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DOI
10.1007/s12685-023-00334-1

Publication date
2024

Document Version
Final published version

Published in
Water History (online)

Water History
https://doi.org/10.1007/s12685-023-00334-1

Dams are fragile: the frenzy and legacy of modern infrastructures along the Klamath and Allegheny Rivers

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Received: 1 August 2023 / Accepted: 28 November 2023

Abstract
This article discusses the socio-technical process of dam construction in the United States from the early 20th century to the present. It examines how marginal places have been the object of industrial modifications through the inventiveness and entrepreneurship of social groups and local individuals who, supported by federal measures, have built power and cultural relations on territorial scales for decades. Historical reconstructions describe the generative processes of places through dam construction to demonstrate that the contemporary built environment is a product of natural and human-made relationships. Events associated with modern dam constructions and, more recently, with demolitions along the Klamath and Allegheny Rivers are critically discussed to illustrate how environmental resources relate to and interact with technology, human practices, and places. The article suggests that dams have been engines for industrial growth and technological devices to reframe the interdependencies between people and the environment. Dams supply people with water and energy and protect them and their property from droughts, floods, and fires. However, after a century of operations, these structures are reaching the ends of their lifecycles. In light of dam removal trends in the United States, the article presents a historical narrative on the societal legacy of dams. The intent is to share a broad understanding of the current technical and political debates on whether to demolish or maintain US dams in the future.

Keywords Modernity · Dams · Technology · Removal

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Published online: 11 January 2024

Introduction

Dams have been built for thousands of years to control rivers, provide water and later electricity, and protect communities from floods and fires. During the last century, civil engineering projects such as dams were essential to the economic (agricultural and industrial) progress of many Western countries. In the early 20th century, engineers developed great technical expertise in exploiting resources for water and energy supply. Indeed, in the United States, during the Great Depression, the government used dams as a technical solution to a historic socio-economic crisis. Once commodified and distributed, water changed the daily routines of people, promoting dams as a shared hope (Kaika and Swyngedouw 2000; Swyngedouw et al. 2002; Kaika 2005, 2006; Billington et al. 2005; Gutierrez et al. 2019).

Dams supply people with water and energy and protect them and their property from droughts, floods, and fires. However, after a century of operations, these structures are reaching the ends of their lifecycles. More than 80% of US dams have already reached the ends of their design lifespans (Graf 2002a, 2002b; Lane 2008; Wieland and Muller 2009; Wieland 2010; Schmutz and Moog 2018; ASCE 2021, Perera et al. 2021). Despite their benefits, dams also stop the migration of fishes and accumulate silt and sediments, exacerbating coastal erosion. Dams and auxiliary structures alter the climate of whole regions, reshaping, in a few decades, millennial ecological models (Magilligan and Nislow 2005; Degu et al. 2011; Barbarossa 2020; Magilligan et al. 2022; Chirag 2022; Spinti et al. 2023). Several environmentalist organisations, such as American Rivers, along with professionals and federal agencies, support dam removal projects aimed at restoring the natural flows of rivers (Aspen Institute 2002; Lowry 2003; DamNation 2014; Bellmore et al. 2016; Headwaters Economics 2016; Magilligan et al. 2016; Chaffin and Gosnell 2017; Scudder 2019). Since 1912, 1,951 dams have been demolished in the US. The trend of dam demolition is growing: 65 dams were demolished in 2022 alone (American Rivers 2022).

Recent scientific research suggests that dams undermine the purposes for which they were built. This article examines whether dam removal is a panacea for correcting the negative externalities caused by dams (Sneddon et al. 2017a, b). The text suggests that technological networks are not separated from the environment, from places, and from people, which broadens the dam removal issue from a socio-historical perspective. This article describes how modern society and nature have paradoxically been brought closer together by the development of dams (Tunnard and Pushkarev 1963). Dams have been engines for industrial growth and technological devices to reframe the interdependencies between people and the environment (Fox et al. 2016; Magilligan et al. 2017; Dunham et al. 2018). Indeed, we are more dependent today on the benefits dams provide than we were a century ago. Our daily lives are not only subordinated to the supply of water and energy and the protection of communities from floods and fires but also greatly susceptible to the ecological status of rivers.

Historical reconstructions are used in this paper to examine the interdependence between natural resources and commodities' producers and consumers. The section *Modernity: Politics and Ideology* summarises the early 20th century political and ideological status of the US and describes how government agencies and small social groups established dams and auxiliary structures along the Klamath (OR–CA) and Allegheny (NY–PA) Rivers. The technological modifications of these rivers are paradigmatic cases in the history of the US used to discuss and question recent trends in dam removal. The demolition of four dams along the Klamath River, begun in 2023, is the largest dam removal project ever conducted in the US and has been extensively debated. Among many water projects developed along the Allegheny, the case of the Kinzua Dam is particularly symbolic: the dam, which the Seneca people strongly opposed, today represents an economic opportunity for the Native American tribe. Both cases are elaborated in this paper to demonstrate that modern water infrastructure comprises technological objects historically embodied in our contemporary built environment. Our current way of life is strongly connected to and even made possible by modern infrastructure.

The *sectionsDams for Water* and *Dams for Power* describe how the Klamath River has been exploited to supply water and energy. These sections illustrate how, in a programmatic vision of modernity, dams became the instrument to achieve abundance and prosperity for the local inhabitants. The sections *Dams for Movement* and *Dams for Protection* describe the development of dams along the Allegheny River. The historical narrative describes the hydraulic transformations of the river basin to create a navigation infrastructure and protect an economically significant city from flood risk. In the 2000s, dams became the subjects of conflicts among various social groups living near the rivers. The sections *Controversy* and *Tragedy* describe events associated with these conflicts to reflect, in the discussion, on the contemporary legacy of modern dams.

Modernity: politics and ideology

Exploitation of rivers in the US has a long history. After the First Industrial Revolution, especially in the central areas of the US, the first modern steamboats required modifications to the banks to make portions of rivers navigable (Shaw 1993). In the 19th century, American rivers were primarily exploited to transport goods and people. With the invention and diffusion of the turbine, a multipurpose development phase began: water could be used for energy production, and the consequent construction of derivation, storage, and channelling systems allowed the construction of an infrastructure that was also favourable to irrigation (Palmer 1986; Arnold 1988; Reisner 1993; Grace 2013).

Flooding of the Ohio and Mississippi Rivers in the early 1900s, among other floods that devastated large areas of many states during the same period, drove the US Congress to develop a national flood control program. The government's interest in the issue evolved in a series of legislative acts (the Reclamation Act of 1902, the General Dams Acts of 1906 and 1919, the Flood Control Act of 1917, the Water Power Act of 1920, and the Flood Control Act of 1936) which resulted in the construction of several dams. Politicians saw the water projects as the best way to manage and control water on the continental surface and continue its multipurpose exploitation (Palmer 1986; Arnold 1988; White 1995). Furthermore, the government, through dam construction, was even able to manage and direct the developments of economic and demographic trends into specific regions or districts (Smith 1972; McCully 1996; Hughes 2004; Lowry 2003; Forest and Forest 2012; Sneddon 2015; Billington and Jackson 2017).

In those years, the frenzy of dam building also meant electricity and work for everybody. Their construction was the vehicle for consolidating agricultural production and mechanisation and supporting the growing development of manufacturing (Billington et al. 2005). Civil engineering works embodied economic prosperity for the private sector and immediately became the most visible symbol of Roosevelt's philosophy. The national policies implemented during the New Deal years intended dams to be the paradigm of a necessary process of modernisation of the country. They seemed to be the best idea to come out of the Great Depression. Dams were concrete proof that large-scale engineering interventions were feasible and able to distribute commodities that also supported industrial development (Kaika and Swyngedouw 2000).

