European Influence on Water Management in the Valley of Mexico

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Abstract

The Valley of Mexico's historical susceptibility to flooding underwent a significant environmental transformation during the Spanish colonization, when Spaniards, influenced by their Roman and Muslim heritage, built extensive hydraulic works including the *Desagüe*, exerting their control over the Indigenous population. This undertaking led to the desiccation of the Valley and the exploitation of Indigenous labour. With the belief that stagnant water caused miasmas, these efforts persisted throughout the nineteenth century in the Gran Canal waterwork, concluded in 1900 under President Porfirio Díaz. European scientific perspectives, including those of Alexander von Humboldt and Jean André Poumarède, played an influential role in water management policy decisions.

This thesis examines how European views shaped water management in central Mexico with a long-lasting effect on its modern-day society and environment. The basin's desiccation continues to pose an array of challenges in Mexico City, including subsidence, drainage and water supply inefficiency, social inequality, and flooding.

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Introduction

Throughout history, the evolution and growth of any society has been determined by its relationship with water. It is no coincidence that great cultures of the past, such as Ancient Egypt or Rome, thrived by developing inventive agricultural methods or lasting hydraulic works. Countless cultures have also granted symbolic significance to water, understanding its utter importance within nature and for the survival of humankind. At the same time, as stated by author R.D.V Glasgow, "water is inextricably tied up with power, therefore, its history inseparable from manifestations of might".[1] Therefore, access to water, as this thesis will demonstrate, has also been exploited as a means of control over colonized populations.

This thesis will focus on the ways in which European views have affected water management in Mexico City throughout its history. First, it will analyze the initial desiccation project of the seventeenth century during the Spanish colonization; secondly, it will examine the last drainage project completed in 1900, considering the nineteenth-century European influence regarding sanitation.

Long before the Spaniards arrived in 1519, the Valley of Mexico was a greatly populated area, and intensive agricultural practices implemented by Indigenous peoples led to the modification of the environment's composition. However, we cannot assume that the exploitation of natural resources, the introduction of European crops and animals, mass-scale production, and the establishment of colonial cities did not have a significant impact on the region. Yet colonization forced a reconfiguration of the social and natural space with a series of changes regarding water management, and considerable permanent environmental

[1] R.D.V Glasgow, *The Concept of Water* (UK: R. Glasgow Books, 2009) 59.

transformations took place.[2] The desiccation of the lake basin became the most significant transformation in Mexico City, which will be the focus of this thesis.

This research will consider how European views on nature during the sixteenth and seventeenth centuries affected the way the Spaniards implemented their agricultural practices and water management, reflected in various hydraulic works in Mexico. These will be essential aspects to take into consideration in the analysis of the first waterwork dedicated to the desiccation of the lake basin in the seventeenth century, the Tajo of Nochistongo, the first of many hydraulic works throughout the centuries pertaining to the Desagüe ("drainage" in Spanish).

However, the weight of European ideas extended beyond the colonization period, even after Mexico became an independent country in 1821. This influence was reflected not only in the final Desagüe work implemented by the turn of the twentieth century, but also in the time's urban landscape, sanitation, and scientific developments. In the mid-nineteenth century, health concerns due to great outbreaks of diseases such as cholera or typhus had a great effect on the way water was managed in Europe, and eventually, in the Americas. Stale water from constant flooding, as well as Mexico City's bad smells or "miasmas", were thought to be the main causes of epidemics, which is why during President Porfirio Díaz's regime (1876-1910), it became a priority to finish the Desagüe project started by the Spanish rule in the seventeenth century, this time largely financed by a British company.

Europe's influence over water management throughout Mexico's history is, therefore, undeniable when we examine how Europeans imposed their ideas and methods on the native

[2] Margarita Loera Ch. y Peniche. "La conservación de la obra hidráulica colonial en el Estado de México", *Revista de ciencias sociales* (Mexico: UAEM, no. 5, March 1994), 173. [All literature and primary sources in the Spanish language cited in this thesis have been translated into English by the researcher.]

population throughout the years, albeit in different ways. As stated by historian Sergio Miranda Pacheco, following the fall of the Mexica[3] city of Tenochtitlan, a pragmatic and utilitarian ideology was placed over nature and over the Valley's populations, prevailing for centuries. During the last third of the nineteenth century, the upper-class society would find a "scientific" justification to change water and land use to align with the establishment of a centralized and authoritarian regime, much like during colonial times.[4]

Literature review: the Desagüe throughout Mexican history

Topics surrounding the lake basin in Mexico have drawn the attention of a wide range of not only historians, but also experts in other disciplines throughout the years. One of the earliest accounts is *Memoria para la carta hidrográfica del Valle de México*, published in 1864 by nineteenth-century Mexican historian Manuel Orozco y Berra, in which he describes topographic studies and mapping projects of the Valley, records the lakes' altitudes in different parts of the city, and he discusses the topic of water supply and the construction of Spanish aqueducts. He demonstrates a high regard for European authors such as Alexander von Humboldt.

Going forward to the twentieth century, an important work is *El desagüe del valle de México en la época novohispana*, by historian Jorge Gurria Lacroix, published in 1978. This author details in chronological order the different instances in which the Valley suffered from flooding and the diverse drainage projects carried out from the colonial period to the Porfiriato, from 1876 to 1911. However, according to historian Mayra Sheila Olguín Ortiz, Lacroix based his work on

[3] Pronounced */mɛʃikas/*, this term is used in Mexico to refer to the Indigenous people known internationally as the Aztecs. Legend says the Mexica left the city of Aztlan, ruled by the Aztecs, before establishing their own city, Mexico-Tenochtitlan, hence the name of Mexicas. Since this is the more correct term, the researcher will be using it throughout this thesis.

[4] Sergio Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental* (Mexico: Instituto de Investigaciones Históricas, UNAM, 2021), 71.

the assumption that the flooding did not affect the Indigenous population in their daily lives since they had built simple hydraulic works to contain the water, whereas the Spaniards saw the flooding as catastrophic for their new city, rebuilding dikes, dams, and other works, eventually leading to drainage and desiccation projects.[5]

This assumption can be refuted by analyzing the article "Propuestas para la crisis del agua en Zona Metropolitana del Valle de México", by Erick A. Aguilar Obregón, Martín Vera, and María Martínez Rodríguez, published in 2017, in which the authors state that the Mexicas in fact dealt with constant flooding as early as 1382, for which they constructed great hydraulic projects to protect the city. According to these authors, the Indigenous logic was based on coexisting with the "agua viva" (living water), whose force was capable of either destroying or bringing life to the city.

Back in the 1990s, new perspectives began to be written regarding the drainage. In 1994, historian Margarita Loera published an article called "La conservación de la obra hidráulica colonial en el Estado de México", where she argued that what is most important about the hydraulic works carried out by the Spaniards is their relationship with power acquisition and population control. The author suggests that in early colonial hydraulic engineering works from the sixteenth century, clear evidence of Indigenous influence can be found both in Spanish architecture and engineering. If we consider the fact that most Spanish constructions were erected by Indigenous labour, these statements become more powerful. Loera states that "the materials that made up the hydraulic works still seem to keep the voices of the several generations, social and ethnic groups who fought for the control of the precious liquid".[6]

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[5] Mayra Sheila Olguín Ortiz, "El desagüe del Valle de México para el saneamiento del medio ambiente en el Porfiriato", M.A. Thesis, Mexico, Universidad Nacional Autónoma de México, 2018.
[6] Loera, "La conservación de la obra hidráulica colonial", 172.

Ecologist Exequiel Ezcurra, in his 1996 work *De las chinampas a la megalópolis. El medio ambiente en la cuenca de México* analyzes how the basin's environment gradually changed due to Spanish water management. Ezcurra states that Spanish hydraulic works from the seventeenth century caused gradual changes in the basin's environment. He relates the environmental damage to the introduction of livestock raising, tree felling, forced displacement of the Indigenous population, and more during the Conquista in the sixteenth century and to hydraulic and other urban constructions of the colonial period. He also analyzes the deterioration of the environmental situation in Mexico over the last 40 years, claiming that nowadays, neither the city nor the basin is self-sufficient regarding the supply of goods, particularly water.

In 1998, following Loera, historian Louisa Schell Hoberman, in her chapter "Technological change in a traditional society: the case of the Desagüe in colonial Mexico" from the book *Land Drainage and Irrigation,* focused on power dynamics, arguing that the drainage was carried out to prevent the loss of power and to maintain the *status quo*, since the constant flooding during the rainy season forced people to migrate and caused disease, property damage, with supplies cut off.

Throughout the 2000s, different perspectives on the lake basin's history examined social and economic issues, as seen in sociologist José Esteban Castro's *Water, Power and Citizenship. Social Struggle in the Basin of Mexico*, published in 2005. Castro states that confrontations over water in Mexico reflect a deep social struggle, a prevailing exclusionary model of social organization: first, the Mexicas controlled water over their vassal peoples, then the Spaniards over the indigenous population, and during the nineteenth century, private companies and landowners over marginalized and poor sectors of the population. According to the author, water control has played a key role in shaping human history, which is evident in Mexico's case.

In the last decade and in recent years, historians have taken more of an environmental approach as well. In her 2014 book *Dreaming of Dry Land. Environmental Transformation in Colonial Mexico City,* historian Vera S. Candiani argues that the drainage projects are the key in understanding the colonization process in Mexico, which had as one of its main consequences the environmental transformations of the lake basin. *Dreaming of Dry Land* has quickly become a classic in the topic; many sources cite Candiani's research, such as urbanist Isaac Acosta Fuentes and historian Sergio Miranda Pacheco. This thesis intersects with Candiani's line of research by considering the environmental impact of the Spanish intervention in central Mexico.

In 2016, Acosta Fuentes wrote his Ph.D thesis entitled "El debate científico en la concepción del desagüe del Valle de México, 1607-1975", in which he analyzes the drainage by taking a slightly different turn, focusing on the history of scientific thought, comparing three periods: the first half of the 17th century, the mid-19th century, and the second half of the 20th century until 1970. According to him, urban living in the basin was built through a process of environmental transformations that have generated a continued need for the efficiency of hydraulic works. He argues that the concept of urban sustainability has a large historical background, developed by the efforts to prevent flooding and to accomplish the desiccation of the region.

For their part, in 2017 social scientist Erick Aguilar Obregón and authors Martín Vera and María Martínez Rodríguez offer a brief explanation of each time the Valley of Mexico suffered from flooding and how the Desagüe projects took place, particularly the 1900 project by Francisco de Garay to ensure the sanitation of the city in their work "Propuestas para la crisis del agua en Zona Metropolitana del Valle de México". In this respect, the authors explore how the new concept of hygiene as a social element during this time played an important role in shaping not only hydraulic works, but domestic ways of water appropriation, meaning people started to

reconceptualize water by getting access to services such as in bathrooms and kitchens inside their homes. The authors state that "a city is not created solely by giving meaning to the space, but also to water".[7] In line with this, the authors point out that great public works are not impactful if they are not planned as social utility projects and cover the minimum for the social wellbeing of the population.

In 2018, Mayra Olguín Ortiz wrote an M.A thesis entitled *El desagüe del Valle de México para el saneamiento del medio ambiente durante el Porfiriato*, in which she explores all of the health and sanitation issues that led to the final project for the drainage, which became an urgent matter during the presidency of Porfirio Díaz towards the end of the nineteenth century and early twentieth century. Olguín states that the project was not only a government initiative, but that it was possible due to the expert opinions and concerns of medics, engineers, agronomists, directives, cabinet representatives, and even foreign companies, who deemed the drainage as the only plausible solution to control the underground water and the air and soil conditions. The author argues that, as well as preventing the spread of illnesses and miasmas, the opportunity to improve national economy convinced the government to approve the project. Her main argument is that sanitation concerns and the need for economic growth drove the drainage project during the nineteenth and twentieth centuries.

Following the environmental approach, other important works are *La caída de Tenochtitlan y la posconquista ambiental de la cuenca y Ciudad de México*, by historian Sergio Miranda Pacheco, and *Impacto ambiental y paisaje en Nueva España durante el siglo XVI*, by Marta Martín Gabaldón, Huemac Escalona Lüttig, and Raquel Güereca Durán. In his work, Miranda Pacheco argues that the flooding, droughts, epidemics and growing shortages of drinking water during the

[7] Erick Aguilar Obregón, et. al., "Propuestas para la crisis del agua en Zona Metropolitana del Valle de México", in Martínez Rodríguez, María Concepción Coord., *Políticas públicas ambientales*, (Mexico: Colofón, 2017) 47.

sixteenth and seventeenth centuries should have been enough to convince Spanish authorities that the solution to the city's water problems was to restore the "coexistence" with water the Indigenous peoples had long conquered centuries earlier. Pacheco suggests that "for a society swollen with triumphalism and racial superiority sentiments, it would have meant to renounce to their *conquista*, to the riches it had brought and kept promising, to the prospect of expanding their city and eventually, their empire on the New and Old Worlds".[8]

As for Gabaldón, Lüttig, and Durán, while the focus of their research is not about the drainage or the lake basin, they do mention that the private appropriation of water deeply upset the sociopolitical structure of pre-Hispanic times; according to the authors, the Indigenous collective work system languished to royal concessions that granted access to water to Spanish individuals, and of the construction and maintenance of their hydraulic works.[9]

It is worth mentioning that these two pieces of research were part of a collection of works released in 2021 by the National Autonomous University of Mexico (UNAM) to commemorate the 500th anniversary of the Conquest of Tenochtitlan in 1521. For the presentation of this collection, the UNAM's Instituto de Investigaciones Históricas (Historical Research Institute) stated their intention to bring light to perspectives produced in recent decades to acknowledge the complexity of these events' "contexts, the diversity of its actors and the scales of its repercussions".[10]

For context, most present-day scholars share the perception that Mexican official history from the previous two centuries had quite a one-dimensional approach, especially in its depiction

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[8] Sergio Miranda Pacheco, *Tenochtitlan y la posconquista ambiental de la cuenca y Ciudad de México*, (México: Universidad Nacional Autónoma de México, Instituto de Investigaciones Históricas, 2021) 41.
[9] Marta Martín Gabaldón, et. al., *Impacto ambiental y paisaje en Nueva España durante el siglo XVI*, (México: Universidad Nacional Autónoma de México, Instituto de Investigaciones Históricas, 2021) 29.
[10] Miranda Pacheco, *Tenochtitlan y la posconquista ambiental,* 13

of Indigenous peoples, often presented as groups without their own agency or voice. According to historian Federico Navarrete, the notion of defeated Indigenous peoples in Mexico devaluates and invisibilizes their true history in what he calls "intellectual dispossession".[11] In this aspect of the nineteenth-century Mexican nationalism, elites that conformed the academic sphere only spoke Spanish and did not consider Indigenous oral history as a valid source. A "catastrophic" view of the Conquista allowed Mexican nationalism to put all the blame on the Spanish empire, hiding its own colonial attitudes.

At the same time, the idealization of Mexico as a mixed nation came from this period, exalting the Indigenous past as well as the Spanish, while completely casting aside Indigenous peoples in the present-day. As a result, Indigenous perspectives from these periods are either too hard to find, or completely disregarded. In recent years, however, new efforts have been made to expand the way Mexican history can be understood and analyzed, from social struggles to environmental issues, which also reflects on the topic of water management and the drainage of the lake basin. For this study, analyzing the involvement of Indigenous peoples in the Desagüe was crucial to understand the social inequalities still reflected in today's society. The Indigenous labour contributing to Spanish control over the land and its environmental transformation is therefore an important aspect to recognize in this thesis.

To conclude this historiographical overview, the common thread between modern scholars is that desiccating the basin was a conscious effort by the Spaniards to exert control over the Indigenous population, and that the Desagüe had irreversible environmental effects. However, while this topic has been covered extensively by many historians and other experts throughout the years, there are perspectives yet to be explored.

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[11] Federico Navarrete, "Cómo los historiadores mexicanos "vencieron" a los indios", *NotiConquista*, Instituto de Investigaciones Históricas, https://www.noticonquista.unam.mx/amoxtli/2653/2651 (Accessed 9 December 2022)

This thesis employs a decolonial lens to highlight the mentalities of external powers during two pivotal periods in history. At the same time, it outlines the social and environmental effects of the region's desiccation as a consequence of the Spanish influence. Water management as a way to exert control over Indigenous populations is an often-overlooked aspect of colonialism, not only in Mexico but in the Americas as a whole. A prime example of this is reflected to this day in countries such as Canada, where Indigenous communities still struggle with having proper access to clean drinking water. The land's transformation and consequential impact on its inhabitants in the wake of the commodification of natural resources, initiated in the age of European imperialism, is a significant aspect of history that must be explored further. This study seeks to shed light on how European power dynamics shaped the development of Mexico City in a land that was once originally lacustrine in nature, a basin altered to a point of no return. Analyzing the first and last Desagüe works is key to understand the development of European ideas and their impact in Mexico, first as a Spanish colony and then as an independent country under a government eager to prove itself up to the standards of Europe. Approaching the complexities of this historical periods from this perspective will contribute to a more comprehensive analysis of the Mexican basin and explain its present and future.

Both at its inception and its conclusion, the Desagüe sought to build a drainage system for the benefit of the upper class: the Spanish elites during the colonization period, and the wealthier sector of the population during the late nineteenth century. In both instances, controlling the basin's water was the main motivation of the elites, albeit for different reasons, which only made class divisions among the population even greater. Demonstrating social inequalities caused by the Desagüe is a significant aspect of this thesis, since it reveals the continuity of this disparity in modern-day Mexican society.

At the same time, both the environmental and social circumstances that resulted from this European intervention are deeply interwoven, emphasized in this research. Present-day water management in Mexico City greatly favours wealthier sectors of the population, while neglecting lower-income inhabitants, particularly in its water supply. The aim of this thesis is to stress these historical and current disparities, as well as how they intersect with the basin's water crisis. Moreover, the environmental effects of the Desagüe have significant implications, especially since they are heightened by contemporary issues such as prolonged droughts in Mexico, an undoubted result of climate change. Additionally, water scarcity is not the only problem that has arisen from this issue. One of the largest environmental problems in the Valley is that Mexico City subsides at an alarming rate of 50 centimeters each year.[12] Flooding is still an issue the city deals with to this day, particularly during rainy seasons.

With that in mind, this thesis analyzes the historical context of the Valley's desiccation in the hopes of capturing people's interest in the topic, creating more awareness and contributing to the vital conversation of current water crises around the world and their developing sustainable solutions. This research also addresses the issue of water management with the aim of contributing to the decolonial discourse which, while in recent years has become more prominent in Mexico, there is still a great deal to be done, both in academia and with the general public. Deconstructing and reevaluating persisting colonial narratives is essential to promote a more critical examination of Mexican past, present, and future, and to confront the prejudices and deep-seated inequalities in its social —and environmental—landscape.

[12] E. Chaussard, et al. "Over a Century of Sinking in Mexico City: No Hope for Significant Elevation and Storage Capacity Recover", *Journal of Geophysical Research: Solid Earth*, vol. 126, issue 4, 2021, https://doi.org/10.1029/2020JB020648 (Accessed 1 June 2023), 7.

1. The Valley of Mexico and Prehispanic Water Management

The Valley of Mexico is an enclosed basin of over 9,000 km^2, surrounded by a mountain range and volcanoes Popocatépetl and Iztaccíhuatl. Before the arrival of the Spaniards, the basin gathered water from perennial rivers, springs, rain, and seasonal currents, with which it formed its lake systems and swamps. At the center of the basin, there were five main lakes: in the south, the freshwater lakes of Xochimilco and Chalco; the biggest lake, Texcoco, was located in the center, and in the north the Xaltocan and Zumpango lakes, all three of saltwater. There were quite varied depths in this lake system, depending on evaporations, rainfall, natural humidity, drought cycles, ground infiltrations, degree of water salinity or sweetness, altitude, and water circulation.[13] However, the Indigenous population of the Valley of Mexico did not entirely live harmoniously with the environment. The central lake of Texcoco was situated at a lower elevation topographically compared to the others, which means it collected all the excess water from the rest of the lakes during rainy seasons. Moreover, according to historian Vera S. Candiani, since the basin's lack of egress did not allow the water to filter easily into the ground, regular seasonal flooding was expected, as well as occasional catastrophic floods caused by high rainfall.[14] This gave the Mexica and other ethnic groups of the region the opportunity to develop their own hydraulic engineering measures.

The Mexica founded the city of Tenochtitlan in 1325 on the small islands located west of Lake Texcoco mostly due to strategic reasons: they were familiar with the exploitation of lacustrine natural resources, and it was an advantageous defensive position.[15] However, the

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[13] Teresa Rojas Rabiela, et al. *Cultura hidráulica y simbolismo mesoamericano del agua en el México prehispánico* (Mexico: Instituto Mexicano de Tecnología del Agua, 2009), 133.
[14]Vera S. Candiani, *Dreaming of Dry Land. Environmental Transformation in Colonial Mexico City* (California: Stanford University Press, 2014), 15.
[15] Alfredo López Austin, Leonardo López Luján. *El pasado indígena* (Mexico: Fondo de Cultura Económica, 2001), 213.

Indigenous population in the basin had little access to drinking water, which meant having to travel long distances; Tenochtitlan lacked stone and wood, was prone to flooding, and was a conflict zone where different ethnic groups had to coexist and compete for scarce resources.

