Hydropower System of the Ural Factory City as a Unique Object of Industrial Heritage

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Abstract. The authors focus on the economic, sociocultural significance, and impact on the urban planning of dams and ponds created in the Ural factory cities in the 18-nineteenth centuries. The article provides the data on dams' construction and their technical and design features. A number of hydroenergetic systems created in the 18–nineteenth centuries at the territory of modern Greater Ekaterinburg are presented: the dams and ponds in Ekaterinburg proper and its districts (former Nizhne-Isetski and Verkh-Isetski ironworks); the dams and ponds in Polevskoy, Revda, and Mariinsk. Their distinctive features are shown in comparison with dams of the seventeenth century in other regions of Russia, and updated quantitative data on these objects are given. The authors use a multicomponent model for the analysis (a dam from the architectural, urban, economic, sociocultural points of view), which contributes to better comprehension of the changing role of dams and ponds in the structure of industrial settlements and outline reasonable ways for their revalorization.

Keywords: Factory city · Dam · Pond · Ironworks · System-structural analysis · Historical landscape · Industrial heritage · Architectural and urban heritage

1 Introduction

Relevance of the topic and problem statement. Modern man does not always realize that large hydrotechnical structures of the 18–nineteenth centuries in the industrial Urals—dams and ponds—radically changed the original landscape (while, in fact, "growing" out of it) and became an integral part of not only factories, but also the cities of the region as a whole. The systemic nature of the creation of objects and the flexibility of implementing the initial matrix of small industrial settlements allowed the Urals to become by the end of the eighteenth century the leading metallurgical center of Russia and the world. It is in this vein, taking into account the diverse economic use, on the one hand, and understanding the initial connection of housing with water as the main energy resource of its time on the other hand, we propose to comprehend it, speaking of the historical and architectural heritage, including the reconstruction of its objects, first of all, dams.

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In purely architectural terms, we rely on an extensive (but still not complete) pool of historical data. The engineering and technical features of the Ural dams are reflected in the fundamental works by Gennin [1], Danilevsky [2], Kozlov [3], Artobolevsky and Blagonravov [4], Chugaev [5] and Shterenlicht [6]. Their architecture has been thoroughly studied by Barabanov [7, 8], and recently, in combination with historical and archival materials, by Korepanov [9, 10]. From their works it follows that in the Urals in the eighteenth–nineteenth centuries, classical examples of hydrotechnical structures were created that impacted spatial organization of settlements. Many of these works were completed quite a long time ago, and their materials need to be included in a new context, primarily due to a change in the paradigm of working with heritage. Today, it is moving from purely conservation to issues of rehabilitation, revalorization, inclusion in educational, economic, touristic and other activities.

Hence, the task of the work is to present large hydraulic structures—factory dams—in the unity of the architectural, technical and urban planning component, taking into account the processes of transformation of cities in the eighteenth–twenty-first centuries.

Work methodology. The most productive for this work is the synthesis of two concepts—the "second modernity" of U. Beck and the topological approach. The concept of "second modernity" that appeared at the end of the twentieth century proves the possibility of rethinking industrial objects in new sociocultural and economic conditions. The authors usually explore this stage itself, which is distinguished by globalization processes, while we emphasize the "reflexivity" of the "second modernity", which U. Beck writes about. This is a time of reassessment of everything that was created in the industrial period. Within the framework of our work, this means that the dam is no longer considered in isolation from the space and era in which it was created; we can see its city-forming and cultural significance, which is important for an architectural object (Fig. 1).

Topology, which is becoming more and more widespread (A. P. Obedkov, L. V. Polubichenko, F. S. Korandey, etc.), is a method of identifying a constant, stable and relatively unchanged, "what characterizes a particular object, despite the presence of certain variables parameters, and ensures its relative identity to itself at different stages of development in time and space" [11], as well as in the specific meaning of the relationship of the object (or its various elements) to space, place and structure. To study the history of individual territories of an industrial settlement born by a pond, this approach is productive in that it makes it possible to analyze the space systematically. In other words, a pond and a dam associated with it, becoming part of a natural, carefully chosen landscape, are the constants of the place and, at the same time, the natural limits of all its subsequent physical and functional changes.

