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Stormwater Politics: Flooding, Infrastructure, and Urban Political Ecology in São Paulo, Brazil

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ABSTRACT: This paper analyses an ongoing paradigm shift in how engineers have responded to the persistent problem of flooding in São Paulo, Brazil. Until recently, civil engineers largely attempted to expel water from the landscape as fast as possible. Over the past three decades, however, engineers have begun to articulate new mechanisms for responding to flooding that store stormwater in the urban landscape. In this paper, I analyse the construction of what are commonly referred to as piscinões, large-scale detention ponds that pool stormwater in the event of heavy rain events. Drawing from literature in urban political ecology, I argue that piscinões attempt to correct for a complex and unequal landscape, but that they do so in a way that mainly prioritises large-scale engineering solutions to the problem of flooding. As such, in spite of being hailed as indicative of a paradigm shift in flood management, piscinões are instead a continuation of the city's broader hydraulic and urban paradigms. In response, I consider alternative approaches to the development of multifunctional piscinões that could serve both social and ecological aims. Ultimately, however, I draw from urban political ecology to argue that flooding is fundamentally a political problem that requires a political solution.

KEYWORDS: Water, infrastructure, flooding, climate change, urban political ecology, São Paulo, Brazil

INTRODUCTION

Persistent flooding marks São Paulo, Brazil, a megacity in a metropolitan region of roughly 20 million people. Floods are a product of the city's location in a floodplain and are also due to its subtropical climate and the explosive urban growth that the city has undergone over the last century. Current climate change predictions suggest that the city will experience heightened rain events in the decades to come and that the problem of flooding will likely worsen (Geraque, 2013; Lyra et al., 2017; Nobre et al., 2010). In the past three decades, the nature of how floods are dealt with in São Paulo has shifted as engineers have attempted to move away from long-standing paradigms that call for removing water from the city as fast as possible, towards paradigms that incorporate water into the urban landscape.

In this paper, I trace the ongoing shift in the nature of flood governance in the city, observing its movement from a previous "hygienic vision" (Canholi, 2014) which is marked by the rapid removal of stormwater, to one marked by the retention and detention of floodwaters in the landscape itself. I focus in particular on a shift in flood governance that is oriented around the construction of large-scale detention ponds, referred to colloquially as *piscinões* (Figure 1). Piscinões are concrete pools that create space for stormwater in the urban landscape as a means of dampening flood events. They draw water in from existing streams (typically channelised) and temporarily delay its re-entry back into the waterway, reducing the flood peak and, ideally, reducing overall flooding. Piscinões are celebrated by engineers throughout São Paulo as a paradigmatic change in flood management and as a simple (and at times elegant) solution to a complex problem. They are less popular among urban residents and critics, who allege that they are overbuilt, unmaintained, and destructive to the urban fabric.

The piscinão is understood as a paradigmatic shift in design responses to flood prevention in São Paulo; the logic, however, remains fundamentally linked to the provisioning of large-scale infrastructure that is designed and built by state entities like the Department of Water and Electrical Engineering (DAEE) in association with private sector engineering firms. They are a deeply "promethean" (Kaika, 2005) response that reflects the critical and persistent role played by engineers in shaping São Paulo's built form (Bueno, 1994). The emphasis on large-scale flood prevention infrastructure in São Paulo is a reminder that promethean infrastructural ambitions remain present throughout the world; they are linked to the relationships between engineering, urban governance and construction enterprises that shape the form of the city (Björkman and Harris, 2018; Usher, 2018). This is a universal story, but it is also one with special resonance in São Paulo given its long history of governance by engineers and the deep entanglements between the state and construction/engineering firms (Bueno, 1994; Haag, 2010; Peixoto-Mehrtens, 2010).

Figure 1. Piscinão in São Paulo; water enters from the right via a tunnel located under the roadway.

Source: Author's photo.

I subsequently argue that the piscinão is reflective of a vision of water and city that understands water as a threat to be managed; I maintain that, as such, it forecloses or stalls the possibilities of multifunctional solutions to flooding that could prioritise water quality and even social/civic life. This vision of water is articulated by hydrological engineers and draws on existing circuits of expertise, knowledge exchange, and capital. It is framed as the only possible response given the city's complexity and its disorganised urban form. This is a vision that is undoubtedly true in many respects given the scale and complexity of São Paulo's urbanisation process; however, piscinões as they are currently designed further degrade the urban landscape in ways that reflect the long history of engineer-led urban

interventions in the city. While they are framed as a necessary response to a disorganised urban environment, they further add to the chaos in ultimately regressive ways. As such, their presence in the city should be engaged with critically, in and beyond their effect on flooding.

As part of this argument, I consider counter projects for managing stormwater that have been developed by architects, designers, artists, activists and engineers. These projects take seriously the need for a multifunctional engagement with water, calling for flexible, creative projects. They often do not move beyond the design stage, but they speak to emergent possibilities that could nevertheless anchor measures that are ultimately less destructive of the urban fabric. While they may also be stopgap interventions (Buck et al., 2020) given the pace of São Paulo's urbanisation process, they speak to possibilities that deserve to be taken seriously. In addition to the more speculative projects developed by artists, designers drawing from green infrastructure and nature-based solutions have created possible designs for greener forms of stormwater management in São Paulo. I consider these as well.

While encouraged by these projects, I ultimately suggest the need for a political response to flooding that understands the social and political production of flood events. I draw from a foundation in urban political ecology (UPE), a theory of the mutual co-constitution of the city and nature that pays attention to the ways that urbanisation produces specific forms of what Gandy (2002) calls "metropolitan nature" (see also Bakker, 2010; Swyngedouw and Kaika, 2014; Swyngedouw, 1996). An approach to flooding that takes insights from UPE seriously would prioritise expansive interventions into the urban landscape that exceed the spheres of engineering and water governance; it would also situate the management of flooding within a broader understanding of the urbanisation of nature and the deep links between the urban landscape and the sociopolitical dynamics that underpin it. Based on an understanding of infrastructure provisioning as being deeply political in nature, I argue that flooding is fundamentally a political challenge and not an engineering one. Without a willingness to grapple with the city's unequal urban form, it is hard to see a solution to the problem that could be adequately scaled to the challenge. While this seems nearly impossible given the scale and scope of São Paulo's inequality, the reality is that a number of policies are already in place that need only to be implemented.

