
– ARTICLES

– FROM THE SANITARY CITY TO THE CIRCULAR CITY? Technopolitics of Wastewater Restructuring in Los Angeles, California

VALENTIN MEILINGER AND JOCHEN MONSTADT

Abstract

This article follows the flow of wastewater in Los Angeles, California, from upstream treatment plants to the Pacific Ocean, to explore struggles over reconfigurations of urban wastewater flows for new policy ambitions in recycling and reuse. We show how ambitious infrastructure visions of circular urban resource management have gained force since California's most recent drought (2011–17) but clash with incumbent gravity-fed water and sewer systems, political economy and urban geographies. Engineers navigate these path dependencies through incremental technical improvements of existing infrastructures to increase wastewater recycling. These interventions largely reproduce given infrastructure configurations and urban geographies of water and wastewater while marginalizing other voices in struggles over water circularity and stymying critical debate about more progressive change. We argue that novel infrastructural practices are deeply political and normative and can be explained by four dimensions of the 'technopolitics' of wastewater restructuring in Los Angeles: materiality and inherited topologies of infrastructures; circularity discourses; entrenched knowledge cultures; and institutional orders of infrastructure management and public control mechanisms of infrastructure investments and tariffs. We conclude by discussing how these four dimensions of an emerging technopolitical regime of wastewater recycling expand concepts of power that explain urban metabolic change.

Introduction

The development of the city of Los Angeles into a modern metropolis features notoriously as a lively history of water infrastructure expansion realized by the Los Angeles Department of Water and Power (LADWP) and the Metropolitan Water District of Southern California (Reisner, 1993). The roll-out of gigantic water import systems has strongly shaped local and regional politics by catalysing Los Angeles' growth into the largest city in California, despite the semi-arid climate. While much has been

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written on Los Angeles' notorious history of water grabs from distant sources, much less is known about how urbanization was co-constructed by the expansion of subterranean sewer networks, which are managed by the Los Angeles Bureau of Sanitation (LA Sanitation). Gravity-fed sewers have been designed to effectively treat and discharge increasing amounts of wastewater¹ into the Pacific Ocean at the Hyperion Water Reclamation Plant (Sklar, 2008). Neighbouring an ensemble of Los Angeles' international airport, two power plants, an oil refinery, aerospace industrial sites as well as affluent beach communities, the treatment plant forms part of an iconographic landscape of twentieth-century Los Angeles (see Soja, 2014).

Today, the socio-technical regime of 'sanitary Los Angeles' is being exposed to increasing pressures that arise from water import restrictions, environmental policies and climate change (Hughes *et al.*, 2013) and from the high costs of maintenance and renewal. In the aftermath of California's most recent drought (2011–17), Los Angeles mayor Eric Garcetti (2019) announced that there will be 100% recycling of the city's wastewater by 2035. Planned wastewater recycling projects are envisioned to pave the way towards a 'circular Los Angeles' in which water circulates through a closed metabolic cycle of water use, wastewater treatment and water reuse to supply the prospering city. Redefining wastewater as a local water resource, this shift towards circularity has sparked a suite of technopolitical reconfigurations of sanitary Los Angeles' modern infrastructures and their urban geographies.

An extensive scholarship has discussed the politics of water management, urban ecologies and infrastructural growth in Los Angeles (e.g. Kahrl, 1983; Reisner, 1993; Erie and Brackman, 2006), and urban political ecologists have skilfully unveiled the socio-ecological ills and injustices of Los Angeles' modern urbanization (Davis 1999; 2006; Desfor and Keil, 2004; Gandy, 2014). Today, ambitious goals for circular urban water management are radically foregrounding infrastructure in urban politics. Circular economy discourses have made their way into engineering debates that present wastewater recycling as a promising technical fix for urban water scarcity (Bichai *et al.*, 2018; Hoffman *et al.*, 2020). As urban water policy is increasingly being shaped by technical concepts of water circularity, there is a growing need to critically examine the underlying social processes of technology and its political entanglements with urban metabolic change.

In this article, we scrutinize the technopolitics of urban wastewater recycling and their broader urban political salience by examining three issues. Firstly, we trace how new infrastructural practices and power dynamics that explain infrastructural change arise from discourses mobilized by progressive engineers, environmentalists and utility managers to promote wastewater recycling. Secondly, we explore the urban geographical and metabolic implications of infrastructural contestations about wastewater recycling. Finally, we demonstrate how hegemonic technopolitical regimes preclude alternative urban water practices.

We address these questions by drawing on the notion of 'technopolitics' to describe 'the strategic practice of designing or using technology to constitute, embody, or enact political goals' (Hecht, 2009: 56). To unveil Los Angeles' shifting technopolitics of wastewater, we pay close attention to the materiality of technology, to discourses and expert knowledge, and to institutional arrangements linked to technology (Mitchell, 2002; Hecht, 2009). Our focus on urban water and sewer systems is intended to expand recent work in urban studies on political actions through technology (Björkman and Harris, 2018; Cousins, 2020). We aim to study and explain interrelated urban and infrastructural change through technopolitical practices that emanate from the materiality of technical infrastructure, discourses on infrastructural renewal, and existing expert knowledge and institutional arrangements. This allows a materially

1 This does not include stormwater, which is managed in a separate system.

grounded analysis of urban politics around infrastructure that links infrastructural practices with the power relations embedded in urban technopolitical regimes. Furthermore, the study of infrastructure technopolitics enhances critical scholarship in urban political ecology by foregrounding how technology matters for urban metabolic change (Monstadt, 2009).

We begin empirically, by portraying the context of wastewater recycling in Los Angeles: visions of circularity clash with inherited socio-technical orders. Next, we uncover how water agencies navigate path dependencies and declining wastewater flows to maximize wastewater recycling. Incremental engineering interventions focus on retrofitting existing treatment plants at the ‘end of the pipe’, thereby marginalizing alternative practices and visions of a circular Los Angeles. These interventions conflict with revitalization plans for the Los Angeles River that take for granted that treated wastewater flows will continue to feed the river. A sustainability fix through technical retrofits leaves social orders of sanitary Los Angeles unchallenged. The discussion reveals how the interplay between given socio-technical orders and an emerging technopolitical regime of circular Los Angeles shapes path-dependent trajectories of change. Finally, we rethink the relations of power underlying urban metabolic change towards circular cities through infrastructure technopolitics.

We collected the empirical data for this article in three long research stays in Los Angeles between 2016 and 2019. Firstly, we qualitatively analysed planning and policy documents, technical manuals, legislation, newspaper articles and official statistics. Then we conducted 54 semi-structured, qualitative interviews with engineers and managers of Los Angeles’ water agencies as well as with politicians, environmental organizations, activists, private businesses and researchers. Our questions were intended to enable us to understand and explain the various actors’ interests and the actors’ technical or non-technical choices in their decisions on circular Los Angeles. In addition, we asked questions that examined connections between reconfigurations of wastewater flows and their distinct spatialities. Our qualitative content analysis centred on relating reconfigurations of wastewater flows to shifts and continuities in industrial structures, forms of expertise, governance structures of resource management, and concepts of technology and nature.

Recycling wastewater: from sanitary city to circular city

Contemporary practices of urban water and wastewater management can be seen as the historical product of a co-evolution of technology, scientific knowledge, shifting modes of economic production and reproduction, cultures of hygiene and the organization of the state (Gandy, 2014). Melosi (2008) traces the rise of the ‘sanitary city’ in nineteenth-century North America as the formation of a rationalized socio-technical regime of urban water, wastewater and solid waste management, designed to overcome limitations of urban development by preventing disease and ensuring pure drinking water.