The concept of commodity was introduced for the first time by Emerson (1836) in *Nature.* To Emerson, the energy of nature assumes an operative form only through the activity of humans. Technology was an expression of the romantic idea of energy – a way to free people from efforts and social conflicts by exploiting the power of nature. In the late 19th century, dams and hydroelectric plants had a large electricity production capacity hidden in calm architectures which had nothing in common with the smoking chimneys of the old fossil fuel power plants. Their shapes appeared as extensions of nature and affirmed modern man's understanding of nature and the appropriateness of his use of its resources. Hydroelectric plants, such as large dams, became icons of American grandeur and modern tourist destinations, just as the Natural Bridge in Virginia or Niagara Falls had been a few decades before. Tours to great monuments of technology such as these helped to fill a need to build a distinct national character (Nye 1995; Jackson 2013).

The popular consensus concerning dams, arising from the infrastructural and urbanisation interventions of the Roosevelt era's vision of the United States, demonstrates that the construction of dams translated into a collective *credo* about the future. Modernity was not only a programmatic vision of the future, which exploits resources through technology to follow a trajectory of growth, but also a necessary, exciting, and liberating discontinuity with the previous historical period. This period in North America coincided with a process in which large infrastructure projects (bridges, railways, ports, dams) disrupted environmental balances, improving the quality of the daily lives of the citizens (Tunnard and Pushkarev 1963; Hughes 1989; Nye 1995; Graham and Marvin 2001; Kaika 2006). For example, the shift to hydropower as a dominant energy source had dramatic effects on society. It contributed to the decontamination of cities polluted by coal fumes, its local distribution allowed the relocation of small manufacturing companies, and it encouraged the repopulation of rural areas by workers. Electricity promoted independence and decentralisation in opposition to the process of centralisation and the monopoly of the steam engine. Hydropower laid the foundations for environmental rebalancing: it was a process of *clean and silent* industrialisation, and its turbines, once installed, did not require human intervention and had virtually no maintenance costs (Mumford 1934, 1964; White 1995).

In conclusion, dams illustrate how the exploitation of nature coincided with economic growth. After the Depression, this was vital, as was the technology that supported it. During those years, politics placed environmental resources in the hands of engineers, and only a few areas of the US were unaffected by their plans. The hydrogeological design of the American landscape has been a period in which rivers were central to transformative projects carried out by the US Army Corps of Engineers in the East and by the Bureau of Reclamation in the West. The rush to dam construction after the economic crisis of the Depression was linked to the historical (social, political and economic) context of the 1930s, and the role of the government in promoting these public works was decisive.

Dam: an extraordinary tool

The article is based on the generative processes of the cases reconstructed by the author, with specific attention to the development of civil infrastructure projects. Historical facts, provided by original archival records and the bibliography, are fundamental to understand the roles of specific social groups in creating the Palimpsest (Corboz 1983) of the Klamath and Allegheny Rivers. The objective is to discern the slow and complex stratification of natural resources and engineering interventions by which 'the inhabitants of a land tirelessly erase and rewrite the ancient scrawls of the soil' (Corboz 1983).

A dam can be an extraordinary tool to illustrate how, in the first half of the 20th century, technological networks (Hughes and Mayntz 1988; William 1993) reconceptualised resources, turning them into normalised commodities that were taken for granted. Dams have mostly been constructed to supply water and energy and for navigation and flood control. Following this logic, subsequent paragraphs are complementary organised and focus on the development of dams to provide specific commodities (water, power, movement, protection). This narrative offers a broad perspective on the modern industrial modification of rivers using dams. The descriptive narration emphasises how technology has mediated the spatiotemporal relationship between urbanised areas and natural resources.

The history of dams in the US includes great icons, such as the Hoover Dam and the Tennessee Valley project, and a multitude of more contained projects that have also had important spatial, economic, cultural, and environmental impacts on the country. These smaller projects have contributed to the *middle landscape* that Leo Marx defined as 'a new, distinctively American, post-romantic, industrial version of the pastoral design' (Marx 1964: 32). Maps and drawings highlight, at different scales, the logistic and spatial interrelations between rivers and the middle landscape, illustrating how dams transformed the pastoral into the industrial.

Dams along the Klamath river

The hydrogeological basin of the Klamath River, which flows between Oregon and California, covers approximately 12 square miles of biological, morphological, and climatic diversity. The upper and lower portions of the basin (referred to hereinafter as the upper and lower basins, respectively) – one marked by natural lakes and bas-relief deserts and the other characterised by steep mountains and forests (Andersson 2003) – have for years been the centres of two massive transformation projects: the Klamath Reclamation Project and the Klamath Hydroelectric Project.

Since the first settlements of Euro-Americans from the East, the upper basin was characterised by agricultural areas (mainly orchards) that were an important source of income for the local communities. The Upper Klamath covers approximately 40% of the entire basin but receives only 12% of its annual rainfall, and the lake, despite its large surface area, holds little water because it is relatively shallow. The natural supply system, therefore, has a limited storage capacity, and in 1878, a group of resident farmers established the first company (Linkville Water Ditch Company) for the control and management of the system's fresh water for irrigation purposes. The consequent rush to construct pumping stations and small hydroelectric power facilities (thanks to the invention of the Francis turbine) resulted in an epochal change: water could be extracted, stored, and distributed more quickly and could easily reach different heights. In 1902, President Theodore Roosevelt signed the Reclamation Act. In 1903, the engineers J.T. Whistler and H.E. Green looked for potential wetlands in the area to be reclaimed for agricultural purposes. In 1905, the Secretary of the Interior, E.A. Hitchcock, authorised the Klamath Reclamation Project. As a consequence, the Wood, Williamson, and Sprague Rivers (which are the major tributaries of Upper Klamath Lake) and the Clear and Gerber Lakes become the main water resources for approximately 235,000 acres of reclaimed land.

The region then experienced a period of abundance called *orchard boom*. In those decades, there were also stories of successes, failures, envies and business challenges that resulted in the Klamath Reclamation Project being merged into the Klamath Hydroelectric Project. The construction of two power plants, one in Yreka, California, in 1891 and the other in Klamath Falls, Oregon, in 1985, demonstrated how the economic interests of the area ignored geopolitical boundaries. In 1852, the foundation of the State of Jefferson was conceptualised. The frustration of the local population arose from a certain disregard for federal policies to drive the economic development of the region. Several attempts were pursued in an effort to form a separate state between Oregon and California, but the secessionist movement failed. However, the regional cohesion was compensated a few years later by the California Oregon Power Company, which constructed several dams along the Klamath River, giving the area a reputation reflected in its being paternalistically called Copcoland (Kramer 2003a). Beginning with the construction of the first dam in Fall Creek in 1903, a linear corridor of hydropower facilities was built, marking the landscape of the Lower Klamath.

The next section, *Dams for Water*, describes in detail how both Klamath projects developed along the river. The reclamation and development of agricultural areas, combined with the construction of dams for electricity production in the 19th and 20th centuries, contributed to the slow decline of the water quality, which adversely affected the fish population and, consequently, the Klamath, Modoc, and Yahooskin tribes who have inhabited those areas for hundreds of years, triggering a social dispute that exploded in the 2000s. The *Controversy* section describes the social conflict and how the movement for dam removal rose.

Dams for water

The Klamath Reclamation Project was a land modification plan for irrigation purposes undertaken between 1906 and 1966 in the Upper Klamath River basin (California and Oregon). Beginning in the 1880s, the private interests of some farmers led to the construction of wide canals – the Adams Canal from the White Lake in 1886 and the Ankeny Canal from the Link River in 1887 – to supply their fields. However, most landowners still lacked enough water for farming. Under the Reclamation Act of 1902, the government proposed investing in irrigation infrastructure by founding the Reclamation Service (known since 1923 as the Bureau of Reclamation), whose engineers started approximately 30 hydrogeological projects in 17 Western states between 1902 and 1907 (Donnelly 2003). Before the engineering process took place, the water of Upper Klamath Lake flowed into Lake Ewana through a short segment of the Link River. In the spring, 94,000 acres of marshlands of the Lower Klamath Lake flooded. In its initial phase, the project provided for the reclamation of the western areas of the Lower Lake and the construction of a canal that would have conveyed the river water directly to the converted lands (Robbins 1997).

