


Article

Managing Water and Wastewater Services in Finland, 1860–2020 and Beyond

Tapio S. Katko ^{1,*} , Petri S. Juuti ¹, Riikka P. Juuti ¹ and Eric J. Nealer ²

¹ Capacity Development in Water and Environmental Services (CADWES) Research Team, Faculty of Built Environment, Tampere University, P.O. Box 600, 33014 Tampere, Finland; petri.juuti@tuni.fi (P.S.J.); riikka.juuti@tuni.fi (R.P.J.)

² Department of Public Administration and Management, College of Economic and Management Sciences, University of South Africa (UNISA), Pretoria 0003, South Africa; eric.nealer@gmail.com

* Correspondence: tapio.katko@tuni.fi

Abstract: Water and wastewater services are invaluable for communities. The aim of this article is to understand and explain the overall long-term development of water services in Finland in the wider PESTEL framework with policy implications for the future. The original megastudy was based on an extensive literature review. The article first covers the birth and development of urban and rural water systems in Finland. This is followed by analysing selected decisions with long-term impacts, institutional issues, discussion and lessons learnt, and conclusions. The development of water services in Finland has largely been based on trust. In socio-institutional factors, institutional diversity is fundamental. Gradual expansion of water supply and wastewater systems has brought technical, economic and social benefits in a country with quite a dispersed population. Efficient water pollution control in communities was implemented within two decades through developing technology and applying proper legislation and control. Continuous and dynamic development has been a key principle. Nature-based solutions include raw water source selection, treatment processes such as managed aquifer recharge, sites for final effluents disposal, and water related land use planning. Aging infrastructure is the most pressing future challenge in Finland and worldwide and will need new requirements and innovations.

Keywords: history; water supply; pollution control; management; governance; institutional diversity; futures



Citation: Katko, T.S.; Juuti, P.S.; Juuti, R.P.; Nealer, E.J. Managing Water and Wastewater Services in Finland, 1860–2020 and Beyond. *Earth* **2022**, *3*, 590–613. <https://doi.org/10.3390/earth3020035>

Academic Editor:
R. Thomas Fernandez

Received: 1 April 2022
Accepted: 26 April 2022
Published: 30 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

In Finland, a Nordic country, the people in human settlements survived using traditional water sources for centuries: wells, springs, and surface waters. Along with the growth of population and increase of population density, water became gradually scarce, and the environment started to show symptoms of deterioration. Thus, the need for municipal water supply and related sanitation, called “water services”, started to emerge. In this article, stormwater management, the third pillar of the urban water management, is excluded throughout.

After the quality of water from wells deteriorated and groundwater levels dropped, new ways of satisfying water needs had to be developed. In Finland, the risk of city fires in particular speeded up the birth of public water supply in the nineteenth century. At that time, people still believed in the so-called miasma theory, according to which humidity and dirty air would spread diseases. Yet, this belief for its part also facilitated the introduction of sewerage [1].

Somewhat similar developments and questions can still be seen in developing economies: how to organize and develop water and sanitation services for billions of people lacking potable water and safe sanitation. In this context, historical experiences can be useful, although not necessarily directly applicable to other conditions. Already at the dawn of

the International Drinking Water Supply and Sanitation Decade (1981–1990), Pacey, 1977, pointed out that “technology alone is not enough” [2].

In 2020, one fourth of the global population lacked safely managed drinking water in their homes and nearly a half lacked safely managed sanitation. At the start of the COVID-19 pandemic, approximately thirty percent of people worldwide could not wash their hands with soap and water within their homes [3]. According to McDonald et al., 2011, up to two thirds of mankind will suffer from chronic water scarcity and/or polluted water by 2050 if proper improvements are not made [4].

