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Subterranean Aqueducts of Pune: Exploring the Role of 18th-century Water infrastructure in Shaping the City's Growth and Urban Landscape

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Abstract: *The Deccan Plateau region of India saw the construction of several subterranean aqueducts between the 15th and 18th centuries CE using Persian hydraulic technology, marking a significant milestone in the historical development of urban water infrastructure. While these aqueducts have been largely analysed from a technical perspective, their spatial, aesthetic, and cultural dimensions remain underexplored. In response to this gap, this paper explores the subterranean aqueduct network of Pune built in the 18th century by the Peshwa rulers as a spatial structure that emerged from and simultaneously shaped the urban landscape of the city. To begin with, it investigates the interaction between aqueducts and Pune's topography and their contribution to the city's growth. Next, it examines the aqueducts as creators of quality urban spaces and identity. Lastly, it seeks to find out how urbanisation and changing values have affected aqueducts, resulting in their continued use or neglect. Employing a qualitative historical research methodology, relevant information have been gathered through archival research, documentary analysis, and field observations. Despite their deterioration, the historic aqueducts preserve hydro-geological knowledge that remains relevant to the design of contemporary water infrastructure. In conclusion, the paper recommends exploring the integration of historic aqueducts with modern networked water infrastructure to diversify water sources and enhance system resilience in the context of rising water demand and climate change. It also highlights the need to conserve the surviving aqueduct network due to its historical value, as it embodies context-specific water infrastructure design strategies and socio-cultural dimensions of water management.*

Keywords: *subterranean aqueducts, water infrastructure, historic, urban landscape, Peshwa, Pune, Deccan*

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Introduction

Background

Aqueducts have long been a subject of scholarly research. They are regarded as historic marvels that demonstrate the advanced engineering and hydrogeological knowledge of our predecessors. De Feo et al. (2013) have elaborated on the systematic evolution of aqueduct technology from prehistoric to medieval times, citing examples of aqueducts worldwide. They believe that aqueduct technology originated in Greater Mesopotamia during the Bronze Age (ca. 3300–1100 BCE) and later diffused to other parts of the world through technological exchange during migration, trade, and military operations (De Feo et al. 2013: 1998). While the focus of their research is primarily on surface aqueducts, Valipour et al. (2020) have reviewed subterranean aqueducts worldwide from prehistoric to modern times to assess their potential to achieve sustainable water distribution. Similarly, Angelakis et al. (2026) have presented the evolution of aqueducts in Greece from the prehistoric to the modern era, spanning the Mycenaean, Classical, Hellenistic, Roman, Byzantine, Venetian, Ottoman, and Modern Greek eras. Moreover, they consider that aqueducts offer valuable precedents for current adaptation to hydroclimatic variability and need to be integrated with the contemporary water supply systems.

Based on their mode of conveyance, aqueducts can generally be classified into three types: subterranean, surface (at ground level), and elevated. Subterranean aqueducts may convey surface water or groundwater. Those that specifically convey groundwater and are dug at or below the groundwater table are known as *qanats* (De Feo et al. 2013: 2000). They primarily comprise gently sloping tunnels that operate on the principle of simple gravity to transport water from a higher to a lower altitude. During *qanat* construction, a shaft known as the *mother well* is first dug in the upslope area until it reaches the permanent water table. After determining the receiving point based on the intended gradient (usually 1:1000 or 1:1500), a tunnel is dug back toward the mother well (English 1968: 170–173). Along the length of the *qanat*, vertical shafts connecting the tunnel to the surface are dug at about 20 m intervals, creating the appearance of a dotted string in the desert landscape (Hodge 2000: 37).

While the term *qanat* is commonly used in Iran for the system of subterranean tunnels, similar systems are known by different names elsewhere, including *karez* in Afghanistan, *fuqara* in Syria, Palestine, and North Africa, *gallerias* in Spain, and *puquios* in Latin America (Ahmadi et al. 2010: 126, Boselli et al. 2025: 58–59).

Studies suggest Iran to be the place of origin for *qanats* in the 7^{t}h century BCE. During the rule of the Achaemenid Persians (550–331 BCE), the technology of constructing *qanats* spread to Mesopotamia, Egypt, parts of Africa, Afghanistan, and parts of Central Asia. Later, *qanat* technology spread to North Africa, Cyprus, Italy, Spain, and Latin American countries such as Mexico, Peru, and Chile through the early Arab invasions of the 7th century CE (Ahmadi et al. 2010: 127, Boselli et al. 2025: 56–58, English 1968: 175–176).

While the scholars mentioned so far have made significant contributions to the study of subterranean aqueducts, particularly in understanding their origin, engineering principles, and technological evolution, an important gap remains in the literature. It does not adequately address the process through which aqueduct technology reached the Indian subcontinent, and is largely silent on the diverse subterranean aqueduct systems that exist in India, particularly in the Deccan Plateau region[1]. Addressing this gap requires reference to the works of scholars who have studied aqueducts in the Deccan and other parts of India, shedding light on processes of technological transfer, cultural adaptation, and regional development.

Medieval and Early Modern Subterranean Aqueducts of Deccan

Mate (1998: 127) argues that the Deccan Sultanates[2] introduced the technology of building underground aqueducts similar to *qanats* in India during the 15th and 16th centuries CE. Govindankutty (2020: 662) supports his claim and suggests that the diffusion of *qanat* technology from Persia to India may have happened through trade relations and knowledge transfer during the migration of influential and skilled groups between the two regions. Moreover, the Deccan Sultanates had ethnic and religious linkages with the Middle East, which may have facilitated this technological transfer (Michell and Zebrowski 1999: 2).

Subterranean aqueducts in India are predominantly found in the Deccan Plateau towns of Bidar, Ahmednagar, Bijapur, Hukeri, Aurangabad, Burhanpur, and Pune. They were constructed by different dynasties over time, primarily to address the growing water demand associated with population growth and urban expansion in the Deccan towns. These aqueducts reflect variations in their names and the sources of water they conveyed (see Gadre 1986, Mate 1998, Govindankutty 2020). Table 1 provides a comparative overview of these key features.

Table 1: Subterranean Aqueducts of the Deccan Plateau

Sr. No.	*Towns*	*Dynasty & Period*	*Name*	*Source of water supply*
1	Bidar	Bahmani (15th century CE)	Karez Surang-Bavi	Reservoirs or wells
2	Ahmednagar	Nizamshahi (15th–16th centuries CE) Mughals (17th–18th centuries CE)	Nahar/ Nahr	Wells, reservoirs, or tanks
3	Bijapur	Adilshahi (16th century CE)	Kharejari, Surang-Bavi	Wells, reservoirs, cisterns, or tanks
4	Hukeri	Adilshahi (16th century CE)	Karez	Wells (entirely groundwater)
5	Aurangabad	Nizamshahi (17th century CE) Mughals (17th–18th centuries CE)	Nahar/ Nahr	River and reservoirs
6	Burhanpur	Mughals (17th century CE)	Kundi Bhandara	Wells (entirely groundwater)
7	Junnar	Nizamshahi (17th century CE)	Nahar/ Nahr/ Naḷa	Reservoir and wells
8	Pune	Peshwa (18th century)	Nahar/ Nahr/ Naḷa	Reservoir and wells

Source: Author. Adapted from Govindankutty 2020: 666.

Table 1 indicates the variation in the water supply sources for the subterranean aqueducts across different locations. Except for Burhanpur and Hukeri, where the aqueducts relied entirely on groundwater, aqueducts elsewhere received a combined supply of surface water and groundwater. This characteristic distinguishes these aqueducts from the *qanat* systems of Persia, where groundwater constituted the principal source of water supply.

Many of these Deccan towns are located in a shallow valley surrounded by hills. The construction of bunds across valleys and natural drainage channels facilitated the storage of rainwater runoff in reservoirs (Mate 2002: 96). Occasionally, wells were dug near the reservoirs, as seepage from the stored water helped recharge the surrounding groundwater and maintain a high-water table. From these reservoirs or wells, water was transported to the settlement through a network of subterranean aqueducts by means of gravity. Airshafts were located along the aqueducts at regular intervals, which helped to release air pressure from the flowing water. Some of them had a provision for a person to enter the tunnel for maintenance purposes. Cisterns or tanks commonly stored the water conveyed by the aqueducts. Collectively, the wells or reservoirs, aqueducts, airshafts, and cisterns constituted the urban water infrastructure of the Deccan towns.

Previous Work

The historical significance of subterranean aqueducts, as the earliest known attempts to use Persian technological knowledge to develop elaborate subterranean water supply networks in Indian towns, has attracted the attention of many scholars.

Based on archaeological evidence, Gadre (1986) has analysed the historic network of subterranean aqueducts developed by the Nizamshahi rulers in Ahmednagar. Apart from mentioning the engineering details of aqueducts, he also records the names of Persian engineers such as Salabat Khan Gurzi, Nimat Khan Samnani, Murtaza Khan Fikiti, and Farhad Khan, who supervised the construction of aqueducts. However, local artisans carried out the actual work under their guidance, highlighting a collaboration between imported technical expertise and indigenous craftsmanship.