2 Results

Consideration of the dams of Ekaterinburg and its immediate surroundings, created in the eighteenth century, shows their specific regional differences, primarily due to the peculiarity of the economic use of the water wheel energy in a particular area. It is shown that the structure of the Ural dam is determined by its location on the terrain

Fig. 1 View of the historical square and the dam. Ekaterinburg. *Photo* by E. Alekseeva. 2021

and the tasks of regularly supplying the plant (with the features of its blast furnace and sawmill) with energy.

A comprehensive analysis of the construction processes of a dam, a factory, an industrial settlement in the Urals of the eighteenth century, based on a topological approach, reveals their additional connectivity—with a decisive influence of the structure, size, location of the dam on the rest of the elements and levels of Ekaterinburg as a system, starting with the location of "factories" (workshops) of the plant in the center of the settlement and along the river at the point of its exit from the dam, and ending with larger urban planning solutions. This determines the uniqueness of the Ural dams as objects of historical-architectural and historical-cultural heritage (Fig. 2).

Fig. 2 **a** Production buildings at Plotinka before the start of work on the creation of the historical square. Sverdlovsk. Early 1970s GASO (State archives of the Sverdlovsk region). F-1. Op. 6. D. 6376; **b** Dam before reconstruction. Sverdlovsk. Early 1970s GASO. F-1. Op. 6. D. 6388

The study of the Ural dams in the unity of architectural and urban planning aspects shows their connection with all other city processes of the eighteenth–twenty-first centuries, in particular, the change in their significance within the settlement from purely economic to sociocultural. Changing externally and functionally, the dams have remained key locations of industrial Ekaterinburg and satellite towns for three centuries already.

The refined parameters of a number of dams of the eighteenth century located in Ekaterinburg and its environs are given. In particular, the dimensions and specifics of the creation of dams at the Isetsky, Verkh-Isetsky, Nizhne-Isetsky plants in Ekaterinburg, dams in Polevskoy, Revda and Mariinsk are indicated.

3 Discussion

3.1 The Dam Gives Birth to a Settlement

The stability and efficiency of the mining industry functioning in the eighteenth century, the rhythm of its activities were determined not only by mining reserves and factory capacities, but also by the reliability, stability of the operation and the potential of its hydropower system. The system of water and energy resources of the factory cities in the eighteenth century Urals predetermined the planning structure of factory settlements, influencing the formation of a specific identity of the place, which makes it possible to consider it as a complex architectural and town-planning object of industrial heritage.

Analyzing the water and energy heritage of Ekaterinburg, a quite typical industrial settlement of that period, which was part of a rationally equipped and rather dense settlement system, we should primarily consider that the plant would not exist without a dam. The entire subsequent town-planning structure depended on its location on the river, the features of the relief. As a point of connection between the given natural environment and technical and technological processes in the age of the water wheel, the dam set the volume of factory production, the orientation of the settlement and the direction of the streets, always regularly organized according to the town planning guidelines of the Enlightenment.

The first water-operating enterprises appeared in Russia in 1620–30s—Nitsynsky ironworks (1631) and Pyskorsky ironworks (1633) [2]. According to the reconstruction of the Porotovsky ironworks of the seventeenth century, carried out by N. B. Baklanov, the settlement next to such plants was not designed as a regular one and occupied one bank of the river next to the dam. Both the dam itself and the settlement differ from those that arose in the Urals in the eighteenth century. The dams of the European part of Russia, for example, the Verkhnetsninskaya dam in Vyshny Volochek (1703), which were created almost simultaneously with the Urals, were wooden two-span (beishlots) with wooden lockshields. The dam served purely hydrotechnical purposes—maintaining the water level in the canal between Tvertsa and Tsna, so it is not tied to residential areas.

On the territory of the industrial Urals, a characteristic canon for the construction of mining settlements has developed around their key elements—a dam, in the downstream of which there was a plant with mechanisms driven by water, and a pond where water was concentrated. The presence of the required amount of water in the pond and the rhythm of its supply to water wheels or turbines completely predetermined the seasonal and monthly efficiency of factories of any profile. On the contrary, insufficient water

supply led to long shutdowns and significant downturns in the activities of enterprises. For example, the insufficient supply of water resources to the metallurgical Nizhne- and Verkhne-Uktussky plants caused their uneven work and by 1750 led to the closure [12].