METHODS

This paper draws from a broader project that involved an approximately six-year engagement with the politics of water in São Paulo; it included semi-structured interviews with state officials, civil engineers involved in flood prevention, community activists interested in water governance, and members of neighbourhood associations. The primary data for this particular paper draws from site visits with DAEE representatives to a number of key water infrastructure sites in São Paulo. These visits, which included extensive conversation and discussion, were recorded and transcribed where possible; they were supplemented by semi-structured interviews with DAEE representatives as well as participation in visits by local engineering students to the sites themselves. Additionally, semi-structured interviews were conducted with municipal representatives who were active in infrastructural provisioning and water governance. In 2017, I also participated in a multi-day academic workshop with key actors from São Paulo which was dedicated to piscinões. In addition to interviews and site visits, this project draws from extensive analysis of policy documents related to flooding and flood prevention, archival analysis of media coverage, and participation in events dedicated to water governance in São Paulo between 2013 and 2019. Analysis of archival material from between 1990 and the present was conducted using the Folha de São Paulo online archives.

FLOODED CITIES: URBAN POLITICAL ECOLOGY AND THE PERSISTENT PROBLEM OF FLOODING

Flooding is a socionatural process, and the production and experience of urban floods reflects the political and social realities of particular landscapes. Within UPE scholarship, urban nature – whether understood

in the form of floods, proximity to toxic by-products, or access to urban green space – is produced through processes of urbanisation that metabolically remake the biophysical landscape (Bakker, 2010; Furlong and Kooy, 2017; Gabriel, 2014; Goh, 2019; Heynen, 2014, 2016; Swyngedouw and Heynen, 2003; Swyngedouw, 1996). Flooding is one of the most immediate examples of this. It is not a pure result of the city's location in a floodplain; instead, it is a product of histories of urbanisation that reflect the city's economic and social foundations, in particular the steady expansion of residential areas into floodplains and the continued expulsion of low-income communities from the urban core into increasingly vulnerable fluvial landscapes (Fix, 2001; Batubara et al., 2018). Floods are a product of the interconnection between infrastructure, sociotechnical systems, political and administrative dynamics, and climatological factors (Carse, 2017). Engineering practices are also inseparable from the political economy of specific cities, and engineers are critical urban actors in many ways (Björkman and Harris, 2018). One of the foundational ideas of this paper is that the neutral categories used by urban planners and engineers cannot be separated from political-economic contexts that are central to the development of urban environmental projects and programmes. As the next section demonstrates, engineers are key actors in the city, and have been for at least a century. Their interventions profoundly shape the built form of the city.

In the past three decades, there has been a global paradigm shift in flood management. Initiatives to deploy natural processes in the service of groundwater recharge, flood prevention and green space provisioning, alongside processes of stream daylighting and river restoration, have been gathered together under terms such as sustainable urban drainage solutions and nature-based solutions (McHarg, 1969; Usher et al., 2020; Waley and Åberg, 2011; Wild et al., 2012). Importantly, Usher et *al. (*2020) note that a changing relationship to water at the global level is reflective of new relationships between the built environment and the fluvial landscape as the previous hydraulic model of 'big water' (Bell, 2015) gives way: "The shift to sustainable drainage, river restoration and daylighting in particular, is reflective of a profound change in attitude towards water, as something that is intricately embedded in society" (Usher et al., 2021: 5; see also Mathur and da Cunha, 2014). Examples include the Dutch Water Sector's *Room for the River* programme as well as canonical examples of stream daylighting such as the Cheonggyecheon River in Seoul. While São Paulo makes clear that the so-called "promethean model" (Kaika, 2005) of large-scale infrastructural provisioning is still in place, nature-based solutions, green infrastructure, and river restoration through projects like linear parks are discursively present in Brazil, and in some cases have institutional support (Herzog, 2013; Millington, 2018; Diep et al., 2019). The piscinões I describe in this paper are not nature-based solutions by any means, but in their embrace of retention/detention they are reflective of changing paradigms of stormwater management at the global level (Canholi, 2014; Abril, 2017).

Attention to flooding and flood prevention has taken on added relevance in this climate change moment. While flooding and other forms of environmental crisis have long marked São Paulo, the ability of cities like São Paulo to hold together is being stretched by climate change as existing infrastructures are proving insufficient to the task of a changing climate (Cohen, 2016, 2020; Bigger and Millington, 2020). Dramatic examples of urban flooding – such as those provoked by recent storms in Houston, New York City, and throughout Southeast Asia – exist alongside experiences of drought-induced water scarcity in Cape Town, Chennai and São Paulo. These events suggest the need for systematic, structural change at the scale required to respond to planetary climate change, as well as the need for cities to position themselves at the forefront of both mitigation and adaptation (Anderson et al., 2020; Angelo and Wachsmuth, 2020; Aronoff et al., 2019; Bulkeley et al., 2010; Koslov, 2016).

ENGINEERING SÃO PAULO

The history of São Paulo is intimately tied to the power and visibility of engineers. For over a century, engineers have made and remade the urban built environment; in the process, a marshy, flood-prone city marked by hundreds of streams was transformed into a megacity. São Paulo's early development

was intimately linked to its status as a watery city that was crisscrossed by hundreds of small streams and rivers, many of which were prone to flooding (Jorge, 2006; Júnior, 2012; Kogan, 2013; de Sant'Anna, 2007; Seabra, 2019). This fluvial landscape slowly disappeared from view as the city expanded in the 19th and 20th centuries. As the city grew, engineers in São Paulo 'suffocated' its rivers, enrolling them into broader processes of flood prevention and electricity generation (Custódio, 2012; Jorge, 2006; Seabra, 2019). Rectification and channelisation remade the city's waterways, reflecting the principle that Jones and Macdonald (2007) call "rapid transit", that is, the expulsion of water from the landscape as fast as possible; Canholi (2014: 16) refers to this process as serving the "hygienic vision", a reference to 19th and 20th concerns about the role of stagnant water in the proliferation of disease. Rectification, channelisation, and other bank stabilisation measures essentially enlarge and straighten stream channels in order to increase the velocity of a storm flow (Riley, 1998). These typically take the form of culverts in which streams are entirely encased below ground, or open-air, flat-bottomed channels with either horizontal or trapezoidal walls (Riley, 1998: 162). In all these cases, the purpose is to speed up water flow in order to reduce the possibility of flooding, while limiting the surface area of the project due to the cost of land and materials.