Agarwal and Narain (1997), in their seminal work Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems, shed light on aqueduct-like water transportation structures such as channels, diversion systems, and gravity-driven networks in the semi-arid and hilly regions of India that transported water over long distances with optimum energy inputs. However, their research is directed more toward community-managed irrigation systems rather than urban water supply systems. Nevertheless, their work significantly influenced subsequent research on historic water supply systems.

Mate (1998, 2006) has explained the chronological development of subterranean aqueduct systems in Ahmednagar, Bijapur, Aurangabad, Burhanpur, and Pune. His research compares the similarities and differences in the aqueducts found in different towns, focusing on their history and technological details. He argues that these 16th-century urban subterranean systems mark a major shift in water management technology, where water was brought to the habitations instead of habitations being situated near water. Most of the pre-Deccan Sultanate towns were located near rivers and streams or relied on the water of wells, kuṇḍa and tanks. Although bunds and dams were constructed across rivers and streams, and water was conveyed through canals and channels, these systems were used primarily for irrigation rather than for urban domestic supply.

While Mate (1998) regards the aqueducts of Ahmednagar to have been constructed first, Govindankutty (2020) argues that those at Bidar, which he rediscovered in 2012, predate the Ahmednagar aqueducts. In an earlier study, he focused specifically on the *Surang-Bavi* system of Bidar, examining its construction details (see Govindankutty 2016). Based on archaeological evidence and field documentation, Govindankutty has provided a summary of the similarities and differences between the various aqueduct systems.

Similarly, Raghuwanshi (2006) has explained the aqueduct system of Burhanpur that was constructed based on the investigation of the recharge potential of the Satpura valley by the Persian geologist Tabkutul Arz in 1615 CE. As per his recommendation, the groundwater flowing toward the Tapti River from the Satpura ranges was trapped by constructing bunds and transported to the settlement through subterranean aqueducts.

A few other studies explore the subterranean aqueduct systems of specific locations. For instance, Kamlapurkar (2006) has given a brief account of the aqueduct system of Pune and explained its significance in imparting the early-modern town its distinct socio-religious character. While this study is important as one of the earliest investigations of aqueducts in urban spaces, it lacks depth on the technical details of the system, its spatial extent, and the mechanism through which water was conveyed. Gokhale and Deo (2016) have addressed this gap through GIS mapping and a digital reconstruction of Pune's aqueduct system, referring to historic maps and a few physical remains of the system. Similarly, Garge (2018) has analysed the subterranean aqueducts of Aurangabad.

While most of the studies mentioned so far have investigated aqueducts from a technical perspective, concentrating on their construction and structural features, Wong and Kallianpur (2006) adopt a socio-political interpretation of the water infrastructure of Golkonda Fort, Hyderabad, viewing subterranean aqueducts as means of expressing and legitimising political authority. They argue that these aqueducts facilitated glorifying the Qutubshahi Sultans and perpetuated their power by creating convenience and dependency.

Research Gaps

While the studies discussed so far are significant for developing an in-depth understanding of the subterranean aqueducts, certain gaps persist and require further scholarly attention.

Firstly, most studies focus primarily on the technical, managerial and socio-political aspects of subterranean aqueducts. In comparison, the landscape and socio-spatial aspects remain underexplored, despite them being intertwined with the broader urban landscape, each actively shaping and being shaped by the other. Such analysis is essential for understanding the spatial relationship between a town and its water infrastructure, as the development of water systems often shapes urban growth and spatial organisation.

Secondly, the aesthetic and cultural dimensions of the subterranean aqueducts remain unexplored in the current literature. In many pre-modern Deccan towns, water from subterranean aqueducts became a key element in shaping the visual and spatial experience of the town through the creation of gardens with water channels, fountains, and recreational public places. In many contexts, even when aqueducts are no longer operational, their references appear in place-based stories and songs. Therefore, it becomes essential to examine subterranean aqueducts not only as water provision infrastructure but also as elements in the production of urban space, memory, and identity.

Keller (2023) also observes these research gaps where studies focus on stepwells, tanks, and dug wells in an isolated manner, lacking contextualisation. Taking the case of waterscapes developed in Western India during the Solanki, Vaghela, and the Muzaffarid dynasties, she proposes a fresh look at the water elements in the larger context of the city, with water appearing as an essential identity marker of urbanity. Hegewald (2002: 3) makes a similar observation in the case of the water architecture of ghāṭa, tanks, kuṇḍa, wells, and ornamental pools in South Asia and India.

In response to the identified gaps, the present study argues for a shift in perspective on subterranean aqueducts from being solely understood as utilitarian infrastructures to being recognised as spatially and culturally embedded elements within the broader urban landscape. Such analysis may reveal the relationship between water infrastructure and urban landscape. Analysing this relationship can help extract strategies for aligning future water infrastructure with a city's natural topography, hydrology, and existing landscape features. The study may further emphasise the importance of designing water infrastructure not only as a technical service system, but also as a spatial system that contributes to public realm quality, shapes identity and enriches experiential quality. Such an approach could encourage context-sensitive, resilient, and culturally grounded water infrastructure design strategies in urban environments. This research approach was employed by the author in a previous study (see Marathe 2019, 2024). The present study builds upon that work and applies it to the study of aqueducts in Pune.

Aim and Objectives

Taking the case of 18th-century subterranean aqueducts built in Pune town during the reign of *Peshwa*[3] rulers, this study aims to understand the historic water infrastructure as a spatial structure having aesthetic and cultural value that evolved from and shaped the urban landscape of a place. The study seeks to answer the following questions:

Firstly, as water infrastructure, what was the spatial relationship of aqueducts with Pune's topography, and in what way did they contribute to the physical growth of the city? The objective is to investigate the design of aqueducts as part of larger water infrastructure, comprising reservoirs, airshafts and cisterns and to find out their interaction with the topography of Pune. Further, the study attempts to examine aqueducts as a determining factor in the urban growth of Pune. It analyses water infrastructure as a structuring element for Pune that guided the development of the town along the routes of water supply.

Secondly, what role did water infrastructure play in the development and shaping of landscaped areas and public spaces in the city? This study attempts to look at water infrastructure beyond its utilitarian function and explore its role in the creation of quality urban spaces and landmarks. It also looks at the symbolic value of water infrastructure capable of expressing meanings and creating elements of comfort, glory and identity.

Lastly, how was the historic water infrastructure destroyed over time, and what place does it have in the collective memory of the people? This aspect tries to find out how urbanisation and changing values have affected aqueducts and cisterns over time, resulting in their continued use or neglect. It also examines the way people remember and relate to them today.

Methodology and Data Sources

To seek answers to the above questions, the study employed a qualitative historical methodology that combined archival research, literature review, cartographic analysis, and field observations to reconstruct the spatial, aesthetic, and cultural significance of subterranean aqueducts in Pune.

The first stage of the methodology involved a systematic analysis of secondary and primary sources, including rare books, historic documents, official documents, and journal articles in English and the regional language Marathi. These sources were systematically reviewed to understand subterranean aqueducts and their historical context. A key aspect of this stage was the collation of fragmented and dispersed data across multiple sources, languages, and formats, and synthesising it into a clear interpretative structure. This process enabled the gathering of information related to the construction, expansion, and simultaneous growth of the aqueduct network and the town.

As part of this first stage, preliminary data on the aqueducts has been gathered by referring to the Gazetteer of Bombay Presidency, 1885. The physical characteristics of aqueducts such as their diameter, length, material, and overall functioning were documented.

Simultaneously, data on aqueducts have been collected from books and scholarly research articles. These secondary sources are noteworthy since most of them are based on data retrieved from the administrative documents of the Peshwa court. For instance, Sovani (2017) has explained the aqueducts in his book, written in Marathi titled '*Haravlele Pune*', which has been referred to in this paper for understanding aqueducts in greater detail. Similarly, the research report of a survey published by Karve (1942) in Marathi titled '*Pune Nagar Samshodhan Vrutta'* has been useful in understanding the various cisterns connected to the different aqueduct lines. Additionally, a few other reports published in the first half of the 20th century have been consulted for collecting data on Pune as it existed in the 18th century, its growth, and the spread of the aqueduct network.

The second stage involved analysing historical maps to understand the spatial extent, alignment, and distribution of the subterranean aqueducts relative to the surrounding urban landscape. In the present study, historic maps published by the British in 1876 under the title 'Poona City Survey' have been referred to explore the spatial extent of the aqueduct network and generate architectural drawings, wherever required. The title comprises a collection of 45 maps, each drawn at a scale of 50 feet to an inch. They are catalogued under the reference IOR/X/9864/1–45, with IOR referring to India Office Records and X indicating the Map Collection at the British Library, London.[4] These maps provided a clearer understanding of the aqueduct network and served as reference material for developing some of the figures presented in this paper.

The third stage consisted of field visits to sites where traces of the aqueduct system are still visible. The purpose of these visits, after reviewing the historic documents and secondary sources, was to validate the information through on-site observations and examine the current physical condition of aqueducts, cisterns, and reservoirs. A physical verification of the surviving traces of the aqueduct system facilitated understanding of their spatial alignment and transformation within the present-day urban landscape. A few of the surviving remnants have been documented through photographs.

Overall, the methodology integrated document analysis, cartographic study, and field-based documentation to form an in-depth understanding of the subterranean aqueducts of Pune.