Water management in prehispanic agriculture was quite diverse. Hydraulic works had many different functions, which included water supply, control and drainage of rainwater to prevent flooding; water provision for irrigation; control, usage, and drainage of swamp and lake areas, and also recreation and rituals.[16] Production was intensified through irrigation, water abstraction, and humidity retention techniques. The most significant agricultural systems implemented by the Mexica were the *chinampas*, artificial, rectangular islands believed to have been conceived during the times of tlatoani Izcóatl, [17] from 1427 to 1440.[18] Built for intensive agriculture, these islands functioned as "elevated fields within a network of dredged canals above the lake floors"[19], in shallow lakes of freshwater, according to ecologist Exequiel Ezcurra's definition.

As for Indigenous systems for water usage, these varied from domestic works to agrarian works, such as canals, terraces, cisterns, aqueducts, wells, and even baths, to name a few.[20] Notably, in 1433 the Acolhua people in the northwest quadrant of the basin diverted the Cuautitlán River, the most important river in the basin, by building a diversion dam made of rammed earth secured by vertical stakes, consolidated with rhizomatous grasses. The dam required constant maintenance during both the dry season and at the beginning of the wet season. All of this speaks of the Indigenous people's familiarity with local soils and vegetation, as well

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[16] Rojas Rabiela, *et al*. *Cultura hidráulica*, 19.
[17] *Tlatoani*: náhuatl word for ruler.
[18] Gabaldón, et. al. *Impacto ambiental*, 22.
[19] Exequiel Ezcurra. *De las chinampas a la megalópolis. El medio ambiente en la cuenca de México* (Mexico: Fondo de Cultura Económica, 1996) 3.
[20] Gabaldón, et. al. *Impacto ambiental*, 22.

as their knowledge of seasonal fluctuations and how they would affect humidity and plant growth. With this diversion they also developed a new network of four canals, which fed a series of ditches that brought water to 8000 planted hectares, turning it into one of the largest irrigation systems in the basin.[21] This accomplishment would become essential for the Hispanic Desagüe project a couple of centuries later.

At the same time, another waterwork built in 1449, the *albarradón* (dike) of Nezahualcóyotl, became the largest prehispanic hydraulic work of the time. Nezahualcóyotl was the *tlatoani* of Texcoco, one of the city-states of the Mexica empire in the northeast section of Valley of Mexico and home to the Acolhua people. After Tenochtitlan suffered its first great flood in 1449, the city's *tlatoani*, Motehcuzoma Ilhuicamina assigned Nezahualcóyotl the task of blocking the water, to which the Acolhua leader proposed and designed a twenty-two-kilometer dike to go across the lake of Texcoco, from the region of Atzacualco in the north to Iztapalapa in the south in a straight line.[22] To prevent the erosion of the stones used for its construction, palisades were installed on the sides, and gates would regulate the entrance and exit of water, allowing the passage of canoes. Thus, the lake was divided into two parts, the Texcoco Lake and the *laguna* (lagoon) de Mexico. Remarkably, this work eventually separated Texcoco's saltwater from the lagoon and the south lakes' freshwater. Nevertheless, Nezahualcóyotl's dike trapped water coming in from the basin's southern springs and from aqueducts such as Chapultepec. Therefore, the Mexica built a second dike (*albarradón* de Ahuízotl) closer to the city, from Tepeyac Avenue in the north to Iztapalapa Avenue in the south.[23]

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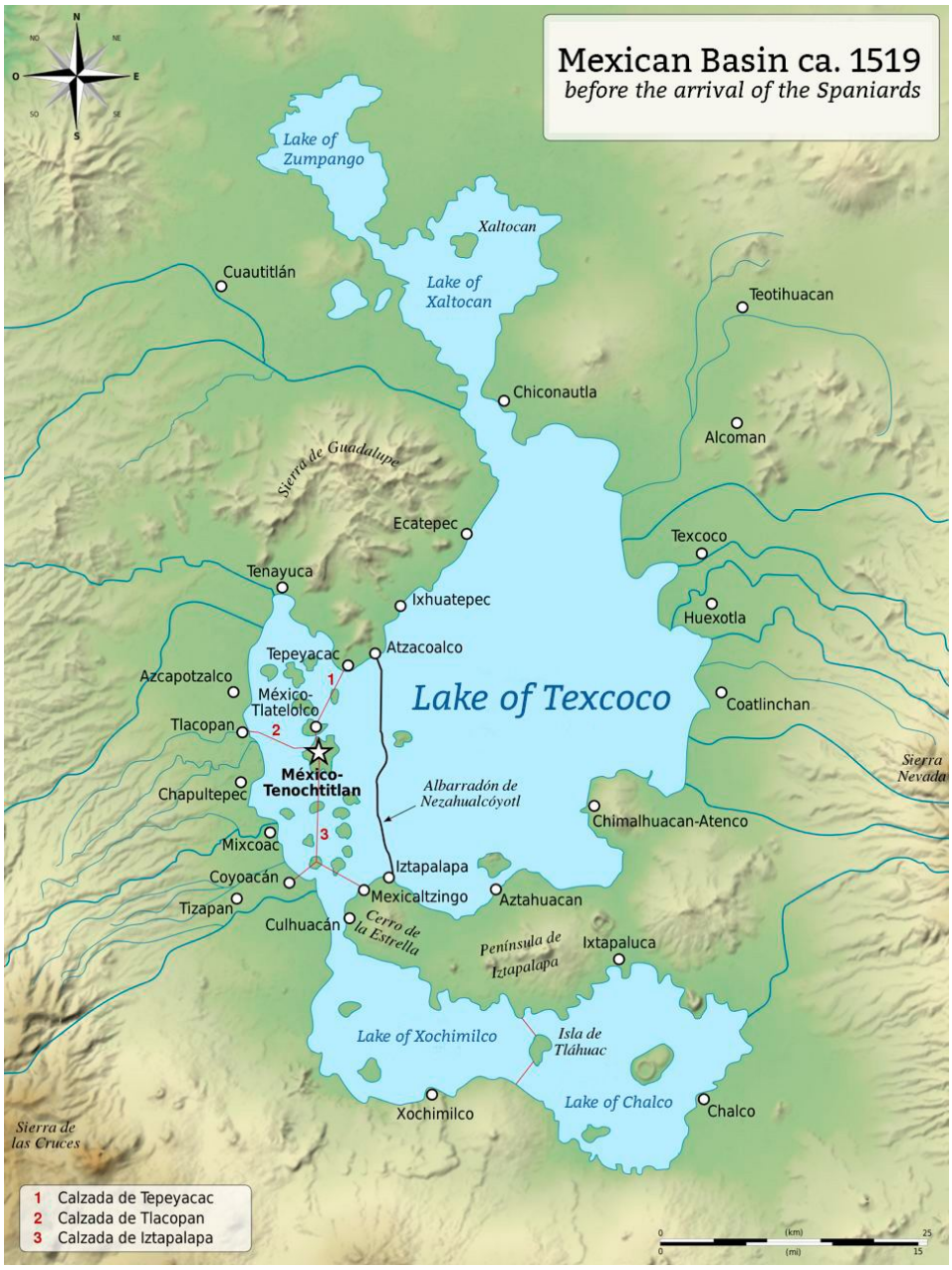
[21] Candiani, *Dreaming of Dry Land*, 20-22.
[22] Jorge Gurría Lacroix. *El desagüe en el valle de México durante la época novohispana* (Mexico: Instituto de Investigaciones Históricas, 1978), 23-24.
[23] Beatriz Barba Ahuatzin, "Dioses, reyes, hombres y agua en el México antiguo", *Ciencia*, July-September 2007, https://www.amc.edu.mx/revistaciencia/images/revista/58_3/PDF/11-552.pdf (Accessed 27 June 2023) 85.

While on the subject, Chimalpopoca, who became *tlatoani* of Tenochtitlan at twelve years old in 1416, granted the Mexica a concession to build an aqueduct from the Chapultepec springs in the West to Tenochtitlan, in order to supply drinking water to the city. Chimalpopoca eventually requested materials and Tepaneca workers from his grandfather Tezozomoc, *tlatoani* of Azcapotzalco, which resulted in a series of confrontations with the Tepanecas who did not want to pay allegiance to the Mexicas. After some decades of political conflicts, the Mexica rebuilt the aqueduct in 1466 under the rule of Motecuhzoma I. The aqueduct, which consisted of two underground ceramic pipes of about 50 cm in diameter, one for daily usage and the other for maintenance,[24] became an essential waterwork in Tenochtitlan.

[24] Raquel Pineda Mendoza, *Origen, vida y Muerte del acueducto de Santa Fe* (Mexico: UNAM, 2000) 21-29.



The Mexican basin circa 1519, two years before the fall of Tenochtitlan at the hands of the Spaniards. Numbers 1 to 3 indicate the main avenues that connected different cities in the basin. The black line across the lake represents the albarradón de Nezahualcóyotl. Image by © CC Attribution-Share Alike 4.0 International, 3.0 U ported, 2.5 Generic, 2.0 Generic, and 1.0 Generic license. The original image was modified to include titles in English. https://es.m.wikipedia.org/wiki/Archivo:Basin_of_Mexico_1519_map-es.svg (Accessed 24 May 2023)

Once the Spaniards arrived, however, most of the basin's cities were redesigned according to Spanish layouts. The Spaniards' European views on natural resources would eventually determine their approach to water management, agriculture, and the overall imposed way of life in the colonies.

2. Water and Nature in Renaissance Europe

2.1 Views on Natural Resources

Imperialism fundamentally changed the relationship between people and nature, which had irreversible effects on the environment, from the commodification of natural resources to the creation of colonial cities; from the extraction and exploitation of raw materials to the establishment of plantations, not to mention the displacement of indigenous peoples. To fully grasp the ways in which Spanish colonization impacted Mexico, particularly regarding water management in the seventeenth century, it is important to understand the European mindset during this time, their views on nature, and how this affected their approach in the colonies.

When the Spanish empire began its colonization process in the Americas (in Mexico's case, in 1521 after the fall of Tenochtitlan) evangelization—the conversion of indigenous peoples into Catholicism—was a key element of their colonizing practices. During the Renaissance, the idea of having new territories to conquer was believed to result in utopian Christian communities with an idyllic social life in communion with God and nature.[25] Most importantly, Spain's need for taking control over these new lands, particularly over indigenous peoples, was part of a moralizing mission where Spanish convictions of salvation accompanied their colonial domination.[26]

Sixteenth-century writers such as chroniclers, explorers, and missionaries explored a wide range of narrative tropes from modern political thought to describe the New World, such as premodern states of nature, or dramatizations of the perils humans faced against the harsh

[25] Marta Martín Gabaldón, et. al., *Impacto ambiental y paisaje en Nueva España durante el siglo XVI* (Mexico: Universidad Nacional Autónoma de México, 2021), 15.
[26] Caraccioli, Mauro José Caraccioli, *Writing the New World: The Politics of Natural History in The Early Spanish Empire* (Florida: University of Florida Press, 2021), 17.

environment. For some writers such as royal historian Gonzalo Fernández de Oviedo, the unknown and exotic were used as "proof of God's favored view of the Spaniards as bearers of the Christian faith, as well as Satan's exile from Heaven into a forgotten and dangerous world of seduction". [27] For others, like missionary friar Bartolomé de las Casas, the Americas were a lost paradise, proof that God had once ruled over those "seemingly untouched lands" and that the Spanish Conquest threatened its pristine order. So, while some Spanish authors of the time may have differed in how they regarded nature in the colonies, it is certain that they were not considering Indigenous peoples' interventions in their own environments.

An important concept to consider in this respect is the Doctrine of Discovery. This principle came from a series of Papal Bulls written by Pope Alexander VI in the late fifteenth century, in which Christian Europeans could stake claim to lands beyond Europe in the name of their respective sovereigns. This doctrine, used by the Spanish, Portuguese, and English empires, among others, "was used as legal and moral justification for colonial dispossession of sovereign Indigenous Nations."[28]

Throughout the Age of Enlightenment during the seventeenth and eighteenth centuries, rationalism was a particularly relevant philosophy that had a great impact on the way the New World was viewed. Contrasting the idea of a truly rational man, cultured and "civilized", nature was associated with humanity's primitive state. Thus, the Indigenous person as the good or "noble savage" living in harmony with nature was a notion that played a big part in European colonizing practices.[29] Due to their perceived closeness to nature, Indigenous peoples were thought to lack rationality, and in need of white Europeans to show them the right way of things,

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[27] Caraccioli, *Writing the New World*, 24.
[28] Assembly of First Nations, *Dismantling the Doctrine of Discovery*, January 2018, https://www.afn.ca/wp-content/uploads/2018/02/18-01-22-Dismantling-the-Doctrine-of-Discovery-EN.pdf (Accessed 4 January, 2022)
[29] Gabaldón, et. al., *Impacto ambiental y paisaje*, 16.

rather than communities capable of having a significant impact on their environment. As established by author Mauro José Caraccioli, "nature, if at all depicted…[was] a symbolic space used to distinguish the modernizing process from backwardness or barbarism".[30] In this sense, white Europeans were thought of as superior for overcoming and conquering nature, whereas othered groups were linked to nature only as primitive versions of humanity.

In the colonizers view, they were spreading enlightenment and civilization.[31] They often attempted to recreate in the colonies the conditions they were familiar with in their homelands, without any consideration for the existing nature. As stated by author Val Plumwood, in anthropocentric cultures, nature was seen as interchangeable and its resources replaceable: The colonial failure to value the difference of…biodiversity, plants, and animals… is expressed in the widespread, and often indiscriminate, destruction of indigenous ecosystems in order to create short-term productivity.[32]

Finally, nature's transformations in the Americas had a direct relationship to other processes and structures that constituted colonial societies, such as work organization, land possession, and market articulation.[33]At the same time, growing networks of trade and production intensified the human exploitation of nature. In that vein, author Vera S. Candiani proposes that Europeans, as participants of the creation of early capitalism, were as "heavily influenced by their class characteristics as they were by philosophical outlooks" [34], colonizing water and land, their relation to each other and what water and land meant to humans.

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[30] Mauro José Caraccioli, *Writing the New World: The Politics of Natural History in The Early Spanish Empire* (Florida: University of Florida Press, 2021), 41.
[31] John Broich, "Engineering the Empire: British Water Supply Systems and Colonial Societies, 1850-1900," *Journal of British Studies* Vol. 46 (2) (Cambridge: Cambridge University Press, 2007) 347.
[32]Val Plumwood, "Decolonizing relationships with nature", in Adams, William M, Martin Mulligan, ed., *Decolonizing Nature. Strategies for Conservation in a Post-colonial Era* (London: Earthscan Publications Ltd, 2003) 64.
[33] Marta Martín Gabaldón, et. al., *Impacto ambiental y paisaje en Nueva España durante el siglo XVI* (Mexico: Universidad Nacional Autónoma de México, 2021), 15.
[34] Candiani, *Dreaming of Dry Land*, xvii.

2.2 Spain's Hydraulic Heritage: Roman & Muslim Water Management and Sixteenth-Century Spanish Waterworks

Spain's history of hydraulic engineering is quite vast, and it goes back to the Roman Empire (218 BCE – fifth century CE in Spain). According to author R.D.V. Glasgow, the Romans understood the importance of flowing water, "building luxurious baths and a great system of brimming aqueducts that by 97 CE was bringing the city [of Rome] 100 gallons a day per capita from the Apennines, ten times more than the inhabitants of London, Paris or Frankfurt were getting in 1936."[35] Vestiges of their structures survive to this day throughout Europe, particularly Spain, such as dams, aqueducts, and even a bath complex that was recently discovered in Andalusia.[36]

Some of the most famous ones in Spain are the Aqueduct of Los Milagros and the Segovia Aqueduct, the latter being a monumental work of almost 30 meters high with 167 arches held by 120 pillars, built around the first years of the second century BCE.[37] Other famous Roman-Spanish waterworks include the dams of Proserpina and Cornalbo.[38] There are over fifty Roman dams in Spain, which authors Manuel Díaz-Marta and José A. García-Diego divide into four categories: those formed by a simple stone wall, usually less than 5-meters-tall; those built with buttresses; those built with embankments to counter the hydrostatic pressure; and finally, earth dams, such as the Cornalbo dam.[39]

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[35] Glasgow, *The Concept of Water*, 266-267.
[36] Nora McGreevy, "Sand Dunes Preserved These Roman Baths in Spain for Thousands of Years", Smithsonian Magazine, May 26, 2021, https://www.smithsonianmag.com/smart-news/ancient-roman-bath-complex-unearthed-spanish-beach-180977826/ Accessed February 12, 2023.
[37] Guiomar Huguet Pané, "El acueducto de Segovia es más recietne de lo que pensábamos", *National Geographic*, https://historia.nationalgeographic.com.es/a/acueducto-segovia-es-mas-reciente-que-pensabamos_10826 (Accessed 10 June 2023)
[38] Manuel Díaz-Marta, José A. García-Diego, "Las obras hidráulicas españolas y americanas", *LULL*, vol. 13, 1990, 61.
[39] Díaz-Marta, García-Diego, "Las obras hidráulicas", 66.

Since dry farming was the basis of their agriculture, most of the Roman hydraulic works were primarily focused on water supply and storage.[40] However, olives, cereals, and grapevines, all native to the Mediterranean, were the main crops the Romans cultivated and adapted to the peninsular region.[41] They avoided artificial irrigation in the fields, only using it in urban orchards, devoted to fruit trees and vegetables.

As for the Muslims' water management in Spain a few centuries later, their focus was almost entirely on agriculture, helping change the Mediterranean landscape drastically. The Muslims dominated the Iberic Peninsula from the eighth century to 1492, a time when they introduced new crops from Africa and Asia and improved and increased the region's knowledge of various cultivation methods. Botanist Jan C. Zadoks refers to this sudden development as a "Muslim Green Revolution.[42]

The expansion of Islam in Spain, as well as their commercial and cultural relationship with the Middle East gave way to the adoption of different agricultural techniques. Whether Arab or Berber, the Muslims that settled in Spain implemented hydraulic systems that had never been seen in the Iberian Peninsula. For instance, they developed *aceñas* or *norias*, watermills in which a wheel lifted water from a stream and poured it into an elevated canal; or the *acequias*, irrigation canal systems that reduced runoffs from rain or snowmelt, allowing the land to absorb the water and replenishing the aquifers; the *acequias* in some cases were rebuilt and extended from somewhat irrigated Roman areas. The most important technique was the *azud,* which

[40] Thomas F. Glick, "Hydraulic technology in al-Andalus", in Salvatore Ciarocono. ed. *Land Drainage and Irrigation*, vol. 3 (USA: Ashgate Publishing Limited, 1998), 45.
[41] José Francisco Ruiz Ruiz, Ph.D Thesis. *Gestión del agua y resiliencia en los sistemas de riego tradicionales. Una comparativa socio-ecológica entre los agroecosistemas del sureste español y los de México central* (Spain: Universidad de Granada, 2017), 102.
[42] Jan C. Zadoks, *Crop Protection in Medieval Agriculture. Studies in Pre-Modern Organic Agriculture* (Netherlands, Sidestone Press, 2013) 211-213.

consisted of a diversion dam that allowed the abstraction of water through the deviation of natural water courses.[43] These developments peaked in southern Spain, particularly in Andalusia.

A noteworthy Muslim irrigation system is the Palmeral de Elche, located in the city of the same name in the Valencian Community. It consists of rows of palm trees "flanking rectangular fields [*huertos*] and serving as a windbreak and shade for the cultivation of wheat, alfalfa, fruit trees and vegetables"[44]; a canal system in the area irrigates the land while watermills generate waterpower for flour production. The fields' edges were shaped as flat dikes to prevent the outflow of irrigation water, supplied by lateral ditches from secondary canals; "irrigation water was supplied according to a strictly timed regulation and proportional to the available water flow."[45] These systems were kept in use by the Christians throughout the Middle Ages, and the site was named UNESCO's World Heritage Site in 2000. Other notable waterworks across Spain include the Guadalquivir mills in Córdoba, particularly the Albolafia watermill. These implementations, in addition to the cultivation of new crops such as rice, citrus fruits, watermelons, and bananas, resulted in a deep landscape transformation.[46]

The Islamic conquest not only entailed a deep agricultural change but also a social one, due to the fact that it coincided with the decline of the Roman Empire, and thus substituted their social and cultural structures.[47] Indeed, all the great Roman hydraulic works were mostly meant to bring water to the cities, which significantly benefited the elites. In contrast, Muslim changes in irrigation and cultivation methods reached communities in rural areas, not only the upper classes. During the Al-Andalus period, according to historian José Francisco Ruiz Ruiz,

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[43] Ruiz Ruiz, *Gestión del agua y resiliencia*, 104
[44] Ignacio Melendez-Pastor, José Navarro Pedreño, Hartmut Wittenberg, "Watermills in the historic irrigation system 'Palmeral de Elche', Spain: an example of early hydropower exploitation", *Water Science & Technology: Water Supply*, 15.5, 2015, https://doi.org/10.2166/ws.2015.067 (Accessed 8 June 2023) 1140
[45] Melendez-Pastor, et. al. "Watermills", 1141.
[46] Ruiz Ruiz, *Gestión del agua y resiliencia,* 102-104.
[47] Ruiz Ruiz, *Gestión del agua y resiliencia*, 103.

irrigation crops were the main source of livelihood for each domestic group in the rural context, so water was seen as a very precious resource, and people were under high pressure to keep getting access to it.[48]

Water distribution was also divided based on three criteria: demonym—common during the first centuries of the Islam period due to tribal and clan relations—, topography—propagated as property distribution changed over time, particularly during the Nazari period (1238-1492)—, and buying and selling—where water property was considered to be separate to land property.[49] In fact, some authors connect the Andalusian communities directly to the development of irrigated cultivation since they had autonomous management of the land with respect to the State, which was a key factor in the management of their cultivated areas since feudal lords would have influenced the choice of crops through their demands for rent.[50] During the Nazari period, irrigated areas were the most important in rural settlements or *alquerías*, and most inhabitants owned some plots in these lands, which were usually organized in a series of terraces, and lived immediately above them.[51]

By the sixteenth century, these important Roman and Muslim waterworks had created a conducive atmosphere for the development of hydraulic works, particularly after the unification of the kingdoms of Aragon and Castille due to the marriage of the Catholic Monarchs Isabella I and Ferdinand II.[52] Following the last series of wars they initiated for the *Reconquista* of

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[48] Ruiz Ruiz, *Gestión del agua y resiliencia*, 110.
[49] Ruiz Ruiz, *Gestión del agua y resiliencia*, 110.
[50] Miquel Barceló, "Vespres de feudals. La societat de sharq al-Andalus just abans de la conquesta catalana", *España. Al-Andalus. Sefarad: Síntesis y nuevas perspectivas*, (Salamanca: ed. F. Maillo Salgado, 1988), 99-112. Barceló, "El diseño de espacios irrigados en al-Andalus: un enunciado de principios generales", *Actas del I Coloquio de Historia y medio físico. El agua en zonas áridas: Arqueología e Historia*, 2 vols (Almería, 1989), vol. I, 15-51, as paraphrased in Carmen Trillo San José, "A social analysis of irrigation in Al-Andalus: Nazari Granada (13th – 15th centuries)", *Journal of Medieval History 31* (Spain: University of Granada, 2005) 167.
[51] Trillo San José, "A social analysis of irrigation in Al-Andalus", 171.
[52] Manuel Díaz-Marta y José A. García-Diego, "Las obras hidráulicas españolas y americanas", *LLULL* vol. 13, 1990, 68.