Rectification began in São Paulo in the early 1800s. Over the course of the 19th and 20th centuries, the Tietê, Pinheiros, Anhangabaú, and Tamanduateí Rivers, along with their many tributaries, were encased in concrete and in many cases buried underground. While flood prevention was a reason for early river rectification, concerns about sanitation played the primary role in initial modifications made to the city's waterways. The full-scale burying of streams eventually came to a halt and was replaced by open channels (Júnior, 2012), but rectification continues into the present. Indeed, as Júnior notes, much of the channelisation of the city's waterways occurred after the 1960s and intensified further in the 1970s and 1980s. This had to do, in part, with changing budgetary regimes, in particular the shift from municipal to federal funding for infrastructure projects (Júnior, 2012: 33). Large sums of money could thus be generated from federal infrastructure projects, which led to economic incentives for channelisation and large-scale drainage infrastructure. At the same time, the city continued to densify. As it did, it put pressure on pre-existing floodplains, causing the rectification of the city's waterways to be perceived as more urgent.

The hydraulic paradigm that saw water as a threat also saw it as an opportunity for the generation of electricity and in due course a series of hydroelectric dams were constructed at the edge of the city (Bueno, 1994; McRae, 2021; Keck, 2002; Rolnik and Klink, 2011). This hydraulic paradigm, a Paulista variant of "big water" (Bell, 2015) is one in which engineers play a substantial role in designing, and intervening in, the city's physical landscape. In this paradigm, engineering firms also benefit financially from lucrative contracts with state entities. Large-scale drainage infrastructure is mainly provided by the provincial Department of Water and Electrical Energy (DAEE) and by the municipal Secretary of Urban Infrastructure and Public Works (SIURB); these work alongside private engineering and construction firms. Given the scale of interventions necessary and the challenge of profitability, water services tend to include considerable involvement by the state (Bueno, 1994: 56).

It is not surprising that drainage systems are designed by engineers, but it is worth noting that engineers in São Paulo have played critical roles in the history of the city's landscape and have played prominent roles in the city's politics for over a century (Haag, 2010). For Peixoto-Mehrtens (2010), the power of engineers in São Paulo can be traced to the failed revolution of 1932 in which São Paulo elites rebelled against the federal government. She notes that the revolution rearranged political power by putting engineers into key sites of authority that were linked to the rise of public works. For Laura Bueno, the relationship between engineering practices and urban infrastructure is a political-economic one that has to do with the specificities of large-scale infrastructural provisioning. She notes that,

Figure 2. Tamanduateí River in 2019.

Source: Author's photo.

In the specific case of sanitation, the historical mapping of the characteristics of State – private capital relations points to the strategic role of professional/business entities of engineers and engineering companies in the creation of investment policy and in the execution of the policy for the sector. Sometimes employees of the state apparatus, sometimes technicians in the areas of design and technology, sometimes businessmen, this professional category crystallizes as a channel of permeability between private capital and the state apparatus in the formulation and management of public policy (Bueno, 1994: 33).

This is borne out by the fact that engineers have played a critical role in the city's political culture over time; over the last century, for instance, they have provided many of the city's mayors. The DAEE, which is the entity responsible for the bulk of the policy I reference in this paper, is reflective of the political authority of engineers. Founded in 1951, initially its primary function was developmental in nature and was linked to the generation of electrical energy. It now supervises water resources in the state of São Paulo and is responsible for the management of a series of dams that are used for both water supply and electricity. According to Keck (2002: 167), organisations like the DAEE are marked by "strong career-based organizational identities and close linkages with private firms active in the same field", resulting in a "status-quo organization". As she clarifies, "common, especially for the high-level management of these institutions, is elite circulation between public and private sectors, in particular large engineering firms that derive much of their revenue from government contracts" (ibid). Keck highlights the degree to which these entities are marked by considerable debate and discussion from within, but that institutional

culture tends towards continuity rather than change. She notes that this is both a cultural and a structural condition and that, "[p]rivileging accumulation over livability is a central part of the problem" (ibid: 162).

In spite of significant investment into reshaping the rivers, flooding remained a problem in São Paulo throughout the 20th century due to the continued expansion and increasingly impermeable nature of the city, its location in a floodplain and the changing dynamics of the city's microclimate (Custódio, 2012). The increasing impermeability of the city exacerbated the existing tendencies towards flooding, which occurred alongside – and were profoundly affected by – the city's highly unequal and uneven growth. São Paulo is a famously unequal city, juxtaposing great wealth with deep poverty and inequity (Alves, 2018; Caldeira, 2001; Fix, 2001, 2007; Feltran, 2020; Rolnik, 1997). As the city grew, so too did its periphery, where low-income residents have long gone in search of more affordable housing. While the centre/periphery distinction has shifted in the last few decades in favour of a more complex geography of wealth and poverty (Caldeira, 2001), the nature of São Paulo's urbanisation process has seen the relentless occupation of vulnerable environmental areas by members of low-income groups who are unable to afford housing in the urban core and who are often violently evicted from it (Fix, 2001). At the same time, the city has densified along its waterways throughout the urban core, most notably in the case of the Pinheiros River. There, a channelisation project inaugurated in the 1930s effectively reclaimed the land that now underpins the city's most elite neighbourhoods (Seabra, 2019).

The expansion of the periphery coupled with the densification of the city along its waterways has created a profoundly impermeable landscape marked by extensive flooding. There is fundamentally nowhere for water to go and not enough conduits for the water's expulsion. At the same time, intense rainfall events have increased over time, furthering the flood dangers borne from the city's humid, subtropical climate. Additionally, due to the city's pollution and heat island effect, recent decades have seen a shift from a city defined by overcast skies and light drizzle to a city marked by higher temperatures, longer periods of water scarcity, and the intensification of rain events (Geraque, 2013; Lyra et al., 2017; Nobre et al., 2010).

NEW PARADIGMS: SITUATING THE PISCINÃO IN A BROADER CONTEXT

The 1980s and 1990s were critical for Brazil's water governance and for infrastructural politics more broadly (Abers and Keck, 2013; Keck, 2002). For Keck (2002: 167),

> a disruption occurred in the 1980s, resulting from diverse factors: democratization of the political system, which created democratizing pressures within the technical agencies themselves; economic crisis, which reduced budgets and salaries; and a shift in policy by multilateral lending agencies away from their support of large engineering works, especially dams.

Writing mainly about sanitation and water delivery, Keck highlights the complex politics of path dependency in the system, in which networks of individuals, social movements and organisations worked to push against a broader paradigm associated with megaprojects. Many of these initiatives failed, as the story of piscinões makes clear, but they reveal the overlapping tendencies and reform impulses within the entities themselves. Much changed in the 1980s, particularly around the governance of drinking water, but much also stayed the same.