The spatial relationship of aqueducts with topography and their contribution to the physical growth of Pune

The 18th-century settlement of Pune was situated in a low-lying basin surrounded by hillocks. The river Mutha, along with the streams Ambil Odha, Nagzari, and Manik Nala, were the freshwater sources for Pune. However, they dried up during summer. Consequently, people had to use groundwater as an alternative source and had dug several wells on their premises to ensure a continued water supply (Sovani 2017: 123). The Gazetteer of Bombay Presidency (1885: 326) records 1290 wells in Pune during the second half of the 19th century, but also mentions that most contained brackish (salty) water, unsuitable for drinking. Another survey conducted in the 1940s records 1511 wells in Pune, of which only 86 contained potable water (Karve 1942: 13). From a rough backward projection, one could assume that the number of wells in the first half of the 18th century could have been in the range of 900–1100. Despite the large number of wells, the available supply of potable water may have been inadequate for the estimated population of about 40,000 (Kosambi 1980: 146) and the additional floating population who gathered on festive occasions. Moreover, groundwater depletion during summer may have caused water stress and acute shortages during droughts.

As recorded by Bhave (1976: 39–40), the year 1745 witnessed severe water scarcity in Pune, causing unrest in the community. At that time, Balaji Bajirao alias Nanasaheb (1740–1761), the third Peshwa ruler, was away from Pune. In his absence, Nanasaheb’s grandmother Radhabai ordered the ministers and the rich people to stop watering their gardens and instead make available the water from their private wells for the use of common people. This incident left a lasting mark on Nanasaheb, who subsequently thought of exploring alternative water sources and the adoption of more reliable water supply technologies.

As mentioned previously, before the beginning of the 18th century, the subterranean aqueduct systems in the Deccan towns of Bidar, Ahmednagar, Bijapur, Aurangabad, Burhanpur, and Junnar, constructed by the Deccan Sultanate rulers, were already functional. These towns, including Pune, display a basin-like topography, where the main settlement occupies a lower elevation than the surrounding terrain, consisting largely of hillocks. Such topographical conditions provided a favourable setting for constructing subterranean aqueducts that would convey water with the aid of gravity. It is plausible that Nanasaheb observed the aqueduct systems in Deccan towns during military campaigns and political engagements, which informed his decision to commission the construction of a similar system for Pune.

Accordingly, the work of constructing the first subterranean aqueduct system for Pune began in 1749. Two reservoirs were created by damming the streams flowing from the hills at Katraj, a place about 8 km south of Pune. This aqueduct scheme was completed in 1755, following six years of construction (Sovani 2017: 124). It became popular as *Katraj Nahar* or *Katraj Naḷa*, after its place of origin. The length of the main aqueduct, along with its distributing channels, was about 11 km. Katraj aqueduct became famous as a major infrastructure work in those days, which earned Nanasaheb glory and fame. It resolved the issue of water scarcity to a large extent (ibid).

Later, toward the end of the 18th century, with Pune's expansion, the construction of three additional aqueducts took place. Around 1790, Nana Fadnavis, a minister in the court of the Peshwa, commissioned the construction of an aqueduct starting from Narhe Ambegaon, a place about 9 km to the south of Pune. Similarly, Anandrao Raste and Ruparam Chaudhary commissioned the construction of two aqueducts starting from Kondhwa, a place about 10 km to the southeast of Pune, as shown in Figure 1. Thus, four aqueducts were functional in Pune by the end of the 18th century with a daily water supply of approximately 3.84 million litres (Gazetteer of Bombay Presidency 1885: 326–327). The aqueduct network seems to be designed thoughtfully with essential consideration for Pune's topography.

Strategic Design of the subterranean aqueduct network

Firstly, the reservoirs at Katraj were constructed at a higher level than the settlement by damming two streams coming down the hillocks. The dam wall was about 183 m long, 9 m high and 2.5 m wide (Gokhale 1914: 3). This reservoir acted as a settlement tank, allowing the mud and sediments to settle down. The dam wall contained small openings fitted with wooden plugs. On removing the plugs, clean water from this reservoir flowed into another one, located at a slightly lower level. The dam wall of this reservoir was about 300 m long, 12 m high and 3 m wide (ibid). Openings, similar to those present in the wall of the previous reservoir, allowed water to enter the aqueduct.

In addition to the upstream reservoirs at Katraj that supplied water to the aqueducts, a supplementary downstream reservoir was created by damming the Ambil Odha at the foot of Parvati, a hillock located to the south of Pune, as indicated in Figure 1. Before it was dammed, the Ambil Odha used to flood often during the monsoon. However, in 1752, the flood was severe, which washed away many people staying on its bank (Karve 1942: 191–192; Sovani 2017: 120). To avoid the recurrence of such an incident, Nanasaheb decided to build a dam on the Ambil Odha and divert its flow away from the settlement. Accordingly, a 25-acre artificial reservoir was created at the foot of Parvati. This work began in October 1753 and was completed after 17 months in March 1755 (Sovani 2017: 108).

The Parvati reservoir became a critical component in the water supply system of aqueducts. Firstly, in case of a shortage of supply from the two reservoirs at Katraj, the one at Parvati that functioned as a backup reservoir from which water could be released into the aqueduct through an appropriate arrangement. Secondly, it helped recharge the aquifers, which increased the water table in the surrounding areas and benefited the nearby wells. The availability of a good water supply encouraged settlement and resulted in the expansion of Pune. The hard basalt rock quarried while constructing the reservoir was used for the construction of houses and other structures (ibid). Thus, the three reservoirs, two at Katraj and one at Parvati, were sources of water supply to the aqueduct commissioned by Nanasaheb.

Secondly, the aqueducts were laid strategically along the natural slope of the ground, avoiding installation of any mechanical devices for lifting water. In the case of the Katraj aqueduct, a slope of about 100 m prevailed from the origin, i.e., Katraj, up to the settlement adjoining the Mutha River

(Gokhale and Deo 2016: 656). Starting from Katraj, the aqueduct ran parallel to the stream Ambil Odha for some distance. A provision was made to release the muddy water, if any, from the aqueduct into the Ambil Odha at the time of the first monsoon showers. This arrangement prevented the mixing of any impurities into the clean potable water. The aqueduct was an arched tunnel 0.7 to 0.9 m wide and about 1.8 m high, lined by brick or stone (Gokhale and Deo 2016: 656; Mate 1998: 140–141). As the aqueduct line approached the settlement, stone or terracotta pipes of diameter 75 to 100 mm, joined with lime mortar, were laid inside the tunnel. These pipes had different interlocking arrangements for branching out from the main line.

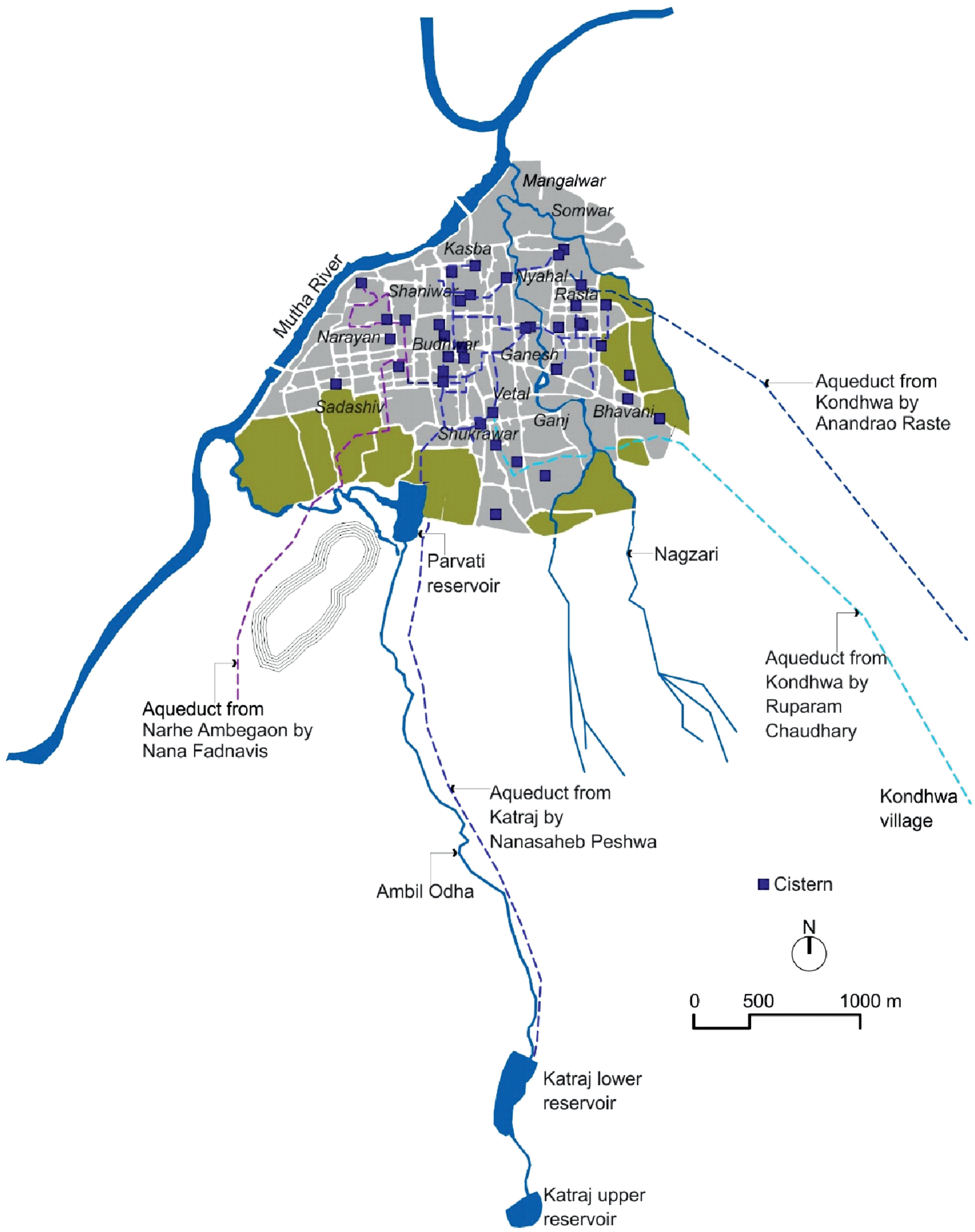

Figure 1: Late 18th-century map of Pune showing the aqueducts.