Technically, the sanitary city’s sewer networks collect wastewater across the urban area, treat it in centralized plants and discharge treated wastewater into open water bodies. Hydraulic pipe design and gravity ensure an effluent metabolism: clean water is brought in upstream and treated wastewater is discharged downstream. Since the late nineteenth century, urban sanitation has evolved into a comprehensive technoscientific project, managing pollution at the ‘end of the pipe’ (Karvonen, 2011: 7–9). Instead of targeting high water consumption and wastewater production, innovation has focused on universalizing centralized sewer networks and improving treatment technologies. The sanitary city has cultivated a ‘professional bureaucracy’ (Melosi, 2008: 75) of highly developed water and wastewater industries with task-specific standards and regulations, budgeting practices, revenue models and patterns of service. High public spending, far-reaching public regulation and public ownership

turned the universalization of urban wastewater networks into a predominantly public endeavour (*ibid.*: 86). Over time, urban water and wastewater management have matured into distinct epistemic realms with specialized knowledge. In many cities, expertise, operational processes, and the governance of water and wastewater are organized in separate agencies with distinct institutional, financial and political control mechanisms (Pincetl, 2010: 45–46).

Overall, the operational logic of the sanitary city is geared towards a safe disposal of wastewater. Technical networks mediate the social differentiation of water as consumable good and wastewater as disposable public bad, which facilitates processes of valorization and devalorization of resources. However, since the 1990s the sanitary city's regime of resource extraction and waste accumulation has come under increasing criticism. Apart from the high operational costs of centralized sewer networks and their limited adaptability to changing urban environments, the model of a sanitary city has been criticized because it 'assumes a linear economy pattern ... and fails to ... take into account the exhaustible nature of natural resources' (Ghisellini *et al.*, 2015: 16) and natural assimilation capacities of human waste (Arup *et al.*, 2018). Sparked by discourses on a 'circular economy' or 'circular city', an abundant engineering literature has mobilized visions of circular urban wastewater systems targeting the recovery and revalorization of resources from wastewater (primarily water, energy and nutrients) (e.g. Bichai *et al.*, 2018; Hoffmann *et al.*, 2020). Wastewater reuse and recycling, particularly in dry cities, has been portrayed as a promising solution for urban water scarcity (Arup *et al.*, 2018). Different technologies are available: Non-potable reuse systems supply recycled water from the treatment plant via dedicated pipes for irrigation and industrial purposes. Indirect potable reuse is based on an environmental buffer such as a groundwater aquifer where recycled water is mixed with groundwater between the treatment plant and the reprocessing of the water for potable reuse. Direct potable reuse entails a fully engineered water metabolism in which the boundaries between wastewater treatment and water supply have been removed (Cotruvo, 2016). Other alternatives for resource recovery are the reuse of greywater from the laundry or the shower for garden irrigation, and more decentralized wastewater treatment and recycling facilities (see Hoffmann *et al.*, 2020).

Critical urban scholarship has scrutinized the uptake of circular economy and circular city discourses in urban policies (Savini, 2019; Williams, 2019) that pursue a 'technology-led dematerialisation geared towards resolving the tension between the scarcity of resources and economic growth' (Kębłowski *et al.*, 2020: 143). Technoscientific endeavours to revalorize waste informed by concepts in industrial ecology increasingly frame discourses and practices of urban and infrastructure development. Urban imaginaries of circularity through wastewater recycling are a case in point here. Nonetheless, scant attention has been paid to how those imaginaries materialize locally and how they are shaped by urban technopolitical regimes. Positioned at the interface of siloed water and wastewater institutions and industries, wastewater recycling implies conflictual reconfigurations of existing patterns of financing, resource management and governance. Crucially, it turns the sanitary city's operational logic of rapid waste disposal inside out. Modern ideals of sanitation, progress and control over nature are translated into a new—and fundamentally more complex—socio-technical form that is envisaged to supply growing cities with locally circulating water and other resources, to align water, wastewater and energy systems (at least partially), and to fix urban resource scarcity and pollution.

The technopolitics of changing urban infrastructures

Research on urban political ecology has greatly contributed to a deeper understanding of urban metabolic change of water infrastructures as a contested process that intersects with reconfigurations of the city's urban nature, its social and

technological fabric, and its cultural representations. Urban political ecologists have studied water infrastructures as an empirical entry to examining the politics of the urban metabolism that conceptualizes how social and biophysical processes co-produce urban nature in dialectic relationships (Gandy, 2004). Uncovering the uneven power relations underlying the production of urban nature is central to this scholarship (e.g. Swyngedouw, 2004; Heynen *et al.*, 2006). Water infrastructures feature not only as objects of policymaking but also as bearers of social meaning and mediators of material flows (Kaika and Swyngedouw, 2000). Other studies have focused on (storm) water infrastructures to criticize techno-managerial expertise dominating urban environmental management (Karvonen, 2011) or to explain socio-spatial injustice as an outcome of global–local histories of urbanization (Goh, 2019). Although the hybrids of technology and institutions, governance structures, expertise, cultural meaning and economic relations that constitute infrastructures are implicit in this work, they remain less explicitly analysed and conceptualized (Monstadt, 2009).

Urban infrastructure scholars read infrastructures as aggregates of technical artefacts linked to ‘actors, skills, knowledges, practices, cultural meanings and values, resources, money, and politics’ (Coutard and Rutherford, 2016: 13). With Hecht (2009), we argue that these multiple social and material elements of water infrastructures condense into place-based technopolitical regimes. They form a configuration of heterogeneous elements, combining technical materialities, discourses, a knowledge base, institutional and political components, etc., ‘which are rendered mutually interdependent and support one another’ (Callon, 2009: xiii). Often, the tight linkages between regime elements create ‘a self-perpetuating cycle of enormous stability’ (Gopakumar, 2020: 360) that is resistant to change beyond established development patterns, but is neither uncontested nor fixed (Monstadt, 2009). Thinking through the technopolitical regimes of a sanitary city reveals how current infrastructural decisions are linked to the engineering choices, values, knowledge and institutional arrangements prevailing when a sanitary city was constructed and consolidated, and how inherited configurations can compete with alternative visions of a circular city. We argue that the envisaged transformations from a sanitary to a circular city can be framed as a technopolitical process that is inextricably linked to urban metabolic change but is characterized by distinct social dynamics underlying technology and by the power relations technology enables. When the concept of technopolitics is applied to cities, it foregrounds the city’s physical artefacts that ‘are constituted through arrangements of power and authority that embody or enact political goals’ (Foley *et al.*, 2020: 324). To demonstrate this, we highlight and describe four dimensions of technopolitics: the mere *materiality of technology* limits political choices; *discourses* form a political force influencing infrastructural practices; *expert knowledge* inscribed into technology influences how actors partake in decision making; and *institutional arrangements* linked to technology shape infrastructural practices.