In 1905, after a detailed survey of the hydrogeological characteristics of the area (Fig. 1), the Klamath Project was approved. The objective of the Secretary of the Interior was to reclaim wetlands to establish new economies: farms and ranches. The water of the Klamath River and its branches was essential to the plan. Two years later, in 1907, an agreement was reached between the State of California and the Northeastern Railway that involved the construction of a railway whose track, built on an embankment, would have interrupted the connection between the two lakes. Beginning in 1917, when the railway embankment construction was completed, approximately 85,000 acres of the Lower Klamath wetlands were drained (Stene 1994; Kramer 2003a). The first canal project was partially abandoned because of further investigations: other lands to be reclaimed were found. The construction of a series of artefacts followed: Clear Lake Dam, the Lost River Diversion Dam, and the A (Main), B (East Branch), C (South Branch), D (Adams), and G (Griffith) canals. The Clear

Fig. 1 'Klamath Project general progress map', US Geological Survey, Reclamation Service, F.H. Newell, A.P. Davis, J.B. Lippincott, T.H. Humphreys, April 1905, map no. 6092, Klamath Irrigation District, historical topographic maps of the US Geological Survey, ngmdb.usgs.gov

Lake Dam impounded the Link River, and its regulated water flows irrigated the additional reclaimed land to the south. In the 1920s, the Bureau of Reclamation allocated new lands to the north. Irrigation was possible thanks to the Gerber, Mill Diversion, and Malone Diversion dams. Their construction was followed by the North and West canals and then by the E (North Poe), F (South Poe), and J branches. After the Second World War, part of the Tule Lake was drained to expand agricultural production. In the following years, it was necessary to build the M, N, P, Q, and R canals (Souza 2022).

The production processes in the Tule Lake led to a massive ecological impoverishment of the National Wildlife Refuge. As it had been established after the Reclamation Project, according to the Californian Water Right doctrine, *first in time, first in right*, its water right was the last in the supply chain (Milligan 2015). In 1964, thanks to the Kuchel Act, the management of the NWR's wetlands changed, and in the 1990s, a series of experiments to restore the ecosystem followed. According to the Walking Wetlands Program, agricultural grounds, following a four-year cycle, were flooded to support fauna and flora recovery. Over the years, the program has also proven to be effective for the maintenance of nutrients in agricultural soils. Today, under a system of state government incentives, several private lands are periodically converted into wetlands (US Fish and Wildlife Service 2021). To date, approximately 80 per cent of the former lakes and marshlands have been converted into fodder, alfalfa, potatoes, and cattle farming through a supply machine in which Upper Klamath Lake, Gerber Reservoir, Clear Lake and all their tributaries exchange water – via the Lost River Diversion Canal, the Klamath Straits Drains, the Tule Lake Tunnel, and the D-Pump – with the Klamath River and the wetlands of the National Wildlife Refuge (Fig. 2).

The Klamath Project. The two maps show the geographical change caused by the construction of the Klamath Reclamation Project. A 1905 survey highlights the system of streams, rivers, wetlands, and lakes which characterised the area before human interventions took place. Tule Lake, Lower Klamath Lake, and Upper Klamath Lake worked on the principle of communicating vessels. The two southern lakes tended to flood only during the spring, when the Klamath River's flow increased dramatically.

The second map shows, with arrows, the canals' flow directions, revealing that the Upper Klamath Lake, the Gerber Reservoir, and the Clear Lake are the inputs of the machine. Water from storage impoundments is diverted to the lands, and the excess resulting from the irrigation process is conveyed towards the National Wildlife Refuge. This is made of two separate lakes which exchange water residues through the D Pump.

Dams for power

The Klamath Hydroelectric Project is a plan to develop and exploit the Klamath River for hydroelectric production. Built between 1911 and 1962, it is made up of six dams, seven hydroelectric plants, and several other facilities. The first step towards the Hydroelectric Project was the construction of the pioneering hydropower plant at Klamath Falls (1895), east of the Link River, run by the Gates family. Initially, despite the installed low capacity, the energy that entered the market was sufficient to meet the neighbourhood demand. Later, some local entrepreneurs, including Jerome Jr. and Jesse Churchill, sensed that electricity would change how people lived and was worth additional investment. In 1903, they built a new powerplant on the Fall Creek: the newborn Siskiyou Electric Power Company established itself as the main electricity distributor in the region with transmission lines that

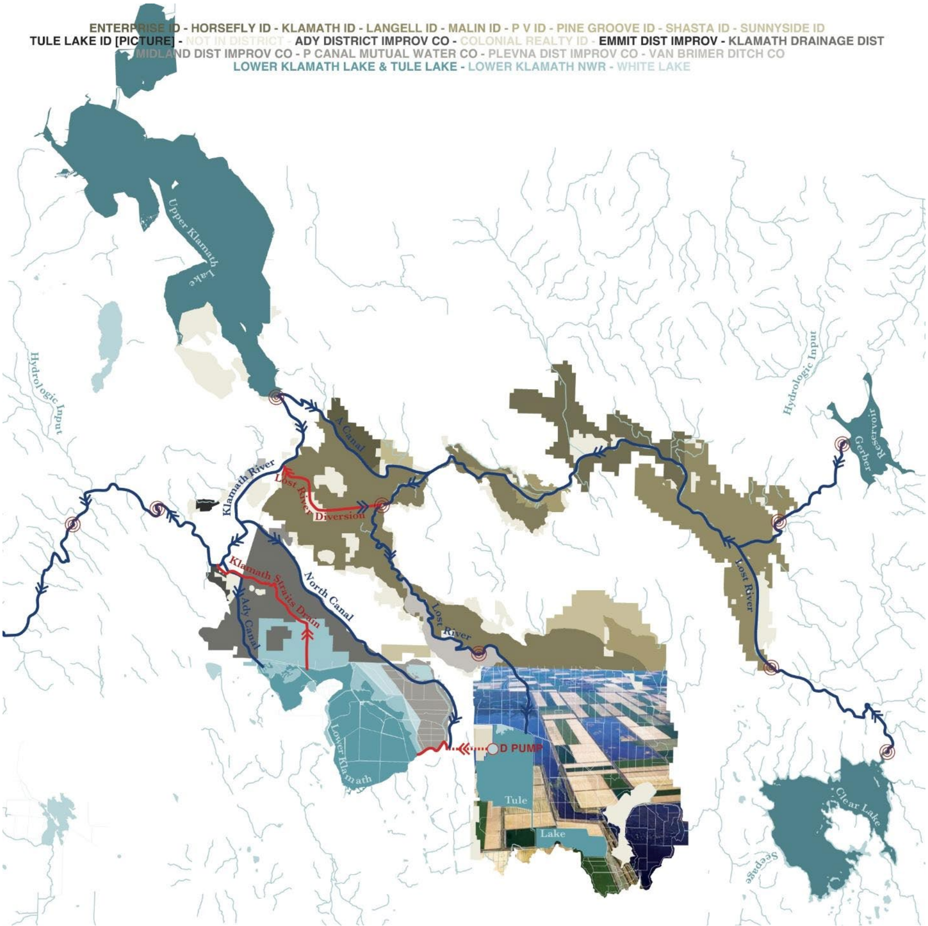

Fig. 2 Map elaborated by the author, 2023. Data: California environmental protection agency, Oregon environmental protection agency 2023, epa.gov; Klamath Watershed Partnership 2023, klamathpartnership.org

crossed the Siskiyou Mountains between California and Oregon. The small hydroelectric facility supplied the cities of Yreka, Henley, Hornbrook, Ager, and Etna (Most 2006).

In 1906, the Moore family acquired the first hydroelectric station on Link River, founding the Klamath Power Company; in 1910, this combined with ten local distributors and with the Churchill family's company, founding the Siskiyou Electric Power and Light Company (SEP&LC) which would, then, manage twenty-seven generating stations, distributing electricity throughout the territory (Kramer 2003a, b). The company continued to expand and increase its electricity production; in 1909, a survey study (concluded in 1911) was begun to design a long-term development plan for the Klamath River. The first constructed dam was the Copco No. 1, not far from the Fall Creek plant, whose first 10,000 kW were marketed starting in 1918. In 1920, SEP&LC was reorganised and changed its name to the California–Oregon Power Company (COPCO). In 1924, the second Copco dam was built. Its power plant added 30,000 kW to the company. In 1926, the Keno Dam was constructed to manage the river level to keep the upstream irrigation machine working. The initial timber construction was completed in 1931 and replaced by a concrete structure in 1966 (PacifiCorp 2003f).

