced as a small creek (*Grottenbach*) crosses the canal and mill race on a lower level *Source* OeStA, FHKA, Sus KS, N 061

to the city centre on the right bank of *Wien River*, from which the water was discharged into the river.

Although transport was the main purpose of the canal, practices of “secondary” water use soon gained importance. This included energetic use of the canal's slope at the shipping locks (Fig. 11) as well as water use for industrial and agricultural purposes and forbidden—but nevertheless frequently conducted—practices such as bathing, washing of laundry, watering of animals, bathing horses and extracting fire-fighting water (Riebe 1936). Within the present city limits, mills were situated at six locks and at the fall of the discharging channel between the port basin and *Wien River* (Fig. 12, left). During the first 20 years of canal operation, water rights and parcels were allocated to state institutions and private businesses by the state-run *Canalfonds*. Hence the construction of the canal had a bearing on the commercial development of the neighbouring areas that went far beyond its importance as a transportation facility. Several private businesses and public institutions such as Vienna's main customs office, the imperial mint and *Rudolfstiftung* hospital received water from the canal (Hradecky and Chmelar 2014).

All water rights were granted indefinitely, either free of charge or for an annual fee. However important this type of water use was for certain companies and institutions, in 1846 revenues from the fees accounted for only 1 % of the canal's return. Water rights nevertheless proved decisive for further development. In the middle of the 19th century, when trains became a much more powerful means of transportation than the shipping canal was, they prevented the filling up of the canal in most parts. At that time, Vienna had already two railway terminals—one of *Nordbahn* (established in 1838, connecting Vienna

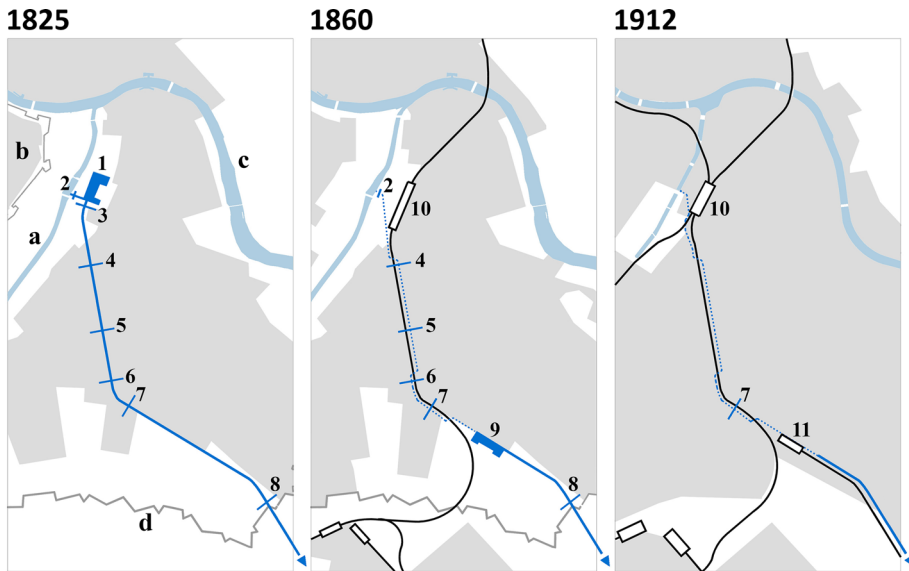


Fig. 12 The transformation of Wiener Neustadt Shipping Canal (dark blue line) into an underground canal (broken dark blue line) and railway lines (*Verbindungsbahn* and *Aspangbahn*, black lines) from 1825 to 1912. 1 Original port basin (1803–1848), 2 Stubentor mill at the discharging channel, 3 Landstraße lock with cutting mill, 4 Rabengasse/Beatrixgasse double lock with gun boring mill (1860 also mint), 5 Gragasse/Neulinggasse double lock with metal work factory, 6 Weber lock with metal work factory, 7 Rennweg double lock with veneer cutting mill, 8 Kirchhof lock with grain mill, 9 Second port basin (1848–1879), 10 *Verbindungsbahn* train station (Bahnhof Hauptzollamt), 11 *Aspangbahn* terminal train station (opened 1881) a Wien River, b Vienna city centre, c Donaukanal (side arm of the Danube), d Linienwall fortification lines. Based on digitalisations of Franziszeischer Kataster by Stadtarchäologie Wien (1825), Historischer Atlas Wien, 1987: 2.6.1/4 (1860), WStLA, Kartographische Sammlung, 1701a: Generalstadtplan (1912)