3.2 Technical and Technological Features of the Ural Dams

For all its "invisibility" for a modern person, the dam is a cluster of construction and landscape engineering technologies, and over time, a certain part of the urban planning ensemble is formed on it, which will be discussed separately. The architectural value of dams must be taken into account in restoration work, since they are an essential element in the development of technological progress and constitute a capital heritage of great originality, which must be preserved.

The hydrotechnical complexes of the Ural factories assumed the construction of water reservoirs with a desirable uniform distribution of water energy throughout the year with the necessary safety measures during critical periods of spring floods [13]. The hydraulic structures of ironworks in Germany, France and Sweden that existed at the time of V. de Gennin's arrival in the Urals in 1722 used, as a rule, the bottom shot wheels which were here inappropriate due to the harsh Ural winters and often freezing of shallow rivers.

The size and dimensions of the Ural dams—for example with a crest width of up to 30–40 m [14]—were aimed to completely exclude the possibility of the dam's break. In order to avoid seepage of water through the body of the dam and its destruction due to floods, the earthen dam was made solid right at the time of the construction, and then it was constantly strengthened, by dumping production waste on the crest and slopes. Builders led by dam master Leonty Zlobin relied on this approach during the construction of a short, but wide and high dam on the Iset river—in contrast to the long and low European dams of the seventeenth century—with a large and fairly deep pond, and in the dam itself with a large main slot for discharging the main water drain and two parallel side conduits for supplying water to chests with water wheels to drive factory mechanisms.

The place of the future dam was marked with stakes, a ditch was dug along its entire length, reaching solid layers of soil. The edge of the moat on the side facing the pond was reinforced with two or three rows of piles. Between them lay a lattice of logs. The gaps between the bars were filled with clay. The holes for the slots were enclosed with quadrangular wooden log cabins, which were also filled with clay ("pigs"). Since the 1740s the lower part of the dam was often reinforced with a vertical frame. The back wall of the moat was strengthened with bundles of brushwood with turf [7]. At the same time, the bottom of the future pond was being cleared from the forest. The earthen embankment towards the pond was made as sloping as possible, from a third to half the width of the entire dam. Later, slag, a waste from metallurgical production, could be used as a reinforcing addition.

The main working element of the entire dam structure were water conduits, i.e. a piping system that carried water from a pond to the wheels of factory machinery. The conduit system included chest wells—hollow wooden log cabins connected by pipes to the chest, a kind of intermediate reservoirs to increase water pressure.

The diameter of wooden factory wheels at the Ural water driven ironworks averaged 3.6 m. Later, the iron wheels of the nineteenth century had a diameter of up to 2 m. In order to avoid freezing of the wheels in winter due to the weak pressure of water and the difference in its level in the chest, the latter at the Ekaterinburg plant fundamentally differed from the chests of the seventeenth century not only by the absence of an inclination, but also by the greater depth of the chest with a constant cross section throughout its length and in the branches to the factories. Moreover, since the late 1730s chests that were previously open from above began to be closed from above and rounded, so that in the middle of the eighteenth century, almost round "pipes" were already leading from the chests to the wheels, and the closed sections of the chests were additionally upholstered with iron to be able to heat them with fires during frosts. As a result, in the XIX century chests almost everywhere in the Urals acquired a round or oval cross-section, were made of metal, and were much larger than the former wooden ones. Optimum water pressure in them was achieved by placing a chest window and regulating the level of the pond through the spillway, and additionally in the chest itself, where it was regulated by a system of mechanical pistons installed in the slot directly behind the window entering the chest and further at the joints along its entire length. The chest bottom was arranged parallel to the water horizon in the river, and the chest itself was located as low as possible, which gave more energy to the water, and together with the chest wells, hollow wooden log cabins made it possible to regulate the water pressure and change the water flow to the desired direction. The higher the trough of the chest was attached above the wheels, the greater the energy of the falling water from them could be transferred to the wheels, rotate them faster and provide more mechanisms with proper energy [15].

The logic of the water wheel also dictated the layout of the plant and its "factories" (workshops). So, the blast furnace factory was built in the immediate vicinity of the dam and was technically connected with it. Ore and coal were brought along the top of the blast furnace. Near the dam, but at a safe distance from the blast furnace, a sawmill was built. Workshops that did not need the power of a water engine were located further from the dam.