Firstly, political objectives of redesigning urban infrastructures are contingent on the materiality of technology. The sheer bulk of installed pipes, pumps, treatment plants, etc., hampers a radical recomposing of urban water and sewer infrastructures. These technical artefacts do not determine a specific course of action, but rather modify the ‘field of possibilities’ (Foucault, 1982: 221) for social operations and technical innovation in sewer systems, or what is perceived as ‘doable and not doable’ (Tiwale, 2019: 169). In particular, sewer networks that collect wastewater from all urban residents and transport it to centralized treatment plants define corridors of infrastructural change that are difficult to ignore. The limited compatibility of these networks with alternative approaches (e.g. decentralized wastewater reuse) restricts political choices and obstructs proponents of disruptive technologies. When novel social demands such as circular flow management appear, technical artefacts matter politically because they shape the practices of urban and infrastructure reconfigurations.

Secondly, discourses around urban water and wastewater management have significant impacts on practices. Together with Hajer (1995: 44), we argue that discourses can be defined ‘as a specific ensemble of ideas, concepts, and categorizations ... through which meaning is given to physical and social realities’. Common storylines form the basis of ‘discourse coalitions’ reflecting actors’ shared understandings and definitions of a given problem (Hajer, 1995). Discourses result from practices of ‘like-minded’ actors and, at the same time, produce, reproduce and transform a particular set of practices. In technopolitical regimes, discourses essentially surround distinct technical designs. Accordingly, storylines and imaginaries of urban wastewater as a local water resource enabled by recycling technologies constitute a broader political discourse that frames how circular urban water management is negotiated in practice, promoting distinct technopolitics while marginalizing technopolitical alternatives.

Thirdly, expert knowledge powerfully mediates urban infrastructural change. Mitchell (2002) underscores that modern expertise is not a given but is accomplished in material practice. Hegemonic expert knowledge, he argues, is frequently legitimated through the functionality of technical artefacts that are portrayed as embodiments of pure reason, while their messy histories and ambivalent decisions taken in the past are downplayed (*ibid.*: 36). With the rise of the sanitary city, knowledge hierarchies have been consolidated and inscribed in technical designs, institutionalizing expertise on how to design, operate, use and govern wastewater infrastructures. This hegemonic expertise, primarily of engineers and utility managers, can impede the deployment of alternative technologies and forms of knowledge required for these technologies, thereby constraining the political possibilities for urban technological change (Karvonen, 2011; Björkman and Harris, 2018). By delving into the relations between expert knowledge and technical artefacts, we can better understand how knowledge hierarchies are enacted and exert power.

Finally, the institutional embedding of urban infrastructures frames, and is itself altered by, the politics and practices of infrastructural change. Hughes (1983) famously illustrated how, throughout the evolution of large technical systems, distinct institutional arrangements arise together with technical designs. Taking this further, Hecht (2009: 16) understands technopolitical regimes as being ‘grounded’ in institutions; power emanating from these heterogeneous regimes frequently serves distinct institutional interests. Equally, in cities, practices in infrastructure management and governance are profoundly shaped by institutional orders (Monstadt, 2009), and infrastructural innovation depends on the openness and flexibility to change and readjust the ‘overall rules of the game’. For example, market rules, finance mechanisms and shared beliefs guide and structure infrastructure investments and the delivery and use of water and wastewater services. Other examples are hegemonic assessment criteria and standards of technical designs which obscure these designs’ inherent politics—that is, they can sustain distinct orders of rule and prevent technopolitical alternatives (Hecht, 2009: 323).

Altogether, we conceptualize urban infrastructural change as a technopolitical process shaped by materialities, discourses, knowledge and institutions. These dimensions, we argue, help trace technopolitical practices and their significance for wider urban metabolic dynamics. Using this perspective, we seek to explain infrastructure shifts and continuities and to critically question the urban technopolitical context of water circularity ambitions. Highlighting the underlying social dynamics and politics of infrastructures adds to scholarship in urban political ecology that is otherwise well equipped to unearth the social, ecological and spatial unevenness of urban production of nature under capitalism. Next, we scrutinize reconfigurations of wastewater flows to forge a circular Los Angeles by foregrounding technology as an important realm of negotiating urban metabolic change that brings together various human and non-human agencies.

The rise of sanitary Los Angeles

The story of Los Angeles' twentieth-century urbanization prominently features a powerful urban growth machine. Vast available land, booming industries, a cheap labour force and the expansion of infrastructure networks have been cobbled together by a local business elite to realize the suburban dream on the Pacific Ocean. Besides oil, water has arguably been the most important fuel of this booming 'infrastructural city' (Varnelis, 2009; see also Soja, 2014). The construction of modern water and sewer networks has turned Los Angeles into an urban machine of high water consumption and vast wastewater discharge: sanitary Los Angeles. Since the inauguration of the city-owned Los Angeles Aqueduct in 1913, large amounts of fresh water have been flowing by gravity into the Los Angeles Basin. Under rampant post-war urbanization, a culture of abundant consumption took root: booming industries required vast amounts of water, gardens became semi-tropical, and a hygienic culture emerged in the private bathrooms of Los Angeles' mushrooming single-family homes (Davis, 1999).

Since its foundation in 1902,² LADWP has ensured there is a reliable, abundant and affordable water supply for the city (Reisner, 1993). As one of Los Angeles' three proprietary departments (the others govern the harbour and the airport), LADWP operates as a quasi-independent public entity with its own board of commissioners. Water rates are subject to California's Proposition 218 (1996), which binds them to the per unit costs of service. At the same time, due to drastically reduced public investments after California's infamous local property tax cut measure Proposition 13 (1978), the public utilities rely on revenues from water sales (see Kirkpatrick and Smith, 2011). Since 2011, LADWP's tariffs have been controlled by a 'ratepayer advocate' (Hughes *et al.*, 2013: 55). This institutional architecture makes increasing water rates a politically sensitive issue, complicates the introduction of progressive rates that stimulate conservation by the largest water users, and leaves LADWP with a tight budget for investments. Meanwhile, LADWP's energy revenues are channelled into the city budget, constituting a 'profit centre for the city', as an interviewed water policy expert put it, while granting LADWP political leverage in city council decisions.³

Los Angeles' wastewater flows by gravity. Making use of the region's steep topography, a separate sewer system was steadily expanded throughout the twentieth century to discharge wastewater in compliance with the US Clean Water Act and to enable urban growth (Sklar, 2008). Today, Los Angeles' sewage disposal system intercepts some of the wastewater in two upstream treatment plants (Donald C. Tillman Water Reclamation Plant and Glendale Water Reclamation Plant) but deals with most of it downstream. Here, the Hyperion Water Reclamation Plant⁴ (formerly named the Hyperion Sewage Treatment Plant) treats about 80% of Los Angeles' sewage before channelling it into the Pacific Ocean (LADWP, 2016: 4–10). The Terminal Island Water Reclamation Plant uses advanced treatment to purify wastewater mostly from industries in a small collection area around Los Angeles' harbour.

Throughout Los Angeles' modern history, sanitation engineers have struggled with recurring sewer overflows caused by rapidly increasing volumes of wastewater. LA Sanitation is exposed to the same stringent tax regime as LADWP but is even more closely tied to city politics: the agency reports directly to the city council, operates with a substantially smaller budget and pays significantly lower salaries than LADWP. Historically, sewer rate increases were only politically approved when urban growth was threatened and when, in the 1980s, environmental pollution in the Santa Monica Bay sparked a large environmental movement fighting to 'Heal the Bay'.⁵ Only then

2 LADWP started to deliver electricity in 1917.

3 Los Angeles water expert (University of California, Los Angeles), interview, Los Angeles, 2 March 2018.

4 The Donald C. Tillman Water Reclamation Plant and the Hyperion Water Reclamation Plant are hereafter referred to as 'Tillman' and 'Hyperion' respectively.