Beginning in the early 1990s, engineers in São Paulo began to articulate a shift in the nature of flood prevention. In lieu of simply attempting to remove excess water from the city as quickly as possible, engineers began to cultivate strategies that effectively incorporated water into the urban landscape. Engineers in the 1990s turned towards the city's rivers through the emergent development of what are often referred to as 'unconventional' approaches such as piscinões, linear parks, and other forms of nominally green infrastructure. The state and municipal governments also began to institute new forms of data-driven flood response and planning. In 1999, for instance, SIURB inaugurated the Centre for Emergency Management (Centro de Gerenciamento de Emergências), a form of soft infrastructure

designed to increase awareness of flood events and respond more effectively to them through real-time monitoring. Changes like this, alongside smaller-scale attempts to develop linear parks and increase porosity and permeability in the city (Millington, 2018; Henrique and Tschakert, 2019a, 2019b; Diep et al., 2019), began to situate the experience of flooding in a more expansive watery geography. If the earlier paradigm had attempted to move water out of the city as quickly as possible, the emergent paradigm of flood governance that evolved in São Paulo understood the persistence of water in the city in new, albeit limited, ways.

Of primary interest for this paper was the creation of the Master Plan for Macro-Drainage of the Alto-Tietê Basin (Plano Diretor de Macrodrenagem da Bacia do Alto Tietê), which laid out a broader vision for managing drainage at the regional scale (DAEE, n.d.). The plan developed what was referred to as an integrated approach, consolidating stormwater management through a series of targeted stages at the regional level. Now in its third version, the document has laid out a new set of guidelines for stormwater management and drainage. As part of the plan and the associated shift in policy, restrictions have been placed on how much water the Alto-Tietê system could effectively hold in the Tietê and its key tributaries (the *vazão de restrição*) (Abril, 2017: 31). This policy change effectively meant that the Tietê and its tributaries could no longer be deepened or expanded to increase their volume, and that more water storage thus needed to be found in other locations.

These changes were a result of the recognition that channelisation did not necessarily solve the problem of flooding but rather moved it elsewhere (Abril 2017, 29-30; Personal interview with SIURB representative, 2019). This acknowledgement of the limitations of channelisation formed part of a broader shift in the nature of stormwater management in the city, one that increasingly began to push towards regional planning and the retention and detention of water in the landscape (Júnior, 2012; on the difference between retention and detention, see Canholi, 2014: 71). Inspiration came from global sources and examples, including those in the United States and France. The concept of piscinões, for instance, was inspired by cases in Bordeaux and the United States, though as Davis (2015) notes, stormwater retention had been increasing in popularity globally since the 1970s and 1980s. Sustainable urban drainage systems (SUDS) and other forms of unconventional stormwater management figure in documents and plans and were clearly present discursively as these new approaches were being articulated, but they appear to have largely been understood as only one possibility among many. For Aluísio Canholi, the designer of the first piscinão in Brazil and a central figure in the history of stormwater management in São Paulo, the fundamental shift is not necessarily towards sustainable systems; rather, it is a shift from the concept of canalisation to the concept of retention (Canholi, 2014: 31; Karvonen, 2011; Walesh, 1989).

THE PISCINÃO AND NEW PARADIGMS OF FLOOD MANAGEMENT

In the section below, I discuss the piscinões in three ways: as imagined by engineers, as constructed, and as critiqued/contested.[1]

Imagining the piscinão

A piscinão is a large-scale detention pond that is designed to collect excess stormwater in periods of high rainfall. Piscinões are essentially large-scale short-term reservoirs, places where water can be briefly delayed from entering the sewage and river networks. They slow the arrival of water into the streams and rivers that function as stormwater channels, and in doing so lessen the impact and possibility of flooding. As Canholi notes, "urban drainage is fundamentally a question of the 'allocation of spaces'" (2014: 15). In a simplified sense, piscinões create spaces for water to go, delaying flood peaks and ideally minimising the amount of water in specific sub-basins. There are two kinds of piscinões in São Paulo: in-

[1] This organisational structure was suggested by an anonymous reviewer of the paper, to whom I am grateful.

line where the reservoir is located within stream channels and water is returned by a weir, and off-line where the reservoir is located outside of the channel and is connected through pumps. In the latter case, water is diverted from a stream or river into the piscinão itself and then pumped back into it after the flood event has passed. In both cases, the central principle is detention; piscinões fill with water during periods of high rainfall and then the water is subsequently returned to stream channels. In contrast to what is referred to as 'retention at source' – including permeable pavements and small-scale reservoirs – piscinões collect water at the regional rather than local scale (Canholi, 2014: 41).

Piscinões are largely understood by engineers and designers as being a first step towards a more sustainable model of flood management, a stopgap solution that is a necessary response to a disorganised urban landscape. In describing the role of the piscinão, for instance, São Paulo's Department of Water and Electrical Energy notes that "piscinões fulfil the role of floodplains occupied in a disorganized way" (DAEE, n.d.). By this they mean that the piscinão modulates flows of water in a way that mimics the role of floodplains that have largely been occupied over the past century of urban expansion. During a December 2019 visit to the Guamiranga piscinão in the western zone of São Paulo, I asked an engineer if other cities had piscinões. He told me that other cities did not need them and that in places that have urban planning these sorts of solutions are not necessary. This is untrue, but it speaks to the way that piscinões are framed in São Paulo as a necessary solution to a highly chaotic urban landscape. While broadly celebrated by the civil engineers I spoke to during my research, piscinões range from being seen as marvels of engineering practice to being a kind of necessary evil. They are often understood as being a requirement for dealing with water in a city that is deeply impermeable and whose patterns of urban development are disorganised at best.

Canholi, in his book *Urban Drainage and Flood Control*, suggests that the future of drainage in São Paulo will involve the development of sustainable approaches, but only once the immediate problem of flooding has been resolved. As he notes, "While in more developed countries the emphasis in questions of urban drainage is concentrated on the aspects related to the quality of the collected water (…), in Brazil the quantitative control of floods is still the principal objective of actions" (Canholi, 2014: 17). As a result,

> The most adopted 'innovative' concepts for the readjustment or the increase of the hydraulic efficiency of the drainage systems have as objectives the delay of discharges, in order to increase the concentration times and reduce the maximum outflows; the weakening of the peaks and reduction in flood volumes through retention in reservoirs; and containment, as much as possible, of run-off in the precipitation region, in order to improve the conditions for infiltration (Canholi 2014: 16).

Ultimately, for Canholi (2014: 16),

> This signifies a radical change in the philosophy of structural solutions in urban drainage, because earlier canalization works were implemented that accelerated the flow in order to quickly move the flood peaks to downstream water bodies This 'hygienic' vision was adopted by those responsible for the drainage of stormwater (…). Currently, the 'conservationist' vision, which attempts to delay the discharges of rain flows close to their sources, constitutes the paradigm of modern urban drainage.