During the Second World War, the construction of two military cantonments at Klamath Falls and Jackson added 100,000 units to the region. The demand for energy increased dramatically. After the war, John Christie Boyle – who had previously worked with the Churchill family at Klamath Falls – became the chief engineer of the Klamath Hydroelectric Project. He planned the expansion of COPCO to the north: the construction site of a system of eight interconnected plants. The expansion began in 1947 on the North Umpqua River, Oregon, bordering the National Forest (130 km north of Klamath Falls). Between 1940 and 1960, the population growth rate reached 72%, and the new power plants in the north would not have been able to respond to the region's energy needs. Boyle's goal was to obtain the maximum return from the Klamath River by building a linear hydroelectric production development (PacifiCorp 2011b, c).

During the last century, the river's exploitation was regulated by a complicated system which crossed economic and productive networks in an inter-state legal and bureaucratic context. The conflicts between farmers, fishermen, and indigenous groups concerning economic interests linked to tourism and hydropower have been a constant in recent decades (Doremus and Tarlock 2003; Most 2006; Albertson 2019; Shapiro 2023). In 1956, after a series of negotiations, COPCO signed an agreement with the Federal Power Commission, the Hydroelectric Commission of Oregon, the Public Utility Commission (Oregon and California) and the Bureau of Reclamation (which provides guidelines) for the construction of two new hydropower dams on the river. In 1958, the Big Bend Dam (later named for J.C. Boyle) was completed. The Iron Gate Dam (1962) that closed the 60-k m corridor of artefacts (Fig. 3; PacifiCorp 2003e) followed.

The human-made Klamath Corridor. The main artefacts which characterise the landscape of the Upper Klamath Basin are schematised in the drawing. Intake/outtake canals and drains connecting the Klamath River to the irrigation districts are evident to the north. Downstream, the drawing shows all of the dams with combined powerplants and corresponding installed power capacity. The drawing also indicates Klamath segments where seasonal streams and tributaries increase the river's flow rate and, therefore, its productivity.

Controversy

Competitions over water rights or allocations and disputes about recreational or fishing economies based on the Klamath River have emerged on a regular basis since the initial phase of its exploitation. A few years after the development of the power production corridor, battles over the river intensified: indigenous groups, farmers, ranchers, fishers, PacifiCorp, and local residents all claimed rights to parts of the river. In addition, a series of state and federal measures intervened in the unstable balance between the groups, exacerbating the social conflict (Diver et al. 2022). The river supported a vigorous fish canning industry that suffered a drastic decline after the construction of the first Copco Dam (Hamilton et al. 2016), creating an economic crisis related to salmon migration for the indigenous groups[1]. By the end of the 1960s, several ecological studies had reported the disastrous conditions of

[1] The decline of Klamath River salmon migration began in the mid-1800 due to changes in water quality caused by mining extraction. Overfishing also contributed to the decline of the salmon population on the river. The definitive disappearance of fish, in the Upper Klamath Basin, is due to the construction of the

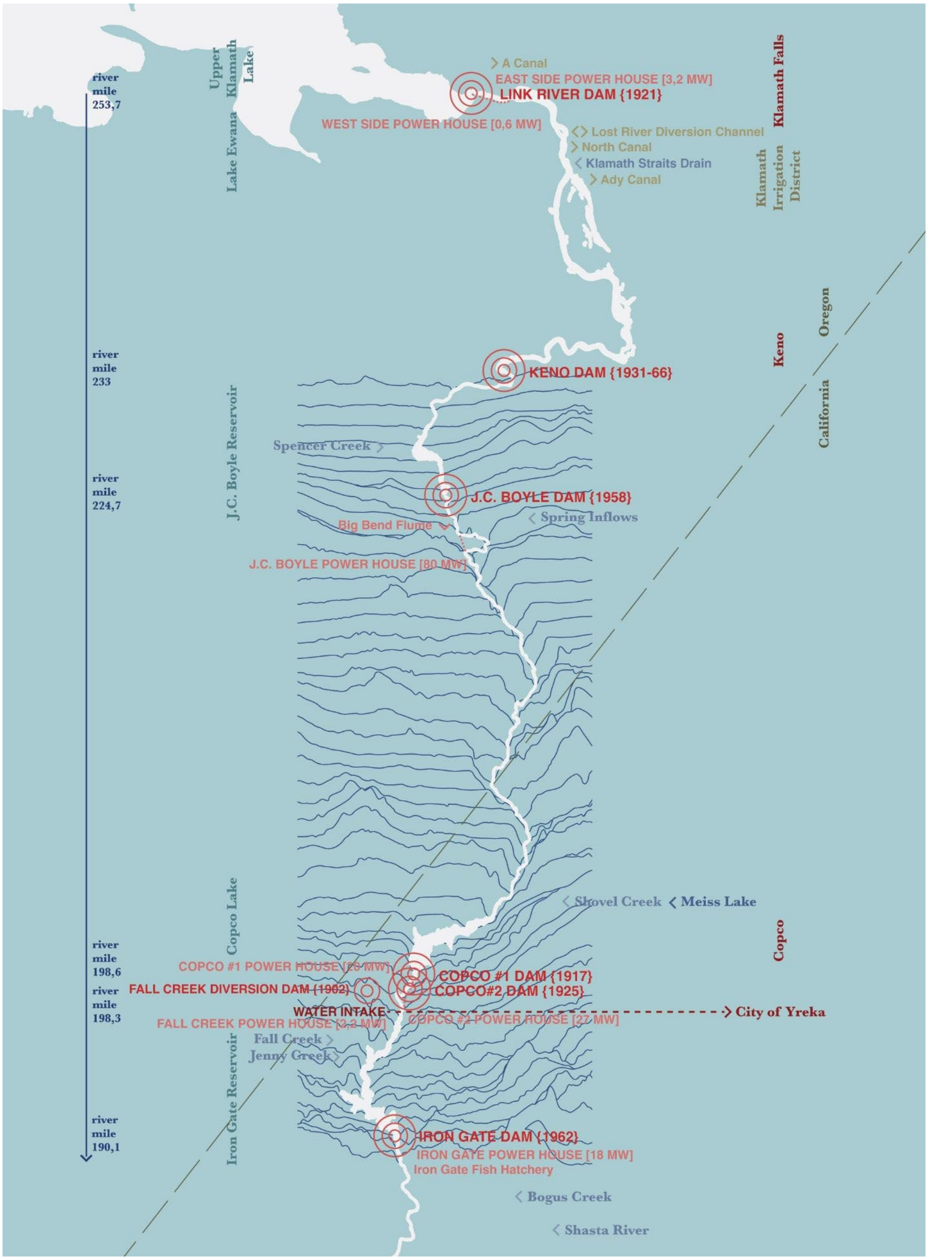

Fig. 3 Graphic elaborated by the author, 2020. Data: PacifiCorp 2011a,b,c, PacifiCorp 2003a,b,c,d,e,f,g

American rivers, and various laws were passed to advocate for better management of fresh water. In 1967, the Lost River Sucker (a ray-finned fish) in the Klamath was listed as a rare

Copco No. 1 dam, precisely in October 1912, when river flow, to construct the cofferdam, was diverted into a tunnel, making fish passage impossible (Hamilton et al. 2016).

species by the State of California. Crucial events then started to overlap, building a complex story of ecological and juridical knots.