5 The name of the environmental non-profit organization that was leading this movement.

was Hyperion upgraded with full secondary wastewater treatment to ensure a safer discharge of wastewater (Sklar, 2008: 196).

From a wastewater recycling perspective, however, the historical expansion of sanitary Los Angeles that was intended to solve the city's wastewater problem for decades to come appears to be far from satisfactory. In fact, since 1979, in the wake of a drought, wastewater has been recycled for non-potable purposes on a small scale at the Glendale plant. The Tillman plant came online in 1985, discharging its tertiary-treated effluent into the Los Angeles River. Today wastewater recycling is exclusively deployed to produce non-potable water for irrigation, indoor use (cooling, toilet flushing) and industrial purposes, and to block saltwater intrusion in groundwater basins around the Terminal Island plant. Despite the progressive discourse on wastewater recycling, the socio-technical structures of sanitary Los Angeles complicate a straightforward engineering of a circular water metabolism. Hitherto abstract concepts of circularity are taking shape in this environment, making visible the complex relationships between technology, water consumption, public policy, expert knowledge and urban space.

Assembling circular Los Angeles: from upstream treatment plants to the Pacific Ocean

Prior to 2014, when rules for indirect potable reuse came into force, wastewater recycling in California was restricted to non-potable reuse (LADWP, 2016: 4–8) and fragmented governance responsibilities stymied recycling in the state (Hughes, 2013). However, following the most recent drought in California, municipalities have increasingly mobilized discourses on circular water management that reframe wastewater as a local water resource. California's water industry has been diligently improving direct potable reuse technology, and a legal framework for it is due by 2023 (California State Water Resources Control Board, 2019). As noted previously, in 2019 Los Angeles mayor Garcetti announced that the city would be recycling all its wastewater by 2035. Despite ambitious recycling goals, between 2013 and 2018 imported water still accounted for 86% of Los Angeles' average annual total water consumption of 646 million m³ (City of Los Angeles, 2019). Currently, only about 10 million m³ of wastewater are recycled annually (LADWP, 2019b: 19). To explore struggles to achieve a circular Los Angeles, we will now follow the flow of wastewater in Los Angeles from upstream treatment plants to the Pacific Ocean.

– Maximizing 'infrastructure assets' at Tillman

The Tillman plant was constructed to 'scalp' wastewater flows upstream to prevent sewer overflows at Hyperion. Facing a severe drought in the early 1990s, LADWP instigated the East Valley Water Reclamation Project to maximize 'infrastructure assets' at the plant for wastewater recycling.⁶ The project envisaged groundwater replenishment on so-called spreading grounds north of Tillman. These vast water storage basins would be deployed to infiltrate recycled water into the San Fernando Groundwater Basin, where the city of Los Angeles owns substantial groundwater rights. This water would then be reused as a local resource and distributed by gravity through existing drinking water networks, thanks to the plant's high elevation (see Figure 1).

The \$55 million project ran only for a few days in 2001, until a secessionist movement that aimed to separate the San Fernando Valley from the city of Los Angeles rallied against it. Voicing mistrust in Los Angeles' water technocracy, the so-called toilet-to-tap campaign mobilized health concerns as a vehicle for its own political objectives and caused the project's failure.

6 Treatment plant manager (LA Sanitation), interview, Los Angeles, 21 February 2018.

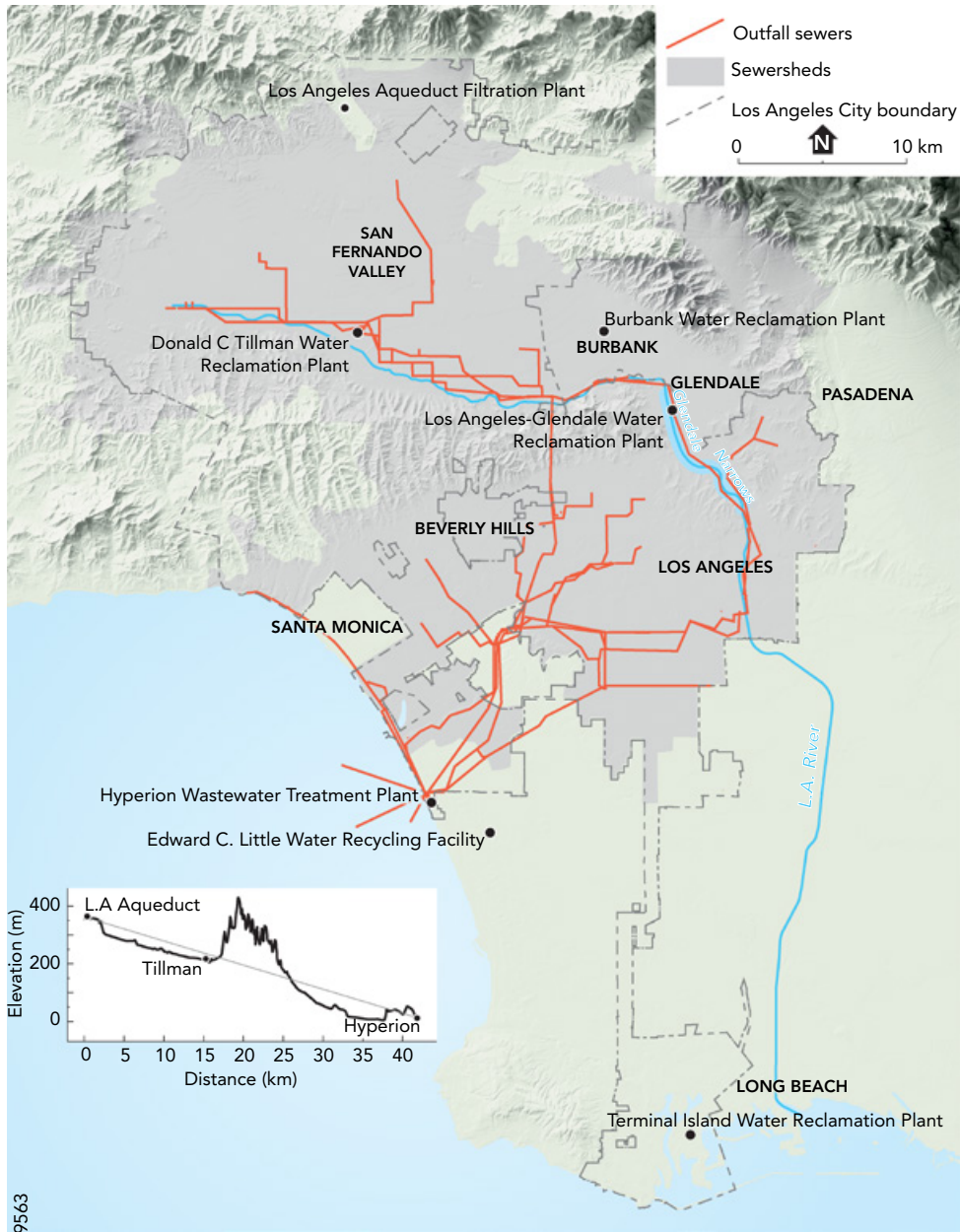


FIGURE 1 Los Angeles’ gravity-fed sewer system (map produced by authors with cartography by Ton Markus)

Only since 2012 have Los Angeles’ water agencies again embarked on a mission to improve the public perception of recycled water. Besides public education programs, treatment technologies came into focus as facilitators of the political success of wastewater recycling. Despite the better water quality at Tillman, the recycling plans for this plant mimicked ‘full advanced treatment’ technology that had been used by the Orange County Water District since 2008. This technology physically removes salts, microplastics and pharmaceutical contaminants, but it has proven to be energy- and

water-intensive, losing 20–25% of the treated water as a by-product of the treatment process.⁷ Nonetheless, to reduce political risk, managers opted for the technology to produce potable recycled water through groundwater replenishment at Tillman.