Interestingly, for Abril (2017) what differentiates the piscinão from other forms of flood prevention infrastructure is its specific visibility; the "monumentality" (ibid: 36) of the piscinão suggests a different and more public relationship to drainage infrastructure that can create opportunities for engagement. While drainage has long been one of the canonical examples of infrastructures that functions best when largely invisible, the piscinão calls attention to water in the landscape in ways that were previously impossible.

Constructing the piscinão

The first piscinão was built in 1994, underneath the parking lot of the iconic Pacaembu Stadium in the leafy, wealthy neighbourhood of Pacaembu. In many ways, this piscinão is the gold standard of piscinões

in the city; it is underground, completely out of sight, and has had a marked impact on flooding in the surrounding region. The project involved the excavation of 180,000 cubic metres (m^3) of soil and 6000 m^3 of concrete; it cost US$ 8 million to complete and holds up to 74,000 m^3 of stormwater (Davis, 2015). While the project has since been declared an unqualified success, not everyone was convinced. In an October 1993 article discussing the inauguration of the project, an engineer critiqued it, noting that the best possible way forward would be to construct an open-air lake that would constitute a 'natural' solution (Reportagem Local, 1993).

In response to the success of the Pacaembu project, the state government embraced piscinões in the following years (Davis, 2015). Canholi himself figured prominently in this process, developing a plan for the construction of eight piscinões in the watershed of the Aricanduva (Davis, 2015; Canholi, 2014). In the years since the construction of the Pacaembu piscinão, engineers and construction companies have built more than 50 piscinões, with nearly 200 planned. Of the piscinões that have been completed, 33 are managed by DAEE, with a total volume of nearly 13 million m^3.[2] The bulk of piscinões are located in the southeastern region of the metro area, in the Billings-Tamanduateí sub-basin, as well as in the southwest, in the Cotia-Guarapiranga sub-basin. While Pacaembu was buried underground, the vast majority of piscinões are located above ground. They are often massive, holding huge volumes of water. As a result, they are highly visible interventions into the urban landscape, even though they are typically located in peripheral and broadly inaccessible parts of the city. Like the bulk of São Paulo's waterways, they are typically reached only by car and appear to be in a state of severe deterioration; they resemble ruins more than they do monumental infrastructure (Abril, 2017).

The largest piscinão in São Paulo is the Guamiranga. It was inaugurated in February 2017 and is in the region of Villa Prudente, situated between a metro station and a prison. It is 22 metres deep, covers an area of 70,000 m^2, and can hold 850,000 m^3 of water. The project cost R$ 162,746,835 (US$ 30 million); it was inaugurated two years behind schedule and at a significant cost overrun (Estadão Conteudo, 2017). Guamiranga is representative of piscinões more broadly; it is located in a marginal area of the city and reflects both the monumentality of piscinões and their relative invisibility. Despite its size, it is inaccessible and out of sight, and it is both technically complex and profoundly simple. Three weeks after its inauguration, it flooded; this both revealed the limitations of piscinões and suggested that without it the flooding would have been significantly worse.

Contesting the piscinão

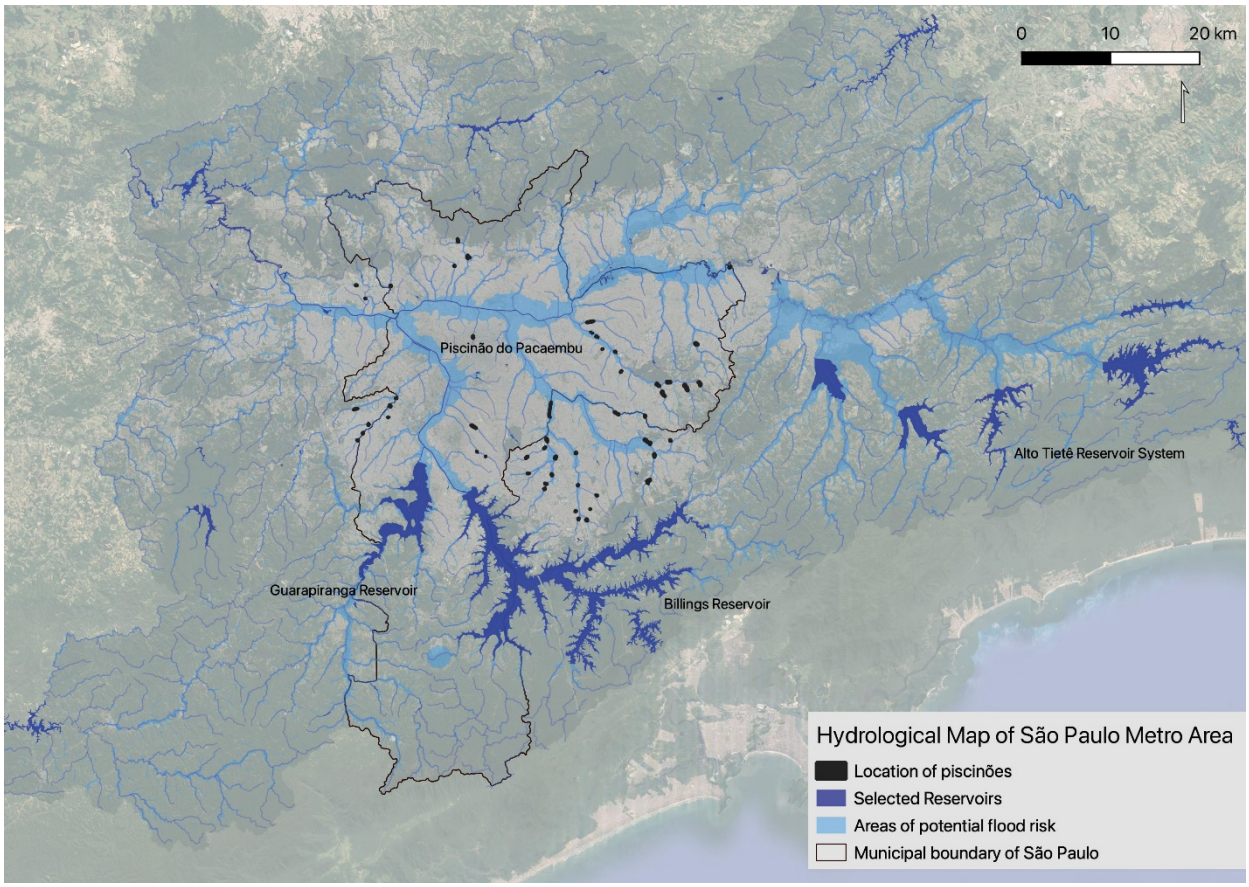
Critics have disagreed with the piscinão strategy since its inception. Indeed, the limitations of the piscinão are not lost on engineers themselves. Kanashiro, for instance, writing in the trade publication *Engenharia,* notes that while often piscinões are the cheapest way to deal with the problem of flooding, they are marked by limitations. These include the difficulties of building them due to lack of space, their constant need for maintenance, and the fact that they do not help with the problem of river sedimentation which is itself a cause of flooding (Kanashiro, 2013: 613). Their monofunctionality makes piscinões aesthetically and environmentally problematic and their vast scale and scope opens them up to criticism.