In 1973, the Endangered Species Act (ESA) established fixed minimal water flows on rivers exploited by hydroelectric production to keep native fish species alive. In 1986, Congress passed the Klamath Act, a twenty-year program whose ambition was the repopulation of anadromous fish species. In 2001, to respect the ESA, farmers and ranchers had to decrease their consumption of water because of a serious drought (Braunworth et al. 2002). The following year, the Government authorised exceptional minimum flows of the river for agricultural purposes, causing an enormous die-off of salmon (US Department of the Interior 2012). In 2006, federal authorities stopped fishing activities on the coast to allow the fauna to recover. Economic and ecological disasters looped and aggravated by a series of legal battles over water rights among indigenous people, farmers, ranchers, fishers, environmentalists and local communities. In 2007, the Federal Energy Regulatory Commission started to re-license the Klamath Hydroelectric Project (expired in 2006). According to FERC (2007), fish ladders and screens needed to be provided to keep the dams operational. An overall view of the system and a shared water management of the hydrological district was necessary to address the interests of all the involved parties. The Klamath Settlement Group formed, and during 24 meetings between 2005 and 2010, it is discussed the future of the J.C. Boyle, Copco Nos. 1 and 2, Iron Gate dams: the possibility of removal emerges. Removing the dams was economically more reasonable than adapting them to the new standards (PacifiCorp 2011d). In February 2010, the Klamath Basin Restoration Agreement (KBRA 2010) and the Klamath Hydroelectric Settlement Agreement (KHSA 2016) were signed by all parties. The first agreement included an operation plan for the fish fauna reintroduction, a water resource distribution program and an economic plan to support the implementation of the two. The second agreement was a design proposal to demolish the four dams, which was associated with a preliminary study on its resulting environmental impacts and benefits. In this document, PacifiCorp committed to convert its water rights into instream flows and to contribute to the cost of restoring the river's environment with $ 200 million – which means higher electricity bills for its customers (California Public Utilities Commission 2011; Oregon Public Utilities Commission 2019); California committed to contributing $ 250 million. The agreements needed to be passed by Congress, but as of 2015, they had not become law. The KHSA, however, does not provide for Federal funding and, therefore, to bypass Congress, it has been decided to opt for a variation of the same Agreement. In 2016, PacifiCorp asked FERC to split the *original* Klamath Hydroelectric Project into two separate licenses: J.C. Boyle Dam (OR), Copco No. 1 Dam (CA), Copco No. 2 Dam (CA) and Iron Gate Dam (CA) formed the *new* Lower Klamath Project, whose concession has been transferred to the non-profit Klamath River Renewal Corporation.

The newly founded non-profit Corporation, in June 2018, publishes the report *Definite Plan for the Lower Klamath Project* (KRRC 2018). It defines the removal project of the four dams and the subsequent environmental restoration of 8,000 acres of land, subject to the Federal Energy Regulatory Commission's approval. Partly replacing the *Detailed Plan for Dam Removal* of the US Bureau of Reclamation (2012), the report consists of more than 2,000 pages describing the techniques, methods, tools, times, and costs for (i) maintenance operations and improvements to roads and bridges to allow hauling trucks access to the construction sites, (ii) the reservoirs drawdown, (iii) any sediment management measures, (iv) the complete demolition of dams, (v) disconnection of facilities from the transmission lines of the PacifiCorp, (vi) the removal of developments at recreational sites replaced by small structures to access to the river. The report also provides (vii) the results of several studies on the downstream effects of demolition, including hypotheses on the 100-year flood hazard areas, and (viii) a strategic and monitoring plan for restoring native aquatic and terrestrial fauna and flora.

In November 2022, the FERC (2022) approved the removal project – the largest in history – which was planned to start in 2023. PacifiCorp continues to operate the dams under an annual license. Part of the population that still benefits from the dams for water and energy supply in Siskiyou County continues to oppose the demolition.

Dams along the Allegheny river

The Allegheny River originates in northern Pennsylvania and flows for 325 miles to the south towards Pittsburgh, joining the Monongahela to form the Ohio River. The Allegheny River basin covers approximately 11,000 square miles between the states of Pennsylvania and New York. Approximately 4,000,000 people live in the counties within the basin perimeter. The region is primarily rural, except for Pittsburgh, which is the largest city in western Pennsylvania.

Historically, the economic activities of the region have been based on the river, but the Allegheny, unlike the Klamath, has not been at the centre of crucial hydrogeological transformation plans. Several projects at different scales and different times, beginning when the first European traders and settlers appeared in the area, have modified the Allegheny. The area was initially inhabited by the Confederation of the Five Nations, which consisted of the Mohawk, the Oneida, the Onondaga, the Cayuga, and the Seneca. The Tuscarora were admitted to the tribal union in 1712. These indigenous groups engaged in modifications to the rivers' banks to facilitate access and improve navigation. However, during the American Revolution (1775–1783), the French and English began to build fortifications and levees, beginning the process of water engineering in the area, which continued for more than two centuries (Johnson 1979).

In the early 19th century, the logging industry expanded in northern Pennsylvania, and wood from the virgin pine forests in the Upper Allegheny Valley (Warren County) provided the construction material used to build several villages and towns along the Allegheny, Ohio, and Lower Mississippi Rivers as far south as New Orleans. Local companies started to operate the rivers to transport logs; inland waterways were the fastest way to move goods. When Edwin Drake discovered the *liquid mineral* in 1859 near Titusville in Crawford County, Pennsylvania, a proliferation of oil wells followed. The region was transformed into a centre of commerce and industry in North America (Ross 1994). Retailers and business owners exploited river waterways to haul oil barrels to the Pittsburgh market, refineries, and power plants. Between the 19th and 20th centuries, Pittsburgh became one of the most important industrial cities in the world. It was constantly expanding, requiring a series of territorial-scale infrastructure projects to support its economic development. Between 1879 and 1903, engineers took steps to clear the Allegheny River of obstacles. In 1903, the first lock and dam on the river was completed at Herrs Island. By 1938, eight navigation dams had been added to the Allegheny, providing a waterway 72 miles long from Pittsburgh to East Brady.

The beginning of the 20th century was a turning point for the US, as it was for Pittsburgh. Numerous floods that threatened the city became the reason to promote a hydrogeological vision for the region. Through the construction of a set of dams for navigation and protection, the government essentially consigned control of the rivers to the US Army Corps of Engineers. In 1936, Congress authorised the construction of five reservoirs along the Allegheny and its tributaries. By 1975, the Corps of Engineers had built a flood protection ensemble consisting of 16 large dams and 83 small projects in the Pittsburgh District.

The next paragraphs focus on a detailed reconstruction of how dams developed along the Allegheny to implement navigation across the inland system and protect Pittsburgh from floods. The Kinzua dam, built as part of the Flood Control Act of 1936, is a paradigmatic case to elaborate on the socio-economic impact dams have on the local community; its genealogy is reported in the paragraph Tragedy.

Dams for movement

Modern navigation on the Allegheny started in the late 18th century with the first efforts by private and municipal groups to remove snags and boulders. Given the strategic position, (the Allegheny flows into the Ohio River and then the Mississippi River), shipping and travel on the river increased. In 1798, the government declared the Allegheny a public highway (Dinsmore 2000). In 1824, military and civil engineers, authorised by the General Survey Act, started to survey the region, advancing improvements projects to facilitate river navigation: snag boats were used to clean channels, removing rocks, boulders, sandbars, and other hazards. Later, through the construction of a series of small dams, the first commercial channel in the United States opened.

In the 19th and 20th centuries, Pittsburgh became one of the most important industrial cities in the world. It was constantly expanding, requiring several infrastructure projects to support its economic development. As the construction of the national railway network began, the demand for iron equipment, tools and machines produced a growing market for the steel mills of the city, stimulating further commercial development along the northern Allegheny. Rivers typically were exploited to move down logs and run timber industries developed along the banks, but as the extractive activity boomed, the Allegheny and its tributaries became the freight transport mode to haul salt, coal, oil and natural gas to the West (Johnson 1992; Ross 1994).