to the north) and one of *Südbahn* (established in 1841, connecting Vienna to the south). In 1847 the national railway board (*Staatseisenbahndirektion*) drew up a project to connect the newly erected main customs office next to the port basin to the two railway lines (Kurz 1981). The new link called *Verbindungsbahn* would use the innermost stretch of the canal's bed, while the train station was built on the site of the former port basin (Fig. 12, middle) (Schlöss 2003). The reasons for this remodelling of transport infrastructure were the shortage of available space, the possibility to use already state-owned property as well as safety concerns.²⁶ Shortening the canal by approximately 1700 metres and constructing a new port basin were considered reasonable by all parties involved. However, the obligations resulting from water rights had to be satisfied, so an underground feeder canal preserving water flow and fall was built to replace the parts of the canal used for the railroad bed. Construction work started in 1848, but it took 12 more years until the railway line could be operated at its full length (Kurz 1981; Riebe 1936).

When the canal was sold in 1871 to relieve the state treasury, the purchase agreement determined that all water rights had to remain unchanged and that the buyer, an incorporated company named *Erste österreichische Schifffahrts-Canal-Actien-Gesellschaft*, had

²⁶ Because the railway used the canal bed which was below street level at most parts this solution was considered safer for traffic in adjacent areas.

to maintain the feeder water canal.²⁷ In 1878, the new owner changed the focus of business to the operation of another new railway line called *Aspangbahn*. In the wake of these changes the second port basin and part of the shipping canal had to make way for the tracks and a new terminal station (Fig. 12, right). The underground feeder canal had to be extended, as water rights still had to be satisfied, and the remaining above-ground canal was reduced in width. After 1879, there is no evidence for regular shipping traffic within the city limits (Lange 2003). The main scope of this artificial water body had shifted from transportation, which had been completely taken over by railways, to water supply stipulated in older water rights. This was possible only because the south-eastern part of Vienna in the 19th century was an area of vast and rapid urban development and at the same time poor in terms of available energy and water resources. These functions had not yet been taken over by city wide networks of water pipes and electricity grids. However, the lack of investment in maintenance made water flow unreliable. Around 1900, the canal's hydropower use was down to only one manufacturing firm. City authorities started severance pays for remaining water rights in 1906. Until 1930 the last remaining parts of canal infrastructure were demolished (Hradecky and Chmelar 2014; Riebe 1936). Today, only few physical relics of the shipping canal remain within the city limits, while the transportation corridor determined by the canal lane has prevailed. *Wien Mitte* station, one of Vienna's most important transport hubs, is situated at the very location of the first port basin (Schlöss 2003; Hradecky and Chmelar 2014).

The large impact of small water bodies: *Währing Creek*

Währing Creek (Währinger Bach) is one of the smaller Danube tributaries flowing through what used to be a rural area northwest of the town. On its course down from the western Viennese mountain range towards the Danube floodplain, the stream showed straight to sinuous channel sections that partially incised into the landscape. With a length of roughly 5.4 kilometres, it ran through the villages of *Pötzleinsdorf*, *Gersthof*, *Weinhaus* and *Währing* before flowing into *Als Creek (Alserbach)*, a slightly larger stream. 800 metres further downstream, the waters of both flowed into *Donaukanal*. Today the vaulted stream meets the intercepting sewer at this spot.