In 2016, The World Economic Forum (2016) ranked the water crisis as the highest global risk to economies over the next ten years [5]. The largest human health/mortality risk comes from inadequate water supply and sanitation. This is due to inadequate institutions and infrastructure that are unable to provide potable water and safe sanitation [6]. Yet, this is effectively a man-made hazard. Lack of good governance is also related to this [7]. In fact, international discussions on water policy development and the principles of sustainable water and sanitation services (e.g., [8] (pp. 4, 30)) clearly imply that many of the problems related to water services are of institutional nature—even though they often lead to technological failures.

While water and sanitation is one of 17 Sustainable Development Goals agreed upon by the United Nations, water is also a connector of many sectors, and without proper water management most of the other goals will not be met [9] (pp. 1–17).

A UNESCO-supported publication [10] noted that, due to floods, the number of deaths worldwide is approximately 25,000 per annum. Floods, together with other water-related disasters, cost the world economy approximately USD 50–60 billion per annum. Yet, due to the lack of safe Water Supply and Sanitation (WSS), several million people die every year from water-related diseases. In any case, the lack of WSS kills several hundreds of times more people than floods worldwide.

There is also a strong consensus that the majority of diarrhoeal disease burden is due to poor Water, Sanitation, and Health (WASH), which is an essential component in reducing undernutrition. Furthermore, clean water was considered as the most important medical breakthrough since 1840 by approximately 11,000 readers of the British Medical Journal in 2007 [11]. This indicates that sanitation and clean water are judged to be more important than advances in DNA research and vaccines. The International Law Association (2004) reminds us that water and wastewater services fulfil the “vital human needs” of communities and therefore play a fundamental role in societal and community development [12].

At the level of systems, risks, vulnerability, and, more recently, resilience have been focused on. Although there is a growing body of literature on water resources and climate change resilience and resilient urbanization, there seems to be far less literature on the resilience of water service systems and institutions. In any case, water and wastewater systems are one of the cornerstones of the built environment in any community, in everyday security, and are one of the most essential parts of the critical infrastructure of communities [13,14] and [15] (pp. 1–7).

As for resilience, Brown et al. distinguished three major elements: persistence, adaptability, and transformability [16]. While some experts refer to the conventional natural and medical science definition of resilience, “capacity to recover from shocks”, others have more recently pointed out the flexibility of change [17]. Juuti et al. [15] (p. 11), remind us that resilient water management should be based more on the use of accumulated local knowledge rather than top-down approaches.

The innovativeness of this study on the development of water services and systems in Finland is linked to persistent and dynamic development. Instead of striving for one single mode, a variety of institutional arrangements have been used. Such institutional and relational innovations [18] are based on a pragmatic, common sense approach. As for research traditions, we have noted that history researchers are commonly interested in history only, while futures researchers almost only focus on futures. By this approach, both

will lose. In water services with exceptionally long timeframes, we should rather combine these two approaches together with current thinking.

Only a few similar comprehensive studies on water service development, focusing on one country with international reflections, could be found in the literature [19,20], although those on water resources seem to exist more frequently, such as the World Water Resources Series by Springer Nature. Here, the evolution of water services is explored through the combination of technological development linked with changes in the operational and institutional environment. Furthermore, the authors represent a multidisciplinary team, with backgrounds in Environmental History, Civil and Water Engineering, Environmental Engineering, and Public Administration.

The relevance of the case country may be considered to be well justified, because many international comparisons on water and environmental management rate Finland among the top countries. These include, i.e., the Water Poverty Index [21], and the Environmental Performance Index [22], as well as those in other sectors such as education [23], the Corruption Perceptions Index [24], and those on wider social development: SDG Achievement [25], Sustainable Society Index [26], Social Progress Index [27], and even Country Happiness [28]. Furthermore, Finland was, in many respects, a European hinterland until the late 1940s, but has since developed at a fast pace. In international comparisons, together with the above-mentioned rankings, this makes it interesting to explore the reasons behind this development more deeply. Figure 1 presents an orientation on the location of Finland, its cities mentioned in the text, and its neighbouring countries: Estonia, Norway, Russia and Sweden.



Figure 1. Locality map of Finland.