Meanwhile, non-potable wastewater recycling to supply golf course irrigation or industrial facilities through a separate pipe system has scarcely been expanded in recent years (LADWP, 2019b: 19). This is not only because new pipes are costly, but also because agencies fear economic risks and are wary of the health risks associated with non-potable recycled water.⁸ Furthermore, a decentralized wastewater recycling project in a San Fernando Valley brewery was opposed by LA Sanitation; as a local neighbourhood council member reported, the agency anticipated less wastewater would be available for recycling at Tillman.⁹ Public engineers are thus redesigning infrastructures to ensure control over wastewater flows and the end use of recycled water.

Wastewater recycling projects are realized by an expert community trained to manage and plan for increasing wastewater flows. However, urban and metropolitan water efficiency policies, and particularly the mandatory water conservation during California's most recent drought, have, for an LA Sanitation manager, resulted in a 'drastic reduction' of wastewater flows.¹⁰ These fell by 27%, from about 620 million m³ in 2005 to 453 million m³ in the peak drought year of 2016 (LA Sanitation, 2018: 2-4, 2-5). This is a major headache for water agencies. Not only do lower flows jeopardize recycling goals, but pollutants are more concentrated in the smaller volume of incoming wastewater, creating operational challenges. LA Sanitation finds itself in a financial trap: costs per unit of treated water are rising while infrastructure fixed costs remain relatively stable. As sewage fees were not adjusted, revenues have declined and investments must consequently be curtailed given the strict budgetary control of Los Angeles' water agencies. Lower flows thus invoke either politically sensitive rate increases or a decrease in investments.

Institutional arrangements require public servants to preserve a 'normality' of designing, operating and financing water and wastewater infrastructure in line with a supply-driven and growth-oriented management rationale established under Los Angeles' twentieth-century urban growth regime. In contradiction to this rationale, environmentalists push for further conservation of water to be achieved by raising water prices and by irrigating with greywater (laundry and shower water) to decrease flow in sewers.¹¹ Hence, LA Sanitation engineers, who generally mistrust homeowners operating greywater systems, have never embraced this technology and are seeking to centralize wastewater flows instead.¹² Besides efforts to increase the water efficiency of wastewater recycling technology, much has been done to reroute wastewater flows from other parts of the San Fernando Valley and dry-weather urban runoff that previously bypassed Tillman. That runoff is largely from Los Angeles' lush irrigated landscapes that environmentalists criticize as wasteful.¹³ Construction efforts and pumping against gravity to redirect wastewater flows risk building new material and energy inefficiencies into Los Angeles' emerging circular water metabolism.

Overall, by centralizing reduced wastewater flows at Tillman, water agencies seek to maximize infrastructure assets for the production of potable recycled water while minimizing political risk and ensuring managerial control over recycling. At the same time, this technopolitical strategy constrains decentralized wastewater recycling which redistributes responsibilities and could allow a more differentiated wastewater

7 The number is based on experiments at Tillman and taken from an interview with a treatment plant manager (LA Sanitation) conducted in Los Angeles on 21 February 2018.

8 Wastewater recycling manager (LADWP), interview, Los Angeles, 8 February 2018.

9 Member of Lake Balboa Neighborhood Council, interview, Los Angeles, 30 March 2016.

10 Treatment plant manager (LA Sanitation), interview, Los Angeles, 21 February 2018.

11 Greywater reuse activist, interview, Los Angeles, 5 March 2018.

12 Wastewater recycling manager (LA Sanitation), interview, Los Angeles, 13 March 2018.

13 Environmental activist and horticultural expert, interview, Los Angeles, 13 March 2019.

reuse tailored to local purposes. But rationalizing Tillman for wastewater recycling has even wider urban political ramifications. Los Angeles' water agencies are determined to hold back about 25 million cubic metres per annum (25 million m³/a) of treated wastewater at Tillman that currently sustains the ecosystem of the Los Angeles River (LA Sanitation, 2018: 5–35), which clashes strikingly with revitalization visions for the river.

– Circular Los Angeles' contested urban nature: the Los Angeles River

It is difficult to identify any characteristic of the contemporary Los Angeles River that evokes imaginaries of an unimpaired river ecosystem. To protect Los Angeles from flooding, the river channel was largely concretized in the 1930s. Gang activities and pop culture have created a lasting civic imaginary of the bleak flood-control channel as a space of danger and public neglect. Meanwhile, working-class and Latino communities neighbouring the river share a long history of contesting this 'health-threatening urban landscape' (Gandy, 2014: 177). Not until the mid-1990s did two master plans, one from the US Army Corps of Engineers for flood control and the other from Los Angeles County, bring the river back onto Los Angeles' environmental policy agenda, seeking to revalue the river as a community asset for labour reproduction (Desfor and Keil, 2004). Since 1986, the environmental organization Friends of the Los Angeles River has committed to transforming this 'flood-control channel' into a 'natural' river habitat.¹⁴

Today, the river restoration group's activities are concentrated in the Glendale Narrows north of downtown Los Angeles (see figure 2), one of the river's rare soft-bottom stretches that has made its way into the public imaginary: persons arriving at Los Angeles' airport are greeted by a poster of Mayor Garcetti kayaking through the Glendale Narrows and welcoming visitors to Los Angeles 'where nature catches you by surprise'. Plans by the City of Los Angeles (2007) and private engineering firms (Aecom, 2018) envision the Los Angeles River as a blue-green ribbon with ample flow and lush vegetation catalysing urban development alongside its downtown riverbanks. Although the riverbed has not yet been touched, public debates have heated up. Neighbourhood activists have struggled to fight rising land prices that are fuelling neighbourhood change in former working-class neighbourhoods. Meanwhile, a long-awaited master plan from renowned Los Angeles architect Frank Gehry has sparked further fears—and hopes—of gentrification.¹⁵

A view of the Los Angeles River through the lens of wastewater recycling highlights a socio-technical complexity that is glossed over in river revitalization visions. Since 1985, Tillman has been committed to providing 37 million m³/a treated wastewater to the Los Angeles River, which accounts for a major share of treated wastewater from upstream treatment plants that discharge into the river.¹⁶ In total, an average of about 140 million m³ of water currently ripples down the river each year (Mika *et al.*, 2017: 76). Since the construction of Tillman, discharges of treated wastewater and increased urban runoff entering the river through urban development have changed the river's flow regime drastically; flows have more than tripled in volume (*ibid.*). Whereas prior to urbanization the Los Angeles River regularly dried up in summer, urban runoff and treated wastewater now uphold a continuous flow that has also led to invasive plant species colonizing the riverbed.