The thoughtfulness and experimentally verified pragmatics of the construction of dams and the operation of their mechanisms is evidenced by the fact that the methods of their construction indicated by V. de Gennin in the "Description of the Ural and Siberian Plants", which he called the "fundamental doctrine", existed for earthen mill dams and small ponds until the beginning of the twentieth century [15].

3.3 Architectural Elements of the Ural Dams

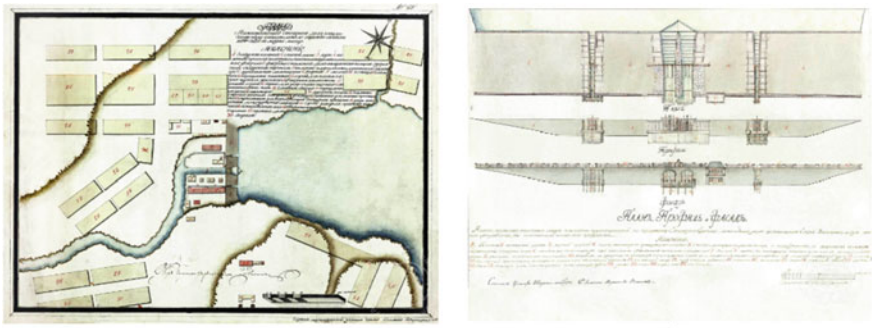
The materials on them are scarce. But those that exist show that the dam was conceived as an integral structure, not only in the physical, but also in the aesthetic sense.

The Verkh-Isetsky plant, including the dam, constituted a single architectural ensemble in the style of classicism. The connection between the topography of the place and architecture is evidenced by the solution of the factory office, which had multi-storey facades due to the level difference between the dam and the factory site. The main facade was one- and two-storey, and those facing the entrance from Ekaterinburg—two- and three-storey (Fig. 3).

a b

Fig. 3 **a** The dam of the Verkh-Isetsky Pond in its current state. Architect K. Gordeev. *Photo* by V. Litovski. 2021; Model of the old office of the Verkh-Isetsky plant. Architect M. P. Malakhov. 1820s–1830s. Ekaterinburg, 28, Kirova st Fund "Drugoi Mir". *Photo* by E. Alekseeva. 2021

Nizhne-Isetskaya dam [16], originally built on the Iset in the 1780s with production buildings of the local branch of the Ekaterinburg Mint, had a width of about 5 m at the base and about 2.5 m on the crest, with a length of 16 m and a height of more than 6 m [17]. It had one spillway and two chest slots (Fig. 4). A guardhouse was built into the body of the dam between the spillway and the left chest slot. The construction of such a structure was carried out for one season [10].

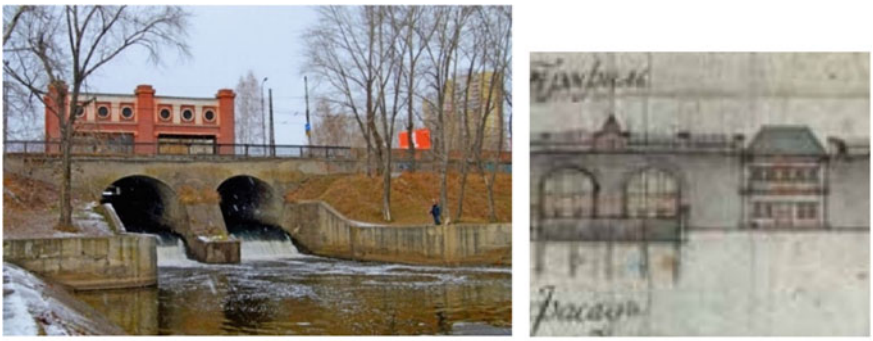


a b

Fig. 4 **a** Plan of the Nizhne-Isetsky plant. 1807 *Source* https://xn--80aaebf3an9auge0i.xn--p1ai/german_2 **b** Nizhne-Isetskaya dam in the 1800s *Source* https://xn--80aaebf3an9auge0i.xn--p1ai/german_2

The Nizhne-Isetskaya dam shows that any architectural elements of dams are made in the style of the time, with all the seriousness of the then approach to architectural design. These are neat and devoid of decoration objects, built into the body of the dam and not violating the overall rational harmony. For example, the dam of the Nizhne-Isetsky plant in Ekaterinburg, built in the 1800s, includes a two-storey guard building, the shape of which refers to the military architecture of the Petrine era. It is a simple, neat rectangular volume with a symmetrical façade and a high hipped roof (Fig. 5b). Its

proportions were continued in 1804 by the Nizhne-Isetsky steel factory, located nearby, forming a recognizable industrial ensemble.