Granada, the last Muslim kingdom in the Iberic Peninsula (1482-1492), according to Zadoks, the Muslim Green Revolution and the vulnerable and complex Muslim production system were largely undone.[53] However, Díaz-Marta and García-Diego argue that Christians did keep the irrigation systems implemented by the Muslims in some regions while perfecting supply management and distribution. However, during the reign of the Catholic Monarchs "hydraulic politics gained amplitude and turned less localist", and most projects and plans for great hydraulic works were conceived during the reigns of Charles V (1516-1555) and Phillip II (1556-1598), thanks to the exchange of ideas and knowledge produced from the colonization processes of the American continent, Africa, and Asia.[54]

Some of the most important works and techniques developed in the sixteenth to the eighteenth century in the Ebro basin were *azudes* and irrigation canals, the latter commissioned by Charles V in 1528, as part of the great Acequia Imperial de Aragón. In the Duero basin, the most important work was the 207-kilometer-long Castilla Canal, which its main purpose was not to irrigate land, but to facilitate communication between Castilian areas that produced cereals and the Atlantic Ocean.[55] This canal, along with the dams, aqueducts, and irrigation methods built during Roman and Muslim times are noteworthy examples of Spanish waterworks to consider when studying how the Spaniards implemented their heritage and knowledge in water management in the Mexican basin.

[53] Zadoks, *Crop Protection in Medieval Agriculture,* 214.
[54] Díaz-Marta, García-Diego, "Las obras hidráulicas españolas", 68.
[55] Díaz-Marta, García-Diego, "Las obras hidráulicas españolas", 78.

3. Colonial Intervention in Mexico: Spanish Hydraulic Works

3.1 Indigenous Labour

First and foremost, the topic of Spanish hydraulic works in Mexico is deeply interconnected to Indigenous labour, and therefore cannot be properly understood without addressing its main aspects. When the Spaniards settled in Mexico, their initial mercantilist approach uprooted Indigenous societies, changing how they organized labour, housing, and overall way of living. Mexico became a mercantilist center for colonial settlement and activity and featured the most intensive systems of labour exploitation for the benefit of the Spanish Crown due to the number of goods exported from the colonies. The size of the indigenous population, as well as their hierarchal organization strongly influenced the colonizers' ability to extract surplus labour.[56] The state-like authorities of Indigenous societies appealed to the Spaniards for two reasons: firstly, the population was already subjected to paying tributes and labour drafts in the pre-Columbian period, so even though the Spaniards adapted these systems to their benefit, such demands were not completely new to the Indigenous peoples. Secondly, the Indigenous societal structures permitted the colonizers to exploit and control the large populations through a small number of native leaders.[57]

The Spaniards established two main labour and tributary systems: the *encomienda* and the *repartimiento*. The *encomienda* consisted of indigenous people assigned either to a Spanish settler as a reward for their war merits, or in some cases to an Indigenous nobleman or former *tlatoani*, who forced them to work and present tributes such as corn, cacao, textiles, and precious metals; in exchange, the Spanish *encomenderos* had to offer their Indigenous *encomendados*

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[56] James Mahoney. *Colonialism and Postcolonial Development,* 52.

[57] Linda A. Newson, as cited in James Mahoney. *Colonialism and Postcolonial Development*, *Spanish America in Comparative Perspective* (Cambridge: Cambridge University Press, 2010), 52.

military protection and ensure their Christianity. The *encomendados* were assigned varied works, from mining and construction to agriculture and other manual labour. According to historian Charles Gibson, the first generation of *encomenderos* understood their Spanish authority as illimited personal opportunism.[58] In 1542 Charles V issued the New Laws in an attempt to prevent this exploitation, following declarations from Bartolomé de las Casas condemning the mistreatment of Indigenous people. From then on, these laws recognized *encomendados* as free individuals instead of slaves; Spaniards could not inherit, buy or sell them, and could not move them from their geographic region.

The distribution of lands granted by Cortés was stopped after the deaths of the *conquistadores*, natives were then considered subjects to the Crown, and only the viceroy would be able to grant *encomiendas*.[59] But despite these changes, many colonists kept abusing their power, often forcing Indigenous people to work without pay, abusing and mistreating them, particularly during the first years after the Conquista; also, the number of tributes the Spaniards collected from the Indigenous population was not regulated by the Crown until 1582. By 1530, 30 *encomiendas* remained in the Valley of Mexico, and Spaniards kept using the system in some areas until the early 1600s.[60]

On the other hand, the *repartimiento* gathered indigenous people in groups to work for different Spaniards in rotation, in cycles of days or weeks for a trace amount of remuneration. In between rotations, indigenous people gathered the tributes that would be presented to the Crown. This system stopped in 1632, but continued in certain instances, particularly in Mexico City, such as for mining and other public works. It officially ended in the nineteenth century.

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[58]Charles Gibson. *Los aztecas bajo el dominio español (1519-1810)* (Mexico: Siglo XXI, 1964), 82.
[59] Corey S. Ragsdale, Cathy Willermet, and Heather J.H. Edgar. "Changes in Indigenous Population Structure in Colonial Mexico City and Morelos", *International journal of osteoarchaeology* 29, no. 4 (2019): 501, 503, 504.
[60] Gibson, *Los aztecas…* 63-67.

However, while the *encomienda* and *repartimiento* ceased to be the main systems in which Spaniards would exploit indigenous people, forced labour would remain, albeit in different ways. From early seventeenth century, an increasing external demand for farming and livestock products from the colonies occurred, for which Spanish farmers and cattle ranchers gradually acquired more lands and rights over water.[61] The land and economic expansion of these industries gave rise to the production units known as *haciendas*. The specialization of *haciendas* ranged from cotton, coffee, and henequen to livestock and more. Additionally, many former *encomenderos* became owners of *haciendas*, increasing productivity by implementing their own European methods for irrigation agriculture, plowing, cattle raising, and the construction of hydraulic infrastructures. Back in the sixteenth century, some local powers still resided with the indigenous nobility, but with *haciendas*, large production units, Spanish officials had full control, which cemented indigenous people's position of inferiority within this new system.

For the indigenous, the rise of *haciendas* meant the loss of their lands, which led communities to a critical situation, losing the ability to support themselves. *Haciendas* took indigenous land for the sake of external markets, stripping them away from their own resources and means to live. This forced people to seek work at *haciendas*, often away from their towns. By the second half of the century, it became forbidden to use *indios* of *repartimiento*, but indigenous people would still work either temporarily or by becoming residents within the *haciendas*. Another important aspect of life at the *haciendas* is that most workers did not receive payment in cash, but rather it was put into ledger accounts the workers could access by acquiring whatever supplies they needed in the *tiendas de raya,* stores within the haciendas. More often

[61] von Wobeser. *La formación de la hacienda*, 49.

than not, the labourers ended up with crippling debt from these stores,[62] which bounded them to the *hacienda* for long periods of time.

Undeniably, the Spanish empire expanded largely due to the exploitation of Indigenous peoples. The implementation of European methods, systems, and constructions, particularly waterworks, would not have been possible without their labour.

3.2 Spanish Water Management: Waterworks, Agriculture, and More

The capital of New Spain was built on the site of the conquered city of Tenochtitlan, a decision based on a political and geographical strategy to exert control over the population, but most significantly it created a superimposition in the same territory of different understandings and usages of land and water.[63] On the topic of the Spaniards' reaction to seeing the city for the first time, *conquistador* Bernal Díaz del Castillo, in his account *The True History of the Conquest of New Spain* stated:

> The next day, in the morning, we arrived at a broad Causeway, and continued our march towards Iztapalapa, and when we saw so many cities and villages built in the water and other great towns on dry land and that straight and level causeway going towards Mexico, we were amazed… And some of our soldiers even asked whether the things that we saw were not a dream.[64]

[62] von Wobeser. *La formación de la hacienda*, 71
[63] Candiani, *Dreaming of Dry Land,* 30.
[64] Bernal Díaz del Castillo, *The True History of the Conquest of New Spain* (Liechtenstein: Kraus Reprint, 1967), 37.

3D reconstruction of Tenochtitlan made by Dutch artist Thomas Kole. © CC BY 4.0. A Portrait of Tenochtitlan, https://tenochtitlan.thomaskole.nl/ (Accessed 13 October 2023)

Certainly, the Spaniards were impressed with the city built by the Indigenous population and their water management, but once they established themselves as conquerors, the city had to change with them.

Once the *Conquista* war was over (1519-1521), the Spaniards started building their new city without full knowledge, or rather, little regard of the hydraulic system they were altering. During the first few years of the colonization period, the construction of heavy buildings and the embanking of canals and waterbeds for the construction of plazas and streets, as well as deforestation and droughts, permanently altered the complex hydrological balance previously achieved by the Indigenous population.[65] In 1568, a few years after taking the city, Bernal Díaz del Castillo wrote:

> I must state that at that time [during Motecuhzoma II and Hernán Cortés's first encounter] this was a very large town, half of the houses being on land and the other half in the water, and now at this time it is all dry land and they plant corn where it was formerly a

[65] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 37

> lake, and it is so changed in other ways that if one had not then seen it, one would say that it is impossible that what are now fields planted with maize, could at one time have been covered with water.[66]

This account demonstrates how the landscape was radically changed, astonishingly, only a few decades into the colonization period. The *albarradón* of Nezahualcóyotl was also partially destroyed by the Spaniards to make way for the passage of brigs, which resulted in the once-separated salt and freshwaters mixing again; this, as suggested by nineteenth-century engineer Francisco de Garay was a premeditated measure, as well as blocking the Chapultepec aqueduct in order to cut the inhabitants' access to drinking water.[67]

At the same time, according to historian Sergio Miranda, after a Chichimeca insurrection in 1540, the Spaniards' fear of Indigenous people taking advantage of their knowledge of the old hydraulic system to overthrow them was a key factor in the "war against water"; to that end, the Spaniards planned to desiccate wide sections of the Mexico lagoon to secure the entrance and exit to the city.[68] Despite facing major problems with water in the region, from flooding and droughts to epidemics—which mostly decimated the Indigenous population—, reinstating the old hydraulic works built by the Mexica would have been unthinkable to the Spanish, since it would have meant acknowledging that the Indigenous engineering practices were better adapted to the environment. In contrast, Candiani suggests that establishing their new capital on the site of Tenochtitlan was not necessarily a liability, since the water barrier probably helped in defending the city and it might have functioned initially as a tool for Hernán Cortés to warn his cohort of Spanish *conquistadores* if they ever considered mutiny.[69]

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[66] Bernal Díaz del Castillo, *The True History of the Conquest of New Spain*, 39.
[67] Francisco de Garay, *El Valle de México. Apuntes históricos sobre su hidrografía desde los tiempos más remotos hasta nuestros días* (Mexico: Oficina Tip. de la Secretaría de Fomento, 1888) 17. Digitized by the Universidad Autónoma de Nuevo León, Dirección General de Bibliotecas. http://cdigital.dgb.uanl.mx/la/1080019535/1080019535.PDF (Accessed 15 June 2023)
[68] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 40
[69] Candiani, *Dreaming of Dry Land*, 26

However, the Spaniards made several attempts—some successful, other not so much—at controlling the flooding and managing the city's water supply. An essential work for the distribution of clean water was the Santa Fe Aqueduct, built in 1620. With nearly one thousand arches, it conducted the water born from a spring in the vicinity of the town of Santa Fe, joined by a stream that came from the Desierto de los Leones, southwest of the Valley of Mexico. It ran along what is now the avenue Circuito Interior to San Cosme, flowing into the Tlaxpana Fountain, and then continuing until reaching the Mariscala Fountain, which would have been located at the rear of present-day Palacio de Bellas Artes, in the Historic Centre of Mexico City.[70] This aqueduct and its beautifully crafted fountains were demolished throughout the second half of the nineteenth century. [71]

In 1555, after the destruction of the prehispanic Chapultepec Aqueduct, the Spaniards began the construction of a new one, which ran from a spring called Alberca Chica (Small Pool) near the Bosque de Chapultepec (Chapultepec Forest) across the avenue of San Juan—today, Chapultepec Avenue—and ended at the San Juan Convent, south of the city.[72] This work became insufficient as the population grew, so from 1771 to 1779 they built a new opencast aqueduct 3907 meters long that consisted of 904 arches. Nevertheless, since hard water streamed with great force upon entering the city, water spills became common. In the 1790s, the city council offered some grants for people to take advantage of the spills, but sometimes it overflowed in such quantities that it ended up spilling into the public roads.[73] The aqueduct stayed functioning

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[70] Rebeca López Mora, "Agua que sobra, agua que falta. Las fuentes públicas y la sociabilidad del agua en la Ciudad de México, 1770-1818", *Historia Mexicana*, LXXI, no. 2, 2021, 758.
[71] Manuel Romero de Terreros, "Los acueductos de México", *Anales del Instituto Nacional de Antropología e Historia*, no. 4(3), 1925, https://revistas.inah.gob.mx/index.php/anales/article/view/6778 (Accessed 03 September 2023)
[72] Notimex, Agencia de Noticias del Estado Mexicano, "Acueducto de Chapultepec, herencia virreinal", nar. Gustavo Toris Guevara, *Youtube*, 6 August 2016, 3:49 min. https://www.youtube.com/watch?v=CirPBXnL4rU (Accessed 25 August 2023)
[73] López Mora, "Agua que sobra, agua que falta", 778.

until 1890. Along with the Santa Fe Aqueduct –which will be discussed in the following paragraphs–, the Chapultepec Aqueduct supplied water through underground conduits called *ramos de agua* (water branches) to various fountains, both public and private.[74] Some of the most important ones were Fuente de Belén, the oldest fountain in the city —built between 1755 and 1760— and the starting place of the aqueduct at the Bosque de Chapultepec,[75] and Fuente del Salto del Agua, inaugurated in 1779, ending point of the waterwork.[76]

Chapultepec aqueduct. Only 22 arches of the aqueduct survive today. Photograph by Víctor Fuentes, 02 September 2023.

[74] López Mora, "Agua que sobra, agua que falta", 755.
[75] Comisión Nacional del Agua, "Belén, la fuente más antigua de #CDMX", *Gobierno de México*, https://www.gob.mx/conagua/articulos/belen-la-fuente-mas-antigua-de-la-cdmx?idiom=es (Accessed 25 August 2023)
[76] "Fuente del Salto del Agua", *Mediateca INAH*, https://mediateca.inah.gob.mx/islandora_74/islandora/object/fotografia:369325 (Accessed 25 August 2023)

Belén Fountain. The Mexico City subway passes right under it, and as a result the fountain now presents a big crack on the right. Historians and conservators have demanded the government make efforts to preserve the fountain properly, to no avail. Photograph by Víctor Fuentes, 02 September 2023.

Original Salto del Agua Fountain. In 1945, the Mexican government relocated the fountain from its original site (present-day Arcos de Belén Avenue) to the gardens of the Viceroyalty Museum in Tepotzotlán, State of Mexico. Photograph by Víctor Fuentes, 03 September 2023.

Replica of the Salto del Agua Fountain built by sculptor Gustavo Ruiz. Photograph by Víctor Fuentes, 02 September 2023.

Fountains had a crucial role in providing water to the city's inhabitants, but by the end of the eighteenth century, the water supply became insufficient for the population. According to historian Rebeca López Mora, there are three main causes of this: number one, water had to be carried for kilometers before reaching the capital, which "favored the abuse of those who took advantage of the stream's course before entering the city"; number two, the aqueducts' system, which was based on gravity, was inefficient; and number three, the location of private and public

fountains in the urban space was uneven, "which determined, in many cases, an unequal distribution".[77] The disparity between who had easier access to water amongst the Mexican population speaks of the privilege certain sectors had over others. During the first years of the colonization period, due to the growing agricultural needs and new land tenure regimes, the Spanish Crown often handed royal grants to mill owners and the like.[78] From then on, this new private appropriation of water would disrupt the Indigenous sociopolitical organization meant for the distribution of the liquid, as well as the construction and maintenance of hydraulic works. This, of course, had a great impact on the development of Mexican society and its relationship with water throughout the Viceroyalty period.

By the early nineteenth century, *haciendas* and mills often monopolized access to water, especially those alongside the Santa Fe Aqueduct.[79] However, even though those who owned private fountains paid a lot of money for the service, they were still required to provide water to whoever required it. Convents and religious schools, particularly, were known for sharing water with the nearby populaces.[80] Indigenous people did not have any grants on private water, but they did have direct management of some public fountains, such as San Martín, Guadalupe and Plaza Mayor de Santiago.[81] It is also worth mentioning that what passed through the Chapultepec Aqueduct was hard water, which contained a higher amount of minerals and was therefore considered low quality, whereas the Santa Fe Aqueduct supplied soft water of higher quality and a more pleasant taste.[82] Chapultepec reached poorer neighborhoods than its Santa Fe counterpart.

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[77] López Mora, "Agua que sobra, agua que falta", 763.
[78] Gabaldón, et. al. *Impacto ambiental*, 29.
[79] López Mora, "Agua que sobra, agua que falta", 774.
[80] López Mora, "Agua que sobra, agua que falta", 767-768.
[81] López Mora, "Agua que sobra, agua que falta", 785.
[82] López Mora, "Agua que sobra, agua que falta", 760-792.

Another noteworthy hydraulic work took place in the early seventeenth century when viceroy Juan de Mendoza y Luna commissioned the *albarradón* of San Cristóbal or Acalhuacan, to prevent the overflowing of the Cuautitlán River into the Zumpango Lake; blocking the river was crucial since Zumpango connected to the San Cristóbal lagoon, which itself flowed into the Texcoco lake and Mexico lagoon, very near the city. The dike consisted of 3.5 km, ranging from four to six meters high. It was reconstructed in 1604 after a major flood, a project overseen by a friar named Gerónimo de Zárate. Over twenty thousand indigenous people worked on the construction of the dike, which made it one of the most ambitious projects of the time, at least until that point.[83]

Present-day view of the Albarradón of San Cristóbal, gate and chapel Cristo Rey, covered in graffiti. Ecatepec, State of Mexico.
Photograph by Víctor Hugo Jiménez Jiménez, 2013. © BY-SA 3.0. "Albarradón de San Cristóbal", *Wikipedia*, https://es.wikipedia.org/wiki/Albarrad%C3%B3n_de_San_Crist%C3%B3bal. (Accessed 24 June 2023)

[83] "Albarradón histórico de San Cristóbal Ecatepec, vista general", *Mediateca INAH,* https://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A320834 (Accessed 23 June 2023)

Another early example of Spanish hydraulic work in the Valley of Mexico is the aqueduct of Los Remedios, located in what is now the State of Mexico. More specifically, in 1616 viceroy Diego Fernández de Córdoba envisioned a work meant to bring water to the Basilica of Los Remedios, ordering the construction of two vent towers, part of a siphon system, which operated through a subterranean pipe. However, miscalculations during its construction failed to consider the topographic conditions, since the Basilica was located at a much higher position, so the towers—now colloquially referred to as "snail towers" or "Babel towers" due to their shape—gradually fell into oblivion. In 1765, viceroy Joaquín de Montserrat resumed the project, ordering the construction of the aqueduct's 50 arches, but they turned out to be insufficient, once again, to carry water to the temple.[84]

A quick search on Google Maps demonstrates that it takes a little over two kilometers to get from the aqueduct (today referred to as *Los Arcos*) to the Basilica, a considerable distance that attests to the inefficiency that went into the planning of the waterwork. As can be seen in the following photographs, the Spaniards' Roman heritage is quite visible in these works, particularly in the construction of the arches. However, regardless of the grandeur of the aqueduct, the circumstances are ironic considering the Spaniards' failure to understand the land's conditions.

[84] Gerardo Díaz Flores, "El acueducto de los Remedios. Una obra novohispana que perdura en Naucalpan, Estado de México", *Relatos e Historias*, https://relatosehistorias.mx/nuestras-historias/el-acueducto-de-los-remedios-0 (Accessed 23 June 2023)

Vent towers Aqueduct of Los Remedios, ca. 1920s. Photograph by *MexicoEnFotos*, © Grupo Editorial Centli. *MexicoEnFotos*, https://www.mexicoenfotos.com/antiguas/mexico/naucalpan-de-juarez/acueducto-de-los-remedios-MX15430262340248/1 (Accessed 22 June 2023)

Arcos of Los Remedios, State of Mexico, present-day. Photographs by Víctor Fuentes (02 July 2023).