Wastewater recycling plans at Tillman imply a radical transformation of this river ecology. Firstly, concentrating wastewater flows at Tillman for recycling strikingly contradicts river revitalization visions that take ample flows in the river for granted. Assuming widespread implementation of stormwater capture infrastructure (less urban

14 Environmental activist (Friends of the Los Angeles River), interview, Los Angeles, 30 January 2018.

15 Social justice activist (Elysian Valley Neighborhood Council), interview, Los Angeles, 2 April 2018.

16 Treatment plant manager (LA Sanitation), interview, Los Angeles, 30 March 2016.



FIGURE 2 The Los Angeles River in the Glendale Narrows (photo by Valentin Meilinger, January 2018)

runoff entering the river) and the reuse of 100% of the treated wastewater that currently feeds the river, Mika *et al.* (2017: 49) predict that flows in the river are likely to drop to zero. Los Angeles' neighbouring municipalities have already filed petitions to reuse wastewater that currently sustains the river.¹⁷ While protesting the city of Burbank's petition, LADWP managers opted to withdraw about 25 million m³/a wastewater from the river for use at Tillman.¹⁸ This technopolitical strategy threatens environmentalist desires for a 'swimmable, boatable, fishable, bikeable river for all' (Friends of the Los Angeles River, 2020) and urban redevelopment interests that exploit such desires to increase land values. Secondly, wastewater recycling plans are intensifying the modernization of the Los Angeles River. Los Angeles' water agencies have proposed engineering solutions such as rubber dams to sustain the river's present-day ecosystem in some areas while maximizing recycling. But LADWP managers also link flow reductions to a vague narrative of restoring a pre-urbanization habitat: 'native plants that *should* be in the river ... want less water' (emphasis in original).¹⁹ They are thus arguing, in line with specific nature conservationist viewpoints, that the 'predevelopment condition is what defines the higher environmental use' (The Nature Conservancy, 2016: ES-3). Nonetheless, while environmentalists advocate expanding riparian wetlands for flood control and removing concrete banks,²⁰ water agencies plan for a *highly engineered* flow

17 Taking water from open water bodies requires permission from the California State Water Resources Control Board. Glendale's public water utility has applied for permission to reduce discharges to the Los Angeles River by 2 million m³/a. Burbank has filed a petition to reduce discharges by over 4 million m³/a (California State Water Resources Control Board, 2017a; 2017b).

18 Wastewater recycling manager (LADWP), interview, Los Angeles, 2 March 2018.

19 Wastewater recycling manager (LADWP), interview, Los Angeles, 8 February 2018.

20 Environmental activist (The River Project), interview, Los Angeles, 7 February 2018.

reduction that is driven by the rationale to utilize Tillman's unused treatment capacities for wastewater recycling, but not by imaginaries of riparian ecosystems.

In sum, we observe that with wastewater recycling ambitions, the Tillman plant has become a political force in contestations over the Los Angeles River. The collective call from engineers, non-profit organizations and politicians for a scientific study to determine 'the proper flow regime for a healthy riparian ecosystem' can be read as an attempt to legitimize future interventions in the river.²¹ However, diverging epistemologies of urban nature obstruct the hopes for scientific truth about a 'natural' river ecosystem and call for a political solution to coordinate plans for the river and circular Los Angeles.

- Repurposing the Hyperion treatment plant, Los Angeles' 'last collector'
Most of Los Angeles' wastewater flows and political debates about recycling gravitate towards the Hyperion treatment plant—sanitary Los Angeles' 'last collector'.²² After a drought in 1991, LA Sanitation started to convey a small share of Hyperion's treated wastewater to the Edward C. Little Wastewater Recycling Facility in the West Basin Municipal Water District (see figure 1). This facility seized the early opportunity to buy 48 million m³/a of Hyperion's 'surplus water' for an extraordinarily low price, to recycle it for non-potable reuse in nearby oil refineries.²³

Although Hyperion has not undergone any larger material changes since then, many environmental organizations, water agencies and politicians are now determined to tap the plant's 'river of treated wastewater that pours into the Pacific Ocean' (Boxall, 2019). In early 2019, Mayor Garcetti announced bold plans to fully repurpose Hyperion as a *recycling* facility. Technical upgrades would equip Hyperion with advanced treatment technology for LADWP to use the highly purified water for recharging groundwater. In conversations with city-adjacent water agencies that hold pumping rights and own water distribution networks and groundwater injection wells in the region, selling and pricing mechanisms are negotiated for the retrieved potable water. In total, the estimated project costs amount to \$8.1 billion over the next 25 years (LADWP, 2019a).

But sanitary Los Angeles' socio-technical regime holds many uncertainties for Hyperion's future. Firstly, existing gravity-fed sewers complicate change: the conveyance of recycled water to groundwater injection wells further inland from Hyperion entails not only heavy construction but also great pumping efforts and high energy costs due to Hyperion's location at sea level. Reconfiguring Hyperion is thus technically complex, requires huge financial investment and is hampered by the limited space available at the plant.

Secondly, groundwater recharge with recycled water engenders governance challenges due to regionally fragmented groundwater rights. In the 1960s, in response to unsustainable groundwater extraction, strictly restricted pumping rights were adjudicated to a plethora of historical pumpers, from private businesses to water districts (Ostrom, 1990). Complex governance structures that have co-evolved with the construction of a regional water import system (Pincetl *et al.*, 2016) and the urban-political fragmentation of metropolitan Los Angeles (MacKillop and Boudreau, 2008) can only be redesigned in meticulous negotiations—and in parallel with socio-technical change.

Finally, the separate industrial and institutional structures of water and wastewater management in Los Angeles obstruct change. Local tax restrictions in California and strict public control of siloed water and wastewater revenues through

21 Wastewater recycling manager (LADWP), interview, Los Angeles, 8 February 2018.

22 Wastewater recycling manager (LADWP), interview, Los Angeles, 22 March 2016.

23 Treatment plant manager (West Basin Municipal Water District), interview, Los Angeles, 22 February 2018.

Proposition 218 leave little leeway for financing wastewater recycling because the technology lies at the interface of water supply and sanitation financing. At Hyperion, this means that LA Sanitation has no institutional incentive to raise sewer service charges for investments in treatment or recycling technologies that exceed the requirements of the US Clean Water Act. Nonetheless, repurposing Hyperion involves technology managed by LA Sanitation and implies costs for the agency, although only LADWP benefits from selling more recycled water. But since LADWP neither operates the plant itself nor has the expertise to do so, heavy investments in Hyperion involve risks.

Under these conditions, and with most of Los Angeles' wastewater concentrating at the plant, Hyperion is simultaneously a huge barrier to and the key site for creating circular Los Angeles. Wastewater recycling pilot projects at Hyperion become crucial arenas in achieving a circular Los Angeles. An advanced wastewater treatment project to supply Los Angeles' airport with water for non-potable purposes is intended to be preparation for wider technical reconfigurations: 'once we perfect that [pilot], we can just expand on that as we move along'.²⁴ Despite the current political directive to replenish regional groundwater basins with Hyperion's treated effluent, purification technology is being tested and new regulations are under way to clear the path for direct potable reuse in California. To remove the salts accumulated at Hyperion, any wastewater recycling alternative at the plant will have to highly purify the incoming wastewater. Engineers thus consider it a 'waste' to infiltrate recycled water into the ground before using it; once purified, the water could be sold immediately.²⁵ Hence, once regulations are in place, LADWP managers are determined to deploy direct potable reuse at Hyperion (Boxall, 2019).