After the 1824 expedition, Major W.E. Merrill managed a new survey in 1874; he recommended the construction of a series of channels and dams to operate the Ohio River from Pittsburgh to Wheeling and of a single movable lock-and-dam in the Allegheny at Pittsburgh. In 1878, the first lock-and-dam on the Ohio was built. In 1879, the construction of two dams – one at Six-mile Island close to Pittsburgh and one 35 miles upstream – on the Allegheny failed due to damages caused by ice. In 1893, the construction of the lock-and-dam at Herr's Island (Pittsburgh) – later known as Lock No. 1 – started; between 1896 and 1898, the Army Corps of the Engineers proposed to build eight additional dams on the river to create a series of pools similar to the one created, years before, on the Ohio and Monongahela Rivers (Johnson 1979). Later, two more dams were authorised by the Congress. Lock-and-dam No. 3 was completed in 1904, but the abutment failed in 1907, causing the collapse of several properties. Lock-and-dam No. 2 became operational in 1906. After World War I, the navigation project restarted: lock-and-dams 4 and 5 were built between 1920 and

1927; lock-and-dam. 6, Freeport, was completed in 1930; and No. 7, Kittanning, was built between 1928 and 1931; the No. 8, Templeton, operated since 1931 (Dinsmore 2000). During the construction of dams 4 and 5, Congress decided to create a deeper navigable channel in the Allegheny, compelling the removal of the former dam and requiring the modification of two. New lock-and-dams 2 and 3 were completed in 1933. In 1935, Congress approved one more dam, which started to operate in 1938 at East Brady, 72 miles upstream of Pittsburgh. In the same year, the first lock-and-dam was removed to accomplish the plan.

For the first time, the Allegheny River was the centre of a regional-scale engineering plan for commercial purposes envisaged by the Army Corps. The construction of the barriers was a way to reorganise the water space and to revise the water intake and sewage networks – in which the river was both input and output – of Pittsburgh and of all the industrial villages which started to appear along the Allegheny. For 80 years, the eight-pool navigation system has been unaltered. Servicing extractive activities, it represented the way to haul construction materials and fossil fuels to the processing mills and power plants from the Allegheny to the Ohio and Mississippi Rivers. Since 2017, locks and dams 6, 7, 8, and 9 have been in caretaker status, 'remaining closed indefinitely except for commercial appointment lockages' (US Army Corps of Engineers 2019). On this portion of the river, waterborne commerce ceased because of the loss of sand and dredge mining industries, calling into question the further maintenance of the four dams which today appear as leftovers of the Pittsburgh District's industrial past.

Dams for protection

Pittsburgh has been affected by floods since the 18th century. In March 1936, one of the most violent storms in United States history hit some of the Northeastern states. During the floods, 107 people were killed (84 in Pennsylvania), and more than 82,000 buildings were damaged, harming the productive and industrial areas of the state. The destruction that occurred in Ohio, West Virginia, Maryland, Pennsylvania, and southern New York contributed to the opening of the land engineering process of the Roosevelt era. The Flood Control Act (1936) authorised the Army Corps of Engineers to take complete control of water to protect people, cities, and productive areas. Hundreds of projects for levees, channels, flood walls, and dams followed in the subsequent decades, resulting in the construction of one of the largest human-made systems in the country – second only to the Interstate highway system (Arnold 1988). The Army Corps became the means to develop, throughout the physical materiality of infrastructures, a progressive era, and the dams, built in the Allegheny watershed, embodied the concept of centralisation trained by politics and civic forces which pushed for flood control management.

Engineers accumulated technological experience by building dams for navigation on the Allegheny, the Ohio, and the Monongahela, but when the 1936 Act passed, they needed to expand their array of designing and planning skills[2]. In March 1936, President Roosevelt, visiting the Johnstown community (devastated by the St. Patrick's Day Flood), announced two million dollars would have been provided to the Army Corps to advance the geological investigation on the nine reservoirs' sites planned in the Act. The initial plan, envisaged

[2] In 1911, the Bulletin No. 3 of the Pittsburgh Flood Commission reveals that a series of flood control dams in the Allegheny Basin were envisaged by Army Corps decades before the Flood Control Act of the 1936 (Pittsburgh Flood Commission 1911).

by the Army Corps of Engineers for flood protection purposes, provided for nine dams: the Tygart, Tionesta, Crooked Creek, Mahoning, Loyalhanna, Youghiogheny, Conemaugh, Kinzua, East Branch Clarion (Allegheny Conference 1947). The dam on the Tygart River is the first project built in the region; its construction was authorised by the Rivers and Harbors Act of 1935; it was completed in 1938. Only one year after Roosevelt's announcement, the Tionesta and the Crooked Creek Dams were constructed on two Allegheny tributaries above Pittsburgh. In 1939, work on the Mahoning Dam started. In 1940, Congress approved further funds to construct three additional dams on the Loyalhanna Creek and the Youghiogheny and Conemaugh Rivers (Smith 1977).

The War in Europe slowed the progress of the flood protection plan accomplishment: by 1940, five dam construction sites (all mentioned above except the Conemaugh) were under construction. The Kinzua Dam construction stopped since the initial stage of its opposition. Its reservoir would have flooded the ancestral lands of the Seneca Tribe that, according to the Pickering Treaty[3], the federal government could not ever claim (Treaty of Canandaigua 1794; Rosier 1995). In 1944, the Allegheny Conference on Community Development was established. Businessmen and elitist clusters wanted to renovate the image of the city of Pittsburgh and inaugurate a new civic phase called Renaissance (Muller 2006). Along with pollution, steel industry losses, railway, highway and mass transportation plans, housing and recreation developments, flood control became an urgent issue. Floods were viewed as a deterrent to additional infrastructure development. Indeed, the Conemaugh Dam construction was vital to the plan (Smith 1977). Congress allocated funds to the preparatory activities, and in 1949, dam construction began. In 1952, the Conemaugh started to run, and in the same year, the Army Engineers completed the East Branch Clarion Reservoir, as well. In 1953, all dams authorised by the Flood Control Act of 1936, except the Kinzua, were built and operational. Today, the Army Corps of Engineers operates and maintains sixteen dams to reduce and prevent flood damages in the Pittsburgh District (Fig. 4): seven dams were added to the initial plan in subsequent decades by the passage of the successive Flood Control Acts.

The Pittsburgh Water Defence Ensemble. In a century of civil works, the Allegheny basin territory turned into a machine to defend the inhabited lands from possible flooding. Morgan (1971) affirms that many flood control projects designed by the Army Corps of Engineers were a way to establish a disciplined space of water onto the continental surface. The distribution of the engineering structures in the District is the result of a military thinking model carried out by the Corps to protect cities and people from water.

The sixteen reservoirs built along the Monongahela and Allegheny Rivers, including their tributaries, are shown on the map. The year shown with each dam name indicates which Flood Control Act authorised it, and the year in parentheses for each indicates when construction was completed. Light blue areas coincide with the drainage basin of each man-made lake. The red circles represent locks and dams (eight on the Allegheny, nine on the Monongahela, five on the Ohio) for navigation. Over the decades, a series of minor civil works joined; they consisted of 40 federal flood protection projects (blue rhombus) and

[3] The Treaty, signed by President George Washington and the Grand Council of the Six Nation, in 1794, established land rights and boundaries of the Indian Reservations in the State of New York to end hostilities and violence occurred during the American Revolution. In 1797, 200,000 acres were reserved to the Seneca Nation, and the Oil Spring territory was added in 1801. Between 1802 and 1842, several lands were taken from the Natives. Today, the Indian territories include three Reservations: Allegheny, Cattaraugus, Oil Spring (Hauptman 2014).