Vent tower in Los Remedios, State of Mexico. Photograph by Víctor Fuentes (02 July 2023).

Another noteworthy example of Spanish waterworks in the basin is the aqueduct of Tepotzotlán, officially known as Arcos de Sitio, or Arcos de Xalpa. The Jesuits commissioned the aqueduct during the second half of the eighteenth century in order to carry water from the Tepotzotlán mountain range to the *hacienda* de Xalpa, which they owned. However, the work remained unfinished due to the expulsion of the Jesuits in 1767, and finally concluded until

1854.[85] Half a kilometer long, it reaches 62 meters high at the ravine, making it Mexico's highest aqueduct and one of its most imposing colonial structures. This work unmistakably evokes Spain's Roman heritage, as exemplified in earlier chapters with the Aqueduct of Segovia.

Aqueduct of Tepotzotlán. Photograph by Tania Fuentes, 2021.

As for other aspects of colonial water management, Spaniards from all regions of Spain arrived in Mexico after the Conquista, bringing with them their regions' agricultural and irrigation methods. While they benefited from the exportation of local products such as cacao and cochineal,[86] they also introduced various new crops trying to recreate their Mediterranean

[85] "Arcos del Sitio, el acueducto más alto de México", *Turismo Tepotzotlán*, 23 October 2019, https://www.turismotepotzotlan.com.mx/2019/10/23/arcos-del-sitio-el-acueducto-m%C3%A1s-alto-de-m%C3%A9xico/ (Accessed 24 June 2023)

[86] Teresa Rojas Rabiela, "Antiguas y nuevas plantas en tierras indígenas en el nuevo contexto mercantil novohispano", in Andrew Roth Seneff, ed. *Caras y máscaras del México étnico. La participación indígena en las formaciones del estado mexicano*, vol. 1 *Dominio y libertad en la historia indígena de México* (Mexico: El Colegio de Michoacán, 2010) 144.

and Iberic lands, such as citrus, onions, garlic, watermelons, and more. Some crops had a more decisive boost than others due to their high demand in the cities, such as wheat; olive and grapevine crops were initially limited to areas such as monasteries to satisfy the needs of its religious communities,[87] although wine production eventually expanded, particularly in northern states. In that regard, religious orders and missionaries played a significant role in the expansion of Spanish agriculture in New Spain since orchard convents "acted as experimental seedbeds in which the acclimatization of the new plants was achieved",[88] and were places where Indigenous people learned the Hispanic practices, techniques, and tools to work the land while being evangelized into Catholicism.

After a few decades, the consumption of meats was also embraced by the Indigenous population, as well as the use of wool thanks to the influx of new animals, which greatly impacted Mexican society and environment alike. Horses and pigs were some of the first animals brought to Mexico, followed by sheep, goats, and cattle, which eventually took over great pieces of land and grazed freely with no control. The expansion of pastoralism was favoured by several social and biological aspects, such as "a favorable climate, grass that had never been stepped on by hooves and the absence of predators and diseases that would affect the introduced species", conditions exploited by the Spaniards to introduce herds that "exceeded the capacity of naturally available areas"[89]. This resulted in the desertification of regions such as the Valle del Mezquital in the state of Hidalgo in the sixteenth century. This, of course, affected Indigenous communities in Mexico and their cultivation methods as well, which facilitated the delimitation and privatization of the land all across New Spain;[90] The expansion of livestock raising caused

[87] Martín Gabaldón, et. al. *Impacto ambiental*, 26.
[88] Ruiz Ruiz, *Gestión del agua y resiliencia*, 121.
[89] Gabaldón, et. al., *Impacto ambiental y paisaje,* 51.
[90] Martín Gabaldón, et. al., *Impacto ambiental.,* 55.

considerable trouble for Indigenous peoples since their own crops were often destroyed by all of these new animals. In 1550, Spanish authorities ordered that cattle ranches should be established far away from villages and croplands.[91] Fences and stone walls were suddenly being built to define spaces according to use and private property, an unexpected territorial configuration for the Mexican landscape.

However, going back to the subject of hydraulic works, in the seventeenth century Spanish authorities conceived the most ambitious project of the colonial period: the Desagüe, a hydraulic work that would permanently change the environment of the Valley and all its residents' lives.

3.3 The First Desagüe Project: Canal of Huehuetoca/Tajo of Nochistongo

As the city of Mexico began to expand, it became a pivotal colonial centre for the Spanish empire. However, throughout the sixteenth and seventeenth centuries, it encountered recurring flooding on several occasions, notably in 1555, 1580, 1604, and 1607, which made the need for a water outlet in the basin urgent.[92] The idea for the Desagüe was initially envisioned by Francisco Gudiel, who presented the project to the city council on the 26th of November 1555. The project consisted of draining the lagoons through a dike system that would allow the regulation and distribution of the water coming from the Cuautitlán river to the Zumpango lake; a canal in the town of Huehuetoca would connect these waters to the Tepejil river, eventually flowing to the Gulf of Mexico.[93] Moreover, Gudiel's Desagüe proposal also intended to exploit the waters from

[91] Martín Gabaldón, et. al., *Impacto ambiental.,* 53.
[92] José Enrique Covarrubias, "Henrico Martinez", Rosa Camelo and Patricia Escandón, coord. *Historiografía mexicana. Volumen II. La creación de una imagen propia. La tradición española. Tomo 1: Historiografía civil* (Mexico: UNAM, Instituto de Investigaciones Históricas, 2018) 395.
[93] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 42

the lagoons for both irrigation and navigation.[94] Still, the project was forgotten for a few decades— according to 20th century historian Jorge Gurría Lacroix— due to low rainfalls; thus, the problem seemed to have disappeared.[95] But the issues with flooding were far from over, so by the early seventeenth century the project was finally revisited.

In 1607, viceroy Luis Velasco entrusted this first large-scale hydraulic project to engineer Heinrich Martin, whose name was translated into Spanish as Enrico Martínez, or Henrico Martín. Born in Hamburg circa 1560, Martínez had previously worked as a translator for the Holy Office and as royal cosmographer for the king of Spain. Once in the City of Mexico, he kept working as a cosmographer and he also established the fourth printing press in Mexico.[96] Regrettably, his only known written work, *Repertorio de los tiempos e historia natural desta Nueva España* was published in 1606, one year before the Desagüe project began. This report is divided into five sections where the author describes the astrological, physical and geographic characteristics of New Spain, as well as some historical facts and related topics. On his opinion regarding why the basin constantly faced flooding, Martínez raises an interesting point:

> It is well known that before the Spaniards came to this land, the naturals did not have horses or cattle, neither did they plow the land, and the slopes and hillsides were little cultivated; because Indians, as it is said, worked their plantings and cornfields on flat land and at the side of their houses, with which the water that rained and the land's gradients [sic], since the land was harsh and tight, it descended less turbulently than in these times. Except now that this kingdom is inhabited by Christians and the land is plowed in many parts, and the continuous footmarks of cattle and horses are cause for the earth to be disturbed, and that [sic] the downpours that come to the plains come with much *lama* [decomposed plants from the water] and dirt, which settles in the lowest parts, gradually growing and rising until they match the surrounding lands… if during the few years that have passed since the high contours of the lagoon are plowed and tilled, the downpours have brought so much dirt to the plains as it was referred…I say, founding my sense on the denoted reasons, that the [waters levels of the] Mexico and Tetzcuco [sic] lagoons do

[94] Archivo General de la Nación, "El Gran Canal del Desagüe del Valle de México: un proyecto que duró casi tres siglos y medio en concretarse", *Gobierno de México*, 17 March 2022, https://www.gob.mx/agn/es/articulos/el-gran-canal-de-desague-del-valle-de-mexico-un-proyecto-que-duro-casi-tres-siglos-y-medio-en-concretarse?idiom=es (Avvessed 29 June 2023)
[95] Jorge Gurría Lacroix, *El desagüe en el Valle de México durante la época novohispana*, 56
[96] Covarrubias, "Henrico Martinez", 395.

> not decrease, since water keeps coming into them, and the earth and land surrounding them grows, compelling its basin to narrow and rise, and the city's detriment could occur by the passage of time.[97]

This statement demonstrates that the Spaniards were in fact cognizant of their own impact on the land, and his assertion on the soil's transformation is quite accurate. Indeed, in addition to the neglect and damage to Indigenous hydraulic works, soil erosion caused by the introduction of plowing, grazing sheep, livestock, and more, was a significant factor that contributed to the increasing flooding.[98] This added to the sense of urgency in creating a drainage system for the city.

Martínez, following Gudiel's initial ideas, proposed the site of Nochistongo in Huehuetoca as a starting point for the canal, which was partially executed from 1607 to 1608, limited by financial restrictions from the city's council. It was financed through two main sources of income: donations and taxes, the latter disproportionately paid by the popular classes.[99]

The project required perforating the northwest hills that ran along the basin for thirteen kilometers when completed, a cutting called Tajo of Nochistongo. A seven-kilometer tunnel was also built, running as deep as fifty-six meters under surface. According to Candiani, it was a herculean work that spoke on the value the Spaniards rendered to the city, making it "one of the most ambitious early modern public works projects undertaken by Europeans anywhere [and] the vastest and most complex desiccation effort in the Americas during the period."[100]

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[97] Enrico Martínez, *Repertorio de los tiempos e historia natural desta Nueva España* (Mexico: En la emprenta del mesmo autor [sic], 1606), https://archive.org/details/reportoriodelost00mart/page/n285/mode/2up?view=theater (Accessed 26 June 2023) 185-186.
[98] Candiani, *Dreaming of Dry Land*, 29
[99] Candiani, *Dreaming of Dry Land,* 56.
[100] Candiani, *Dreaming of Dry Land*, 2-3.

However, for Indigenous people, Nochistongo would become synonymous to a death pit. For ten months, 60,000 Indigenous labourers worked on the cutting, frequently under the most grueling circumstances.[101] In fact, two centuries later, explorer and geographer Alexander von Humboldt, in his *Political Essay on the kingdom of New Spain* would write of the abuse this hydraulic work subjected Indigenous people to:

> The indigenous have a mortal hatred towards the Huehuetoca drainage, and they regard all hydraulic enterprise as a public calamity, not so much due to the great number of individuals who perished in the cutting of Martínez's mountain, but mainly because, by being forced to work and abandon their domestic chores, they ended up living in the greatest indigence for as long as the construction lasted. For over two centuries they have been preoccupied with it by the thousands; and drainage can be considered the first cause of misery among the indigenous people of the valley of Mexico. The great humidity that surrounded the Nochistongo pit caused them mortal diseases. Just very few years ago there was the cruel practice of tying the Indians with ropes and making them work like galley slaves, even while sick and watching them expire on the spot.[102]

[101] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 43
[102] Alexander von Humboldt. *Ensayo político del reyno de la Nueva España* (Paris: Paul Renouard, 1822). Digitized by the Universidad de Nuevo León, Dirección General de Bibliotecas, 410

"Tajo de Nochistongo, parte más profunda". Ca. 1910. Mediateca, Photograph © Mediateca INAH (Instituto Nacional de Antropología e Historia), https://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A53065 (Accessed 29 June 2023)

Reading that statement and observing the photograph above give a clear impression of how colossal and brutal the works for the Tajo of Nochistongo really were for Indigenous workers. They were also brought from other regions of the country by the projects' administrators since deaths and illnesses from the Tajo work, as well as from the constant flooding had taken a toll on the Valley's Indigenous population. Throughout the seventeenth century, in total, according to the aforementioned engineer Francisco de Garay, "in various documents of the time, a dreadful mortality is discussed among the Tajo operators, escalating

from 100,000 to 200,000."[103] Hearer and Desagüe superintendent Juan de Villabona Zubiaurre was quite critical of several aspects of the project's execution when he was appointed in 1631, which included the mistreatment of Indigenous workers, who were either killed due to "pestilent illnesses" caused by the flooding or taken from distant places to work; they did not receive adequate sustenance or fair payment and were executed if they dared to protest, therefore, a great number of them ended up fleeing.[104]

The works continued intermittently in 1614 and 1616 due to disagreements between Martínez, the City Council, and the viceroy. A new proposal by Dutch engineer Adrian Boot introduced how the lakes and canals could be kept by installing dikes around the city and regulating water pressure through hydraulic pumps.[105] In the end, the city opted to continue with Martínez's project, but eventually, it would become insufficient; while the canal of Huehuetoca managed to deviate the water from the rivers, it did not desiccate the lakes nor get rid of sewage water.[106] Moreover, the fact that such a large-scale project was partially completed in the record time of 10 months indicates how fragile the terrain was, which alludes to Martínez statement on soil erosion; the construction of the tunnel constantly collapsed and caused sinkholes that collected water.[107] In 1626, Martínez closed the tunnel due to high maintenance costs, which would have terrible consequences three years later.

In September 1629, the Valley suffered one of its most devastating floods, with the water remaining stagnant across the city for a total of five years. At the same time, the flood caused the

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[103] Garay, *El Valle de México*, 44.
[104] *Archivo General de Indias*, Mexico, 75, R. 1, N. 1 image 1-2, Villabona to HM, Mexico, 7 January 1631, as cited in Ruiz Rivera, *En Pro de la Justicia: Juan de Villabona Zubiaurre*, *rector de Sevilla y juez-oidor en Bogotá y México, 1577-1634* (Spain: Editorial Universidad de Sevilla, 2020)195.
[105] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 43
[106] Horacio Ramírez de Alba, "La casa del virrey Luis de Velasco en Huehuetoca", *Ciencia Ergo Sum*, vol. 8, no. 2, Universidad Autónoma del Estado de México, July-October 2001, 200.
[107] Julián B. Ruiz Rivera, *En Pro de la Justicia: Juan de Villabona Zubiaurre,* 205.

elites to seek higher places in the periphery to establish themselves away from the nuisance of the excess water, which intensified the exploitation and settlement of those lands, to the point where King Phillip II issued a document to prohibit the construction of houses outside of the city, limiting it to territories already approved by him.[108] Colonial authorities accused Martínez of negligence and even imprisoned him for a short period. In his defense, 19th-century engineer Francisco de Garay claims that Martínez had initially proposed a general drainage, but due to a "misunderstood economy" the men in charge had preferred a partial and reduced drainage instead.[109]

However, in 1632 the authorities decided to resume the Desagüe works with his help since he knew most about the project, but eventually, he left after many ongoing complications with the project and multiple slanders from opponents such as superintendent Villabona. The superintendent disapproved of Martínez's management, stating that the engineer knew from the start about the soil's fragility and that he depended almost entirely on third-party reports without visiting the site, lacking visual recognition to actually judge the state of the tunnel and canal for himself.[110] Villabona also condemned the corruption surrounding the construction of the canal, starting with how the viceroy in turn, Cerralbo, who was about to finish his term, had approved late and inefficient procedures to save his reputation and be in good graces with the king of Spain and the Catholic Church.[111] However, since they had already invested so much money on the Huehuetoca canal, abandoning the project was improbable, which became "the greatest obstacle for the adoption of any other solution".[112] In the end, Martínez secluded himself in a

[108] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 46-47.
[109] Garay, *El Valle de México*, 17.
[110] Ruiz Rivera, *En Pro de la Justicia: Juan de Villabona Zubiaurre*, 216-217.
[111] *Archivo General de Indias*, Mexico, 75, R. 1, N. 1 image 1-2, Villabona to HM, Mexico, 7 January 1631, as cited in Ruiz Rivera, *En Pro de la Justicia: Juan de Villabona Zubiaurre*, 195.
[112] Ruiz Rivera, *En Pro de la Justicia: Juan de Villabona Zubiaurre*, 217.

church in Cuautitlán and died in December 1632. The project continued without him, turning all tunneled sections into an opencast canal; other structures were added throughout the years as well. The works carried on intermittently well into the 18th century, up until 1789.[113]

In the end, this first Desagüe project did little to stop the flooding in the city, but it did manage to reduce the size of the lakes Zumpango and San Cristóbal, and in consequence, lake Texcoco stopped receiving water from them. This had a negative impact on the atmosphere's humidity since the desiccation of the lake's margins caused the decline of vegetation and the eruption of efflorescent salts, and by being exposed to sun rays and dry winds, the lake's desiccation only grew more, and more. Moreover, the lack of vegetation caused a decrease in animals, which harshly affected the locals' economy and commerce[114].

Nowadays, a small river runs across the area of Huehuetoca, as can be seen in the following Google Maps screenshots. However, it is hard to determine whether that river stems from what was previously the Tajo of Nochistongo or the Cuautitlán River, since the landscape has changed dramatically over time.

[113] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 47.
[114] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 50.

Present-day Huehuetoca, State of Mexico. Screenshots from Google Maps.

(Retrieved on 02 July 2023)

Undoubtedly, while the Indigenous intervention in the basin's landscape was significant, with the Spanish colonization the Valley's nature and society were irreversibly transformed at an unprecedented rate. The Indigenous population was able to work with the natural landscape and use it for their benefit without altering the ecosystems already in place in a radical way. The *albarradón* of Nezahualcóyotl, for instance, split the fresh and saltwater from the lakes, which helped in the development of "rich aquatic fauna which was exploited by its inhabitants with fruition".[115] While some of the waterworks built by the Spaniards helped with matters such as water supply to the growing city, the colossal work of the Desagüe initiated more hardships than remedied them, starting with the death of countless Indigenous people to the disruption of the environment at a massive scale. Moreover, as will be reviewed in the following chapters, flooding remained a big problem in the Valley of Mexico well into the nineteenth century and even in the present day.

As demonstrated by the exemplified Spanish waterworks—aqueducts, fountains, etcetera—, the Spaniards' choices in hydraulic engineering were distinctly influenced by their own views regarding nature and their Roman heritage. Rather than working with the canals, dikes, and other established Indigenous waterworks, they were seen as an obstacle in the construction of a new city better suited to their European standards. Access to water was privatized in many areas, favouring the growing necessities of the Spanish population over the Indigenous. As for their Roman heritage, it is distinguishable in the physical characteristics of the aqueducts and the like, clearly presenting as imposing structures meant to tower over the inhabitants as a demonstration of the power of the Spanish rule. Their Muslim heritage is also present in the types of crops they brought to the continent and the agricultural and irrigation

[115] Lacroix, *El desagüe en el valle de México*, 24.

methods. However, in the grand scheme of things, any positive aspect of the syncretism of cultures is overshadowed by their focus on commodifying natural resources and the exploitation of Indigenous labour.

The initial Desagüe project, while it somewhat successfully deviated the water from the rivers and lakes, was only the beginning of the desiccation of the basin, reconfiguring the environment in its entirety. And in the end, it did not keep the constant flooding from affecting the city. While the Desagüe works carried on throughout the seventeenth and eighteenth centuries, specific occurrences lie beyond the scope of this research. By 1823, the Huehuetoca Canal had fallen out of use, and for quite some time Mexico's unstable politics, both internal and external would prevent the government from putting an emphasis on the project's completion, but the nineteenth century would also bring a new series of issues surrounding the Desagüe that could not be ignored for long.

4. The Nineteenth Century: European Influence on the Desagüe

4.1 Sanitation and Infrastructure in Europe and the United States

The nineteenth century was a very complex period in Mexican history. The country became independent in 1821, but the next decades would present deep political conflicts, both internal and external. As a new nation, Mexico was determined to establish itself as worthy to other nations and was therefore influenced by ideas, politics, and cultures from Europe and, gradually, the United States. This influence was reflected in public health, sanitation, and infrastructure measures taken by European nations. During the first half of the nineteenth century, the miasma theory of disease still dominated conversations around public health. This theory, popular across Europe as early as the 1300s, argued that infectious diseases were spread by inhaling polluted vapors or "bad air" emanating from rotting organic matter. Therefore, people believed that bad smells or pestilence corrupted the air, water, and earth as well as the animals and humans living in these environments. The English lawyer Edwin Chadwick first linked sanitation to health issues in 1842 when he published *The Sanitary Conditions of the Labouring Population,* but all his ideas were based on miasma theory. It was not until 1849 that physician John Snow, in a paper called *On the Mode of Communication of Cholera,* proposed that the disease was not transmitted by bad air, but by polluted water; in an updated version in 1854, he proved his theory when he realized that the location of most cholera deaths was clustered around a particular public water pump.

However, many in the medical field were not convinced until London's final cholera outbreak in 1866.[116] Thanks to Snow's research and more than came after, along with the

[116] "Cholera in Victorian London", *Science Museum*, 30 July 2019, https://www.sciencemuseum.org.uk/objects-and-stories/medicine/cholera-victorian-london (Accessed 7 May 2023).

development of germ theory and bacteriology, miasma theory was eventually disproved during the second half of the nineteenth century, revolutionizing the way diseases and medicine were understood. Nevertheless, this was such an ingrained belief that it continued influencing Europe and the rest of the Western world up until the turn of the century.

Before it started spreading with such ferocity in the nineteenth century, cholera had been an unknown disease in Europe, so debates arose to determine whether it was contagious –spread by one human to another– or infectious –by direct contact between a human and a certain environmental factor. At first, guided by the belief that it was contagious, governments such as Spain applied severe measures like quarantines, or cutting off food and trade with certain urban populations, but this situation only led to revolts and economic crises,[117] while the disease persisted. In Paris alone, approximately 20,000 people died of cholera in only one month in 1832.[118]As cholera kept spreading, the idea that it was an infectious disease gained support, although during the first years of the outbreaks, most cities did not invest in water supply or sanitation infrastructure.