a b

Fig. 5 **a** Nizhne-Isetskaya dam. Ekaterinburg. Modern look. Photo. *Source* The first bulb of Nizhneisetsk. Museum of Energy of the Urals. URL: http://musen.ru/chronicle/1921/; **b** "Profile plan and facade of the Nizhne-Isetsky state-owned plant to the dam, rebuilt according to the design of the Ekaterinburg Mint by the foreman Egor Usoltsev". GASO. F. 25. Op. 2. D. 7927. *Source* 14, p. 11. Fragment

Later, the dams in Ekaterinburg and other Ural settlements are landscaped, improved, turning into a kind of a promenade.

3.4 Genesis and Development of Hydraulic Structures of Ironworks in Ekaterinburg

On March 12, 1723, the Ekaterinburg fortress with a rampart, a moat and a bastion was laid, and after that, in April, under the leadership of the dam master L. S. Zlobin, the construction of a factory dam began.

Dam and pond of the Ekaterinburg plant. The hydropower base of the plant consisted of a pond and a dam 211.1 m long, 42.7 m wide, 6.4 m high, with a spillway and two working slots, later the dam was filled up and lined with rubble stone. The technologies for erecting a dam in Ekaterinburg have been studied in detail by historians and architects: "The dam was constructed from larch, which became stonelike in the water, log grating was clogged with clay. English cloth was laid between the rows of larches in a log grating. The clay in the log grating had to be tamped" [18]. In the middle of the dam there was a spillway, to the right and left of which there were chest slots through which water was supplied to the water wheels that set the factory mechanisms in motion. At the same time, the conduits had locks, which, opening, let water through. The channels were covered with stone vaults. After backfilling and leveling the surface in the southern part of the dam, a road was made connecting the banks of the Iset river. In the northern part lay wooden shields on which pedestrians walked. Here, the connections between the purely technical, construction characteristics of the dam with urban planning and, further, sociocultural ones are clearly visible. Not only production, but also the city is

organized thanks to the presence of a dam, and until now the main streets of most of the Ural city-factories cross the pond along this line [19]. The dam and pond powered the production system of the ironworks.

Ekaterinburg became a model for most other places here. Factories of the Ural ironworks were built along the river, perpendicular to the dam, they towered over the residential buildings surrounding them, becoming a kind of spatial dominants [20].

One of the most interesting points that should be remembered in today's protection actions is the improvement of dams in the nineteenth–twentieth centuries: as their economic function was lost, their sociocultural function came to the fore, because they were in the center of any industrial settlement in the Urals. So, in 1886, due to the Siberian-Ural Scientific and Industrial Exhibition of 1887, important for the city, in Ekaterinburg, on the upstream of the city dam in its northern part, a square with an area of half a hectare was laid out. From the time of the factory fortress the dam was the starting planning structure, the main road, but earlier it was not equipped with vegetation. Dmitry Ivanovich Lobanov (1852–1916), an employee of the railway and a member of the Ural Society of Natural Science Amateurs (UOLE), played the main role in the implementation of the idea. The square had a free layout with islands of lawns, groups of trees and shrubs, and flower beds. The forms of the dam slots were played up in the final version of the organized space, dividing it into four sections. Bronze busts of Emperor Peter I and Empress Catherine II were also installed there. The square was separated from the roadway by a metal fence along which a hedge was planted. In the warm season, the place was buried in greenery.

By the middle of the twentieth century, the layout of the square began to change towards a regular one. The total area has grown slightly due to the fact that the spillways of the dam were hidden. The lawns were enlarged, and small semi-circular areas were laid out next to the entrances to the square. In close proximity to the pond there was a through path. The trees have almost disappeared, replaced by shrubs. In 1958, a bust of P. P. Bazhov (sculptor M. G. Manizer, architects B. E. Rogozhin, A. P. Velikanov) with stone benches around was installed in the center of the square on the dam. In 1987, a bronze bust of D. N. Mamin-Sibiryak (sculptor A. Antonov) was installed nearby. During the reconstruction of 1962–73 the dam was expanded, lined with granite, and a through passage was made from the side spillway. In the 2000s the territory of the square has lost a significant part of the vegetation, becoming a transit pedestrian zone.