In 1704, when Vienna's outer fortification lines (*Linienwall*) were erected, the area around the confluence of *Währing* and *Als Creeks* was still largely non-urbanised agricultural land. The construction of the wall cut off two old roads paralleling the watercourse and changed the connection to the villages upstream by setting up a gate and tax office on a previously undeveloped location.²⁸ The innermost and relatively steep 260 metres long section of *Währing Creek* was now inside the fortification lines—and therefore partially inside the city's judicial competence area—, all the rest was outside of it (Opll 1986, Historischer Atlas Wien 1984: 4.2.1/1&2). These early 18th century changes in administrative and physical urban layout proved important for the area's development during the next century.

Due to heavy pollution, the streams flowing through the city suburbs had become a serious nuisance and threat to the population by the late 18th century (Neundlinger et al.

²⁷ OeStA, FHKA, Sus FinProk Akten 95 (1867–1901).

²⁸ WStLA, Kartographische Sammlung, Pl.4: Emil Hütter, Burgfriedensgrenze und Vorstädte Alservorstadt und Rossau (1670), 1873 - and WStLA, Kartographische Sammlung, Pl.450: Reichenberger, Alsergrund bis Nussdorfer Linie, c. 1736.

2013; Payer 1997, 2005). After the Cholera epidemic of 1831, city authorities prioritised the building of a city-wide sanitation system for the ever-growing capital of the empire (Gierlinger et al. 2013). In 1848/49, as one of the last urban streams, *Währing Creek* was tunnelled and integrated into the sewage system within the city limits (Kohl 1904; Neundlinger et al. 2013).²⁹ Outside the wall, it remained an open, slightly meandering body of water. Unlike the other vaulted streams inside Vienna's administrative boundaries, the watercourse had not been paralleled by roads and was flowing through private garden plots. Consequently, the creek's vaulted stretch was not turned into a street and retained some of its curved course even in its new form. Easements in property registers secured the municipal authority's right to access and maintain the vaulted stream, on certain parcels even building bans were issued.³⁰

This mid-1800 s transformation of parts of the urban waters was followed by Vienna's great boom phase, seven decades of urban expansion and rapid growth in population that deeply changed the city's face (Bobek and Lichtenberger 1978). What used to be villages in open countryside quickly became new city districts densely covered with 4 to 5-storey buildings. In the 1880 s and 1890 s, the former garden plots around the tunnelled part of *Währing Creek* were developed by private entrepreneurs with perimeter block structures typical of that period. This changed the layout of the whole area, leaving only a green space corridor in the middle of the blocks where the canal was flowing underground: a singularity within a stereotypical and homogeneous urban system (Raith 2000) caused by a transformed former natural element (Fig. 13).

In 1892, the city limits finally were shifted outwards and the *Linienwall* tax boundary became obsolete (Mayer 1972; Hauer 2010). Now, city authorities could realise long planned public infrastructures: the former fortification lines were substituted by a wide new ring road (*Gürtel*) with an urban railway viaduct in its middle, which opened in 1898. The road and sewage networks of the city and the suburbs were joined. Until 1901, the outer stretches of *Währing Creek* were tunnelled (Stadler 1960; Kortz 1905) and transferred to flow beneath one of the main radial roads. The sinuous course of the creek has been conserved in property boundaries of the former village centre (Fig. 13c). However, the natural dynamics of the waters proved the dimensions of the innermost and oldest stretches of the vaulted streams of *Währing* and *Als Creeks* inadequate (Gantner 1991).³¹ In order to meet the requirements of a widely extended sewage network, a new bypass sewer for *Währing Creek* had to be constructed. It was opened in 1911, leaving the inner part of the tunnelled stream only to take flood peaks.³²