Source: Author. Adapted from Gazetteer of Bombay Presidency 1885: 266–267; Gokhale and Deo 2016: 665; Marathe 2019: 97.

Thirdly, an appropriate arrangement was made to ensure unobstructed water flow through the aqueducts. Airshafts were present along the aqueduct at regular intervals of 90 to 100 m (Gazetteer of

Bombay Presidency 1885: 327). They functioned as pressure-relieving devices, allowing the escape of air bubbles formed due to the high velocity of flowing water (Gadre 1986: 75; Mate 1998: 141). Typically, they were known as *ucchavāsa* in Marathi, which means to exhale. Additionally, they provided access to workers for cleaning and maintaining the aqueducts. Certain airshafts had masonry walls inside them with openings that could be closed by inserting wooden plugs. This arrangement made it possible to temporarily stop the flow of water during any repair or maintenance activity and divert water to another branch, if required. Furthermore, a few airshafts functioned as settling chambers and were sunk a little below the aqueducts for any silt to settle down on the way (Sovani 2017: 127).

Lastly, numerous rectangular or square-shaped cisterns known as *haud* stored the water carried by the aqueducts. Their spatial network enabled every household to have comfortable walking access to the nearest cistern. About 80–100 cisterns, both public and private, supplied water to different wards in Pune (Gokhale 1914: 8, Gokhale 2018: 58). The public cisterns were located in community open spaces, sidewalks, and temple precincts, while the private ones were located within the properties of ministers and noblemen.

Altogether, the reservoirs, aqueducts, airshafts, and cisterns seem to be thoughtfully designed in accordance with the topography of Pune, causing minimal alteration of the natural terrain. The reservoirs helped store rainwater during the monsoon and checked excessive surface runoff. The alignment of aqueducts along the natural slope of the terrain ensured a continuous flow of water without the use of any mechanical means to lift water. Simultaneously, the subterranean nature of the aqueducts minimised the evaporation of flowing water.

The presence of multiple and distinct water supply sources likely made the aqueduct system less susceptible to drought. The primary source of water for the Katraj aqueduct was surface runoff, whereas the other three aqueducts were supplied primarily by groundwater, mainly through springs. As different sources supplied water to each of the four aqueducts, a reduction in discharge from one source could potentially have been compensated by continued supply from the others, thereby reducing the risk of widespread water shortages. In addition, the availability of backup reservoirs such as Parvati reservoir would have provided a buffer during periods of reduced water availability. The pre-existing wells, which continued to function alongside the aqueduct network, could also have supplemented the water supply when needed. Collectively, these features may have ensured a continued water supply during years of inadequate rainfall.

To summarise, the subterranean aqueducts of Pune were a continuity of existing infrastructure works found in other towns across the Deccan region. Unlike the aqueducts of Hukeri and Burhanpur, which relied entirely on groundwater for their water supply, the aqueducts of Pune were multi-sourced, similar to the network at Bidar, Ahmednagar, Bijapur, and Aurangabad, using both surface water and groundwater. The primary source of water supply was rainfall and surface runoff, which was dammed in the reservoirs. However, since the aqueduct tunnels were at or below the groundwater table in a few places, they were also able to tap groundwater resources. This arrangement enabled some of the existing wells to be incorporated into the system, allowing their water to be utilised as well. In turn, the construction of Parvati reservoir raised the groundwater table, leading to higher water levels in nearby wells. Overall, the aqueduct system of Pune demonstrates a well-integrated system, combining existing wells with newly constructed infrastructure.

Water infrastructure and Pune's growth

The aqueducts and other water infrastructure-related works, such as diverting the Ambil Odha, were instrumental in shaping the urban growth of Pune. Until the beginning of the Peshwa rule, Pune was a small town located on the banks of Ambil Odha and Nagzari. For administrative purposes, the town was divided into different wards known as *peṭhā*, viz., *Kasba, Raviwar, Shaniwar, Budhwar, Mangalwar, and Somwar*, containing a few houses of artisans (Gadgil 1945: 14).

Pune started to grow gradually once it was made the capital of the Maratha Empire by Bajirao Ballal (1720–1740). He undertook a systematic expansion of the town by appointing a special officer for the task and invited merchants and other people to settle there (Kosambi 1980: 144). He got a mansion built for himself known as *Shaniwar Wada* in 1732 (Sovani 2017: 56). Similarly, he allotted sites to his ministers and other nobles for building their mansions. The old parts of the city were revived by making special offers of tax exemptions to people willing to settle there (Kosambi 1980: 144). Such offers encouraged many outsiders to settle permanently in Pune, leading to its growth.

However, during the initial three decades, from 1720 to 1750, Pune's expansion was mainly southwards, confined within the natural boundaries set by the major waterbodies, viz., the Mutha River to the north, Nagzari and Manik streams to the east, and Ambil Odha to the west. *Shukrawar Ward* was established toward the south of the existing Budhwar Ward during the reign of Bajirao. By 1760, Pune covered an area of about 2.5 sq.km, having a population close to 40,000 (ibid: 146). The construction of the Katraj aqueduct was largely complete by 1755, as a result of which the central wards, viz., Kasba Raviwar, Shaniwar, Budhwar, and Shukrawar, began receiving a reliable water supply, encouraging the growth of the settlement here.

Also, the east-west expansion of Pune started during Nanasaheb's reign. The westward expansion of Pune started with the diversion of Ambil Odha in 1755. Once the Ambil Odha stopped flowing through the main city, it became possible to expand the existing wards and plan new wards in the open area occupied by gardens to the west of the settlement. Accordingly, the Shaniwar Peṭha expanded toward the west up to the edge of the Mutha.

Later, in the 1770s, two new wards came up to the west of Pune, viz., *Sadashiv* and *Narayan.* Both of them were established during the reign of Madhavrao (1761–1772), son of Nanasaheb. For almost two decades, people were not keen to settle in the Sadashiv Ward due to the limited availability of water (Sovani 2017: 198–199). During the planning of the Katraj aqueduct, Pune had not spread to the west, beyond the Ambil Odha. Hence, the aqueduct was designed to supply water primarily to the central wards. Now, rather than adding a new branch to the Katraj aqueduct that would supply water to the newly established Sadashiv Ward, Nana Fadnavis commissioned the construction of a new aqueduct in 1791 that brought water from Narhe Ambegaon, as mentioned before. This aqueduct provided ample water to Sadashiv Ward, thereby solving the issue of inadequate water supply (ibid). Within a few years, many people settled down in this ward.

Narayan Ward, established around the same time as Sadashiv Ward, was the westernmost ward of the town. It became famous for its rice market that flourished due to the presence of rice fields along the Mutha (Gazetteer of Bombay Presidency 1885: 280; Kosambi 1980: 149). It was inhabited by many people toward the end of the 18th century due to the availability of a good water supply from the Narhe Ambegaon aqueduct. Together, the Sadashiv and Narayan wards integrated seamlessly with the existing wards and formed a continuous and cohesive urban fabric in the western part of the city, as shown in Figure 2.