Verkh-Isetskaya dam and pond. Since the dry summer of 1724 showed that the water reserves in the pond of the Ekaterinburg plant were not enough for full-fledged work, it was decided to build an additional dam upstream of the Iset. The dam of the Verkh-Isetsky plant, more than 300 m long, was built in 1725–1726, as a result of which the Verkh-Isetsky pond was formed, five times larger than the pond of the Ekaterinburg plant. The general management of the project was carried out by V. de Gennin, and the construction was directly supervised by Konstantin Gordeev, Larion Pozharov, Danila Borsky, Ivan Melentiev and Leonty Zlobin. The dam was built by the peasants of the settlements assigned to Ekaterinburg—Aramilskaya, Kamyshlovskaya, Kamenskaya, Okunevskaya, as well as regiments from Tobolsk.

The dam is elongated in the meridional direction, forming one of the main compositional and planning axes of the development of the plant and the vicinities, as well as

the western border of the territory of the historical ensemble. Now it is a dam, dissected by new locks for the discharge of spring waters. Structurally, it was made in the form of wooden cages, clogged with selected clay and stone. The dimensions of the dam are: length 320 m, minimum width is 50 m, and height is 5–7 m. Undoubtedly, at present the dam is of historical and architectural value as a genuine element of the plant's hydraulic engineering system, preserving its historical city-forming significance. In terms of identified and recognized cultural and industrial heritage, today this is the only enterprise founded in the eighteenth century that has survived. There are old production buildings, a factory dam, an office, which requires not only the preservation of their special historical and cultural status, but also tactful updating and refunctionalization.

3.5 Dams and Ponds in Polevskoy

Decree on the construction of the dam of the Upper Pond of the Polevskoy plant on the river Polevaya was signed by Peter I in January 1722. It was erected in 1724, now becoming a monument of engineering art of that time and the "heart" of Polevskoy (Fig. 6). Water not only powered the Polevskoy plant, but also fed below the Shtangovy pond, and partly, together with the river Severushka, the Seversky pond. Below the Upper pond, at the confluence of the Polevaya river with Severushka, another dam was built in 1738, at which the Seversky pond with an area of 2.4 km^2 and an ironworks were formed.

Fig. 6 The dam of the Seversky plant. Polevskoy. *Photo* by V. Litovski. 2022

Now the eastern bank of the dam is reinforced by a bulk dam for 1.5 km, and the pond itself stretches for 8 km, reaching a width of 500 m. In the southern part of the pond, along the flooded floodplain of the Polevaya river was formed by a large arm, regulated above by the Shtangovy pond. The height of the water level in the Shtangovy Pond is 350 m, and in the Seversky pond—339 m.

Nevertheless, in the hydrocascade, the dominant is not the Upper pond with a water level of 365 m above sea level, but the Glubochensky pond, with a water surface in the reservoir of 412 m. Elongated from west to east, it is formed by an embankment dam 800 m long, more than 30 m wide at the base and up to 25 m high, has two small bays formed by the main river Glubokaya and the small river Kamenushka. In general, the length of the Glubochensky pond is 2.1 km, the width in the middle part is from 450 to 800 m, the average depth varies in the range of 5–7 m, and the maximum (near the dam on the site of the old channel of the Glubokaya river) reaches 23 m with a total area reservoir in 1.28 km^2. From this it follows that the volume of water concentrated in it varies from 6.4 to 9 million m^3, and the mass—from 6.4 to 9 million tons.

Polevskoy with its Gumeshevsky deposit and the function of supplying copper raw materials to the Isetsky plant is the place where a unique engineering and technical system of regulating ponds was created from the Glubochensky pond to the Seversky pond (1876–1887). The author of the project of the Glubochensky pond and canal was Fedor Alekseevich Khvoshchinsky [21], who from 1837 to 1853 served as the chief manager of the Sysert plants. The uniqueness of the canal is that it has not only a bed laid on the surface more than 4 km long to the Svetlaya river, but also an artificial underground tunnel 1,780 m long. Its construction was led by the plant owner D. P. Solomirsky and the merchant A. S. Vyatkin.