Abascal (2013: 16) refers to piscinões as "carcasses of disaster" (see also Franco and Coachman, 2013). Urbanists often see them as a means for engineering companies to make vast sums of money, developing large-scale infrastructure in lieu of smaller-scale solutions. Here, the economy of private-sector engineering firms working in collaboration with state entities such as the DAEE is indicative of the fundamental logics of the city's development, which have long marked urbanisation in the city. Indeed, infrastructural provisioning – and the tight relationships between construction companies, elected officials and engineers – have long formed a critical component of the broader political economy of the city, one that continues into the present (Bueno, 1994). A representative of the municipal government in

[2] These numbers are from documents provided in 2019.

São Paulo gave voice to this in a 2013 meeting when he colourfully noted that, "the mayors of São Paulo thought they could cure cancer with concrete". He was referring to the long history of large-scale engineering infrastructure in the management of water in the city and to the succession of mayors drawn from the world of engineering.

Figure 3. Hydrological map of São Paulo Metro Area.



Source: Flood risk data courtesy of the Serviço Geológico do Brasil's 'Cartas de Suscetibilidade a Movimentos Gravitacionais de Massa e Inundações - São Paulo' repository. Data on Piscinões courtesy of the mayor's office of São Paulo's GeoSampa portal. Note that flood risk data for the municipality of Itaquaquecetuba was unavailable, which explains the gap near the NW corner of the São Paulo municipality.

A former director within the city's environmental secretary noted in a 2014 interview that,

> When the [mayoral] candidates take power they are quasi hostages of the [construction] enterprises and the enterprises want construction projects [*frentes de obra*]. They are not going to want to make linear parks. Right? Linear park, they don't know how to make a linear park. They need a place to inject concrete and implant projects, a lot of iron, concrete. And so enterprises are in favour of highways, the railway system, tunnels (…) and piscinões. And principally, I don't know if you understand the size of a piscinão, but a piscinão is practically a buried cathedral.

Rolnik (2019a) makes a similar point, noting that "piscinões are sensational for generating cubic meters of engineering projects and inauguration ceremonies, but the fundamental issue, which is preventative action in the area of occupation and particularly in the area of housing, is (…) ignored".

Their impact on the built environment is often remarked upon as well. For Valin (2009),

> The city is halfway through building 131 of these retention ponds, in Portuguese 'piscinões' – literally 'big swimming pools' – that will draw excess water from overflowing streams and detain it long enough to diminish the storm surge volumes arriving at locations downstream. Because of the uncontrolled growth however, the pools must be 'extracted' from the existing urban fabric: homes must be relocated, roads realigned, community assets replaced. For hydrological, but also for economic and practical reasons, the piscinões constructed or planned fall largely in the poor, peripheral areas of the metropolitan region. In effect, the issue of flooding (which is largely a problem of the center and of the formal sector) is being resolved in areas that stand to gain the least from that solution.

The geography of piscinões is clear. The bulk of them are located in peripheral areas and nowhere near the city's elite heart. In this, piscinões reflect the city's long-standing paradigm of flood response. While the entire city is affected by flooding in one way or another, it is the periphery that bears the brunt of both flooding and flood prevention infrastructure (Henrique and Tschakert, 2019b). Decisions about the location of piscinões are justified according to hydrological factors; however, as with all infrastructure in São Paulo, the costs of relocation and expropriation are extremely high and play a considerable role in all planning. The result is that piscinões are largely built in peripheral areas where land is cheaper and the costs of relocation are lower.

In São Paulo, some neighbourhood groups have pushed back against piscinões and other flood prevention infrastructure, advocating for forms of sustainable urban drainage (Padin, 2020a, 2020b). In a 2020 piece, for instance, journalist Padin (2020a) discusses resistance to a piscinão project in a fairly centrally located neighbourhood. In response to the calls for green space and other forms of sustainable stormwater management that were being articulated by the community, the then mayor noted that alternative projects such as linear parks were impossible due to the excessive cost of relocating communities on the edges of rivers and waterways (Padin, 2020a; Millington, 2018).

While experts and environmentalists have critiqued piscinões, the bulk of critical attention has focused not on the sites themselves as designed, but on failures of maintenance, cost overruns and delays. In the case of the Piscinão Guamiranga that was mentioned previously, local counsellors raised questions about the significant rise in project costs. For Rolnik (2019b), the state is liable for flood damage due to its failure to adequately fund flood prevention infrastructure. She notes that investment in flood prevention infrastructure dropped from nearly R$ 20 million (US$ 5,684,794) in 2015 to zero in 2017, whereas during that same period funding for the resurfacing and paving of roads ballooned. This is echoed throughout São Paulo's recent history, with nearly every mayor dramatically underspending the resources that are allotted for flood prevention infrastructure (Monteiro and Santos, 2021; Rodrigues, 2020; Rodrigues and Seto, 2019; Zylberkan, 2019). Lack of maintenance is also a huge issue for piscinões, and experts note that deferred maintenance can lead to significantly less-effective detention capacity (Davis, 2015; Mori, 2013). Lack of maintenance (as well as illegal dumping into the sites) is a common refrain, one remarked upon by engineers themselves (Kanashiro, 2013) and by media outlets.

Assessing the piscinão

Piscinões are, at best, a kind of mimicry of natural systems and, at worst, big pools that collect stormwater and its associated pollutants and hazards. They corral water rather than flushing it out of the city, but they do so in a way that largely produces urban voids through large-scale infrastructural interventions. Rather than permanently holding back water from the storm sewer network, they merely delay its arrival. This aids in flood prevention but does not help with other priorities such as water purification or groundwater recharge. In an ideal system, infiltration would provide water purification coupled with the provisioning of green or public space to urban residents; however, in lieu of a strategy for managing urban stormwater that genuinely increases permeability or porosity in the city, piscinões are a continuation of a hydraulic paradigm that can be considered through the language of 'command and control' and single-use management.