The aim of the article is to shed light on the historical perspectives of Finnish water services since the 1860s until the early 2000s [29]. Instead of focusing on one or a few specific issues, the purpose is to understand the overall long-term development of water services in the wider (Political, Economic, Socio-institutional, Technological, Ecological, and Legislative (PESTEL)) framework, commonly used in Futures Research and Administrative Studies. As an advantage, the use of the PESTEL framework forces the authors to think about the development in a wide perspective instead of considering merely conventional techno-economic issues, because the other dimensions (political, social, environmental, and

legislative) are equally important. As a disadvantage, potential fragmentation by those not used to such frameworks could be seen.

The aim of the article is to find answers to the following research questions:

- (i) How and why has the operational environment changed over time, and how is it reflected in the evolution and development of water services?
- (ii) How has the role of water services in society changed over time, and why?
- (iii) What are the impacts of the above-mentioned developments and their implications for the current discussion and foreseeable futures?

2. Materials and Methods

The sources of the original megastudy [29] involved an extensive literature review including approximately 115 research projects, over a dozen doctoral dissertations, and 30 master's theses produced by the Capacity Development in Water and Environmental Services (CADWES) research team at Tampere University, Finland, from 1998 until today. An attempt is hereby made to connect historical research to modern policy trends and interests. Additional literature after 2016 has also been explored.

Technological development is here considered to cover: (i) technological artefacts; (ii) procedures; and (iii) the knowledge required to create applications for (i) and (ii) [30]. A fairly similar definition was presented by Jacob Bigelow as early as 1831 (cited by [31] (pp. 2–3)) when he stated that “technology involved not only artefacts but also the processes that bring them into being”. According to Hughes, technology is not limited to technological practices—often considered engineering—but ought to also include the processes that bring technology into being, namely invention and human ingenuity. Regarding innovations, UNEP (2011) reminds us that innovation is not simply about technological solutions but also includes institutional and relational innovations [18] (p. 38). In spite of this, even today when considering innovations, too many seem to focus only on technological artefacts.

The article first deals with the developments and birth of urban and rural water service systems in Finland. Thereafter, selected decisions and findings with long-term impacts will be described and analysed. These are followed by a variety of institutional issues as well as discussion within the PESTEL framework with key lessons learnt and foreseen challenges for the futures.

3. Results

3.1. Early Urban Development and Birth of Water Services in Finland

3.1.1. Early Urban Development

Finland gained its independence in 1917, and at that time had a population of 3.1 million. Now, a century later, the Finnish population numbers 5.55 million [32]. Over time, the population structure has dramatically changed due to, among other things, a decreasing birth rate and longer life expectancy. Industrial structures have also faced radical changes. In the early twentieth century, the country was a mainly agricultural society, while it is now a post-industrial society based on services.

In 1920, approximately seventy percent of the population still earned their living from agriculture and forestry, while by 1995 this share had decreased to one tenth. After World War Two (WWII), the economic structure in Finland started to change dramatically and, especially in the 1960s, the rate of change was one of the fastest in Europe. By the 1970s, Finland had turned to a post-industrial nation and soon thereafter services became the largest economic sector. Accordingly, the share of trade has also grown [33]. These changes can be seen in the development of water pollution control, in particular.

Regarding weather and rainfall, the four-season climate in Finland is quite favourable for water management. Except for occasional drier periods, e.g., during the summertime, rainfall is fairly evenly distributed all year round. In addition, the annual mean precipitation in southern and central Finland, between 600 and 700 mm, except for lower values on the coastal areas, is quite abundant [34].

One single Finnish term “vesihuolto”—meaning integration of community water supply and sanitation, i.e., water services—came into use in Finland through a handbook published in 1953 [35]. This can be seen as an early introduction of integrated water services management (IWSM), later becoming widely known as integrated water resources management (IWRM) and was also the forerunner of cycle economy. Interestingly enough, such integration of water and wastewater utilities is common in urban utilities in Finland and Sweden but is less prevalent in many other European countries [36].