The evolving views regarding sanitation and its connection to health had a significant impact on the urbanization of European spaces. In 1851, The first International Sanitary Conference took place in Paris with the participation of twelve nations, including Spain. This event became a turning point for international cooperation regarding sanitation as forums and governments created laws for the control of infectious diseases.[119] The sanitary movement became popular, as stated by author Martin V. Melossi, "by the notion that the physical

[117] Abellán, "Water supply", 7.
[118] Whitney Calvin, "What History Has Taught Us About Epidemics", *Caltech*, https://www.caltech.edu/about/news/what-history-has-taught-us-about-epidemics (Accessed 12 September 2023)
[119] Mark Harrison, "Disease, diplomacy and international commerce: the origins of international sanitary regulation in the nineteenth century", in *Journal of Global History*, 1, 2006, https://doi.org/10.1017/S1740022806000131 (Accessed 27 February 2023), 197.

environment exercised a profound influence over the well-being of the individual—that health depended upon sanitation."[120] As cities began their rapid industrialization processes, they started facing concerning issues such as mass migration, overcrowding, lack of housing, pollution of rivers, human waste, and chemical waste from industries. Moreover, as suggested by social scientist Javier Abellán, urban populations were farther from clean water sources and had to travel longer distances to get rid of waste, which lead to a rise in both morbidity and mortality.[121] Up until the first half of the nineteenth century, most cities depended upon wells, streams, rivers, or even public fountains, and a piped clean water supply was hardly present. Water and sanitation services had to be developed to improve the living conditions in urban centers, which became dangerously vulnerable to epidemics throughout Europe during the 1830s. Sooner or later, European cities had to address these issues.

The city of Hamburg installed the first great sewage system in 1842 as part of a reconstruction plan rather than a particular focus on sanitation infrastructure.[122] In London, after the hot summer of 1858 caused overwhelming smells to rise from the Thames—an event called The Great Stink[123]—, civil engineer Joseph Bazalgette designed a sewage system involving 1,100 miles of drains that fed into 82 miles of new brick-lined sewers.[124] The sewage system was completed in the 1870s, along with the Albert, Victoria and Chelsea embankments along its sides. In Paris, the construction of a sewage system of 600 kilometers long, including a treatment

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[120] Martin V. Melossi, *The Sanitary City: Environmental Services in Urban America from Colonial Times to the Present* (Pittsburgh: University of Pittsburgh Press, 2008), 28.
[121] Javier Abellán, "Water supply and sanitation services in modern Europe: developments in 19th – 20th centuries", *XII Congreso Internacional de la Asociación Española de Historia Económica* (Spain: University of Salamanca, 2017), 5.
[122] Abellán, "Water supply", 8.
[123] Historic England, "The Story of London's Sewer System", *The Historic England Blog*, https://heritagecalling.com/2019/03/28/the-story-of-londons-sewer-system/ (Accessed 12 September 2023)
[124] Alwyn Collinson, "How Bazalgette built London's first super-sewer", Museum of London, https://www.museumoflondon.org.uk/discover/how-bazalgette-built-londons-first-super-sewer (Accessed 12 September 2023)

plant began in 1850, concluding in 1878. As for Paris, it was in fact the European city that had the greatest transformation of all during the second half of the nineteenth century, all due to the efforts of Napoleon III and prefect of the Seine, Georges Haussman to renovate the city's urban landscape.[125]

In Spain, on the other hand, the industrialization process was much slower; there were stark differences and regional divergences in its industrial development, which was mostly concentrated in two regions in the northeast, Catalonia and the Basque Country[126], and water supply across the country was provided mostly by private enterprises. In Madrid, the lack of water supply was an obstacle to the city's development as a capital.[127] By the middle of the eighteenth century, the city had reached 150,000 inhabitants, making the water supply extremely deficient, and lack of hygiene and poor sanitation were critical. The closest river, the Manzanares "due both to its scant flow and its watercourse running below the base level of old Madrid"[128] was insufficient and not up to the task of supplying drinking water, transportation, or irrigation. Spain was also badly affected by cholera from 1833 to 1835.[129] Finally, in 1851 the government inaugurated the Canal de Isabel II, becoming the first water supply service managed by the state[130]. Moreover, Spanish authorities forced construction, food, and chemical industries to move away from the city center as they considered them unhealthy.

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[125] Mary McAuliffe, *Paris, City of Dreams. Napoleon III, Baron Haussmann, and the Creation of Paris* (Maryland: Rowman & Littlefield, 2020), 1.
[126] Joan R. Rosés, "Why Isn't the Whole of Spain Industrialized? New Economic Geography and Early Industrialization, 1797-1910", *The Journal of Economic History*, Vol. 63, No. 4, Dec. 2003, https://www.jstor.org/stable/3132363 (Accessed 10 March 2023), 996.
[127] Ana Duarte Rodrigues and Carmen Toribio Marín, eds., *The History of Water Management in the Iberian Peninsula (between the 16th and 19th centuries)* (Switzerland: Birkhäuser, Springer International Publishing, 2020) https://doi.org/10.1007/978-3-030-34061-2 (Accessed 10 March 2023), 68.
[128] Duarte Rodrigues, *The History of Water Management*, 69.
[129] Esteban Rodríguez Ocaña, "La primera pandemia de cólera en España, 1833-35". *Jano*, May 1986. Vol. XXX, (728), 72.
[130] Abellán, "Water supply", 9.

On the other side of the Atlantic, before the 1830s, many cities in the United States also faced poor sanitary conditions, and people would rely on individual responsibility for waste disposal, as well as cesspools, privy vaults and sewers that mostly consisted of open ditches.[131] In 1801, Philadelphia became the first city to complete a waterworks and municipal distribution system, an anomaly at the time. According to Melossi, "Despite uncertainty in determining disease causation, the correlation between pure water and good health was nevertheless a driving force in dealing with epidemics."[132] To some extent, people did believe that fevers were caused by polluted water from wells and cisterns, which had been replaced by a community-wide system. By the end of the 1820s, the scale of American urbanization was still limited, but cities still faced health risks, particularly larger ones such as New York, Boston, and Baltimore, which between 1790 and 1830 experienced notable rates of growth in each decade.[133]

Urban growth, as well as transatlantic trade, led to the spread of various diseases such as smallpox, malaria, tuberculosis, diphtheria, and cholera, among others. The threat of epidemics forced cities in the United States to come up with solutions for improving public health, starting with sanitary services and efficient water supply systems.[134]

As Mexico's immediate neighbor, the United States wielded a significant influence on the country when it came to innovations, investments, trade, and more. However, Europe's sanitation and urbanization ideas deeply inspired Mexico City during the late nineteenth century for the incorporation of sanitary and urbanization ideas into the Desagüe project.

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[131] Melossi, *The Sanitary City,* 24.
[132] Melossi, *The Sanitary City*, 19.
[133] Melossi, *The Sanitary City,* 12.
[134] Melossi, *The Sanitary City*, 15.

4.2 European Influence: Urbanization and Sanitation in Mexico City

To contextualize, the nineteenth century was an exceptionally turbulent and unstable period in Mexican political history, starting with the Independence movement from 1810 to 1821, followed by the Texan Independence and the First French Intervention in the 1830s. Afterward came the war with the United States from 1846 to 1848, which resulted in Mexico ceding what are now the states of California, Nevada, Utah, and parts of Colorado and Wyoming; later on, with the Gadsden Purchase, President Antonio López de Santa Anna sold the territory known as La Mesilla, present-day New Mexico and Arizona. Subsequently came the Reform War, a civil war between the Mexican conservative and liberal parties from 1857 to 1861. Right after began the Second French Intervention, from 1861 to 1867, as well as the brief appointment of Maximilian of Habsburg as emperor of Mexico (1864-1867). The relatively politically peaceful period for Mexico during this century came with Porfirio Díaz's dictatorship, a period known as the Porfiriato, which took place from 1876 to 1911. Evidently, all these conflicts were reflected in the country's financial relationships, and external influences on Mexico played a big role in the financial aspects of various infrastructure projects.

When Mexico became independent in 1821, it was already indebted to various European powers. However, as the country started industrializing and opening markets during the second half of the century, Mexico City began growing and establishing itself as a true capital fit for the modern world; communication networks, highways, and rail lines expanded and improved, facilitating trade relations and the concentration of commercial activities. According to author Carol McMichael Reese, these factors, along with internal and external political strife, set in

motion the capital's expansion after 1856, when large-scale exporters, both foreign and local, saw large benefits, and the city's population doubled.[135]

In 1877, one year into Díaz's presidency, the city had a population of 230, 000 inhabitants, and by 1900 the number had reached 368,898[136]; an urban real estate market was developed during this initial industrialization period, "and the physical and social characteristics of the colonial city changed dramatically."[137] However, this quick urbanization did nothing to reduce the inequality gap amongst the population; in fact, a series of laws passed during this time authorized the commercialization of public property or the confiscation of land belonging to indigenous, religious, or city council groups, becoming private property mostly owned by businesses, which expanded the market of lands available for urbanization.

Major cities in the Americas, Mexico City included, looked to European cities such as London, Paris, or Hamburg to learn from their changes in infrastructure. The Mexican government had great modernizing aspirations, which were reflected in the city's urbanization and industrialization process, accelerated during Porfirio Díaz's regime in the last third of the century.

President Díaz was open in his admiration of European countries, particularly France, and so he sought to create a modern and international capital modeled after these cities, whilst exalting its Mexican character. Throughout the nineteenth and twentieth centuries, Mexican nationalism "was a long-term state project whose aim was to build a uniform nation, both culturally and linguistically by the means of politics and integration institutions".[138] In this vein,

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[135] Reese. "The Urban Development of Mexico City", 141-142.
[136] Miranda P., "Urbe…", 200.
[137] Carol McMichael Reese. "The Urban Development of Mexico City, 1850-1930", in Arturo Almandoz ed. *Planning Latin America's Capital Cities 1850-1950* (Oxford: Alexandrine Press, 2002), 140.
[138] Natividad Gutiérrez Chong. *Mitos nacionalistas e identidades étnicas: los intelectuales indígenas y el Estado mexicano* (Mexico: Instituto de Investigaciones Sociales, UNAM, 2012) 17.

a single historical point of view was inculcated by the government through the education system and newfound—or rather invented— traditions where the country's prehispanic past was glorified while "living Indians" had to be assimilated or were cast aside, as they did not fit into the idea of modernity the government had planned for Mexico. Hence, Díaz embraced an export-led economy, embracing foreign capital investments and paying the national debt. Thanks to the Ley de Desamortización de Bienes Eclesiásticos (expropriation of ecclesiastic property law) approved back in 1856, he encouraged private property and the urbanization of lands. To this end he confiscated lands from the Church, as well as communal lands owned by peasants, mostly Indigenous people and *mestizos*,[139] which reflected in the expansion of *haciendas* and the construction of railroads. For peasant communities, this led to a critical situation where they lost the ability to support themselves and were forced to seek work at the same *haciendas* under grueling conditions.[140] After all, the great disparity between social classes is one of the defining traits of the Porfiriato. As for Díaz, when it came to conceiving a sanitation project for the betterment and modernization of the city, finishing the Desagüe became one of his top priorities.

At the same time, many local authorities and men of science realized that the basin's unfinished desiccation was having a considerable effect on the environment and on people's health, which is why they began to think of solutions to the unsanitary conditions spread across Mexico City and the Valley. One noteworthy example is José María Luis Mora, a liberal doctor who in 1823 wrote an analysis on the Valley's drainage in relation to a flood in 1819, entitled

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[139] Sergio Miranda Pacheco. "Urbe inmunda: poder y prejuicios socioambientales en la urbanización y desagüe de la ciudad y valle de México en el siglo XIX", in Dupey García, Élodie and Guadalupe Pinzón Ríos, coords., *De olfato. aproximaciones a los olores en la historia de México*, (México: Fondo de Cultura Económica, 2020), 199-200.

[140] Gisela von Wobeser. *La formación de la hacienda en la época colonial: el uso de la tierra y el agua* (Mexico: UNAM, Instituto de Investigaciones Históricas, 2019) https://historicas.unam.mx/publicaciones/publicadigital/libros/formacion_hacienda/epoca_colonial.html (Accessed 12 July 2023) 57.

Relaciones del desagüe del Valle de México. In this report, Mora established the overflowing waters of the Texcoco Lake as the main cause for flooding: "Preventing the growth of Texcoco was what had to be done to save Mexico, and it was very obvious that closing the flow of the rapids that swelled it presented itself as the easiest way of achieving it." [141]

Overall, the common argument was that the main causes for the unsanitary conditions were flooding, stale water, and waste. By expelling this "bad water" from the Valley, connected to the construction of a new sanitary system, the city would allow the public to achieve what historian Sergio Miranda describes as "the secular longing of environmental wellness, health and hygiene".[142] However, the public's perception of poor sanitation and pestilence was also dominated by socioenvironmental prejudices, particularly regarding the way of life of the poorer sectors of the population; [143] thus, bad smells came to be associated with poverty. On December 17th, 1848, an article from the newspaper *Siglo Diez y Nueve* suggested a connection between poor sanitation and society's morals:

> It is well-known that the floodings that keep repeating in the capital are due, in part, to the lack of leveling of its streets and gutters…these reasons are enough to make Mexico City one of the least clean and most unsanitary cities in the universe… Gutter waters, instead of serving as drainage of the streets often serve as pools in which water accumulates, corrupting the air with its putrid miasmas and weakening the health of the inhabitants to the point of creating all kinds of frequent epidemics…This multitude of continuous evils powerfully influences the physical and morals of the inhabitants… Our neighborhoods are disgusting middens, dens of crime and demoralization…The sad dwellers of our suburbs are at the same time the

[141] José María Luis Mora, *Relaciones del desagüe del Valle de México*, as cited in Isaac Acosta Fuentes. Ph.D Thesis, *El debate científico en la concepción del desagüe del Valle de México, 1607-1975* (Mexico: Universidad Autónoma Metropolitana, 2016) 159
[142] Miranda P., "Urbe…", 195
[143] Miranda P., "Urbe…", 197

> source of vice and pestilence, and the scourge and fear of the rest of the population.[144]

Diseases and infectious epidemics, pestilence, flooding, dust storms, rain and extreme temperature changes, and well as waste and putrefaction were all part of the environmental reality of everyday life for the city's inhabitants.[145] Smallpox, measles, cholera morbus and scarlet fever all had epidemic outbreaks throughout the first half of the nineteenth century, and between 1860 and 1910 typhus prevailed in various communities in the Valley and Mexico City.[146] It is worth mentioning that Porfirio Díaz's own father died from a cholera outbreak in 1833 in Oaxaca.[147]

Thus, in 1876 the Comisión de hygiene de la Academia de Medicina de México (Hygiene Commission of the Medical Academy of Mexico) recommended the Desagüe as indispensable and urged the government to also establish stronger public hygiene measures.[148] The project to conclude the desiccation of the lakes was seen as the only solution on which "not only the future health of the capital and its inhabitants but the dignity of the nation's progress" lay.[149]

However, despite that the majority of the scientific community had placed their hopes on the drainage project for the city's improvement, some still had doubts that the Desagüe alone would eradicate all of its the sanitary issues. Among them was Doctor Domingo Orvañanos, who in 1891 wrote an article for the *Gaceta Médica de México* in which he pointed out that certain

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[144] "Ministerio de Relaciones Interiores y Esteriores [sic]" in *El Siglo Diez y Nueve*, Mexico, 17 December 1848, p. 1, *Hemeroteca Nacional Digital de México*, https://hndm.iib.unam.mx/consulta/publicacion/visualizar/558075bf7d1e63c9fea1a43f?intPagina=1&tipo=publicacion&anio=1848&mes=12&dia=17 (Accessed 14 March 2023)
[145] Miranda P., "Urbe…", 204
[146] Sergio Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental* (Mexico: Instituto de Investigaciones Históricas, UNAM, 2021), 62.
[147] Porfirio Díaz, *Archivo del general Porfirio Díaz. Memorias y documentos*, prologue and notes by Alberto María Carreño, Mexico: Universidad Nacional Autónoma de México, Instituto de Historia, 1947, published online in 2016. https://historicas.unam.mx/publicaciones/publicadigital/libros/archivo/t01/06_diaz01_capitulo%20I.pdf (Accessed 11 March 2023) 27.
[148] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 77-78.
[149] Miranda Pacheco, "Urbe…", 207.

localities near the mountains did not deal with flooding, and yet presented high mortality rates as well, and claimed that other hygiene measures had to be taken to decrease deaths due to lack of hygiene in the city. He also encouraged citizens to stay vigilant of drinking water and to get vaccinated.[150]

At the same time, the opinions of European men of science such as Alexander von Humboldt's were highly regarded in Mexico. Humboldt visited and explored the country in the early 1800s, and in 1822 his *Ensayo politico sobre el reyno [sic] de la Nueva España (Political Essay of the Kingdom of New Spain)* was published in Spanish. This publication heavily impacted academic and scientific spheres in Mexico, and it even kept influencing decades later. In this text, he praised the drainage works of the seventeenth century, but he also stated that they were insufficient for preventing flooding in the capital, which is why he recommended the construction of a direct canal to the lake of Texcoco[151], the biggest of the five main lakes in the basin. He outlined the Valley's constant flooding and the effects of the previous hydraulic works:

> Despite the expenses already taken, the city will always be at risk for as long as a canal to the lake of Texcoco is not built… In 1763 and early 1764 the capital was in grave danger. Flooded everywhere within the space of a few months…water could be seen welling up from the ground, no doubt due to the hydrostatic pressure experienced when it infiltrates through the immediate mountains…On December 6th, 1672, such a heavy and sudden downpour fell in the Valley of Mexico that it presented the full appearance of a waterspout. Luckily, this phenomenon occurred in the north and northwest part of the valley. The canal of Huehuetoca [16th century work by Enrico Martínez] worked admirably, even though great portions of land between San Cristóbal, Ecatepec… flooded in such way that many buildings were ruined.[152]

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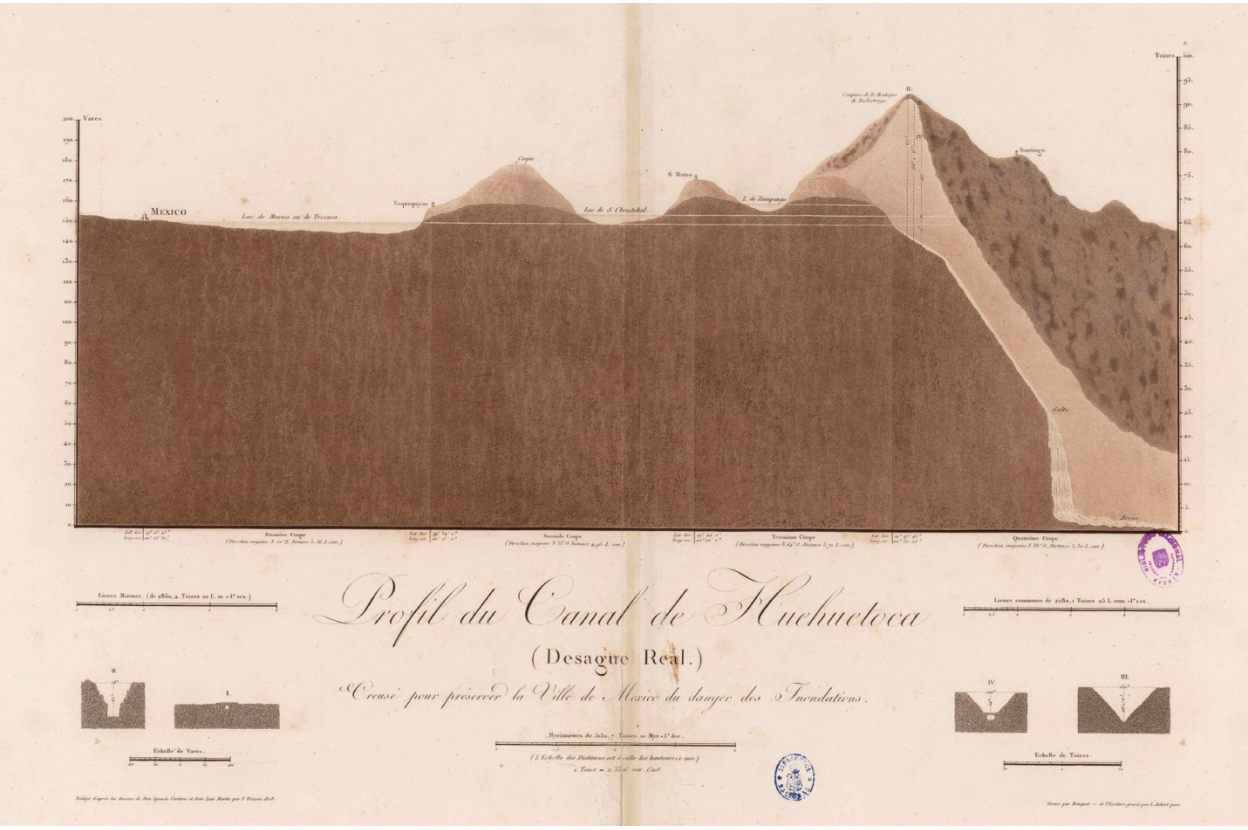
[150] Domingo Orvañanos, "Higiene pública", *Gaceta Médica de México*, vol, XXVI, 1891, 313-315, as cited in Mayra Sheila Olguín Ortiz, M.A. Thesis *El desagüe del Valle de México para el saneamiento del medio ambiente, en el Porfiriato* (Mexico: Instituto de Investigaciones Históricas, UNAM, 2018), 96.
[151] Alexander von Humboldt, *Ensayo político del reyno de la Nueva España* (Paris: Paul Renouard, 1822). Digitized by the Universidad de Nuevo León, Dirección General de Bibliotecas, 405.
[152] Humboldt, *Ensayo político*, 405, 406

Along with the *Essay*, Humboldt wrote *Atlas geográfico y físico de la Nueva España (Geographical and Physical Atlas of New Spain)* which contains detailed maps and depictions of Mexico's geography. This image of the *Atlas* depicts the Tajo (cutting) of Nochistongo created for the Canal of Huehuetoca, built by Enrico Martínez in the seventeenth century.