Evolving in parallel, technical and regulatory innovation and political debate about recycling continuously reshape possible wastewater recycling futures in Los Angeles. Although the pilot projects are addressing a negligible part of Hyperion's total operations, they are establishing new operational procedures as well as patterns of financing and selling recycled water. The ultimate goal is to bypass siloed industrial and governance structures and overcome technical challenges. The technical knowledge created allows water agencies to portray the repurposing of Hyperion as the preferable option for enhancing Los Angeles' local water supply, while decentralized wastewater recycling or institutional reforms are averted. The enormous economic and political costs water agencies have invested in Hyperion are the rationale for such a strict focus on the plant. Together with the city council's fear of antagonizing voters by raising rates, this material obduracy defines the parameters, scope and objectives of realizing visions of wastewater recycling in Los Angeles.

Engineering circularity on sanitary foundations

Over the last 20 years, engineering and policy discourses on water and wastewater management in Los Angeles have changed fundamentally and presently centre on visions of urban water circularity. Nonetheless, material orders of sanitary Los Angeles persist. The configuration of Hyperion as an ocean discharge plant, sewer infrastructures at Tillman and the Los Angeles River's hybrid nature—all massive and capital-intensive artefacts—need to be thoroughly redesigned to engineer a closed water loop. Furthermore, infrastructural change is contingent on existing social orders, especially on entrenched knowledge cultures, separate water and wastewater agencies, the public control of infrastructure tariffs and investments, and a culture of abundant water consumption. Struggles over wastewater recycling take place between the socio-technical orders of sanitary Los Angeles and an emerging technopolitical regime of circular Los Angeles (see Table 1).

24 Treatment plant manager (LA Sanitation), interview, Los Angeles, 21 February 2018.

25 Wastewater recycling manager (LADWP), interview, Los Angeles, 8 February 2018.

TABLE 1 Dimensions of historic technopolitical changes of wastewater in Los Angeles

	Sanitary City Los Angeles	Circular City Los Angeles
Discourses	Ample water supply through water imports and safe wastewater management through 'end-of-pipe' treatment and disposal	Safe wastewater management, local water supply and independence from purchased water imports through recycling of 100% of Los Angeles' wastewater
Technology	Centralized, gravity-fed wastewater disposal system with upstream scalping plants and Hyperion as 'last collector'	Closed urban water loop with direct/indirect connections between water supply and treatment
Material flows	Effluent flow regime with neat separation between water and wastewater	Circular flow regime in highly engineered and integrated water metabolism
Epistemic structure	Rationalization of operational processes to manage wastewater flows between point of consumption (toilet flush) to point of centralized disposal	Blurring of epistemic boundaries between water supply and sanitation; new areas of knowledge (e.g. water 'purification')
Industrial structure	Siloed regulations, management structures and procedures, revenue streams and patterns of service provision for water supply (LADWP) and sanitation (LA Sanitation)	New interfaces between water supply and sanitation; painstaking renegotiation of tariffs for purified water and technical reworking of modern sanitary culture
Governance structure	Separate water supply and sanitation agencies: LA Sanitation controlled by city council, LADWP with own board of commissioners and powerful union	Project-by-project collaboration to pre-empt strong opposition to institutional integration of LA Sanitation and LADWP and lock-in by city charter
Operational logic	End-of-pipe solution for disposal of wastewater as public bad and to accommodate urban growth	Vision of risk-free and inexhaustible recycling of wastewater as public good to sustain urban growth
Ideas of nature	Modernist separation between nature and society mediated by technology; external nature as resource and sink	Intensified modernization: new forms of separation between society and nature mediated by technology

Tracing ongoing reconfiguration of the gravitational flow of Los Angeles' wastewater, we identified four central technopolitical dimensions that explain how circularity visions materialize in Los Angeles: discourses on wastewater recycling; material obduracy and inherited topologies of water and wastewater infrastructures; local expert knowledge; and persistent institutional arrangements of sanitary Los Angeles.

Firstly, infrastructure reconfigurations are driven by a hegemonic discourse of water circularity that portrays recycled wastewater as Los Angeles' future prime local water supply, allowing the offsetting of purchased water imports. While accepted across the city as a general aspiration, this discourse sustains an emerging technopolitical regime of centralized wastewater recycling. At its heart, recycling pilot projects at the Hyperion plant nourish this discourse, rebranding Hyperion as the central site of circular Los Angeles where a river of unused wastewater can be 'tapped'. Furthermore, this vision entails a reframing and refutation of hygienic concerns with recycled wastewater in public discourse, achieved through improving recycling technology. At the same time, decentralized solutions for wastewater recycling or greywater reuse remain caught up with hygienic concerns and fail to become part of a rising circular Los Angeles discourse.

Secondly, circular water ambitions are faced with Los Angeles' urban context of centralized, gravity-fed water and sewer networks that were built to cope with a crisis of ocean pollution caused by explosive post-war urbanization. By design, these networks hamper a more distributed reuse of recycled wastewater or greywater in private homes and businesses or on industrial sites. But what also explains the centralized recycling regime is the focus of policies and infrastructural practices for circular Los Angeles on existing treatment plants. At Hyperion, utility managers and political leaders highlight vast unused capacities for wastewater recycling when outlining a future of direct potable water reuse *within* Los Angeles' city limits. While retrofitting Hyperion aims

at minimizing the economic risks of regional groundwater recharge, it implies high energy costs for the advanced treatment of recycled water and its redistribution against gravity (Porse *et al.*, 2020). More generally, the technopolitics of fixing water scarcity through wastewater recycling at the ‘end of the pipe’ defer pressing questions about the way water is consumed, managed and governed in Los Angeles. Water rate increases to finance retrofits of existing technology are justified with techno-economic reasoning: water from centralized recycling plants is expected to be cheaper than purchasing imported water. As a result, such strategies repel the calls of environmentalists for water rates that stimulate water conservation. In the San Fernando Valley, ‘infrastructure assets’ at Tillman enable a technopolitical agenda of concentrating scarce wastewater flows in the plant to produce potable recycled water that creates future revenues for LADWP. Meanwhile, alternative circular water futures through greywater reuse and distributed wastewater recycling are discouraged or actively opposed by LA Sanitation. Equally significant, in the absence of a political initiative that lifts conflicts between wastewater recycling and river revitalization plans to the centre of public debate, the shifting technopolitics of wastewater at Tillman become active agents in creating Los Angeles’ urban nature.