Piscinões are representative of an approach to infrastructure that generates profits for some through construction contracts while forcing others to live alongside contaminants and pollutants. In this sense, they are examples of the persistence of political formations that privilege the construction of large-scale infrastructure and deepen forms of sociospatial exclusion. While much literature on urban drainage and sustainability has highlighted the move away from large-scale infrastructure, interventions like the piscinão reveal that these forms of promethean infrastructure remain both politically and economically beneficial for many. Existing approaches are, ultimately, reliable. As Moura et al. (2018) note, "the reliability achieved by conventional solutions and large works of drainage and flood control has strengthened the inertia in the transition to low-impact, landscape-based solutions or even the integration among these several management techniques" (Moura et al., 2018: 11.2-11.3).

To the extent that the piscinão constitutes a paradigm shift in flood management, in the end it does so through the diminished language of contemporary infrastructural provisioning. Where monumental infrastructures were in line with the modernist project throughout the 20th century, degraded repositories for polluted water at the edges of São Paulo's landscape lack this romance. Piscinões are testaments to a city and an urban political economy that is often understood as being hostile to life (see, for example, Alves, 2018). They are, in the words of Davis and Jensen (2017), "an appendage to a landscape on life support, existing in a no-man's land between river and highway, detested by local residents yet apparently essential to prevent flooding". Piscinões highlight the degree to which the relationship between water and land in São Paulo is fundamentally broken. It is an urban fabric that is marked by unceasing inequality that materialises in polluted streams, persistent flooding, and generalised water insecurity. While projects to clean up the city's rivers continue, the quality of its rivers remains abysmal and flooding continues to be a problem. Worse still, most proposed piscinões have not been built and those that have been built suffer from neglect and maintenance issues. Even at their best, piscinões are a temporary solution written in the language of infrastructural permanence; they are a recognition of the challenges of intervening in the city's landscape in a way that could respond to flooding in a more holistic sense. Here I broadly echo Buck et al.'s (2020) analysis of environmental stopgaps. The piscinão, like other temporary measures that define much contemporary environmental practice, "is closest, perhaps, to an emergency repair: a temporary resin for a broken tooth; a temporary bridge erected rapidly when a highway bridge fails; plugging a hole in a boat with rags" (Buck *et al.,* 2020: 499).

CREATIVE INFRASTRUCTURES

The disjuncture between the promise of piscinões, the broader paradigm shift they represent, and their ultimate effect in and on the landscape speaks to the persistent need for a more expansive commitment to urbanism from the perspective of flood prevention. In São Paulo, community groups like *Rios e Ruas* (Rivers and Roads) have pushed for deeper relationships with the city's waterways, and organisations that emerged during the water crisis of 2014/2015 pushed for greater transparency in all aspects of water governance (Cruxen, 2016). Examples of informal stream daylighting can be found in São Paulo, including a number of projects that were carried out by communities, often without explicit state approval; these include the Praça da Nascente in the neighbourhood of Pompeia (Torres, 2019) and the Parque Linear Tiquatira in the neighbourhood of Penha.

While there are no green piscinões, there are examples of piscinões that were built with multifunctionality in mind, such as Piscinão Jabaquara. Inaugurated in 2000, the project was celebrated by the mayor's office, which noted in a media release that, "when it rains it is a piscinão, when the sun is out it is a leisure area" (Prefeitura de São Paulo, 2000). The leisure area referred to included a skate park and sports fields, which were evidently in use until the piscinão was temporarily closed in 2013 so it could be converted into a parking lot for a monorail project (Fernandes, 2013). Surveying the scene when it was closed, Fernandes (ibid) noted that, "[t]he frequent floods and the unpleasant smell of the place, a result of its proximity to polluted streams, does not intimidate the residents of the region, who use the site to

walk their dogs, play sports, and walk". Regardless of its evident success, however defined, few publicly accessible piscinões have been built in the years since; this is likely due to the cost of maintenance and cleanup (Davis, 2015).

In the realm of creative projects, the possibility of multifunctional piscinões has interested artists and designers. A project entitled *Watery Voids* by the architectural firm MMBB attempted to rethink piscinões as part of a broader urbanist project (de Mello Franco et al., 2007); the singular function of piscinões, from their perspective, prevents them from being used in more creative ways, as, for example, public spaces. They instead propose a kind of relational infrastructure, that is, piscinões that double as public spaces in communities that lack open space. For landscape architect Brian Davis, piscinões could be reconceptualised as forms of "civic infrastructure"; this would involve limited forms of public access, a focus on multiple rather than single uses, and the development of space for water filtration. Interestingly, Davis notes that these spaces should not be reconceptualised as recreational parks, noting that this strategy has already failed. Instead, he advocates for "experimentation and urban exploration" and for strategies that take advantage of the capacity of piscinões to accumulate water in ways that can encourage productive habitats for hardy species.

At the same time, green infrastructure and other forms of nature-based solutions are increasingly under discussion in São Paulo. These have included broader ambitions around river renaturalisation (Marques et al., 2018) as well as efforts to rethink piscinões from an environmental perspective (Alencar, 2019; Moura et al., 2018). Alongside the continued development of piscinões, over the last two decades municipalities in the São Paulo metropolitan area have developed dozens of linear parks. Efforts to increase permeability in the city have also evolved, including legislation such as the 2002 law referred to as the *Lei das Piscininhas* (Law of small reservoirs). The law mandates that all new structures with over 500 m^2 of impermeable space are required to develop reserves to collect stormwater. While this is a positive engagement with stormwater management and microdrainage, the law possesses little incentive for compliance and the peripheral areas where permeability is a challenge are often left out of the law both formally and informally.

Expanding from the *Lei das Piscininhas* is the *Quota Ambiental* (Environmental Quota), a regulation in the city's strategic plan that requires that small-scale environmental measures are included in all new properties. As Nobre et al. (2015) note, however, the state's capacity or willingness to enforce these metrics is often nonexistent, making it hard to imagine the law being adequately enforced. As with the rest of the city's strategic plan, the inability to adequately ensure follow through is coupled with the immense political power of developers and growth machine actors. The result is a situation in which formal legislation is insufficient to ensure positive outcomes. As Abers and Keck (2013) argue, legislation is often not enough; what is required are the sorts of "practical authorities" and political demands that ensure that legislation is properly implemented. This suggests the intractability of impermeability in São Paulo and the difficulties of introducing green space in a "complex location" (Nobre et al., 2015; see also Caetano et al., 2021).