While Pune was expanding toward the west, the existing wards to the east were gradually expanding, and new ones were being set up simultaneously. Two old wards, *Shahpur* established around 1610, and *Sashtapur,* established around 1630, on the eastern bank of the Nagzari, were renamed by Bajirao as Somwar and Mangalwar, respectively, around 1735. These wards already contained sparse settlements that expanded. Later, in the 1750s, the wards *Guruwar* or *Vetal*, *Ganesh, and Ganj* were established

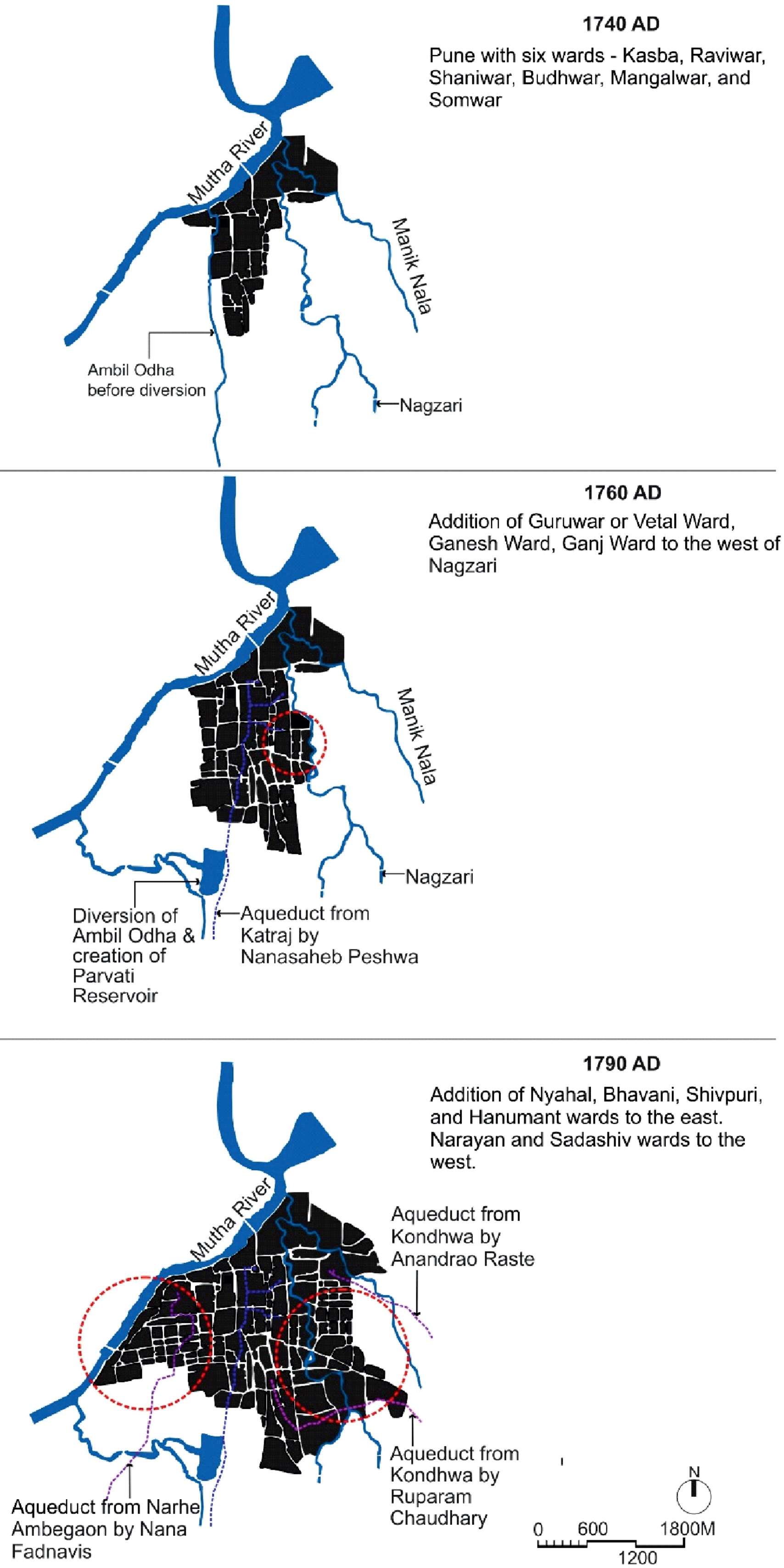

Figure 2: Water infrastructure and Pune's growth from 1740 to 1790.

Source: Author. Adapted from Gazetteer of Bombay Presidency 1885: 266–267; Kosambi 1980: 148.

toward the west of the Nagzari during Nanasaheb's reign (Sovani 2017: 40). An eastern branch of the Katraj aqueduct supplied water to these wards.

Although there were wards to the west of Nagzari, the eastern side was vastly open. Madhavrao envisioned this open space as useful for setting new wards, especially for traders and expanding Pune eastwards. Accordingly, he prepared a master plan for this area in the 1760s, indicating the proposed wards. Soon, the plan was executed, and two wards, *Nagesh* or *Nyahal* and *Bhavani,* were set up in 1766 and 1768, respectively (ibid). As imagined by Madhavrao, Bhavani Ward soon became a busy trading centre; more than a hundred bullock carts loaded with goods came here daily. These goods were unloaded in this ward, and then they went to the main shops in the city. Thus, Bhavani Ward functioned as a wholesale market (ibid: 148). The ward received water from the aqueduct built by Ruparam Chaudhary (Gadgil 1945: 17). Ghashiram Kotwal built a lake in his ward to meet the water requirements of the traders (Sovani 2017: 149).

In 1778, Anandrao Raste established the ward *Shivpuri* to the east of Nyahal Ward, which became the eastern boundary of the town (ibid: 186). He soon got an almost 10 km-long aqueduct built from Kondhwa village that supplied water to the cisterns in the Shivpuri Ward. The availability of ample water soon encouraged settlement here. People soon started calling this ward *Rasta Ward* due to Anandrao Raste, responsible for its establishment and the construction of the aqueduct.

In 1790, Nana Fadnavis established the *Hanumant Ward,* occupying the open space between the wards Bhavani and Rasta. Considering the proximity of this new ward to the already existing Rasta Ward, it may have received water supply from the aqueduct built by Anandrao Raste. Although there is no direct mention of this, the Poona City Survey maps prepared by the British indicate aqueduct lines and cisterns in this ward.

Thus, within 50 years, from 1740 to 1790, Pune had expanded to a major town with 18 wards. Its area had more than doubled, from less than 2 sq.km to more than 5 sq.km (Kosambi 1980: 146, 151). The engineering work associated with the diversion of Ambil Odha and the construction of aqueducts was instrumental in shaping Pune's growth trajectory, especially east-west, and fostering its urban development. The Katraj aqueduct supplied water to the central wards; the Narhe Ambegaon aqueduct supplied water to the Sadashiv Ward in the west, while the two aqueducts from Kondhwa supplied water to the eastern and south-eastern wards, as shown in Figure 2.

This strategic design of aqueducts not only addressed the city's growing water demands but also facilitated its spatial expansion without disrupting the existing urban functions. The aqueducts integrated the different parts of the city, facilitating connectivity rather than fragmentation. Reliable access to water encouraged settlement closer to aqueducts and distribution points, orienting the expansion of Pune toward the water corridors.

Water infrastructure shaping the landscaped areas and public spaces

As Pune grew physically in the latter half of the 18th century, it experienced a significant transformation in its landscape. The availability of ample water supplied by the aqueducts fostered Pune's growth while transforming the landscape into a beautiful one with many gardens, public places, and water features serving as urban landmarks. These features demonstrated the aesthetic sense of the Peshwa rulers.

Gardens as recreational open spaces

Many gardens known as *bāgā*, both public and private, watered by wells and aqueducts, were developed by the Peshwa rulers, their ministers, and moneylenders. A record of 1747 mentions 37 gardens and their owners (Gokhale 1988: 42; Sovani 2017: 163). Many of the gardens were part of temple precincts, adorned with different flowering and medicinal plants. Few gardens were purely designed for recreational purposes, which often contained a palace or a pleasure house. The Peshwa rulers owned seven gardens (Sovani 2017: 163).

A famous garden, imagined as an island in the middle of the Parvati reservoir by Nanasaheb, was the *Sarasbag*. The garden was in the form of a small mound surrounded by water, accessible by a boat. Later, in 1784, Nanasaheb's grandson Madhavrao Narayan (1774–1795) alias Sawai Madhavrao built a Ganesh Temple on the mound. The deity soon became popular as *Taḷyātalā Gaṇapatī*, meaning Ganesh residing in the reservoir (Sovani 2017: 108).

Towards the east of the Parvati reservoir, Nanasaheb created another beautiful garden known as '*Hirabag*'. While the Sarasbag was a public garden, Hirabag was a private one, designed for recreation. This was a beautifully landscaped garden with a series of steps leading to the Parvati reservoir. A pleasure house was constructed in the garden. The Peshwa family celebrated many festivals in this house. During the rule of Sawai Madhavrao and Bajirao Raghunath (1796–1817), the garden and the pleasure house were used particularly to host dinners for the British officers (ibid: 100–102).

In 1803, Bajirao Raghunath hosted a formal meal for Lord Valentine and Pune's resident, Sir Barry Close, at the pleasure house in Hirabag. Bajirao's hospitality impressed both of them, particularly Lord Valentine, who noted the details of the visit in his diary. Similarly, in 1804, Bajirao Raghunath hosted a formal meal for General Wellesley (ibid).