Finland’s Water Services Act (119/2001 and 681/2014) defines that the term water services includes conducting, treatment, and supply of water for household use as well as disposal and treatment of wastewater. These services are integrated in one single system. Yet, since 2014, municipalities have been in charge of managing stormwater, and they also acquired the right to invoice for the service [37]. In practice, integrated water utilities in many cases operate stormwater systems.

3.1.2. Birth of Water Services

Industrialization, together with the growth of towns, started in Finland in the latter part of the nineteenth century. A majority of the houses in Finnish towns, as in other Nordic countries, were constructed of wood. Therefore, there were often serious fires, as in cases such as Turku in 1827 (southwest coast) and Vaasa in 1852 (west coast). Almost the whole township burned down in both cases (Figure 1) [38,39].

In 1876, the first Finnish urban water supply system was established in Helsinki. This was promoted by a new fire code that had become effective in 1861. It was also the concern of the imperial senate that governed Finland as an autonomous part of Russia, 1809–1917. Before the actual planning and design of the water works in Helsinki, several visits were made to Sweden, Denmark, and Germany. The construction of the waterworks started in 1872 by a concession with a private company in Berlin and was the only case of privatised community water services in Finnish history. However, after the Local Government Act of 1875, it was bought back, and the city started to develop its own systems [40] (pp. 15–16), [41].

Before a decision to construct an urban water supply and sewerage system, a thorough public debate was deemed necessary. Due to the request of the municipal authorities in Tampere, the local and originally Baltian–German industrialist William von Nottbeck (1816–1890) offered to build a private water pipe in 1865. He listed ten paragraphs of conditions whereby he would have secured a safe flow of income, whereas the town would have carried all the risks. The offer was declined, and the city started to develop its own water and sewerage systems. In 1882 a municipal low-pressure system was constructed by a private contractor. Finally, in 1898, a high-pressure system supplying the whole city was built [42–44].

By 1903, five cities had established public water supplies, and 20 had their own electricity works. By its independence in 1917, Finland had established 16 water works, 16 wastewater works, and 12 fire brigades owned by the cities. Except for a few cases, urban water and sewerage systems in Finland were first established in larger centres, and gradually spread to smaller ones (Figure 2). The trend is even clearer if population density is considered [1], [45] (pp. 21–22), [46].

The development of rural water supply was, however, quite different from that in urban areas. Rural piped water systems were first devised on a small scale that grew gradually. Development was need-driven and based on bottom-up local initiatives and the use of local materials. The first documented piped rural water supply system was built in rural Ilmajoki in 1872. In this flat region of Ostrobothnia, western Finland, pipes of pine wood were hollowed out by local entrepreneurs, first with a hand drill, and later by machine drill [47] (p. 40), [48–50]. Rural water supply is based on cooperative principles, the first formal water cooperative becoming established in 1907 next to Tampere [42] (pp. 52–53).

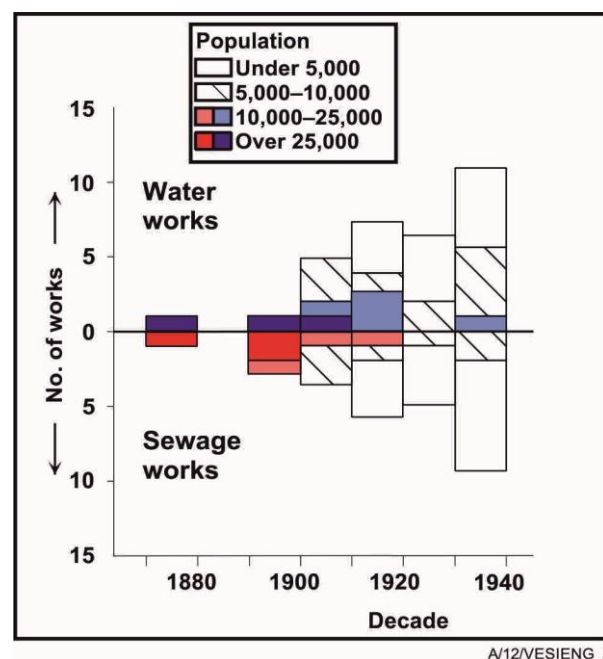


Figure 2. Establishment of urban water supply and sewerage systems versus population size in Finland ([45], p. 22, modified).