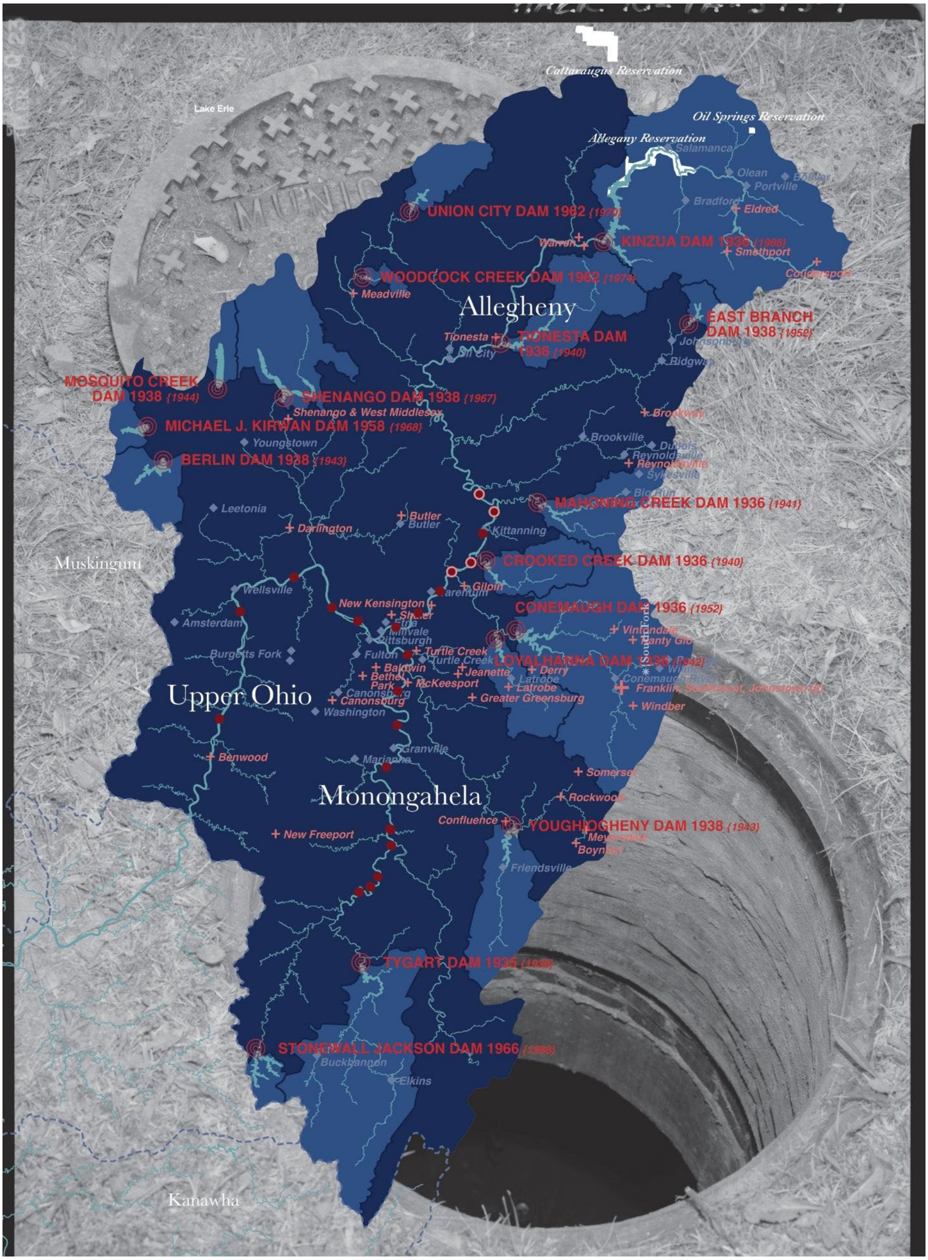

Fig. 4 Maps elaborated by the author, 2022. Data: National Atlas of the United States 2022, nationalatlas.gov; US Geological Survey 2022, usgs.gov; US National Inventory of Dams 2019, nid.usace.army.mil; Geospatial Portal of the US Army Corps of Engineers Pittsburgh District 2019, geospatial-lrp.usace.army.mil. Image: 'Ninth Avenue Regulator at Youghiogheny River, McKeesport, Allegheny County', Brown & Brown Manufacturer, Photograph by J. Lowe, 1955–1960, Historic American Engineering Record, Library of Congress

forty-three non-federal (pink crosses). In conclusion, 83 local projects, 22 locks and dams, and 16 flood control dams make up the *water defence ensemble* managed by the Pittsburgh District of the US Army Corps of Engineers.

Tragedy

The Kinzua Dam on the Allegheny River was built at a cost of $125 million. Its construction began in 1960, and it became operational in 1966 (Smith 1977). The dam meant the completion of a hydrogeologic scenario envisaged by the Army Corps of Engineers and sustained by the local business elite and the federal government. Its construction has been fundamental to protect Pittsburgh from floods, but it implied the flooding of nine thousand acres of Seneca ancestral lands, the dislocation of 127 families, 500 people and the destruction of homes, schools, stores, farms, cemeteries and holy places (Rosier 1995). In the mid-1800s, the Seneca people lived in large matrilineal longhouses in nucleated small villages (Weist 1995). Before the Kinzua Dam was constructed, many original longhouses were altered by additional frame structures, and the agglomerations assumed a different fabric when Natives started to build frame cabins, dwellings and schools along the banks of the Allegheny. Houses and public services were located on both sides of the river, forming linear settlements. Lots within structures were generally intended as small gardens for seasonal food harvesting. When the Flood Control Act of 1936 authorised the Kinzua dam, the Seneca tribe opposed the construction and reclaimed sovereignty over their land under the 1794 Pickering Treaty. The beginning of World War II caused the Army Corps to lose interest in the project, but in 1957, President Eisenhower and J.S. Bragdon (the Director of Public Works Planning) persuaded Congress to allocate, in the Omnibus Public Works Bill of June, one million dollars to begin the construction of the Kinzua Dam (Hauptman 1986a, b). In the same year, the Seneca people renewed their opposition to the government's decision and presented to the Corps an alternative plan designed by Arthur Morgan. Morgan was the first chairman of the Tennessee Valley Authority project (1933–1938) and an influential drainage-control engineer. His plan, during excessive river runoff, would have conveyed the Allegheny into Lake Erie through a diversion channel (Purcell 1997). The project would have cost $30 million less than the Kinzua Dam, saved the Allegheny Native lands, and offered comprehensive flood protection for the valley. When a further dispute between Morgan and the Corps arose, the Senecas reached an agreement with the engineers to ask an independent civil engineering firm to compare the two alternatives. In April 1958, the Tippetts-Abbet engineers completed their study supporting the Army Corps' alternative. According to the study, Morgan's plan would have displaced 150–180 more (non-Senecas) people than the Kinzua, the extra water storage capacity of the Conewango reservoir would have been unnecessary, and its costs would not be economically viable. Morgan's and the Senecas' struggle against the project of the Corps continued for two years through public letters, statements, petitions, and legal battles. In May 1960, the House of Representatives passed a bill for $4.5 million for the Kinzua Dam, and construction began in September of that year. In August 1964, Congress passed a law providing $15 million in compensation to the Seneca for direct or indirect damages, community rehabilitation, and legal fees (Rosier 1995). In the same year, a long-lasting tragedy began for the Seneca: between 1964 and 1966, the inhabitants of the communities of Red House, Shongo, Jimersontown, Cold

Spring, Steamburg, and Onoville had to abandon their houses to move to relocation sites in the suburbs around Salamanca, New York (Fig. 5).

After the construction site of Kinzua Dam, the Seneca experienced a substantial modification of their lands. This occurred because of the formation of the man-made lake and a series of challenges they faced. According to several historians and anthropologists, the Kinzua caused the Seneca to build, for the first time, a strong tribal bureaucracy to reclaim legitimate independence from the government (Bilharz 1988). Until that time, Native tribes were never able to sustain the economic activities of their communities and frequently accepted federal grants to maintain their status. When the dam was constructed, the Seneca initiated a *self-care* program which had strong effects on the economic and spatial development of the Allegheny Reservation. In the last 40 years, tax-free gas stations, smoke shops, one-stop convenience stores, tribal bingo halls, and a casino have been built on the ancestral land to support the economic development of the tribe (Hauptman 2014).

Initially, the Kinzua Dam was for flood control, but in 1965, the Pennsylvania Electric Corporation and the Cleveland Electric Illuminating Company were allowed by the Federal Power Commission to build and license, for 50 years, a hydropower facility. A few years later, the dam was completed, and an additional pumped storage pond – named after the Senecas – was built with an annexed power plant. Since 1969, it has produced 400,000 watts of energy per hour, yielding an estimated (in 1970) profit of $ 13 million per year (Hauptman 2014). In 2011, the license of the Seneca Pumped Storage Generating System needed to be renovated. The FirstEnergy colossus – which in the meanwhile acquired the two former companies – offers the concession for sale. The Senecas applied for the license to be annexed, for the next fifty years, to their own power company (the Seneca Energy LLC) in the name of the suffered ‘historical injustice’ [4]. LS Power of New York eventually acquired the license for the facility in 2013 (FERC 2015).