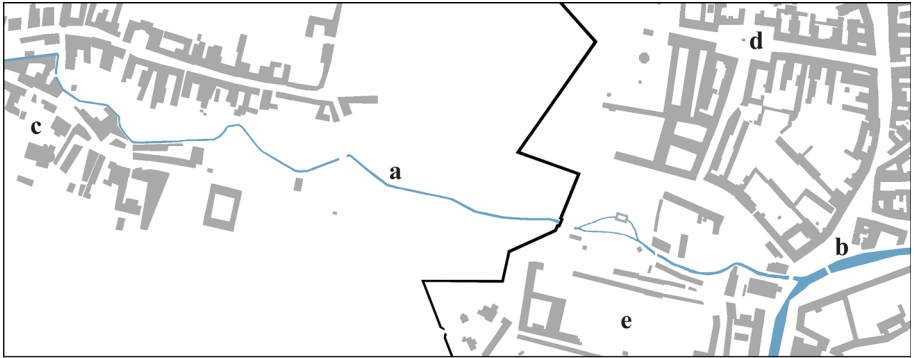
In the area along *Währing Creek* studied here, most of the urban layout it received in the 19th century still exists. Comparing its present state with that of 1825 demonstrates that the

²⁹ See also the construction project: WStLA, Kartographische Sammlung, Plan- und Schriftenkammer, P23.3.101899.

³⁰ See land register excerpt of "Katastralgemeinde Alsergrund (01002)", parcel no. 502/2, EZ 885 (accessed online 20.06.2014). Some of the municipal easements even seem to date back to times before the vaulting, as references to a contract from 1837 indicate, found in: Bezirksgericht Josefstadt, land register of "Katastralgemeinde Alsergrund (01002)", parcel no. 505/2, EZ 886, enclosed judicial correspondence dating from 1927/28.

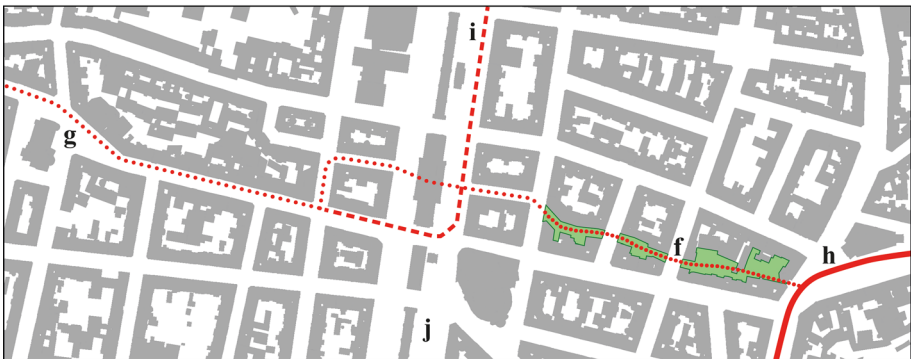
³¹ Heavy rainfalls in June 1898 and July 1907 caused discharge rates of 69 and 90 m³/s respectively, by far exceeding the capacity of the innermost stretch of tunnelled *Als Creek*, which was 50,5 m³/s. This led to severe inundations at the confluence of *Währing Creek* and *Als Creek* (Gantner 1991).

³² According to Hans Stadler (1960) the system of *Währing Creek* sewers has a drainage area of 571 ha. The bypass sewer works at maximum discharge rates of 20 m³/s. It had to be backed up by another bypass sewer running beneath *Gentzgasse* in 1936–38, which is how the system works until today.



1825 (a) Ground figure plan with water bodies

100m



2014 (b) Ground figure plan with vaulted streams



2014 (c) Cadastral plan

- Property limits derived from former water course
- Parcels affected by easements and/or building bans because of vaulted stream

Fig. 13 Urban transformation along Währing Creek 1825–2014. *a* Währing Creek *b* Als Creek *c* Village of Währing *d* Suburb of Himmelpfortgrund *e* Suburb of Michaelbayrischer Grund *f* Währing Creek vaulted in 1848/49, green space corridor highlighted *g* Währing Creek vaulted 1891–1901 *h* bypass sewer built in 1911 *i* Als Creek vaulted in 1843 *j* Gürtel ringroad with urban railway viaduct. Maps are based on digitalisations of Franziszeischer Kataster by Stadtarchäologie Wien (1825) and on information from <http://www.wien.gv.at/kulturportal/public/> and <http://www.wien.gv.at/baugk/public/> (2014)