"Profil du Canal de Huehuetoca (Desague [sic] Real) Creusé pour préserver la Ville de Mexico du danger des Inondations". Alexander von Humboldt, *Atlas geográfico y físico de la Nueva España*, (Paris: Jules Renouard, 1827) p. 28. Digitized by the Biblioteca Nacional de España.

In his *Political Essay*, Humboldt stated that when he visited Mexico in 1804, the viceroy Iturrigaray had already ordered the construction of the Texcoco canal, and then he detailed some of the project's ideas, which planned to give smaller slopes to the canals: "my opinion is that if prudence dictates to create small inclines for the navigation canals, it is commonly useful to

build larger inclines for the drainage canals."[153] In addition, Humboldt was also concerned about the possibility of the volcanoes Popocatépetl and Iztaccíhuatl erupting, since the snowmelt would make water levels rise in the lakes and cause even more flooding in the city.[154]

Interestingly, Humboldt mentioned the environmental impact of the desiccation of the basin. He stated that water had been regarded as an enemy for the construction of hydraulic works of the valley of Mexico, and that this way of proceeding had destroyed the "sprout of fertility" in the great part of the valley:

> Some beautiful savannas have gradually become dry sandbanks. In great stretches of the valley's land there is hardened clay naked from vegetation… it would have been easier to take advantage of the natural disposition of the terrain, making use of the same drainage canals to irrigate the arid plains and for inland navigation. By making big ponds, some higher than others as landings, would facilitate the execution of irrigation canals…It would have been better to take advantage… of these waters for agriculture in the lowest parts of the valley. Water deposits for drought periods could have been built as well.[155]

Mexican geographer and historian Manuel Orozco y Berra shared the same opinion, stating in 1867 that redirecting the water from the lakes for agriculture was better than desiccating them completely. He also affirmed that the lake of Texcoco overflowing and the need for a Desagüe were two separate issues, and that getting rid of the waste had to be done to reclaim control over the water and restore balance; the surrounding land would be cleansed and people whose subsistence was provided from the waters would be left unaffected.[156] But alas, the general consensus among the scientific community was to get rid of the water altogether.

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[153] Humboldt, *Ensayo político*, 408.
[154] "Ministerio de Relaciones Interiores y Esteriores [sic]" in *El Siglo Diez y Nueve*, Mexico, 17 December 1848, p. 1, *Hemeroteca Nacional Digital de México*, https://hndm.iib.unam.mx/consulta/publicacion/visualizar/558075bf7d1e63c9fea1a43f?intPagina=1&tipo=publicacion&anio=1848&mes=12&dia=17 (Accessed 14 March 2023).
[155] Humboldt, *Ensayo político*, 412, 413.
[156] Miranda Pacheco, *La caída de Tenochtitlan y la posconquista ambiental*, 76.

Another noteworthy European figure is French chemist and engineer Jean-André Poumarède, mostly known for discovering the Quercy deposits of phosphorites in France. The 1872 chemistry book *Traité special des phosphates de chaux natifs* by Jacques Malinowski, outlines Poumarède's biography.[157] He arrived in Mexico in 1848, becoming director of a mining company soon after. While he was stationed in the country, he designed a sanitation project for the Valley of Mexico in 1856, which consisted of a siphon from the Texcoco Lake to the Tajo on Nochistongo that would have relied on atmospheric pressure to function and get rid of the stagnant waters around the city, as well as the construction of dams in the mountains to regulate water branches[158]. Poumarède presented two proposals for this project; the first one consisted of a 40-kilometer-long siphon which would have released 564 cubic meters of water per minute at had a budget of 440,000 pesos. The other proposal, with a budget of 980,000 pesos, involved a 12-meter-width canal from Texcoco Lake to the Xalpa *hacienda*, where the siphon would have been established at 7.75 meters above the Texoco Lake. This canal would have also been used as a transportation route for products such as fruits into the city. [159] Ultimately, one of the commissions formed by the Junta Directiva del Desagüe del Valle de México (Board of Directors of the Desagüe of the Valley of Mexico, which will be mentioned in later chapters) voted against Poumarède's projects, considering it too "adventurous", unapplicable to the Valley's Desagüe, and ultimately insufficient.[160]

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[157] Jacques Malinowski. *Traité special des phosphates de chaux natifs. En général, et principalement l'étude des gisements de cette matière, qui ont été nouvellement découverts dans le Quercy* (Paris: Laytou, Imprimeur, 1872) https://gallica.bnf.fr/ark:/12148/bpt6k97702464/f117.item.texteImage (Accessed 21 March 2023), 112.
[158] Acosta Fuentes. *El debate científico,* 166-167.
[159] Luis González Obregón coord., Junta Directiva del Desagüe del Valle de México, *Memoria histórica, técnica y administrativa de las obras del desagüe del valle de México, 1449-1900*, in Internet Archive, https://archive.org/details/memoriahistorica01mexi/page/n3/mode/2up?view=theater (Accessed 12 March 2023), 288.
[160] Luis González Obregón coord., Junta Directiva del Desagüe del Valle de México, *Memoria histórica*, 288-289.

In 1860, he published a book both in Spanish and French describing his proposal and the need for a drainage system in the Valley of Mexico, entitled *Desagüe del Valle de México: nuevo sistema de impedir las inundaciones de la Ciudad y del Valle de México, y hacer desaparecer en parte las causas de insalubridad que ofrecen uno y otro (Nouveau moyen de prévenir les inondations de la Ville et la Vallée de Mexico, et de faire en partie disparaître les causes d'insalubrité qu'elles présentent l'une et l'autre*.) In this book, Poumarède described the Valley's geography, explaining how the lack of a natural outlet of water in the valley caused the constant flooding; he also briefly touched on Enrico Martínez's hydraulic works of the seventeenth century:

> With the purpose of battling these circumstances [the overflowing of the lakes] … more or less two centuries ago, gigantic works were carried out with the object of not only diverting the waters of the Cuautitlán river, which used to be drained in the Valley, but directing the lake waters to the Tula ravine through canals… Unfortunately, all of these works, which have absorbed huge expenses, have only served to this day to make the inundations less frequent, without preventing the danger of one and terrible cataclysm, as history itself has demonstrated… the only useful one that remains is the deep cutting of Nochistongo, which diverts the river of Cuautitlán, as well as the dike of San Cristóbal, realized by Martínez, work that prevents the overflow of the lakes of Zumpango, Xaltocan and San Cristóbal into [the lake of] Texcoco.[161]

Curiously, Poumarède mentioned Humboldt's judgment on the volcanoes as well, mentioning the baron's concern over the possibility of having to face snowmelt from the mountains, which "would submerge the valley into the deepest misfortune."[162] The French chemist also described the various data needed for the new waterworks to function properly, such as the amounts of water entering the lake of Texcoco daily, how much of that was rainwater

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[161] Jean André Poumarède, *Desagüe del Valle de México: nuevo sistema de impedir las inundaciones de la Ciudad y del Valle de México, y hacer desaparecer en parte las causas de insalubridad que ofrecen uno y otro* (Mexico: Imprenta de Ignacio Cumplido, 1860), in *Biblioteca Nacional Digital de México*, https://catalogo.iib.unam.mx/exlibris/aleph/a23_1/apache_media/M86YIJGL8PG6CMX9UH37S43E3BGR3D.pdf (Accesed 1 October 2022) 13.
[162] Poumarède, *Desagüe,* 17.

and how much was from the currents, and more;[163] he specifically mentioned an experiment he conducted to determine the evaporation conditions of the Texcoco Lake: in a branch of the Canal de la Viga near his laboratory, he planted wrought iron cups, which he filled with different volumes of water from the Texcoco Lake, examining the cups over a fortnight. He observed that every square meter of the surface lost on average 3,500 grams every 24 hours; therefore: "the Texcoco lagoon, whose surface equals 2224.989,632 square meters, loses 787,463 cubic meters of water in those same 24 hours, or 543 cubic meters by minute",[164] the amount of water his siphon would have attempted to harness.

Poumarède also mentioned various projects to drain the lake of Texcoco through canals flowing to the north and northwest of the valley, or through mine galleries or open tunnels to the east of the lake of Zumpango, such as the one proposed by the American engineer Martin Luther Smith.[165] However, despite the value of these projects, he expressed that deepening the artificial parts of the Cuautitlán River would have taken immense costs, not only due to the great amounts of earth that would have had to be removed but also because it would have in fact caused the opposite effect and created more flooding since he considered canals to offer limited relief to the deviation of water. To this, he recommended finding a mode of drainage —his siphon project—, that could extract from the lagoon 500 to 600 cubic meters of water per minute in order to maintain the level of the Texcoco Lake 80 to 90 centimeters below the level of the city.[166] Although he himself admitted a siphon was not a perfect measure, he defended it by pointing out it would remove the water faster, avoid siltation (the accumulation of sediments) and only a

[163] Poumarède, *Desagüe,* 23.
[164] Poumarède, *Desagüe,* 23.
[165] Poumarède, *Desagüe,* 37.
[166] Poumarède, *Desagüe,* 33.

narrow gallery would have to be built, rather than a big excavation project. [167] On the matter of sanitation measures, he wrote:

> One does not need to have deep knowledge on hygiene to convince oneself that there are few countries that present causes of insanitation as big and manifest as the city and valley of Mexico. Indeed, it is enough to reside a few months in this capital to recognize… how vicious and miserable the drainage system established here is… it is well-known that the filth from most houses in Mexico drain through a very narrow pipe, which commonly has little slope and connects to the gutter in the middle of the street, draining said gutter into the waters of the Viga Canal, which goes through the western part of the city before flowing into the Texcoco lagoon. If only there existed a difference of some meters between the level of the canal waters and the gutter waters… it would be possible to throw out of the city most of this matter before its entire decomposition…[such filth] form these miasmatic products that science has not defined but imperfectly to this day, but its deleterious effects over the economy of hygiene have been generally proven for them to be called into question.[168]

Finally, one of Poumarède's closing arguments involves his perspective on the environmental changes a drainage project would have on the Valley:

> Conducting the waters of the Texcoco lagoon to the foot of the hills we have discussed, is an easy thing to achieve since the terrains required to break through are lands of flooding, plains, and of very little value, which will not offer any… great obstacles of any genre, which have been necessary to overcome in enterprises of this sort in Europe. In the present case, a hydraulic work of this nature would be completed with such ease that, given its geographical position, it would necessarily become one of the main communication channels of the [Mexican] Republic, and its products would far exceed the interest of the capital invested in this work.[169]

It is worthwhile to compare Humboldt and Poumarède's nineteenth-century European perspectives several decades apart from each other. Both men of science, the authors present their concern over the worst-case scenarios in the event of flooding in the Valley, and they both mention the environmental impact of the drainage. However, Humboldt's stance on how the desiccation of the basin could have been prevented is significant; the geographer, according to author Isaac Acosta Fuentes, regarded with concern the rejection towards the presence of water

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[167] Poumarède, *Desagüe,* 85.
[168] Poumarède, *Desagüe,* 40, 41.
[169] Poumarède, *Desagüe,* 77.

in the Valley and instead favored its productive development, calling for a drainage system that would allow the harnessing of the basin's water resources for irrigation and even transportation, not only to prevent flooding.[170] Moreover, in his *Political Essay*, Humboldt stated that he wrote about his travels in the hopes of sparking the interest of Europeans in the new continent and making it useful to the colonies' government officials, who in fact "took materials [from his work] to [apply in] various trade jobs intended to discuss the interests of the colonies' commerce, industry, and manufactures."[171]

On his part, Poumarède specifically wrote *Desagüe del Valle de México* as a proposal of new alternatives to prevent the flooding in the Valley; as chemist working in the mining industry during a time where Mexico was struggling with external debt as well as increasing disease and flooding, his point of view was most likely driven by a sense of practicality in terms of sanitation and the best economic route. He repeatedly stated his concern over the economic implications of the waterwork projects, such as expenses, interest, and investments, as can be seen in the three quotes mentioned above, as well as the effects of the unsanitary situation on the country's economy. While his siphon project did not endorse the entire desiccation of the lakes and was designed only to reduce the water levels of the Texcoco Lake while advocating for a proper drainage system, he referred to the land as having "very little value", instead showing confidence in the project's potential recovery of investment; however, he did demonstrate environmental concerns regarding the unsanitary condition of the lakes due to a lack of drainage, from decomposition and miasmas to the great number of mosquitoes and salt levels presented on the stale waters, all of which "paralyzed" the Valley's agriculture.[172]

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[170] Acosta Fuentes, *El debate científico*, 156-157.
[171] Humboldt, *Ensayo político*, XVIII.
[172] Poumarède, *Desagüe,* 47-51-73.

These two men's points of view provide a wider picture of the nineteenth-century male European mentality. Both the explorer's and chemist's perspectives on the Mexican basin exhibit concerns regarding the impending danger of flooding in the capital, albeit from different angles; on one side, Humboldt stated that taking advantage of the natural disposition of the terrains would have been a more suitable option, disapproving of the villainization of water; on the other side, Poumarède, while his drainage project intended to remedy the increasing sanitation problems in the city and control floods, his proposal to build a siphon instead of more or deeper canals had more to do with economic concerns rather than environmental. In the end, the project that was finally approved by the Mexican government and the Desagüe's Board of Directors indeed exhibited the influence of European ideals, in which water remained an obstacle to the nation's progress.

4.3 El Gran Canal del Desagüe

Between the years 1851 and 1856, Mexico City suffered yet again from recurring flooding, which is why in 1856, the Mexican government called for a contest for ideas on how to definitively drain the lake basin— Poumarède's siphon being one of the projects presented. The winning idea however, belonged to Mexican engineer Francisco de Garay, who proposed the construction of a Gran Canal starting from the lake of Texcoco to the northwest region of Tequixquiac, complemented with other canals to the south and east, which would also serve as waterways for commerce.[173] He used as a reference a plan from American engineer M.L. Smith,

[173] "#AGNResguarda el proyecto de Francisco de Garay del Desagüe del Valle de México", *Gobierno de México*, https://www.gob.mx/agn/articulos/agnresguarda-el-proyecto-de-francisco-de-garay-del-desague-del-valle-de-mexico (Accessed 15 March 2023).

who had proposed excavating a 26.5-mile canal to conduct water to the Tula River.[174] Garay's project, however, would not be started until almost ten years later, when Maximilian of Habsburg was placed as emperor of Mexico (1864-1867). In Garay's *El Valle de México. Apuntes históricos sobre su hidrografía desde los tiempos más remotos hasta nuestros días*, referring to himself in the third person, he describes his initial project as such:

> Engineer Garay had projected in the Valley a series of staggered canals for its drainage, navigation, and irrigation, with prolongations along the North and the South. The length of the traced navigable lines, whose profiles were presented to the Board, passed 100 leagues. The project named first place by the Board, was the same that nine years prior had been declared worthy of a prize of 12,000 pesos.[175]

Throughout his account, Garay details the development of the project while he was in charge, as well as other proposals he made along the way. For instance, in 1865, the same year the works for the project finally started, there was a major flood that inundated the city and even villages and haciendas[176] and another one the following year, but he points out that the latter one was not as devastating as the seventeenth-century flood during the first Desagüe project. He ascribes this to the construction of his dike of Culhuacán in 1866, without which, in his opinion, the city would have been devastated. When officials were finally able to remove all the water from the city that year, he also asked for all the streets to be embanked, to which they leveled the ground of fifty-two streets and small squares.[177]

However, due to "a lack of resources and the favorable seasons", the Desagüe was forgotten once again for several years. In 1870, the Ministry of Development published a call for more proposals for the project, which were to gain the approval of Garay, but they never came to

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[174] Manuel Perló Cohen. *El paradigma porfiriano: historia del desagüe del Valle de México*, as cited in Erick Aguilar Obregón, María Martínez Rodríguez and Martín Vera Martínez, "Propuesta para la crisis del agua", María Martínez Rodríguez coord. *Políticas públicas ambientales* (Mexico: Colofón. Ediciones Académicas & Política Ambiental, 2017), 44.
[175] Garay, *El Valle de México*, 72.
[176] Garay, *El Valle de México*, 73.
[177] Garay, *El Valle de México*, 79.

fruition. When Porfirio Díaz became president in 1876, Garay was replaced with engineer Luis Espinosa as head of the project but continued as an advisor; the works, however, were put on hold again, resuming until 1881. Garay himself stated that by that point, the Desagüe's management only kept existing by name.[178] Garay died in 1896, four years before the project was finally concluded.

The final works consisted of three main sections: the Canal, the Tunnel, and the Tajo of Tequisquiac (outlet pit). The Canal was 47,527 kilometers long, starting from the neighborhood of San Lázaro east of the city, and ending around Zumpango, State of Mexico; it started at 5.75 meters deep and ended at 21.28. The Tunnel was 10.21 kilometers long, while the Tequisquiac outlet, the first completed section, reached 2,500 meters long; all the wastewater and residues from the city flowed into the river of the same name, continuing through other rivers such as Tlamaco and Tula, finalizing in the Gulf of Mexico.[179]

The Desagüe project –overseen by the Mexican Prospecting & Finance Co. Limited (founded in 1887 and later renamed as Mexican Co. of London)–went through different negotiations with several foreign contractors, such as Wisier & Marshall, and Read & Campbell. In 1889, they finally granted the project to Pearson & Son, run by Weetman Pearson, British contractor, engineer and businessman, who had experience in sewage works, canals, ports and railways, in places such as London, Halifax and Alexandria. According to historians Paul Garner and Marcela Martínez Rodríguez, Pearson secured the Gran Canal due to various reasons, not only his experience with hydraulic engineering project, but mainly because working with a British contractor showed Díaz's strategy of "reestablishing diplomatic and commercial relations

[178] Garay, *El Valle de México*, 93.
[179] "El Desagüe del Valle de México", *El Mirador. Secretaría de Comunicaciones y Transportes*, https://elmirador.sct.gob.mx/manos-a-la-obra/el-desague-del-valle-de-mexico (Accessed 7 March 2023).

with their old European adversaries [which included France and Spain] as a counterweight to the growing economic dependence to the United States".[180]

Also, Díaz seemed to favour various powerful intermediaries who protected Pearson's interests in Mexico, shareholders, politicians, and *hacendados* who thus managed to secure important positions in Díaz's regime.[181] As might be expected, behind the Gran Canal project was quite a number of players that took part in the decision-making, from public institutional mechanisms that included private companies, guilds, political representatives, the City Hall, Congress, and more, as well as the project's Board of Directors, and foreign companies and engineering societies were also essential. However, as stated by historian Manuel Perló Cohen, at the top of the pyramid was the President himself, Porfirio Díaz, followed by the Board and intermediaries who acted as representatives for foreign companies, such as Pearson's, among others.[182]

In 1902, the Board of Directors for the Desagüe of the Valley of Mexico published *Memoria histórica, técnica y administrativa de las obras del desagüe del valle de México, 1449-1900*, where they recount the drainage from the colonial period to the one completed in 1900. The *Memoria* was divided into five books; the first one described the geography of the Valley of Mexico, whereas the second one gave a detailed historical account of the various works dedicated to the Desagüe since colonial times. At the same time, this source stated how the need for the Canal stemmed from the city's poor hygiene and sanitary conditions, dating back to the Colonial period:

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[180] Paul Garner and Marcela Martínez Rodríguez, "Fomento de la inversion británica en el Porfiriato. El caso de Pearson y de la concesión a The Santa Gertrudis Jute Mill Company, Limited", *Revista de El Colegio de San Luis*, VIII, no. 16, May-August 2018, https://www.scielo.org.mx/pdf/rcsl/v8n16/2007-8846-rcsl-16-75.pdf (Accessed 19 September 2023) 82.
[181] Garner and Martínez Rodríguez, "Fomento de la inversión británica en el Porfiriato", 85.
[182] Manuel Perló Cohen. *El paradigma porfiriano: historia del desagüe del Valle de México* (México: Instituto de Investigaciones Sociales, UNAM, 1999) 31.

> …With the pretext of raising the Cross where idolatry prevailed, but rather due to the pride of founding where they had conquered, Cortés built at the old Aztec population's site the new Hispanic city, capital of the Virreinato and today of the Republic. If to the circumstance that the population lives at the lowest part of the basin it is added that the Valley is surrounded by mountains that naturally prevent the outlet of water from the rivers, torrential rains, and the springs that are born from the lakes, it will be understood why, when the rains were excessive, they flooded the entire Valley, and mainly Mexico City… the damages caused by these floods were prejudicial to the interests of the inhabitants and to their health… [who would] suffer from malarial diseases caused by the miasmas of fetid swamps created from flooding…[183]

This account demonstrates the deep influence of miasma theory during this time, refuted thirty years prior. It also reflects how deep the effect of bad smells from stale water and a lack of proper sewage affected cities, in this case, Mexico City.