The Allegheny Reservation. This map shows the relationship between the flooded land and the contemporary boundaries of the Allegheny Reservation in New York. The red area corresponds to the actual reservoir shoreline perimeter, and the pink area corresponds to the planned limits within which controlled floods would occur during specific exceptional runoff events. The black boxes mark the locations of removed, burnt, or flooded houses of the former settlement. The original map, produced by the US Geological Survey in 1962, shows the main streets and buildings of Salamanca, NY. The town stands within the Reservation’s boundaries. In the 1850s, because of the construction of the railway, workers began to establish homes on the Seneca people’s lands. Although this settlement was originally intended to be temporary, it became a stable small town. Today, the 5,500 descendants of the former newcomers pay annual rent to the Seneca Tribe for occupying part of the land. After the construction of Interstate 86 – which crosses 20 miles of the tribal land – part of the Reservation was transformed by many indigenous families to pursue commercial opportunities. Since the 1990s, several smoke shops, gasoline stations and gaming facilities (including the casino) have been built near the highway exit.

[4] From the remarks of President Robert Odawi Porter announcing the Seneca Nation’s application to acquire the Seneca Pumped Storage Facility license, November 30, 2010.

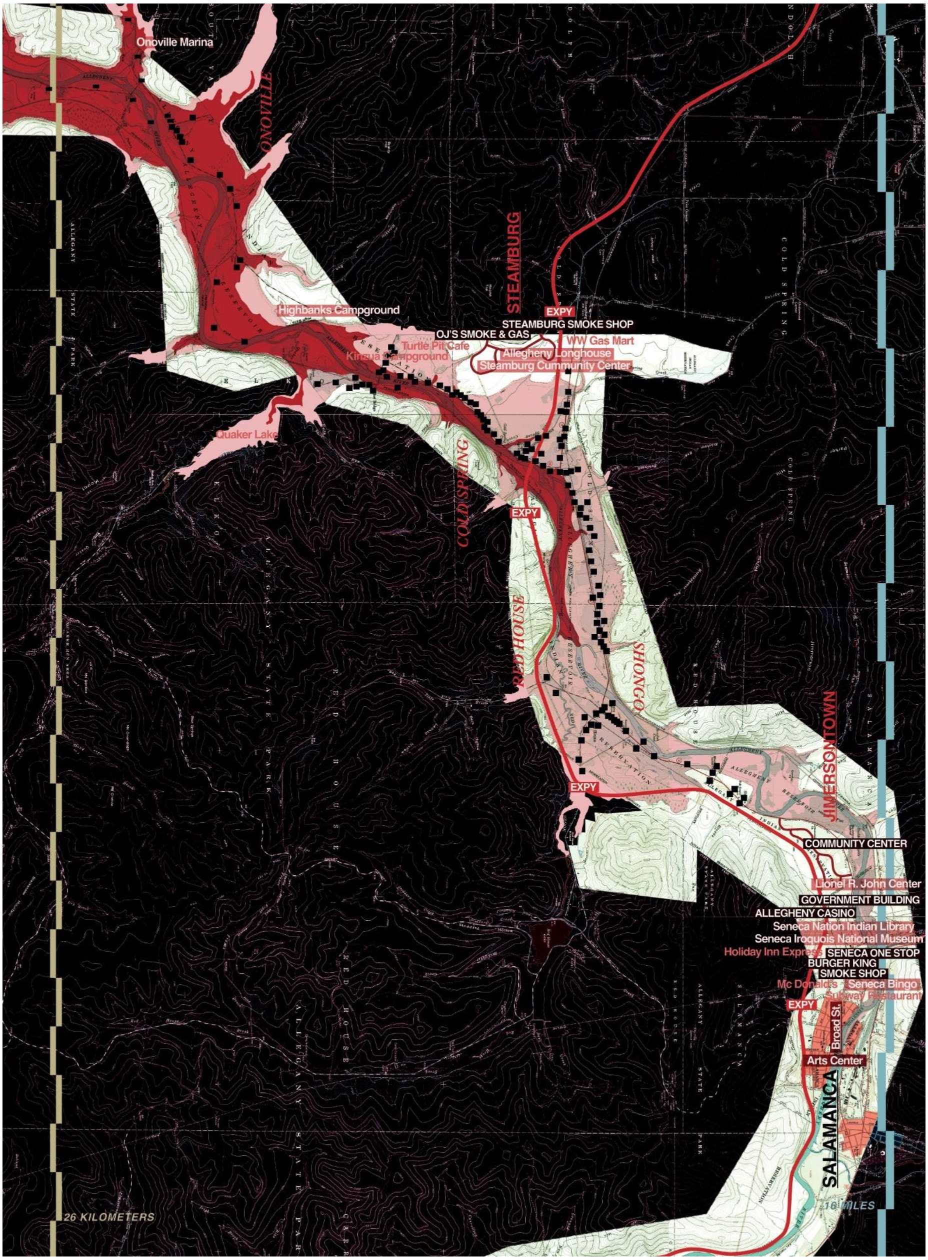

Fig. 5 Maps elaborated by the author, 2019. Data: USGS Historical File Topographic Division 1962, historical topographic maps of the US Geological Survey, ngmdb.usgs.gov; Seneca Nation of Indians GIS Department 2019, gisportal.sni.org; survey of the author, 2017

Dams are fragile

History shows that the construction of water infrastructure in the US has been complex and multifaceted – an intersection of ideology and technology which has supported the construction of a national identity and a modern welfare state. The built environment along the Klamath and Allegheny Rivers transformed marginal territories into inhabited and productive places, demonstrating how technological, urban, social, and natural concepts translate into strongly connected cultural values and practises. Dams have disrupted the natural flow of rivers and flooded ancestral lands in the name of progress pursued to provide social benefits. In summary, infrastructure works are not independent of the environment, places, or people. Today, social groups along the Klamath and Allegheny Rivers fight over the benefits the rivers offer. Native tribes and environmentalist groups support the ecological restoration of the rivers and the demolition of the dams to restore the original natural landscape appropriated by other social groups during the modern socio-technical processes of dam construction. The Seneca people are interested in using the monetary benefits of the power plant annexed to the Kinzua Dam to support the socio-economic growth of their community within the reservation. These social groups claim different portions of the river system because they have, directly or indirectly, created different parts of it. Dams, canals, pumps, power plants, hatcheries, ranches, farms, flooded ancestral lands, tourist sites, and villages are all parts of a river; they are integral components of its functioning.

Meticulous study and documentation of the history and industrial modification of river basins by dam construction have been fundamental in explaining and contextualising why rivers have been disassembled and reassembled. For a century, several actors have, in theory and practice, transformed natural resources into water infrastructure that spreads out as a technological network embedded in the land and the social groups living on it. Because of the multitude of agents that constitute the water infrastructure, it is concluded that dams are unusually fragile. Dams must accommodate the needs of water demand centres and the environmental crises of the areas where they have been built. Dam removal on the Klamath River, supported by scientific evidence and called for by indigenous groups and environmentalists, seems to be the immediate solution to the problem, as in many other cases in the US. However, the ecological processes of dam removal are neither technically nor socially neutral. Environmental restoration is a process of discharge operations, demolishing phases, drainage, dredging, plantation activities, and monitoring, all of which are technical and environmental changes that co-determine each other. Dam removal, like dam construction, can undermine the stability of certain social groups and places and improve the sustainability and growth of others, which raises questions about the geometries of power and fundamentally with politics. In the face of the environmental externalities that dams create, it is crucial to reflect on our dependence on the services they provide. A clear and decisive political vision is needed to weigh the social, technological, and economic issues involved in whether to demolish or maintain specific dams.

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