Fig. 14&15 The present state of the green space corridor above the stream vaulted in 1848/49. Parts of it were converted into a public pedestrian passage in the 1970s. Source orthophoto: City of Vienna, MA 41, photograph by Friedrich Hauer

spatial transformation patterns of this urban water body differed strongly according to the period of urban development and the respective administrative competence zones. They did so even within a comparatively small area: The middle stretch of the former watercourse shows not only the disappearance of the creek, but the complete eradication of the old parcelling and land use. In the inner section, contrary to the logic of stereotype grid parcelling, a charming green space corridor emerged within a densely built up area (Figs. 14, 15). This was due to the vaulted stream flowing underground and the legal measures accompanying its construction. The former village centre of *Währing*, on the other hand, conserves the bygone creek's bends in its irregular parcels, although the water has long been tunnelled and moved to another place.

Permanence and change

Each of the outlined cases is a unique materialisation of a wide range of different socio-natural phenomena. Distinct types of urban water bodies associated with different patterns of fluvial dynamics stimulated or restricted certain human practices. The use and the users of Vienna's waters and the structural permanence of the arrangements they created were an important factor in the diverse processes that shape urban development.

Erdberger Mais at the edge of the Danube's alluvial system is a well-documented example how remote fluvial processes impacted areas later urbanised. Its semi-permanent patterns are a vivid example of urban expansion processes induced by efforts aimed at erosion control. Gaining new land for horticulture and urbanisation was a side effect of stabilising a powerful river. Even when long vanished, natural elements such as meander bends leave traces in urban and peri-urban environments. But if property structures, land use patterns and subsequently the built city-fabric undergo transformative changes, the remains of former natural states may vanish.

The case of *Wien River's* mill creeks shows the importance of water to provide energy for economic urban development in preindustrial times. Mills and their infrastructure were remarkably permanent, large arrangements. They shaped the area along the river both physically and commercially. Although the complex system of mills, weirs and mill creeks was abandoned around 1850, its layout remained largely visible in the road network and

parcelling of land. Socioeconomic trajectories induced by different forms of water use continued after their natural preconditions had long ceased to exist. Material and immaterial factors are intertwined, as this type of persistence makes clear (Law 1987). Their interaction patterns lead to varying degrees of malleability of socio-natural sites.

The transformation of *Wiener Neustadt Shipping Canal* shows the law-induced permanence of a once waterborne transportation corridor and its functional shifts. It elucidates how the unforeseen perpetuation of the canal's secondary use, enabled by water rights, generated economic development and became the reason for its conservation long after the original transportation purpose had been marginalised.

The case of *Währing Creek*, today part of the waterborne sewage system, suggests that even small waters may have a large impact on the urban fabric as soon as permanent arrangements of water use interfere. Its history shows that administrative competence areas, but also asynchronicity in the dynamics of physical urban development and legal institutions such as property registers or laws relating to public water use all play their part in the emergence of structures still effective today. Societal interaction with natural elements such as *Währing Creek*, we conclude, reverberates in the material and immaterial realm alike.

All water bodies at the sites studied have disappeared from the map. This is in accord with a general trend that industrialisation brought with it: the drastic quantitative reduction and qualitative degradation of surface waters in urban environments (Hohensinner et al. 2013a).³³ At the same time, we may also observe the persistence of water vectors, as they were embedded into more or less artificial infrastructures. The only featured example of a water body disappearing completely is *Wiener Neustadt Shipping Canal*, an artificial structure that required continuous maintenance for its functioning.