The third and fourth books recounted the technical aspects of how the Gran Canal work was built and the circumstances of its construction, from the flooding that made it necessary to the engineering and technical aspects, and even mentioned the country's political state of the time. Lastly, the fifth book described all the foreign contracts and economic and administrative challenges faced during its construction. Perhaps unsurprisingly, the *Memoria* is a rather biased piece of work, where throughout its chapters the Board of Directors exalted the Gran Canal del Desagüe and painted it as one of the country's greatest engineering achievements at same the level as any hydraulic work built in Europe.

As for the public's perception of the Gran Canal, there was great anticipation and excitement, at least amongst the elites, as can be read in a note in the newspaper *La Voz de México* of January 18th, 1900:

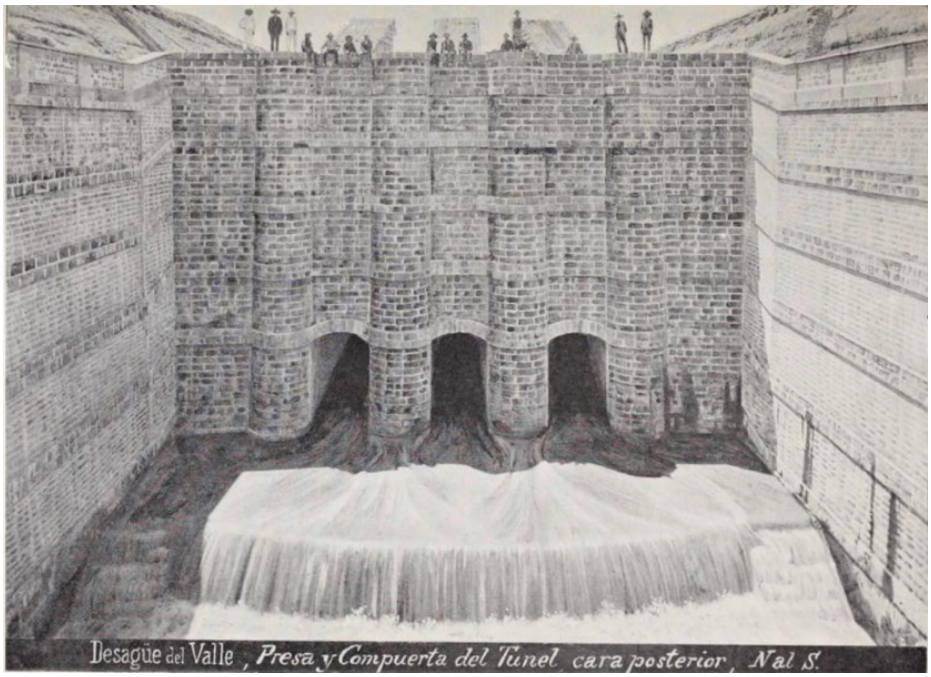
> The souls of the viceroys Velasco and Mendoza will tremble with joy, for, as it is being said, the three times secular works of the Desagüe of the Valley are about to be completed. The gran canal

[183] Luis González Obregón coord., Junta Directiva del Desagüe del Valle de México, *Memoria histórica,* V.

> is already in use in most of its extension; the works have been completed and only some slopes remain to be secured… For the official inauguration, which will be celebrated in the course of this semester, the President will be invited, as well as distinguished people of this capital… It can be safely stated that by the next water season, the sanitation systems and the Desagüe will come into function together, the latter being a worthy complement to the first.[184]

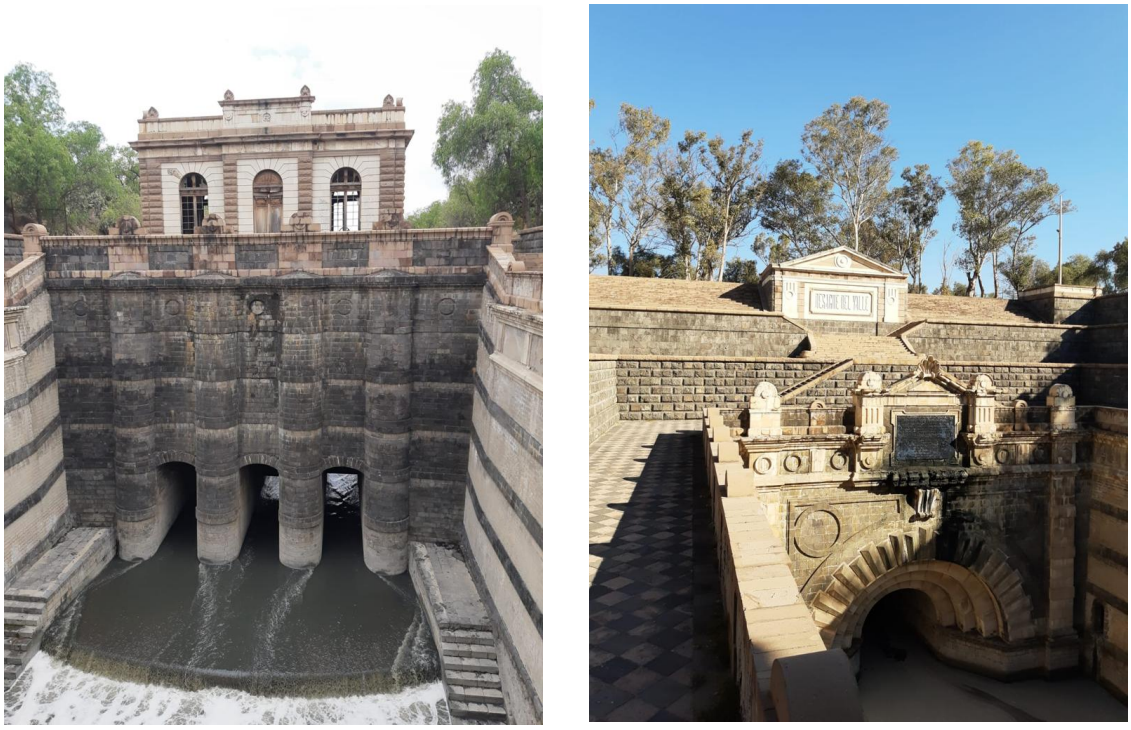
On March 17th, 1900, the Gran Canal was finally inaugurated by President Díaz; 180 guests were present, from ambassadors and businessmen to representatives and doctors. After an early ceremony, the retinue took a train from the Plaza de la Constitución to San Lázaro, where they witnessed the opening of the Canal's gates. Afterward, they left for Zumpango to the section now locally known as La Caja de Agua (the water box), where the Canal and the Tunnel joined. Here, they were treated to a banquet and Díaz made a speech in which he stated that with the Desagüe, "the hygiene of this beautiful country [was] revendicated."[185] The total length of the Canal and its branches consisted of 340 kilometers, with a total cost of $1,780,000 MXN,[186] which in the present day would be equivalent to $14,862,136 MXN ($855,616.51 USD). As can be seen in the photographs, the construction's finishes visibly show European influences as well.

[184] "Información. La obra de varios siglos", *La Voz de México*, México, Jaunary 18th, 1900. *Hemerotéca Nacional Digital de México*, https://hndm.iib.unam.mx/consulta/resultados/visualizar/558a37d07d1ed64f16dea2ad?resultado=1&tipo=pagina&intPagina=2&palabras=desag%C3%BCe (Accessed 13 September 2023)
[185] "El desagüe del Valle de México", 20 de marzo de 1900, *El universal*, núm. 115*,* as cited in Olguín Ortíz, *El Desagüe…para el saneamiento del medio ambiente*, 120.
[186] Luis González Obregón coord., Junta Directiva del Desagüe del Valle de México, *Memoria histórica,* 645.



"Drainage of the Valley. Dam and Gate of the Tunnel, posterior face, North to South". Zumpango, State of Mexico. Photograph featured in: Luis González Obregón coord., Junta Directiva del Desagüe del Valle de México, *Memoria histórica,* 607.

Inauguration of the Desagüe works. Section in Zumpango known as La Caja de Agua. Photograph © Mediateca INAH (Instituto Nacional de Antropología e Historia), https://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia%3A54230 (Accessed 7 March 2023).



Modern-day view of the Gate of the Zumpango Tunnel, “La Caja de Agua” in Zumpango, State of Mexico. Photographs by Cristian López Santiago, April 2023.

With this massive undertaking, it was the government and most scientists’ firm belief that the flooding, along with the sanitation problems of the city, would finally come to an end. Some other public works that followed included paving the streets, hiring drainage collectors, and establishing cleaning carts, which concluded in 1905.[187]As for the sanitation aspect, certain diseases did seem to decrease. Typhus reduced from 1379 cases in 1901 to 248 in 1904, and deaths from smallpox went from 216 in 1903 to 102 in 1904. However, both illnesses once again turned into epidemics in 1905 and 1906, mostly affecting the lower classes. Causes included

[187] Ingrid Brena. “Atención a la salud pública en la época porfiriana”, in Raúl Ávila Ortiz, et. al., coord. *Porfirio Díaz y el derecho crítico* (Mexico: Cámara de Diputados. Instituto de Investigaciones Jurídicas, 2015), 417.

housing deficiencies, bad nutrition, extreme poverty, labour exploitation, and bad hygiene habits.[188]

Thus, while the Desagüe did make positive changes in regard to hygiene, it did not get rid of the problem completely. Throughout the Porfiriato, the government resorted to different measures, which included the construction of various hospitals across the country, transferring ill people, closing of households, incinerating personal items, cordoning off neighborhoods, and promoting good hygiene and vaccines. Yet, popular resistance to vaccinations was common since people believed they produced diseases rather than prevent them, which is why by the last years of the Porfiriato, as opposition to Díaz's government grew and he became more authoritarian, vaccination became mandatory, and people who did not vaccinate their children would receive a fine or even go to prison. A sanitary Code was also promulgated in 1891, which granted the Consejo Superior de Salubridad (Supreme Council of Health), important faculties, such as inspecting private sanitary installations and compelling medics to report any sick patient with a transmittable disease.[189] However, mortality in Mexico among the popular classes continued among one of the world's highest.[190] According to a 1916 report entitled *La Higiene en México* by civil engineer Alberto J. Pani, between 1904 and 1912 the average annual mortality in Mexico City for diseases related to the digestive system was 6,407.3, and 4329.3 for respiratory diseases:

> [T]he enormous figure that expresses the mortality caused by digestive diseases—especially diarrhea and enteritis, which is over four thousand deaths—could be the accuser of the deficiency and low quality in nutrition, including water [in Mexico]; the number, also enormous, of deaths caused by tuberculosis—from the "general diseases" group [4306.8]—could be taken as a sure sign of the sanitary defects of habitations. The importance of mortality caused by respiratory

[188] Brena, "Atención a la salud pública", 418-428.
[189] Brena, "Atención a la salud pública", 418.
[190] Aguilar Obregón, et. al. "Propuesta para la crisis de agua", 45.

> diseases could indicate unsatisfactory conditions in pavements, inefficiency in street irrigation and sweeping procedures, etc…[191]

As for the capital's problems with flooding, they were far from over. In September 1900, just seven months after the inauguration of the Gran Canal, there was another flood that greatly affected the streets of San Francisco (now Francisco I. Madero), Coliseo Viejo (16 de septiembre) and San Andrés (Tacuba).

Flood in Mexico City in 1900; people trying to cross the street. Photograph © Mediateca INAH (Instituto Nacional de Antropología e Historia), http://mediateca.inah.gob.mx/repositorio/islandora/object/fotografia:440100 (Accessed 13 September 2023)

[191] Alberto J. Pani, "La Higiene en México", *Salud Pública de México*, vol. 30, no. 6, November-December 1988, 885-886. https://saludpublica.mx/index.php/spm/article/view/136/129 (Accessed 19 July 2023)

The following year, 1901, heavy rain flooded households and stores, particularly in La Merced, a neighborhood that to this day is famous for its retail market, where the water stalled for days.[192] In the first half of the twentieth century, Mexico City flooded over ten times, and thus people came to the realization that Texcoco and Cuautitlán were not the only rivers capable of causing flooding in the city.[193] Overall, while the Desagüe was able to improve some aspects of the city's drainage and hygiene, it eventually came to be a failed promise which mostly affected the working class.

[192] Olguín Ortíz, *El Desagüe…para el saneamiento del medio ambiente*, 122.
[193] Salomón Abedrop L., coord. *El gran reto del agua en la Ciudad de México. Pasado, presente y prospectivas de solución para una de las ciudades más complejas del mundo* (Mexico: Sistema de Aguas de la Ciudad de México (SACMEX), 2013) https://agua.org.mx/wp-content/uploads/2013/02/El-gran-reto-del-agua-en-la-Ciudad-de-Mexico.pdf (Accessed 27 September 2023) 47.

5. Twentieth and twenty-first centuries: drainage, water supply and subsidence in Mexico City

The twentieth century saw the Mexican capital grow at an unprecedented rate. By 1950, Mexico City had reached its highest demographic growth rate up until that point, with 3,360,729 inhabitants, 55% of which came from other states in the country. The industrial concentration in both the capital and the Valley increased the demand for labour, which of course fostered deeper environmental and urban changes, and poverty visibly worsened. In consequence, the "resulting effects of the unstoppable and disorganized urban growth and industrialization, dangerously manifested in flooding, dust devils, water shortage, and ground subsidence",[194] according to Miranda Pacheco.

The worst flooding took place on the 15th of July 1951, after which authorities decided to extend several hydraulic sections, build a second Tequixquiac tunnel and pipe the Churubusco River.[195] It reached such a catastrophic scale that the government decided to create the Hydrologic Commission of the Basin of the Valley of Mexico, which would take care of solving the flooding, subsidence —which will be addressed in later paragraphs—, and water supply issues in the Valley.[196] After the impact of the 1950s floods, the need for a modern drainage system was incontrovertible. In 1959, the Commission proposed a solution to create a deep drainage system to finally get rid of the excess water for good, thus ignoring once again Indigenous practices and suggestions such as the one proposed by Humboldt to repurpose the water for agriculture.

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[194] Miranda Pacheco, *La caída de Tenochtitlan*, 102.
[195] Centro Nacional de Prevención de Desastres, "La última gran inundación de la Ciudad de México", *Gobierno de México,* 15 July 2020, https://www.gob.mx/cenapred/articulos/la-ultima-gran-inundacion-de-la-ciudad-de-mexico (Accessed 15 May 2023).
[196] Jorge Arturo Galina Macías,"Drenaje profundo en la Ciudad de México", *Administración y tecnología para el diseño. Anuario 2010*, (Mexico: Universidad Autónoma Metropolitana 2010) https://administracionytecnologiaparaeldiseno.azc.uam.mx/publicaciones/anuario_2010/13.pdf (Accessed 23 September 2023) 224.

In 1966, the works for the Deep Drainage System —Sistema de Drenaje Profundo in Spanish— began, its first stage concluding in 1975 with the construction of two tunnels: an east tunnel of ten kilometers long, and a central tunnel of eight kilometers long, both with a diameter of five meters and between 30 and 50 meters deep. These tunnels, named "interceptors", lead to a much bigger 50-kilometer-long tunnel, the "Emisor Central", 240 meters deep.[197]

Nowadays, 80 kilometers of interceptors, nine in total, have been built to carry the capital's wastewater and rainwater to the Emisor Central, and in 2018 a second tunnel, the Emisor Poniente, was built to prevent flooding in the State of Mexico's municipalities of Naucalpan, Atizapán de Zaragoza, Tlalnepantla and Cuautitlán Izcalli, regulating the water flow from the areas' rivers, which are regulated by several dams. The water flows out of the metropolitan area via the Tajo of Nochistongo.[198] However, even these additions are not enough to control flooding in the city. In an interview with the newspaper *Excelsior* in 2018, Herminio Quechol, deputy director of the Deep Drainage of the SACMEX (Waters System of Mexico City), stated the following:

> There are occasions in which the precipitation is so intense that it overpowers the conduction capacity through the tunnels, but then we operate with the gate system to regulate the ingress of water to the [Deep Drainage] System to avoid creating a major problem for society, but more infrastructure is required…[199]

The following year, in 2019, works for a third main tunnel were finally completed, with a total cost of $33,800,000 MXN ($1,731,000 USD). The Emisor Oriental is 62.4 kilometers long with a diameter of 7 meters and 150 meters deep, making it the deepest drainage tunnel in the

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[197] Jorge Legorreta, *El agua y la Ciudad de México. De Tenochtitlan a la megalópolis del siglo XXI* (Mexico: Universidad Autónoma Metropolitana, 2006), 50.
[198] Galina Macías,"Drenaje profundo en la Ciudad de México", 229.
[199] Wendy Roa, "Drenaje Profundo: La obra más grande en CDMX hasta 1975", *Excelsior*, 21 August 2018, https://www.excelsior.com.mx/comunidad/drenaje-profundo-la-obra-mas-grande-en-cdmx-hasta-1975/1260068 (Accessed 25 September 2023)

world, capable of carrying 150 square meters of water per second.[200] As for the Gran Canal, while it still operates it does so at 30% of its capacity, and most of the remaining rivers that flow across the city have been piped to avoid contact between the population and wastewater, although natural river channels are still intact in the mountain areas surrounding the Valley.[201] However, flooding in the Valley of Mexico remains a constant threat every year during the rainy season. But for the time being, these are the last efforts regarding Mexico's drainage history in the basin that began in the sixteenth century. As expressed by architect and urbanist Jorge Legorreta, "The Deep Drainage System is the historic result left by the culture against water."[202]

With the issues of the drainage and the deviation of the lakes' waters seemingly resolved, a question still stands: where does Mexico City currently get its water supply from? In simple terms, The Valley of Mexico gets its water supply from three main sources: dams and springs, the Lerma-Cutzamala Systems—which will be explained in further paragraphs—and the aquifer[203] of the Metropolitan Area of the Valley of Mexico (also called Greater Mexico City). It is located in the basin's southwest zone and occupies seventeen percent of the basin's surface, separated from the city by a clay aquitard;[204] the aquifer reaches depths of 800 meters, with wells

[200] "Así es el túnel de drenaje profundo más grande del mundo que construyó México", *Infobae*, 27 November 2019, https://www.infobae.com/america/mexico/2019/11/27/asi-es-el-tunel-de-drenaje-profundo-mas-grande-del-mundo-que-construyo-mexico/ (Accessed 25 September 2023)
[201] Galina Macías,"Drenaje profundo en la Ciudad de México", 229.
[202] Jorge Legorreta, *El agua y la Ciudad de México*, 53.
[203] According to National Geographic's definition, "an aquifer is a body of porous rock or sediment saturated with groundwater. Groundwater enters an aquifer as precipitation seeps through the soil. It can move through the aquifer and resurface through springs and wells." "Aquifers", National Geographic, https://education.nationalgeographic.org/resource/aquifers/ (Accessed 08 October 2023)
[204] According to *GeologyScience*'s definition, aquitards, as opposed to aquifers, "are geological formations that have low permeability and restrict the flow of water. They are often made up of clay, shale, or other fine-grained materials, and can act as barriers that prevent the movement of water between aquifers or between groundwater and surface water". "Aquifers and Aquitards", *GeologyScience*, https://geologyscience.com/geology-branches/hydrogeology/aquifers-and-aquitards/ (Accessed 08 October 2023)

of between 100 to 400 meters.[205] Sixty percent of the water consumed in Mexico City comes from hundreds of aquifer perforations, making it one of the most overexploited aquifers in the continent.[206]

The overexploitation of the aquifer has resulted in a severe case of subsidence in the Valley. According to chemical engineer and researcher Rafael Molina Berbeyer, the first time anyone reported the city's subsidence was in fact during the construction of the Gran Canal in 1900, when Roberto Gayol, one of the engineers working on the project noticed that the gates at the starting point of the Canal had experienced a loss of stability and had displaced from its base. To save his reputation and the Canal's, he leveled the gates once more, observing that the base had descended a few centimeters in relation to its original leveling. "Thus, the subsidence phenomenon was discovered, which back then caused little interest given the small reach of its effects".[207] Indeed, the government did not center its attention on the land's subsidence until a few decades later, when the skinking started to become more noticeable in certain parts of the city, particularly in the lacustrine areas. Hence, subsidence was not uniform, "its magnitude and evolution varied from one place to another; and although the consequences for some constructions could be minor, for others they could be quite grave if they presented differential subsidence."[208]

During the mid-twentieth century, the sinking started to be reflected in structural damage to several buildings across the city and to the inclines of various sections of the drainage systems

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[205] Gerencia de Aguas Subterráneas, Subgerencia de Evaluación y Modelación Hidrogeológica, *Actualización de la disponibilidad media anual de agua en el acuífero Zona Metropolitana de la Ciudad de México*, (Mexico: CONAGUA, Diario oficial de la Federación, 20 April 2015) https://www.gob.mx/cms/uploads/attachment/file/102942/DR_0901.pdf (Accessed 08 October 2023) 3.
[206] Jon Martín Cullell, "La lenta agonía de una ciudad que se muere de sed", *El País*, 31 October 2008, https://elpais.com/sociedad/2018/10/31/actualidad/1540941849_029005.html (Accessed 5 October 2023)
[207] Rafael Molina Berbeyer, *Boletín de la Sociedad Geológica Mexicana*, Vol. 20, No. 2, (1957), http://boletinsgm.igeolcu.unam.mx/bsgm/vols/epoca03/2002/2002-(1)Molina.pdf (Accessed 10 October 2023) 4.
[208] Abedrop L., coord. *El gran reto del agua en la Ciudad de México,* 48.

based on gravity, which made Mexico City even more vulnerable to flooding.[209] Evidently, scientists started to get worried. The Hydrologic Commission, along with other government institutions, began searching for answers to the flooding and subsidence in the city. In 1947, engineer Nabor Carrillo Flores, in his research for the Promoter and Coordinator Commission of Scientific Research (in Spanish Comisión Impulsora y Coordinadora de la Investigación Científica, CICIC) proposed a theory based on soil mechanics in which he believed that the subsidence of Mexico City was due to the loss of pressure in the subsoil aquifers caused by over-pumping.[210] Carrillo pronounced the basin as being composed of non-consolidated soil, which had triggered an average four-meter subsidence throughout the twentieth century, causing both hydrologic imbalance in the basin and the instability of constructions across the city,[211] which can still be seen to this day, aggravated by the 2017 earthquake in Mexico City.