POLITICAL INFRASTRUCTURE

Better, greener piscinões would create spaces for a more sensitive relationship between city and landscape, but São Paulo remains beset by forms of inequity that complicate any easy fixes to socio-ecological problems. Indeed, throughout the city's recent history, efforts to merge social and environmental goals have been deeply fraught, as continued growth – formal and informal – pushes into areas of environmental vulnerability. Linear parks and other forms of nature-based solutions, often heralded for their environmental benefits, are also vectors for the removal of low-income communities (Henrique and Tschakert, 2019b). Green interventions can yield profoundly regressive outcomes given the density of the environment and the sheer pace of occupation. As such, any intervention into São Paulo has to contend with the fact that the city's landscape is constantly changing in response to the

need for affordable housing and that the city's most environmentally vulnerable landscapes have long provided shelter for the most vulnerable. Without coming to grips with this fundamental fact, any environmental intervention will be complex, expensive and potentially traumatising for the communities that are removed (Fix, 2001).

If the production of the city's landscape through impermeabilisation, channelisation and over a century of near-constant growth has yielded a city that floods, the primary contention of this paper is that responding to flooding needs to take seriously the *production* of flooding in more than technical ways. Drawing from UPE, my argument in this paper is that flooding is a product of the built environment and of the associated patterns of settlement which have yielded an impermeable landscape that is prone to flooding. This impermeability was not a result of an undifferentiated pattern of urbanisation; instead, it was produced through a highly uneven urban process that, for over a century, has pushed low-income residents out of the city centre in search of housing. Impermeability is a generalised phenomenon in São Paulo, but it is highly uneven in its application. Responding to flooding, then, enrols not just the dynamics of permeability, density and water volumes; it requires an engagement with the deeper drivers of urbanisation in the city and with the political production of the built environment. While engineers are clear about the ways that extended urbanisation renders their jobs difficult, the reasons for these difficulties – including housing insecurity, a lack of dignified housing for low-income residents, extensive vacancy in the urban core, poverty and a lack of options – are less remarked upon and are understood as being a general condition of the city. This obscures the role that engineers have played in the city's form over time and neglects the fundamentally political nature of their authority and expertise.

Allowing the design of flood-prevention measures to be guided by attention to how the urban built environment has been produced would require a thorough remaking of the city's urbanisation process in relation to the management of floods. It would require a fundamental understanding of flooding as inherently linked to the city's social as well as environmental landscape. This remaking of the urbanisation process could involve a massive expansion of good quality public housing at an unprecedented scale, the formalisation and upgrading of informal neighbourhoods, expansion of sewage and water-delivery infrastructure to residents across the city regardless of tenure status, and the occupation of the thousands of buildings that currently sit vacant in the urban core. In a practical sense, it would involve the difficult but necessary task of ensuring collaboration between the housing, environmental and engineering sectors, which tend to be intensely siloed. It would involve forms of densification in vulnerable areas; this would need to be in collaboration with housing movements and would require the development of coherent flood-management planning in flood-prone residential neighbourhoods. It would also involve the regular maintenance of existing infrastructure, the cleaning of piscinões and the desilting of rivers, including the Tietê and other tributaries and streams. This is hard, undervalued work that demands considerable investment of money that currently often goes unspent.

While these solutions seem impossible to anyone who is familiar with São Paulo, none of them are particularly radical; indeed, many of them are part of the city's strategic plan and are enshrined in the constitution (Gestão Urbana SP, n.d.). In the case of the Tietê River, they are incorporated into policy documents that are designed to formalise existing housing while freezing any future occupation of vulnerable, flood-prone landscapes (Governo do Estado de São Paulo, 2013). A 2021 plan for the neighbourhood of Jardim Pantanal in the city's eastern zone is a potential model; it calls for a number of green infrastructural interventions in the neighbourhood which are situated within a broader understanding of the city's social makeup and history (IAB, 2021). The management plan for the Tietê Lowlands Area of Environmental Protection is another example (Governo do Estado de São Paulo, 2013). It spells out, in impressive detail, how occupation can be balanced with flooding in the highly vulnerable landscapes along the Tietê River in the eastern zone of the city. There are many other examples that could be drawn from, but priority for managing flooding would need to transcend the politicised authority of engineers. This is a difficult task given the city's institutional culture, but it is ultimately a necessary step to ensure that flood prevention can be carried out in a way that creates space for water and people.

CONCLUSIONS

Responding to flooding is about much more than flooding; it is a deeply political intervention into the urban landscape with distinct implications for the city's form. The strategies deployed to respond to flooding – in particular, the vast voids called piscinões that are built into the urban fabric in places no one goes – are understood as necessary solutions given the disorganised nature of the city's urbanisation process. As engineers themselves note, these solutions are responsive; that is, they are mechanisms for responding to a disorganised urban landscape through the language of large-scale engineering practices. In this sense, piscinões are stopgaps or temporary solutions. Given the disproportionately influential role that engineers have had in shaping the city's landscape for nearly a century, however, these stopgap measures continue to be framed through the logics of large-scale infrastructure that are reflective of the continued political authority of engineers.

Models of green or sustainable infrastructure are emergent in Brazil and are highly in vogue among landscape architects and urban designers (Herzog, 2013). Existing engineering practices, however, frame these as solutions that are not yet possible due to the need to respond to the immediate problem of flooding. In this sense, the piscinão reveals the enduring infrastructural imaginaries and political economies of infrastructural provisioning that underpin contemporary efforts to incorporate floodwaters into the urban built environment. By their nature, piscinões highlight the powerful role played by engineers in shaping the urban environment. While engineers speak of green infrastructural solutions such as linear parks as being a potential way to respond to flooding in the future, the nature and relentless pace of the city's urbanisation process and the histories of infrastructural interventions are understood to compel responses that reject multipurpose engagements with urban water.

In analysing piscinões, I consider alternative ways of responding to flooding, including multifunctional piscinões and other projects developed by engineers, architects and artists. These projects exist and could be implemented at scale, but they are complicated by the institutional realities of governance and the challenges of the city's landscape, notably the quality of the water and the relentlessness of change. While these projects offer exciting possibilities for a different relationship between the city's water and its land, they remain caught in the realities of inconsistent sanitation infrastructure and expansive urbanisation and are largely seen by many as solutions for the future. I celebrate these projects for offering alternative visions to the monofunctional view of water that predominates in São Paulo but note that flooding is fundamentally a political problem which ultimately requires a political solution. Without a set of policies that prioritises addressing the city's housing crisis, flooding will remain a problem and responses will be, of necessity, piecemeal and fragmentary. Attention to the deeply political nature of infrastructural provisioning in São Paulo speaks to the necessity of engaging with both existing and future policies in imagining an end to flooding. Going forward, one wonders what alternatives may look like and how they might be fought for.

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