3.6 Dams and Ponds in Revda

On the Revda river, the dam—also under the leadership of Leonty Zlobin—began to be erected in May 1732 by order of Akinfiy Demidov. Its length was about 160 m, height—8.5 m, and the width of the base—57.5 m. At the base of each of the dikes, a "tooth" was cut—larch wells measuring 2 × 2 and 3 × 3 m. They were clogged with rammed clay. These "teeth" protected the dikes from erosion. The bed of the Revda river was blocked with stones and clay between the mountains … The stream was diverted closer to the right bank. A pond with an area of 800 hectares was formed … at the plant, water turned 33 wheels, each with a diameter of about 4 m, a width of about 2 m. In the spring of 1733, the Revda river showed its temper, and the newly built dam was demolished" [22]. Below, three more dams were formed, which created a water reserve for two auxiliary plants—Sharaminsky and Baranovsky (Fig. 7).

In 1964, the old Revda dam was reconstructed, the wooden spillway system was replaced with a reinforced concrete one (Fig. 8a). "Before backfilling the old spillways, two beams with a section of 600 × 600 mm were removed from their base, stacked one on top of the other. Between them a green cloth pad was found. Larch and cloth, which had lain in the water for 230 years, were like new. The spillway from the new dam started in 1965. The size of the dam: length–70 m, height–8 m" [21].

a b

Fig. 7 **a** Fragments of spiles driven into the base of the dam's log grating. From the exposition of the museum "Ural antiquity" in Revda. *Photo* by E. Alekseeva. 2022; **b** Water intake complex at the dam of the Sysert pond. Sysert. *Photo* by V. Litovski. 2022

a b

Fig. 8 **a** The Revda dam. Modern look. *Photo* by E. Alekseeva. 2022; **b** Wooden dam of the Mariinsky ironworks. The village of Mariinsk. *Photo* by E. Alekseeva. 2022

3.7 The Dam of the Mariinsky Ironworks

In 1840, on the Revda river, 25 km from the main Revdinsky plant, an auxiliary Mariinsky ironworks was founded. It specialized in the production of strip, section, sheet and roofing iron and was closed during the Civil War. In the village of Mariinsk, an old wooden dam is still preserved (albeit partially destroyed) (Fig. 8b). The factory dam with a release slot for 6 locks had a length of about 320 m, and full height of water was 7.3 m. However,

there was still not always enough water in the factory pond, so the factory often worked only 7–8 months a year. At the heart of the dam is a ribbed structure made of larch, filled with earth and clay. The slope is lined with rubble stone. On the left side of the dam, one more spillway is visible—a working one. It is partially covered with wooden structures sticking out there. It was through him that water entered the plant and set its mechanisms in motion. The buildings of the Mariinsky ironworks stood below the dam. They were wooden, by now nothing remains of them. But near the dam there is a lot of slag. From 1945 until the 1950s, a hydroelectric power station operated on the dam of the Mariinsky pond, supplying the village with electricity [23].

Thus, the experience of building dams in Ekaterinburg and nearby industrial settlements was deeply successive: following the dams of the Uktussky, and then the Isetsky plant, it diffused during the creation of a dam at the Verkh-Isetsky, Polevskoy and other plants.

3.8 Historical and Architectural Significance of Dams in the Context of the History of the Ural Region

The industrial and cultural heritage of any Ural settlement that arose as a mining settlement or a factory city [20] can now be judged, first of all, by the preservation of its three main components: a pond, a dam and the structure of the settlement, which determines the historical development of the factory city. If the settlement also served as an outpost, then the degree of preservation of the heritage is also determined by the degree of preservation of the fortress or its elements. In this regard, the key cultural heritage of Ekaterinburg as a factory city (ironworks at the Plotinka) and as an outpost (fortress) have been lost. At the same time, if the fortress was lost in the process of expanding the city, then the plant, due to the "cultivation of the center"—the organization of the Historical Square—is irreplaceable, despite the best intentions, such as the development of the city in line with the concept of "garden city", the creation of recreational and cultural public spaces, etc.