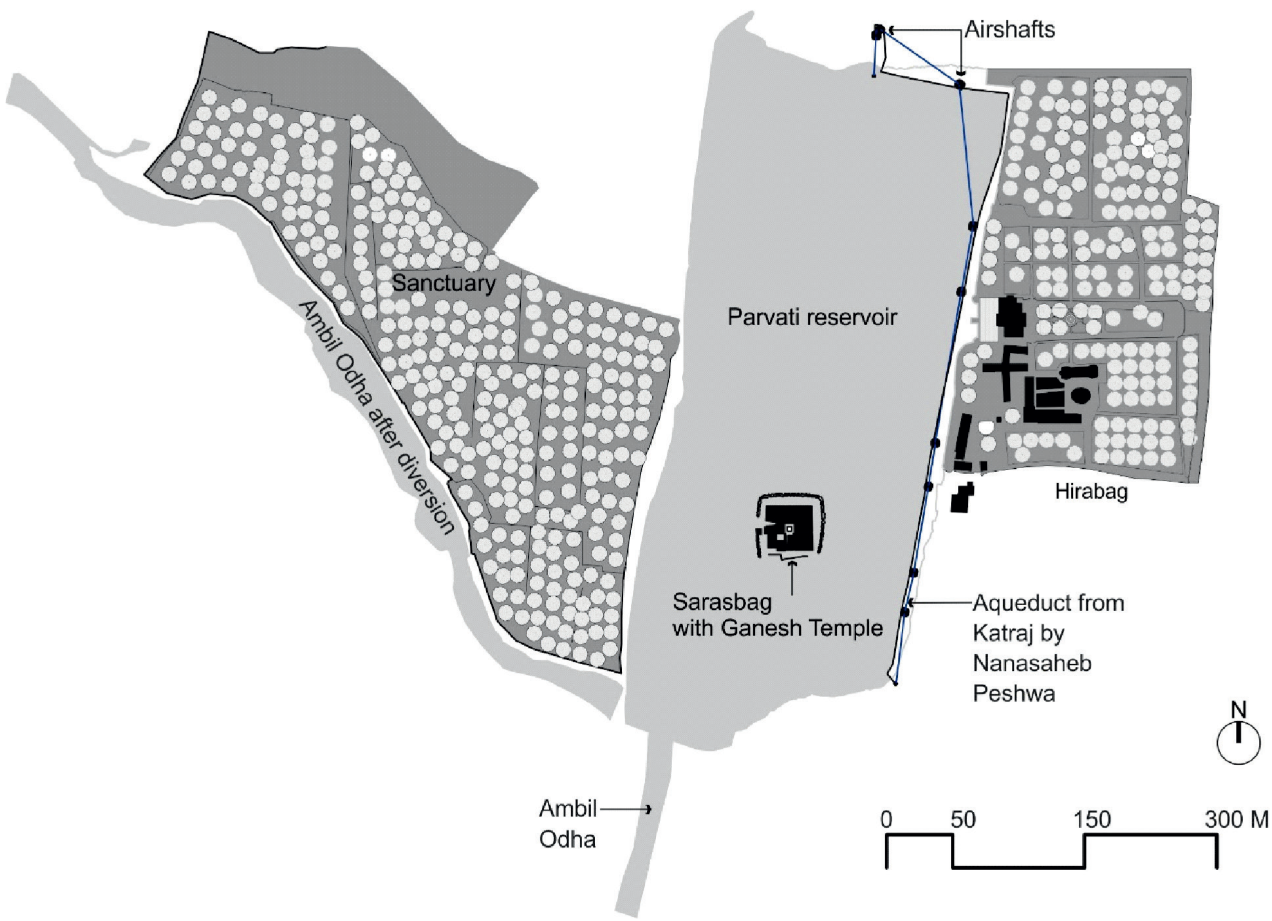

Figure 3: Parvati reservoir with Sarasbag, Hirabag, and sanctuary.

Source: Adapted from (Poona City Survey 1876)

A large open space of about 45 acres existed to the west of Parvati. Nanasaheb conceived the space as a large park or sanctuary, supporting diverse animal and bird species. Animals such as blackbucks, deer, hares, lions, tigers, rhinos, wild boars, and wild cats, and birds such as ducks, larks, myna, parrots, and peacocks were housed in the sanctuary. Thus, the Parvati reservoir, the two gardens Sarasbag and Hirabag, and the sanctuary collectively contributed 100 to 125 acres of green space, as shown in Figure 3, significantly improving Pune's urban landscape (ibid: 112–113).

Another garden of about 18 acres was created by Nana Fadnavis, which also contained his pleasure house in the middle (ibid: 164–166). *Kala Haud*, an important cistern, was located to the east of the garden. The garden was well-maintained until the death of Nana Fadnavis in 1800. Later, as the British captured Pune in 1817, they gifted the garden to their clerk Balajipant Natu. Therefore, the British named the garden *Natubag* in the map of Poona City Survey.

In addition to Sarasbag, Hirabag, and the garden of Nana Fadnavis, certain gardens were part of temple precincts, which contained flowering and medicinal plants essential in the performance of temple rituals. *Belbag* and *Tulshibag* were two such gardens that got their names because they contained medicinal *bel* and *tulshi* plants. Tulshibag was owned by Jivaji

Ganesh Limaye alias Khasgivale, a minister, looked after the private affairs of the Peshwa rulers (Sovani 2017: 136–139). He built a garden spread over seven acres. The main portion of the garden was square in plan and had a small palace. Four fountains were present in the four corners of the garden. A special cistern was constructed in the garden, fed by the Katraj aqueduct to water the numerous flowering plants (ibid).

Tulshibag was a religious complex, containing numerous temples. Although the garden and adjoining areas were privately owned, people were permitted to enter the premises freely, visit the temples, and enjoy their time in the garden. Visiting the temples after completing their household duties was a daily practice amongst the women. Tulshibag met the requirement of a safe public place for women, allowing them to take a much-needed break from their daily routine and interact (ibid).

To summarise, the aqueducts not only met the domestic water needs but also supplied water for gardening and landscaping, improving Pune's green cover and overall environmental quality. Furthermore, the green cover became useful for recreational purposes, thereby enhancing the liveability and overall well-being of people.

Cisterns as meeting points and public places

The people of Pune had a special attachment to the aqueduct system, especially the cisterns storing water. They served as popular community spaces where people gathered for fetching water, bathing and performing religious rituals (Figure 4). *Badami Haud, Bahulicha Haud, Kala Haud, Pushkarni Haud, and Sat Toticha Haud* were some of the cisterns that experienced large crowds.

The Pushkarni Haud (Figure 5) was connected to the aqueduct built by Nana Fadnavis in 1790. With a length of about 15 m, width 12 m, and depth 3 m, it was a major landmark in Sadashiv Ward (Sovani 2017: 200). The residents of the ward gathered every morning on the haud for bathing and fetching water. Trees along the edge of the cistern provided shade and kept the water cool. Often, the evenings saw people sitting on the steps of the cistern enjoying the cool breeze.

Another famous cistern connected to the Katraj aqueduct was the one built by the Peshwa minister Haripant Phadke. Around 1776, Haripant built a grand wada for himself. He constructed one cistern within his wada for private use and another one for public use in the open space toward the north of the wada. It was about 8m long, 4m wide, and 3m deep, making it one of the largest cisterns in those

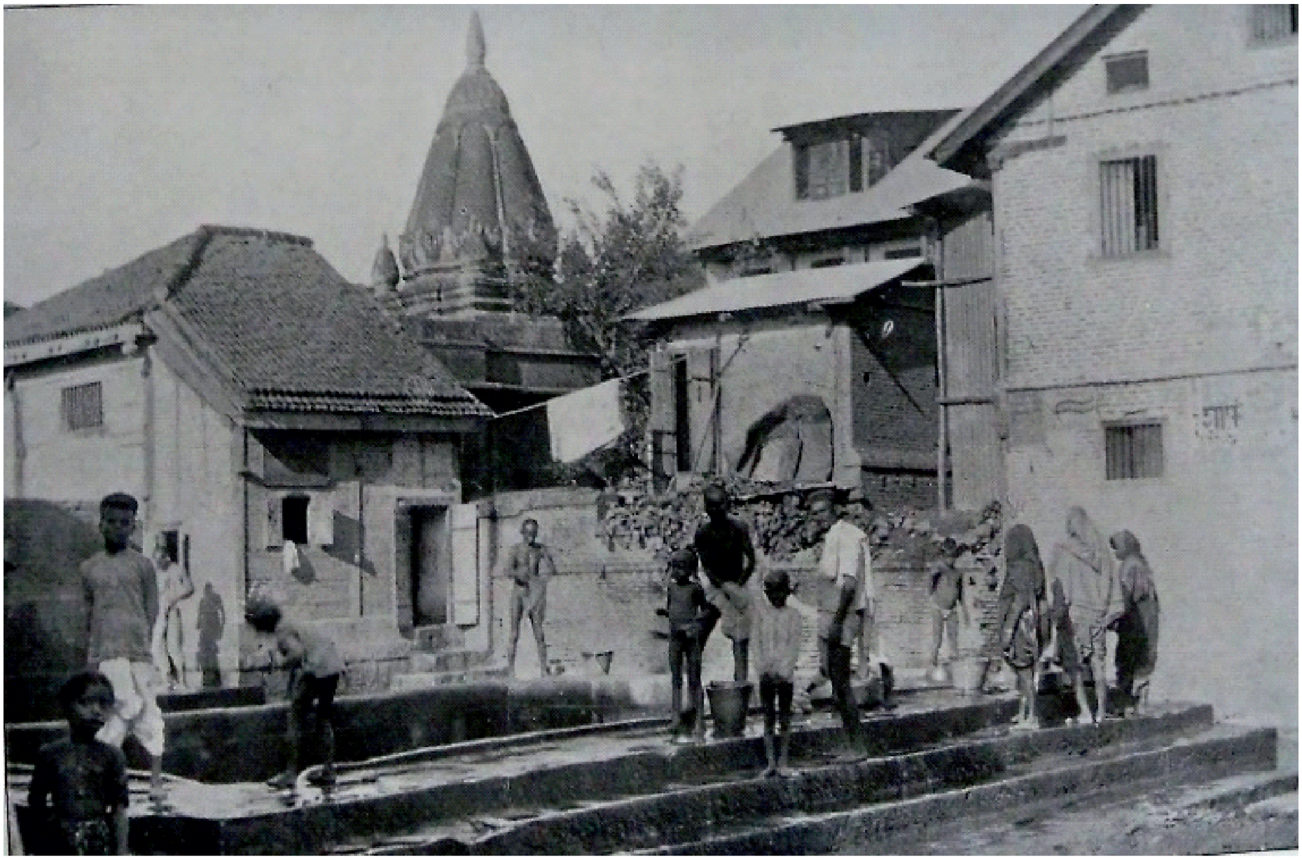

Figure 4: Old photograph of people gathered around a cistern in Pune.