Thirdly, managing water and wastewater in Los Angeles is organized in separate expert tasks of LADWP and LA Sanitation. In struggles over circular Los Angeles, this hegemonic knowledge that is built into inherited infrastructure networks encounters other knowledges and diverging epistemologies of urban nature. Nonetheless, entrenched epistemic cultures centred on controllability, safety and reliability, once established to provide sanitation and ample water for a booming twentieth-century metropolis, continue to guide the actions of Los Angeles’ water agencies. Water managers follow those principles to justify their operations and investments to the public. In pilot projects at Hyperion, new technical expertise is also developed that is geared towards treating the water to the highest level to secure revenues. As a result, the political complexities of public infrastructure financing and regional politics are reduced to questions of engineering. Conversely, neither knowledge of decentralized recycling nor the expertise of greywater systems installers is generally being used when framing circular water policies. The technopolitics of incremental innovation thus actively reproduce hierarchies of knowledge that marginalize socio-technical alternatives. Furthermore, centralized recycling takes little account of environmentalists’ expertise on the sources of wastewater production and these sources’ entanglements with the built environment, lifestyles and economic activities across the city. Instead of preventing entry of certain materials at their source (e.g. micropollutants such as microplastics or pharmaceuticals) and separating highly polluted or toxic wastewater flows for treating them in decentralized plants, circularity initiatives prioritize the mitigation of water scarcity only. Sustaining incumbent expert knowledge in LA Sanitation in operating and retrofitting centralized systems leaves inherited urban geographies of wastewater in place. Finally, whereas since the 1990s revitalization discourses have ‘downplayed the artificiality of the ... river’ (Gandy, 2014: 181), wastewater recycling ambitions strikingly expose this artificiality. But vague revitalization debates disregard the river’s hybrid nature and many controversies over the river play out at the level of technical flow reconfigurations. Uncovering epistemological differences and digging into the river’s artificiality thus help to critically analyse interventions of urban developers, environmental organizations, politicians and LA’s water agencies, all of which claim to act in the name of ecological restoration and the wider public interest.

Fourthly, practices of Los Angeles’ water agencies to incrementally innovate wastewater recycling at the ‘end of the pipe’ have become the dominant rationale and political force for realigning water, wastewater and urban life in a circular water metabolism. These particular practices are rooted in persisting institutional orders of sanitary Los Angeles. LADWP decides on investments and technical interventions

according to cost-efficiency goals for a safe, abundant and affordable water supply. LA Sanitation has traditionally considered wastewater to be a cost item, not a potential source of revenue. Although wastewater recycling distorts the cost-benefit patterns of LADWP and LA Sanitation, both agencies and LADWP's labor union fiercely oppose any attempt at institutional integration, which would also require an amendment to Los Angeles' city charter.²⁶ Nonetheless, as revenue-dependent industries and with a strict public control of tariffs, both agencies seek to minimize risks. Incremental innovation practices thus help secure revenue streams for Los Angeles' siloed water agencies in circular water futures, thereby sustaining an institutional set-up that seems increasingly dysfunctional in a circular city. Utility managers justify such incremental innovation solely with hegemonic techno-economic reasoning of mediating water scarcity. Yet this reasoning downplays an inherited consensus on low water prices and vested institutional interests that are inseparable from ongoing engineering interventions. Conversely, environmentalists' interests in the Los Angeles River or their demands for locally more differentiated wastewater recycling fail to be widely accepted as hegemonic infrastructural practices in an emerging circular Los Angeles.

Conclusion

Wastewater recycling in California has seen an immense advance since the state's most recent drought (2011–17). Aiming to repurpose its modern sewage plants for wastewater recycling, Los Angeles joins the ranks of many dry cities around the world that are mobilizing circular economy discourses and embracing large-scale engineering projects to enhance local water supplies. This article has analysed struggles over reconfiguring wastewater flows to create a city in which water is reused in a locally more circular water metabolism—the envisioned circular Los Angeles. To expose the distributed agencies involved in this urban reconfiguration process, we have applied to the city the concept of technopolitics that locates power in hybrids of technology and political practice. In particular, the notion of urban technopolitical regimes, which we have applied here to circular Los Angeles, can bring attention to how the politics of the urban metabolism are co-constituted through infrastructural practices. Thus, technopolitical regimes form nodes of power in the urban metabolism that have their own inner workings that result from context-specific practices shaped by technical artefacts, discourses, institutions and knowledge.

Public engineers in Los Angeles are retrofitting existing technology to promote wastewater recycling as a sustainability fix for urban water scarcity. Obdurate technical artefacts, together with entrenched expert cultures and a rigid public control of water and sewage tariffs, explain the creation of circular Los Angeles at the 'end of the pipe'. These technopolitics of incremental innovation reduce political questions about how water is consumed, managed and publicly governed in Los Angeles to technical problems addressed by path-dependent engineering practices. As a result, other possibilities for urban metabolic transformation, such as water saving, decentralized wastewater recycling, greywater reuse or energy recovery from wastewater, are marginalized. Similarly, conflicts over flows in the Los Angeles River associated with shifting technopolitics of wastewater are rarely subjected to open political debate on how to better align plans for the river restoration and for circular Los Angeles. Overall, we argue that considerable socio-technical change towards wastewater recycling and reuse is taking place in Los Angeles. However, this change projects the inherited technopolitical orders and geographies of water supply and wastewater management into the future through additive technologies and institutional arrangements. Understanding how trajectories of infrastructure change are achieved through technopolitics and with

what effects advances debates about urban technology and infrastructure, urban environmental politics and the politics of urban space in three ways.

Firstly, infrastructural artefacts act as urban metabolic mediators that both enable and are shaped by distinct technopolitical strategies. This article shows how the material obduracy of technical artefacts and political practices oriented towards these artefacts can narrow the political pathways of metabolic change despite radically altered imaginaries of the ‘circular city’. Adding to concepts in urban political ecology, this finding underscores the political relevance of distinct technical characteristics of infrastructural artefacts that are foregrounded in political decisions about urban metabolic change. In this way, urban technopolitical regimes expand or secure influence over urban nature and space. In addition, centralized wastewater recycling in Los Angeles has geographically extensive energy and material footprints, which demonstrates how urban technopolitical regimes wield power over metabolic processes beyond city boundaries (Connolly, 2019).

Secondly, the Los Angeles case suggests that technopolitical power emanating from dynamic entanglements between expertise and technical artefacts shapes urban metabolic change. Here knowledge hierarchies are frequently rooted in technical artefacts of past urbanization. This might partly explain why hegemonic techno-managerial forms of urban environmental governance have persisted, as discussed by urban political ecologists (Karvonen, 2011). As inherited artefacts become key foci of novel environmental policy and infrastructural reconfigurations, alternative knowledges may rarely achieve the status of ‘expertise’ in aspired urban circular futures. Thus, urban futures contingent on alternative knowledge are stymied. Technical concepts of circular resource management that are realized in entrenched knowledge regimes of urban infrastructures therefore need to be scrutinized as emerging forms of governing urban nature and space.

Finally, applying to the city Hecht’s (2009) emphasis on technopolitical regimes as ‘grounded’ in institutions can help politicize what is considered ‘normal’ urban infrastructural and related urban metabolic change. This perspective can draw the focus to how institutionalized political economies of urban infrastructures come into being through political practices oriented towards technology. We have highlighted the fundamentally more complex form of an emerging circular Los Angeles through which institutional orders of a tax-constrained public infrastructure financing in California are preserved. Beyond Los Angeles, scrutinizing the technopolitics of large-scale engineering can thus enrich critical urban studies of political economies of urban infrastructure.

Adding to a nascent critical scholarship on circular cities, we argue that an urban technopolitics lens helps reveal how circular city imaginaries and discourses matter politically and how they are actually translated into urban and infrastructural practices. Such a research agenda examines how a technology-led revalorization of waste to fix resource scarcity and environmental pollution gives rise to technopolitical regimes that become powerful governing forces of urban space.

Valentin Meilinger, Department of Human Geography and Spatial Planning, Faculty of Geosciences, Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands, v.u.meilinger@uu.nl

Jochen Monstadt, Department of Human Geography and Spatial Planning, Faculty of Geosciences, Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands, j.monstadt@uu.nl

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