Even though it has largely vanished from the surface, water and its use has left a deep imprint on the city. Long after their diversion or disappearance, the water bodies left traces in the urban fabric—most tangible in parcelling and spatial characteristics, but also in socioeconomic dispositions. They became structurally permanent. All the studied sites underwent major physical reorganisation after 1850,³⁴ but the patterns of urban transformation differed considerably in time and intensity. Depending on a site's prior urban development, urbanites and planners faced the resistance of existing technological frames (like communication networks), buildings or key arrangements (bridges etc.). This was also conditioned by the respective geographical and socioeconomic positions in the agglomeration: unbuilt, semi-peripheral horticultural land such as *Erdberger Mais* would be reconfigured more easily than the densely populated commercial neighbourhoods stretching out along *Wien River* and its mill creeks. On the other hand, economic pressure on central areas would be higher. 19th century perimeter block grids eradicated earlier patterns in some cases (*Mais*, *Währing Creek*) and were adapted to existing frameworks in others (*Wien River*). Ambiguous examples such as the inner stretch of *Währing Creek* or the transportation corridor laid out by *Wiener Neustadt Shipping Canal* stand out as atypical materialisations of developments typical for their era. Yet there is more than just a material side to the mutations of water use and urban form. Virtually all of our case

³³ Compare 'Urban Stream Syndrome' according to Walsh et al. (2005) or recent examples from China described in Du et al. (2010).

³⁴ Public regulating institutions proved a driving force in the remodelling of Vienna's waters in the 19th century. While state institutions were the dominant actors on the Danube (Hohensinner et al. 2013a), municipal authorities were decisive for the city's smaller waters. As shown, they were mainly concerned with sanitary matters, the establishment of new infrastructures (be that pipelines, sewers or streets) and the spatial regulation (block alignment, density etc.) of urban expansion in general.

studies highlight the importance of judicial, i.e. immaterial aspects (water rights, land property etc.) in transformation processes. Not least, they show that structural permanence itself is a temporary phenomenon.

Conclusions

Shaping the city always implies the shaping of society. However, existing urban configurations are not infinitely malleable. Any major intervention faces the resilience of already existing material and social frameworks—which mould and mediate our relation to nature and to our fellow humans.

This paper advocates the compound study of the evolution of fluvial and urban form, tracing the structural permanence of urban water bodies in a period of massive transformation. The focus on the material effects, side-effects and afterlives of socio-natural processes offers novel perspectives to the reconstruction of city development. Establishing a joint framework between the study of urban development and urban design remains an important task.³⁵ With their ideas about stability and persistence (Connell and Sousa 1983; Turner et al. 1993), obduracy (Hommels 2005a, b), structural permanence and emergence (Malfroy and Caniggia 1986; Weinstock 2010), the fields of fluvial morphology, landscape ecology, STS, and urban morphology offer compatible concepts. Where the long-term focus of environmental history, the study of physical form, urban studies and urban design meet, new insights can emerge.

Our research shows a general, long-term interaction of urban development with economic and political macro-developments playing out at a local level. Technology, territorial organisation and administrative competences all have a part in this. Certain types of water bodies foster the intensification of particular forms of human water use, which are associated with the development of adjacent urban areas. Practices centred on water trigger the materialisation of human interventions that follow their own logic.

The interplay between practices, arrangements and intensified urbanisation leads to the transformation of water bodies. Urbanites attempt to regulate flow, they channelise streams, reinforce and heighten banks for better flood protection. The modified waters consecutively enable, foster or exclude specific forms of human practices which feed back on the built environment.

The socio-natural hybridity of all human endeavour becomes clearly visible in the featured cases. They show that long-term studies are not only vital in understanding the genesis of urban water bodies as a product of socio-natural interaction, but also in grasping their material permanence and their impact on urban form. They teach us about the inertia of arrangements and the unforeseen perpetuation of site-specific effects of interventions, such as transportation infrastructure emerging from former water courses or economic dispositions inherited from obsolete patterns of water use. What transpires is a certain heteronomy of the city and its waters with regard to its inhabitants and its planners. This heteronomy is material and socio-cultural at the same time. Cascading problems and attempts to engage with them generate both physical and social urban development on different spatial and temporal scales. In order to inform, rethink and adapt the way we

³⁵ Recent works by Scheer (2010), Marshall and Çaliskan (2011), Dotson (2015) and Caputo et al. (2015) explore different sides of this endeavour. Planners had and will always have to deal with complex, 'wicked' problems (Rittel and Webber 1973), each being essentially novel and unique.

conceive of planning, we need to look at the past of nature-society interaction in urban contexts.

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