Source: Elwin 1907: 15.

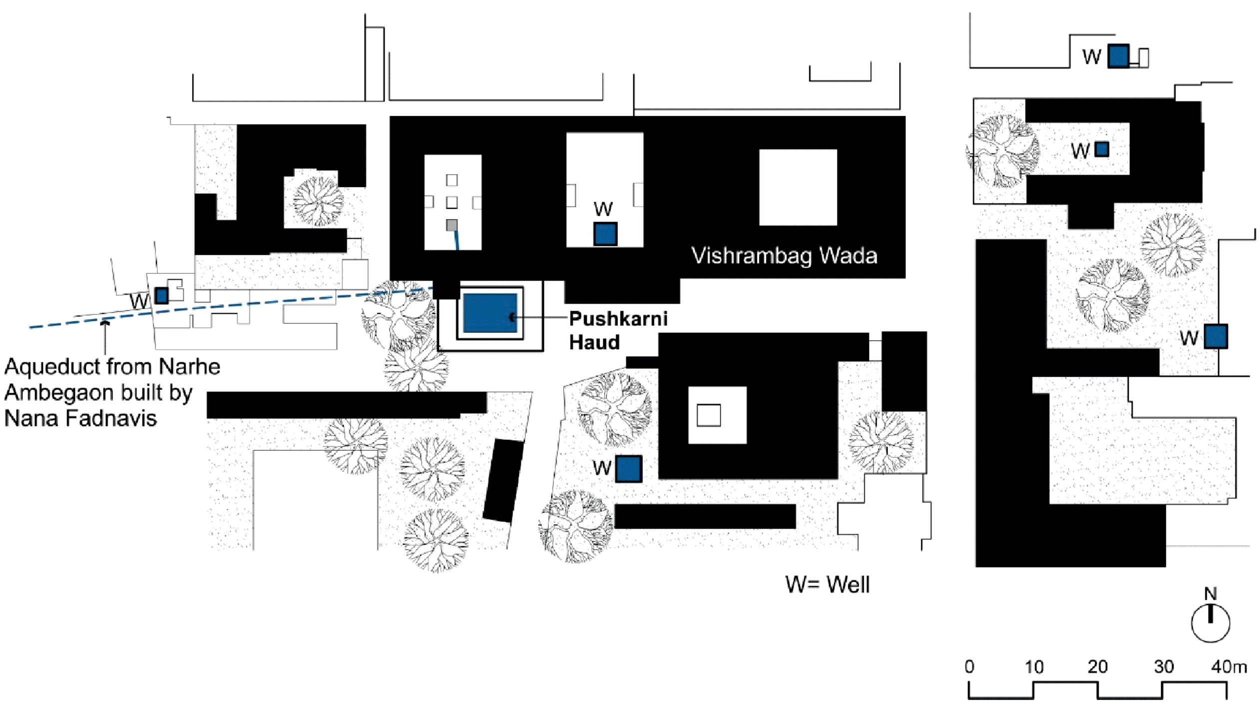

Figure 5: Plan showing the setting of the Pushkarni Haud.

Source: Author. Adapted from (Poona City Survey 1876) days. It was divided into two parts and had a fountain in the middle. It was a crucial source of water supply (ibid: 176).

Similarly, other cisterns that were part of temple precincts with flowering trees around which created vibrant community space, essential for the performance of religious rituals. Chanting of Vedic hymns and religious bathing before entering the temple took place at these cisterns, making them religiously significant structures. The author could not locate reliable data on the distribution of cisterns across different socio-economic groups. Similarly, no evidence was found regarding class or caste-based restrictions on access to specific cisterns. Nevertheless, given the prevailing socio-religious conditions during the Peshwa period, the possibility of such forms of segregation or restricted access cannot be entirely ruled out.

Fountains as artefacts of comfort and glory

One observes the emergence of fountains for the first time in Pune during the Peshwa period. Shaniwar Wada had many fountains in its courtyards and meeting halls that attracted many visitors. One such fountain that was famous amongst the foreign diplomats and guests visiting the court of the Peshwa was the *Hajārī Kārañje,* i.e., a fountain with a thousand spouts (Figure 6). It was located in the western part of the Wada and received supply from the Katraj aqueduct. Parasnis (1921: 17) describes it as,

[*Hajārī Kārañje*] had the shape of a lotus flower of sixteen petals – each petal having sixteen spouts with a circumference of 80 feet. It is said that in India, there is not a single fountain like this anywhere having 196 jets, not even in Europe, excepting the celebrated fountain 'Fountana di Trevi' at Rome. The water of this great fountain played a hundred patterns while the sun for its amusement would make and break a thousand rainbows.

Thus, Hajārī Kārañje symbolised the royal comfort of the Peshwa court, fascinated foreign guests, and facilitated the development of diplomatic relations.

Figure 6: Remains of the fountain Hajārī Kārañje

Source: Marathe 2024: 273.

Traditional songs on water infrastructure

The aqueducts and public cisterns built by the Peshwa rulers helped them to earn the goodwill of their subjects. Poets known as *śāhīra* have composed *povāḍe* (similar to ballads) in Marathi that describe Pune's water infrastructure.

In one of the ballads composed by poet Ramjoshi, Pune is described as a city of grandeur with a dense network of aqueducts (Kulkarni and Moraje 2002: 130). Various cisterns add to the charm of the city. Similarly, the Sarasbag reservoir with an island in the middle having the Ganesh Temple, and the Ambil Odha flowing adjacent to it are all beautiful. The gracious Peshwa rulers who have developed the city in this manner have considered the welfare of their subjects.

In another ballad, Ramjoshi portrays *Shukrawar Wada*, one of the mansions of the Peshwa, as a place containing many cisterns with sweet water comparable to nectar. Many people bathe and perform religious rituals at these cisterns (ibid: 126–127).

Since ballads were intended to glorify the ruler, the narrative descriptions of Pune may be slightly exaggerated. Nevertheless, Ramjoshi's reference to the water infrastructure, as part of Pune's detailed representation, highlights its importance in the city's urban and cultural landscape.

The deterioration of aqueducts over time and their place in the collective memory of the people

Following the defeat of Peshwa Bajirao Raghunath and the establishment of British rule in Pune in 1818, the colonial administration depended on the existing aqueducts to supply water to the city. As documented in the Gazetteer of Bombay Presidency (1885: 327), the water supply by the four aqueducts was 850,000 gallons or 3.84 million litres per day, as elaborated in Table 1.

Table 1: Water supply by the aqueducts of Pune

Origin of the aqueduct line	*Commissioned by*	*Year*	*Water supply (million litres)*
Katraj	Balaji Bajirao alias Nana-saheb	1750	2.95
Narhe Ambegaon	Nana Fadnavis	1790	0.45
Kondhwa	Anandrao Raste	--	0.22
Kondhwa	Ruparam Chaudhary	--	0.22
		Total	3.84

Source: After Gazetteer of Bombay Presidency 1885: 327.

According to an estimate by Gokhale (1988: 38–39), Pune's population in 1765 would have been somewhere between 40,000 and 80,000. At the time of special festivals such as *Dussehra* and *Diwali*, around 50,000 Brahmins used to come to Pune to collect *dakśiṇā* (i.e., donations) from the Peshwa. Thus, on festive occasions, the total population of Pune would reach around 100,000. Kosambi (1980: 179–180) predicts the population of Pune in 1819 to be 110,000, which declined to about 80,000 in 1822. Similarly, Gadgil (1945: 19–20) predicts the population of Pune to be between 100,000 and 113,000 by the beginning of British rule in 1817.

The Gazetteer of Bombay Presidency (1885: 327) mentions that Pune received an average per capita daily water supply of 15 gallons, i.e., about 68 litres, toward the end of the 19th century. Dividing the total water supply of the aqueducts by the daily average, the population works out to be 56,470.

From the data above, it is safe to assume that when all four aqueducts were fully functional, they would have fulfilled the water requirement of 55,000 to 60,000 people. Existing wells would have fulfilled the additional water requirement.

In the latter half of the 19th century, as the water demand of Pune increased due to an increase in the city's population, many British engineers initially came up with proposals to construct new aqueducts for increasing the city's water supply. Hart (1858) has presented a summary of these proposals. However, the British administration accepted the proposal submitted by Fife in 1866 to construct a dam over the Mutha River at Khadakwasla, a village on the outskirts of Pune at that time and supply water to different parts of the city through a network of underground pipes (Fife 1866).