The range of values of water in the process of development and the nature of the settlement system of the Urals is very wide, from purely economic to state-symbolic. Quite in the spirit of its time, able to "read" any iconological systems and loving allegories [24], the confluence of waters is interpreted as an increase in the power and strength of not only nature, but also power. By the nineteenth century, this value-semantic continuum was losing its integrity, making it possible to transform the original forms and often lose their integrity. So, in 1808, the retaining wall of the dam of the Verkh-Isetsky plant was lined with cut stone from the downstream side, which led to the loss of a wooden construction over the lifting mechanisms. With the construction of a new sluice and a building of locking mechanisms, the old water conduits were dismantled and the chest and spillways were filled in. Later, the plant's dam was reconstructed many times [25]. Ultimately, road and rail access roads are arranged on the surface of the dam. At present, the locks of its spillways have not been preserved, and the new one is made of reinforced concrete. The preserved retaining walls of the dam and canals lined with stone are of historical value.

Comprehending the architectural, urban planning and socio-cultural value of the ponds and dams of Ekaterinburg and its vicinities has a long history. Its completeness

and adequacy largely depend on museum representations. A large-scale and successful example of the representation of industrial, including hydraulic, heritage is the Severskaya blast furnace Museum Complex, which is based on a monument of urban planning and industrial architecture of the nineteenth century, an object of cultural heritage of federal significance in the city of Polevskoy. Together with the plant and the dam, it is one of the few industrial complexes of the middle of the nineteenth century that have been saved in such a high degree of preservation, not only in Russia, but also in Europe, giving a complete picture of the production metallurgical process, and the hydropower infrastructure of factory city of that time [26].

4 Conclusion

It is necessary to draw the attention of scientists and citizens to ponds and dams, if only because many people do not perceive them as an industrial heritage. Based on the idea of heritage revalorization [27], we can say that the very fact of designating a place plays a big role in attracting attention in this way.

The city-forming role of water and energy facilities and their unique function in shaping the settlement system of the mining Urals are obvious. This is largely due to the connection of the energy of the water wheel, later the hydro turbine, with production, on the one hand, and the layout of the city-factory, on the other. In turn, the totality of such connections sets the boundaries of the settlement and significantly affects the mentality of its inhabitants.

Speaking of industrial processes and objects of the eighteenth century, we cannot lose sight of their value-semantic aspects for contemporaries. In addition to the originality of building technologies and structures noted above, there was a specific symbiosis of pragmatic and symbolic principles that well characterize the era.

The transformation of the dams in the region under consideration in history has been repeatedly associated with capital work to increase, strengthen or change the structure. Decorative landscaping was also timed to coincide with image or anniversary events. The dams have come down to us in a significantly altered form, but at their base the original structural elements have been preserved—log cages filled with clay and lined with rubble on the outside, currently "chained" in concrete and granite shells.

The remains of the ancient dam of the Isetsky pond with fragments at the locations of spillways are part of the cultural heritage site of federal significance "Buildings and structures of the Ekaterininsky plant "Monetka" (Sverdlovsk region, Ekaterinburg, the central part of the city), and included in the unified state register of cultural heritage objects (monuments of history and culture) of the peoples of the Russian Federation.

It is difficult to overestimate the hydrotechnical, urban planning, infrastructure and cultural significance of the dam for Ekaterinburg and the surrounding cities. Its location set the direction of the main streets, the vectors of further development of settlements. The central highway always ran along the axis of the dam. Among the many dams that blocked the Iset and other rivers of Ekaterinburg in different places (Sukhaya, Olkhovka, Melkovka, Osnovinka) to ensure the operation of saw and flour mills, gold washing factories, the dam of the Ekaterinburg plant, of course, is of particular importance, especially since most of the old dams over time were dismantled, their ponds were

lowered, and the rivers themselves were covered up. In varying degrees of preservation in the urban environment, the remains of the log-earth dam of the Uktus plant, the Nizhne-Isetskaya and Verkhne-Isetskaya dams are represented.

Thus, the fundamental technological construction of metallurgical plants of the eighteenth century has been the main "backbone" of the settlements under study for three centuries, linking the banks of the rivers and symbolically connecting generations. The technological functions of dams in the nineteenth century came to naught. In the last quarter of the XIX century their role has increased as a part of urban improvement, a communicative, household, leisure component of urban everyday life, a road and transport artery. Throughout history, the town-planning and town-forming (holding the pond) functions of the dam continue to be preserved. At the same time, its utilitarian purpose is transformed into a symbolic, cultural, aesthetic, commemorative significance. As the functions of the dam changed—from production and hydropower to infrastructure and transport—in practice, the industrial heritage object was revalued.

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