According to urbanist Isaac Acosta Fuentes, from the years 1898 to 1937, the city had sunk at an average rate of 5 centimeters a year. By 1947, it reached a rate of 18 centimeters a year. In the present day, Mexico City sinks at an alarming rate of 50 centimeters a year, and it is almost fully irreversible,[212] being impossible to recover "the great majority of the lost elevation and the lost storage capacity of the aquitard".[213]

Another key factor that plays into the city's sinking —and flooding—is rainwater. Water gathered from rainfall can infiltrate into the subsoil and recharge the aquifers naturally. However, by being mostly covered in asphalt, only 24% of Mexico City's surface can infiltrate

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[209] Acosta Fuentes, Isaac. Ph.D Thesis, *El debate científico en la concepción del desagüe del Valle de México, 1607 1975* (Mexico: Universidad Autónoma Metropolitana) 2016, 225-226.
[210] Molina Berbeyer, *Boletín de la Sociedad Geológica Mexicana*, 5.
[211] Acosta Fuentes, *El debate científico*, 230-231.
[212] E. Chaussard, et al. "Over a Century of Sinking in Mexico City: No Hope for Significant Elevation and Storage Capacity Recover", *Journal of Geophysical Research: Solid Earth*, vol. 126, issue 4, 2021, https://doi.org/10.1029/2020JB020648 (Accessed 1 June 2023), 1.
[213] E. Chaussard, et al. "Over a Century of Sinking in Mexico City", 14.

rain back to the aquifers.[214] Therefore, since rainwater has nowhere to go, it reaches the drainage system and exceeds its capacity, as explained above. Hence, flooding is set to occur every rainy season. In the Valley, the infiltration area consists of around 577 thousand hectares, but as urban settlements continue to expand, as well as the effects of climate change, rainwater infiltration will decrease. Currently, the area infiltrates 986 million cubic meters a year, but according to a 2020 study, it is estimated that infiltrations will decrease to 145 million cubic meters a year by 2045-2069.[215] Consequently, as the aquifers cannot be fully replenished, they face a continuous subsidence rate.

Moreover, according to a 2021 study, the differential subsidence across the city exposes the social landscape as well. The study observed that areas with low and very low socioeconomic levels usually present high subsidence gradients, reflected in damages to buildings and infrastructure. This correlation is explained by the fact that "low-income and very low-income inhabitants cannot afford to relocate as their real estate value is increasingly depressed by fissuring and fracturing",[216] as opposed to high or medium-income inhabitants who have the luxury of resilience and being more adept to overcome the associated challenges. After Carrillo's research in the mid-twentieth century, the Mexican government started looking at different regions and water sources to both slow down the subsidence rate and take care of the increasing need for water supply.

The Lerma River, the second longest river in Mexico, is born from the springs of Almoloya del Río in the State of Mexico, passing through the northwest of the Valley of Toluca,

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[214] Iván Sosa, "Afecta asfalto recarga de acuífero en CDMX", *Reforma*, 21 February 2021, https://www.reforma.com/afecta-asfalto-recarga-de-acuifero-en-cdmx/ar2353410 (Accessed 28 November 2023)
[215] Alianza Latinoamericana de Fondos de Agua, *Estudio hidrogeológico de zonas de recarga acuífera para el abastecimiento de agua a la Ciudad de México*, May 2020, https://www.fondosdeagua.org/content/dam/tnc/nature/en/documents/latin-america/estudiohidr.pdf (Accessed 28 November 2023) 131.
[216] E. Chaussard, et al. "Over a Century of Sinking in Mexico City", 13.

and the states of Querétaro, Guanajuato, and Michoacán, flowing into the Chapala Lake. In 1942, plans for extracting water from the Lerma basin and its aquifer into the city began; its first stage was completed after ten years and inaugurated in 1952 with the construction of a 780-meter filtering gallery, a 62-kilometer underground aqueduct, and underground water collection works.[217] The work ended at a distribution and supply system called Cárcamo de Dolores located at the second section of the Chapultepec Forest, commemorated with a mural by Diego Rivera entitled *El agua, origen de la vida en la tierra*, intended to remain underwater, and a giant sculpture of the Mexica god of water and rain Tláloc, also by Rivera.[218]

[217] Legorreta, *El agua y la Ciudad de México*, 72-74.
[218] Comisión Nacional de Agua, "Cárcamo de Dolores, fusión de arte y urbanismo", *Gobierno de México*, https://www.gob.mx/conagua/articulos/carcamo-de-dolores-fusion-de-arte-y-urbanismo?idiom=es (Accessed 26 September 2026)

Mural *El agua, el origen de la vida en la tierra* by Diego Rivera at the Cárcamo de Dolores. Photograph by Tania Victoria, © CC BY 2.0 https://es.wikipedia.org/wiki/C%C3%A1rcamo_de_Dolores#/media/Archivo:Mural_El_agua,_origen_de_la_vida.jpg (Accessed 13 October 2023)

However, in the sixties, a water crisis forced the government to initiate the second phase of the project, extracting more water from the Lerma and authorizing larger exploitations of the aquifers in the region, drilling 230 more wells, which created tensions between Mexico City and the State of Mexico. After a drought in 1973, peasant communities from the State of Mexico started accessing the water from the river's aqueduct and wells, thinning the water flow to the city.[219] Eventually, despite the construction of more water supply works, regional conflicts and the progressive subsidence in the Valley caused the city to look to another of the surrounding basins for water supply.

[219] Legorreta, *El agua y la Ciudad de México*, 78.

Due to the depletion of the Lerma basin and the increasing subsidence, in 1976 the works for the Cutzamala system began from the Cutzamala River, a tributary of the Balsas River that passes through the states of Mexico and Michoacán. It is one of the most complex civil engineering works in the world, functioning as a hydraulic system for the storage, conduction, potabilization, and distribution of drinking water to the State of Mexico and Mexico City.[220] The water is pumped from a height of 1,600 to 2,702 meters above sea level, which requires the consumption of 2,280 million kilowatts per hour. By 1992 the third stage of the Cutzamala System concluded, with seven dams, six pumping plants, and over 330 kilometers of open channels, tunnels, and aqueducts.[221]

In 2005, the National Water Commission (CONAGUA) reported that the Metropolitan Area of the Valley of Mexico consumed an average of 61,000 L/s of drinking water; 39,700 L/s came from the Valley's subsoil, 14,700 L/s from the Cutzamala System, 5,100 L/s from the Lerma System and 1,100 L/s from superficial exploitations from dams and springs.[222] In 2023, however, the numbers have changed quite a bit. According to an article from the newspaper *La Jornada*, the Cutzamala supplies an average of 8,000 L/s, almost 30% less than in 2019.[223] On September 6th, 2023, the newspaper *Expansión política* stated that nowadays, the Cutzamala System brings to the city 23% of water supply, while only 8% comes from the Lerma System, 2% from dams and springs, and 67% comes from the aquifers.[224] In the last years, Mexico City

[220] Abedrop L., coord. *El gran reto del agua en la Ciudad de México,* 55.
[221] Abedrop L., coord. *El gran reto del agua en la Ciudad de México,* 57.
[222] CONAGUA, *Sistema Cutzamala. Agua para millones de mexicanos* (Mexico: Secretaría de Medio Ambiente y Recursos Naturales, 2005) https://www.conagua.gob.mx/conagua07/publicaciones/publicaciones/sistema-cutzamala.pdf (Accessed 2 October 2023)13.
[223] Elba Mónica Bravo, "Pese a reducción del Cutzamala, hay un mejor reparto de agua, dice el Sacmex", *La Jornada*, 28 July 2023, https://www.jornada.com.mx/2023/07/28/capital/034n3cap (Accessed 2 October 2023)
[224] "Pese a lluvias, presas del Cutzamala están al 37.8% de su capacidad", *Expansión política*, 6 September 2023, https://politica.expansion.mx/cdmx/2023/09/06/pese-a-lluvias-presas-del-cutzamala-estan-al-37-8-de-su-capacidad (Accessed 4 October 2023)

has suffered from prolonged droughts,[225] which has meant water supply cutbacks from the Cutzamala System in various boroughs and municipalities in the city and the State of Mexico on various occasions, which has led the government to implement measures such as cloud seeding.[226] Moreover, Mexico City loses 40% of its water supply to leaks and illegal connections. All of this speaks not only of Mexico's issues with long and increasingly regular droughts but mainly of the insufficiency and unsustainability of the current water supply systems.

In a city with over 9 million inhabitants, it is evident that water demand is an increasing problem. According to the World Resources Institute, Mexico is currently among the first 25 countries in the world exposed to extremely high water stress annually, which means they use "over 80% of their renewable water supply for irrigation, livestock, industry and domestic needs".[227] Without intervention, water stress in places with rapidly growing populations and economies will only get worse.

As for water distribution and management, history repeats itself, or rather it remains unchanged. Wealthier neighborhoods have 24/7 uninterrupted access to water, poorer communities that are furthest from the capital, including areas surrounding the Cutzamala System, generally lack proper water supply, only getting water one or two hours a day in some cases, if they get water at all.[228] But water shortage not only affects the Valley of Mexico, but the

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[225] Georgina Zerega, "La falta de agua castiga a México", *El País*, 24 March 2023, https://elpais.com/mexico/2023-03-25/la-falta-de-agua-castiga-a-mexico.html (Accessed 04 October 2023)
[226] Almudena Barragán, "México bombardea las nubes para mitigar la sequía en el sistema Cutzamala", *El País*, 29 March 2023, https://elpais.com/mexico/2023-03-29/mexico-bombardea-las-nubes-para-mitigar-la-sequia-en-el-sistema-cutzamala.html?event=go&event_log=go&prod=REGCRARTMEX&o=cerrmex (Accessed 04 October 2023)
[227] Samantha Kuzma, Liz Saccoccia, and Marlena Chertock, "25 Countries, Housing One-quarter of the Population, Face Extremely High Water Stress", *World Resources Institute*, 16 August, 2023 https://www.wri.org/insights/highest-water-stressed-countries (Accessed 25 September 2025)
[228] Jon Martín Cullell, "La lenta agonía de una ciudad que se muere de sed", *El País*, 31 October 2008, https://elpais.com/sociedad/2018/10/31/actualidad/1540941849_029005.html (Accessed 5 October 2023)

whole country. While water is consumed at an average of 366 liters per person a day in Mexico City[229] only 33% of the country's municipalities have daily access to water.

According to an article from *El País*, there is a lack of regulation regarding water concessions, granted by the National Water Commission (CONAGUA), which only enables the concentrated privatization of the liquid. In addition, it is impossible to determine whether water gets more extracted than permitted due to these concessions, which can result in unsustainable exploitations of the region's aquifers.[230] In Mexico, 75% of water goes into the agricultural sector, and most of it is managed by concessions granted to irrigation districts, which have great influence over water distribution, public resources, and even fees paid by users, to the point that some local governments are forced to ask them to sell them water for urban usage.[231]

Furthermore, twenty companies own the fifty concessions that the CONAGUA allows for a larger volume of water to be exploited for industrial use; among them are the state-owned Federal Commission of Electricity (CFE) and Petróleos Mexicanos (PEMEX), but also corporations such as Kimberly Clark.[232] Another company that benefits from large concessions is Coca-Cola, allowed to exploit 28 million cubic meters of water a year. In fact, Coca-Cola, Pepsico and Danone control over 80% of the bottled water business in Mexico, which in 2020 became the world's biggest bottled water consumer. Despite that more than half of the city's

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[229] "Comprender las dimensiones del problema del agua", *ONU Habitat*, 22 March 2021, https://onuhabitat.org.mx/index.php/comprender-las-dimensiones-del-problema-del-agua?fb_comment_id=1919706488040991_2396617700349865 (Accessed 10 October 2023)

[230] Viri Ríos, "México seco", *El País*, 20 August 2023, https://elpais.com/mexico/2023-08-21/mexico-seco-las-cifras-ocultas-de-la-carestia-del-agua.html (Accessed 05 October 2023)

[231] Ríos, "México seco", (Accessed 05 October 2023)

[232] Dora Villanueva, "México, el mayor consumidor de agua embotellada en el mundo", *La Jornada*, 02 April 2021, https://www.jornada.com.mx/notas/2021/04/02/economia/mexico-el-mayor-consumidor-de-agua-embotellada-en-el-mundo/ (Accessed 11 October 2023)

water has potable qualities,[233] the notion that people should not drink tap water in Mexico is widely spread, even worldwide,[234] which means most Mexican homes end up paying for both tubed and bottled water. According to a 2015 article by *BBC News Mundo*, Mexico's inhabitants throw away 21 million plastic bottles daily, and only recycle 20%.[235]

On that note, Mexico City's water problems are all aggravated by two key factors: pollution and the inhabitants' lack of water conservation culture. Unfortunately, littering is a very a common practice in Mexico, making it one of the main causes of flooding since trash— which includes plastic bottles and jugs— accumulates in the sewers and impedes the flow of water.[236] Additionally, there is a persistent lack of awareness and proactive measures from both the population and the authorities when it comes to preserving water, mindset that urgently needs to change if Mexico is to fix its growing water crisis.

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[233] Areas where water pressure is continuous are safer to drink tap water from. Water cuts can expose pipes to a change of pressure that can create bacteria; water storage units such as tanks can also compromise water quality. In addition, some areas around the city have very old piping systems, which causes distrust amongst the population. Carmen Morán Breña, "El agua, un fracaso público y un negocio privado en México", *El País*,14 January 2020, https://elpais.com/sociedad/2020/01/10/actualidad/1578614115_842168.html (Accessed 11 October 2023)

[234] This notion began in 1991 after a cholera outbreak in the city killed 34 people, but the media study of why that notion remains to this day both in Mexico and the world lies beyond the scope of this research. Arturo Solís, "Agua embotellada, el negocio multimillonario que México no necesita", *Forbes México*, 25 December 2017, https://www.forbes.com.mx/agua-embotellada-el-negocio-multimillonario-que-mexico-no-necesita/ (Accessed 11 October 2023)

[235] Juan Paullier, "Por qué México es el país que más agua embotellada consume en el mundo", *BBC News Mundo*, 28 July 2015, https://www.bbc.com/mundo/noticias/2015/07/150722_mexico_consumo_agua_embotellada_jp (Accessed 11 October 2023)

[236] Galina Macías,"Drenaje profundo en la Ciudad de México", 233.

6. Conclusions

6.1 The Desagüe and Social Divisions in Mexican Society

While both social and environmental issues regarding water in Mexico —which include pollution, unequal access, unsustainable water management practices, and subsidence—are extensive and exceptionally complex, they all have their roots in a historical context that traces back to colonial times. The Desagüe was a monumental hydraulic work that played a fundamental role in the development of Mexican society and the Valley of Mexico itself. Seemingly, its development throughout the centuries had the same purpose: stopping the flooding of the basin. However, as this thesis demonstrates, the Desagüe helped to exert control over the population and for the benefit of the higher classes, albeit in different ways depending on the mentality of the period. After all, the European culture of the nineteenth century had changed drastically since the seventeenth century, along with the day-to-day lives of the Indigenous population, peasants, and working classes.

The Indigenous worldview of coexisting with water was abruptly put to an end with the arrival of the Spaniards, whose vision consisted of man *versus* nature. For the Spaniards, the constant flooding was an obstacle to the expansion of the city and a nuisance for the growing colonial population. However, Indigenous peoples were the most vulnerable to flooding, undergoing epidemics, death, forced relocation, and working strenuously under the Spaniards' imposed labour systems. The Spaniards used the Desagüe and other hydraulic works to exploit the Indigenous people of the basin and other regions and to control water as a natural resource.

As for the nineteenth century, while epidemics were also a problem two centuries earlier, discussions about sanitation and epidemics in Europe after the 1850s brought attention to the

problems that stemmed from the lack of a proper drainage system and recurring flooding in Mexico City. Moreover, class divisions were particularly accentuated during the Porfiriato. As previously stated, the Mexican elite associated illness and lack of hygiene with poverty and crime, a problematic situation considering the working class consisted predominantly of Indigenous people and *Mestizos*. The complexities of classism and its relation to colorism in Mexico lie beyond the scope of this research, but it is a significant aspect of Mexican society that should be reflected on in this context, particularly since it remains to this day. The white sector of the Mexican population is generally the most privileged and lives in wealthier neighborhoods, whereas people with brown skin tend to live in poorer areas of the city and suffer from discrimination based on skin color and social status.

The working class of the late nineteenth and early twentieth centuries was the most affected by flooding and diseases. Yet, these issues were affecting the image of the country indiscriminately, which was one of the government's main concerns. Therefore, undertakings such as the Gran Canal and other sanitation projects were built predominantly for the benefit of the upper classes in the name of progress; wealthier areas finally got rid of bad smells, and the streets' layout significantly improved in the process.

In the present day, social disparities in Mexico are mostly felt through the water crisis. As mentioned in the previous chapter, even communities adjacent to the Cutzamala system do not have proper access to water, and water cutbacks in low-income neighborhoods all across Greater Mexico City are becoming a usual occurrence. Meanwhile, wealthy areas remain untouched, a reality to most places around the world, but no less unfortunate. In Canada, for instance, many First Nations communities across all provinces lack proper access to safe and clean water. Parallels such as this one help us realize how deep this matter truly is and how it mostly affects

vulnerable groups around the world. Analyzing the Desagüe case and its effects on Mexican society was a priority for this research. Bringing attention to this issue from an international stage will hopefully create awareness regarding water conservation to a wider audience.

6.2 Environmental Consequences of a Desiccated Land

As mentioned in the introduction of this thesis, the Spaniards established a utilitarian ideology over nature and Indigenous populations, an ideology that persisted and evolved throughout the centuries, being justified with scientific advancements and ideas of progress. The Desagüe was undoubtedly a large feat of hydraulic engineering, and yet it did not stop the flooding nor helped improve the lives of all the Valley's most vulnerable inhabitants, which speaks volumes of what those in power thought of the Valley's landscape, disregarding its colossal and harmful transformation and ignoring nature's warnings in that, despite their centuries-long efforts, flooding was inescapable in a city founded in unstable, lacustrine terrain.

The steadfast decision to desiccate the land without considering alternatives for the correct utilization of water within the basin certainly had long-lasting environmental consequences and damages to the Valley of Mexico. Most noticeable is the high subsidence rate at which the city is sinking. Fifty centimeters a year is quite a shocking number that certainly should not be disregarded, since the threat of the city's collapse may be more imminent than we think.

The inefficiency of our city's water supply system may be the most concerning issue as well. This is not only due to the inequality of its distribution, but also due to the senseless amount of energy it requires to function, making it unsustainable to the environment. While the initiative to extract water from other basins and rivers for water supply may have been

considered the best solution back in the mid-twentieth century to counter the effects of subsidence, it has had other damaging effects to the detriment of the area's inhabitants as well as the area's environment. In addition, in a country where the most vulnerable sectors of its population—mainly Indigenous peoples— don't have access to their basic needs, the large amount of money that goes into the Cutzamala system's maintenance cannot be overlooked.

Furthermore, climate change, as proven countless times, is continuing to have a deep effect on various aspects of our everyday lives. In this particular case, it is reflected in the prolonged droughts that make it harder to gather water for the city's supply every year, and in the heavy rains that cause flooding, worsened by the people of Mexico City's habit of littering, clogging the drainage systems.

With the future looking this bleak, it seems as though there is nothing the average Mexican can do while those in power keep prioritizing profit over the environment, as well as the population's best interests. However, while all these issues do stem from our history as a colonized country, Mexicans are used to putting all the blame for the country's problems on the past and present governments, without taking responsibility for our harmful actions that contribute to flooding and pollution every year.

It is difficult to say what the basin might have become without the Spaniards intervening the way they did and instead had combined their and the Indigenous' knowledge at a large scale regarding water management. Throughout the years, researchers, environmental specialists, and urbanists—such as the aforementioned Nabor Carrillo and Jorge Legorreta in the twentieth century— have proposed numerous projects to either restore the lakes to their original state or create new bodies of water across the city, proposals that, regrettably, are beyond the scope of this thesis. However, as a recommendation for future research, these projects may help bring

insight into the Valley of Mexico's current state and what solutions might be best, both for its people and its environment.

As for this research, seeing water management issues through a historical lens is of vital importance, in the hopes of reaching both Mexican and international readers. On the one hand, its importance lies in understanding the environmental context of the European influence on Mexico City's development from the Spanish colonization to the nineteenth century, and its modern consequences to the environment and to its people. Colonization greatly affected many nations across the world in uncountable ways. This thesis has focused on Europeans' approach to natural resources. Moreover, as the Western mentality spread around the world with the technological and scientific advancements of the nineteenth century, its reach on countries such as Mexico, a newly independent nation eager to prove itself, had a great effect on the development of various industries, such as water management and urbanization projects.

On the other hand, as mentioned above it is essential to make people reflect on the importance of water and the urgency of water conservation, particularly seeing as the water crisis in Mexico increases in floods, droughts, and pollution. Optimistically, this research will shed light on the long history of interventions in the water of the Mexico basin and, guided by the three pillars of sustainability —economic, social, and environmental—, make people more open to find solutions for the betterment of the situation.

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