Before the construction of Khadakwasla Dam, the Municipality set up by the British maintained the Katraj aqueduct, while the other three were maintained by the descendants of Nana Fadnavis, Anandrao Raste, and Ruparam Chaudhary. According to Karve (1942: 23, 221), for a few years, the Municipality utilised the water of the aqueduct built by Raste. Later, as the construction of Khadakwasla dam was complete, the British administration supplied 5000 gallons (22,700 litres) of water to the Raste family as compensation for utilising the water of their aqueduct. Such incidents indicate the dependency of the British administration in the first half of the 19th century on the water supply of the four aqueducts built during the Peshwa rule.

Gradual neglect and deterioration of the aqueducts

Work on constructing the Khadakwasla dam began in 1869 and was majorly complete by 1879 (Gazetteer of Bombay Presidency 1885: 20). Pune started receiving water supply from the Mutha Right Bank Canal. In 1876–1877, 549 houses received water from the canal (Khopkar 1951: 29). The first piped water supply scheme for Pune became functional by the beginning of the 20th century, around 1915 (Poona Metropolitan Regional Planning Board 1970: 112). The convenience of receiving water at the doorstep through a piped network discouraged people from walking to public cisterns and fetching water. Gradually, due to the widespread availability of piped water, people's reliance on aqueducts diminished. People stopped cleaning and maintaining the aqueduct lines and cisterns, leading to their neglect. Over time, the aqueducts faded into the background.

Soon, the piped water supply from Khadakwasla reservoir proved insufficient, as the water demand further increased. Consequently, in the post-independence era, the State Government of Maharashtra undertook the construction of an additional dam in the upstream area of the Mutha River, near Panshet village. Its construction began in 1957 and was completed on 5th July 1961 (Gogte 1988: 12–14). However, continuous rainfall in the catchment area of the dam from 5th July to 12th July 1961 overfilled the reservoir. The dam wall broke on 12 July, suddenly releasing the stored water. Within a short time, Pune was flooded, with water level reaching almost 3 m in most parts of the city. This catastrophic incident failed the piped water supply (ibid).

At this time, many citizens utilised the water supplied by the aqueducts. In short, although the historic water infrastructure was largely non-essential for daily use due to the availability of a networked water supply, it played a critical role as a backup system during periods of water shortage or system failures.

However, despite its historical value and usefulness as a backup system, the historic water infrastructure was severely damaged by haphazard and careless construction activity. New construction failed to take into account the existing underground network of aqueducts during the execution of foundational works, resulting in its destruction. Similarly, many cisterns were damaged during road-widening activity. The Parvati reservoir dried up due to deliberate damage done to its springs, which were the principal source of recharge. It remained covered with weeds and wild grass until 1968, when the Municipal Corporation of Pune decided to convert it into a public garden (Sovani 2017: 108–109).

Present condition of Katraj upper reservoir

Present condition of Katraj lower reservoir

Sarasbag with Parvati in the background

A private cistern in use in one of the old houses

A deity enshrined in place of the cistern Badami Haud

A road junction named after the cistern Kala Haud

Figure 7: Traces of the historic water infrastructure in Pune

Source: Author.

Today, only a few traces of the historic water infrastructure that once played a defining role in Pune's development remain. The two reservoirs at Katraj are neglected, their surfaces covered with water hyacinth and wild grass. Many people visit the Sarasbag daily, yet very few are aware that the public garden was originally a reservoir at the foot of Parvati. Although the network of underground aqueducts has largely deteriorated, some buried lines are suddenly revealed during ongoing infrastructure projects, such as the Pune Metro. Surprisingly, few cisterns that have survived in the old part of Pune for so many years still receive water from the Katraj aqueduct. Although the water is unsuitable for drinking because of pollution, people use it for washing clothes and utensils. A car servicing centre located close to one of the surviving airshafts has installed a motor pump and is using the water for washing cars and motorbikes. Thus, only a few remnants of the historic water infrastructure remain; the complete network has deteriorated over the course of urbanisation.

Historic water infrastructure in collective memory

Despite its deterioration, the historic water infrastructure still holds a place in the collective memory of the people, especially the earlier generation. People still remember many streets and junctions by the names of cisterns that once existed in those places. Signage displaying the names of cisterns such as *Bahulicha Haud, Kala Haud, Pushkarni Haud, Sat Toticha Haud*, and a few others can be seen along the street junctions and sidewalks. These instances suggest the significance of cisterns in shaping the spatial identity of a locality, leaving an imprint in people's memory.

In a few cases, though the cistern that once occupied the site has been destroyed, the site has transformed into a place of worship due to the enshrinement of a deity there. Interestingly, the deity worshipped bears the very name of the cistern, establishing a symbolic association between the historical and the sacred. For instance, a shrine has been enshrined in place of the *Badami Haud,* which is worshipped by the people in memory of the cistern, as shown in Figure 7.

To summarise, until the 1970s, aqueducts and wells were relevant before the development of the modern networked water supply as an efficient alternative. The ease of managing and maintaining the new piped network gradually reduced the use of aqueducts, even though they proved to be critical backup sources of water supply during incidents of system failures. Today, only a few remains of the historic aqueducts and water infrastructure can be seen, but people still refer to their names to identify road junctions and landmarks, showing they are still part of the collective memory.

Conclusion

From the discussion so far, one may safely conclude that the 18th-century aqueducts of Pune, built during the reign of the Peshwa rulers, played a pivotal role in shaping the urban growth of the city and enhancing its urban landscape by ensuring a reliable water supply.

The design of aqueducts demonstrates a sound knowledge of the existing topography, which resulted in minimal environmental disturbance while planning the routes. Aligning the aqueduct routes along the natural gradient facilitated an efficient gravity-fed delivery system, eliminating the requirement for any mechanical devices for pumping. The timely and efficient setup of aqueducts seamlessly supported the city's growth.

The aqueducts and cisterns transcended their utilitarian purpose, facilitating the transformation of the urban landscape and improving the overall environmental quality. The public cisterns, fountains, and other water features were designed to create vibrant gathering places and pause points. These features invited people to connect with their surroundings, fostering a sense of community living.

Fountains became a symbol of comfort and glory. Water infrastructure found an expression in the ballads and traditional songs, conveying a sense of celebration and honour toward the patrons.

However, the convenience of household water access offered by the modern piped network saw a gradual decline in the use of historic aqueducts. Many cisterns fell into disuse and were destroyed later during road widening works and the construction of new buildings. Over time, rapid urbanisation has almost destroyed the historic aqueducts, airshafts, and cisterns, with only a few remnants still visible; their memory lives through the names of road junctions and roadside shrines that once marked their presence.

In the current context, although historic aqueducts may appear functionally obsolete, it would be worthwhile to explore ways to adapt and reuse them to address present-day challenges such as supply diversification, resilience, and sustainability.

Integrating historic aqueducts with modern water infrastructure for diversified water supply

Amidst increasing water demand, it is essential to explore the possibility of reviving the historic aqueducts, cisterns, and wells, and using them as supplementary sources along with the existing networked water supply. Although the historic aqueducts may not match the volume or efficiency of modern piped networks, even a little addition from them may contribute to overall water security, especially in the old parts of the city. Thus, integrating the historic aqueducts with modern water infrastructure can help diversify the overall water supply sources. Such diversification can shift water provision to a more localised system, thereby minimising the dependence on a single supply system.

Enhancing water system resilience

Historic events have shown that continued dependence on a single water supply source, mainly large storage reservoirs, significantly increases the risk of system failure during droughts or accidental disruptions. For instance, Pune and many other cities obtain water from a single large water catchment area. A particular year of deficit rainfall in the catchment area can cause severe water stress conditions in the city. Instead, having the flexibility to access diverse smaller water sources along with the main centralised source can make the water infrastructure more resilient amidst increasing risk of climate change.

Intangible heritage and cultural significance of subterranean aqueducts

Even under the most adverse conditions, when the aqueducts may not supply the desired quality and quantity of water, their conservation becomes worthwhile due to their historical value, traditional hydro-geological knowledge, context-specific water infrastructure design strategies, and socio-cultural dimensions of water management. As shapers of urban space, these can strengthen the cultural identity and sense of place of many cities. More importantly, historic water infrastructure can guide decision-makers and planners to take environmentally and socially informed decisions while executing modern water infrastructure.

Notes

***This paper follows the Library of Congress system for transliteration of non-Roman words. However, the non-Roman names of books and authors that are already transliterated in English have been retained as they are.*

1. The Deccan Plateau is that region of India bounded by the Vindhya Mountains and River Godavari to the north, the rivers Krishna and Tungabhadra to the south, and the Eastern and Western Ghats to the east and west respectively (Gribble 2002).

2. Toward the end of the 15th century, five kingdoms known as Deccan Sultanates were ruling over the Deccan Plateau, i.e., roughly the central region of India, viz., the Nizamshahi of Ahmednagar, the Adilshahi of Bijapur, the Qutubshahi of Golkonda, the Baridshahi of Bidar, and the Imadshahi of Berar (Mate 1961: 9). These rulers had ethnic and religious linkages with the Middle East (Michell and Zebrowski 1999: 2).
3. Peshwa is a Persian title that means Prime Minister, an office that became hereditary. The Peshwa rulers were the commanders of the Maratha kingdom. The Peshwa rule extended from 1714–1817, until the East India Company defeated the last Peshwa ruler, Bajirao Raghunath, in the battle of Kirkee. For more details, see Kosambi (1980: 138).
4. The maps were consulted in person in the library's physical collection.

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