Along with the first urban water and sewerage systems, a debate was held on the role of flush toilets. After two decades, in Helsinki they became accepted around 1900, followed by other cities. Yet, the flush toilets gradually led to the need for wastewater collection, the problem of polluted water bodies, and the challenge of wastewater treatment [51].

3.2. Selected Decisions and Principles with Long-Term Impacts

3.2.1. Impact of Time

A key character of water service development in any country is its exceptionally long timeframe: over 100 years into the pasts and 100 years into the future, both of these being interconnected. Therefore, instead of one year, as in many normal business areas, a quarter of water services need to be counted in millennium terms. This very long timeframe also partly explains the difficulties faced by private companies that are not interested in the required long-term investments (e.g., [52]).

The long timeframe refers especially on the networks and their locations. Path dependence commonly refers to the fact that “history matters”, because earlier choices limit the options available today. Furthermore, the current view of futures research is that it identifies desirable futures and then explores alternative strategies and paths for reaching them.

The path dependence theory was developed by social scientists and economists in the 1980s and was aimed at explaining how “the present state of a system is constrained by its history”. Path dependence through the made decisions in several cases limits the current state of the services and desirable future options and available development paths or options. It is obvious that such dependencies and decisions should be explored and identified for a better understanding of long-term development. As George Santayana (1863–1952) noted: “Those who cannot remember the past are condemned to repeat it” [53].

Path dependence seems to apply particularly well to the evolution of water services and systems where the impact of past decisions is still visible today. Yet, contrary to the impression gained from the literature, path dependence should not be seen only as a negative lock-in, because historical decisions can also have positive long-term impacts. Water and wastewater systems are very capital-intensive and, due to path dependence, it is not possible to completely redesign them in the short-term [54] (p. 51), [55] (pp. 33–35).

In terms of technology selection, some very wise decisions with positive long-term impacts have been realised. Experiments carried out in 1880 in Helsinki showed that lead dissolved into the water due to slightly acid waters; therefore, the use of lead pipe was abandoned. This principle was followed by other Finnish cities, and lead was used only to join cast-iron pipes or as pipe material in rare cases [56] (pp. 301–303). The replacement of lead pipes is still a challenge in many European and North American cities, causing health problems, such as in Flint, USA, in 2016 [57].

In rural water supply in Finland, wooden pipes were replaced by plastic pipes when Finnish companies started manufacturing and developing them in the late 1950s. They were gradually extended to urban settlements. As for wastewater treatment, a gradual development of technology and size has occurred, bringing several advantages. It has taken time to develop treatment processes and to train skilled manpower [45] (p. 59).

3.2.2. Networking of Experts

In the period 1809–1917, Finland was an autonomous Grand Duchy, and the connections with Western Europe in technology and knowledge transfer were overwhelming. This was also true with many coastal and inland cities, which often communicated with foreign water experts as well as with each other. Around 1900, it was decided that Helsinki should become a modern European capital, and many civil servants were sent to Central Europe to explore the latest knowledge in their fields [40]. In the 20th century, new networks of experts were set up. After independence in 1917, communication dwindled until the next wave of international cooperation after WWII [29] (p. 55).

After World War II, Finland was left with the task of absorbing approximately 300,000 refugees from the areas ceded to the Soviet Union, while at the same time paying war reparations. Despite these obstacles, Finland quickly recovered [58]. In the context of reconstruction, Finnish experts were granted scholarships by UN agencies for foreign field trips. Several Finnish national professional associations were created, and they joined international networks and associations, such as the International Water Supply Association (IWSA) in 1958, and later the International Association on Water Pollution Research and Control (IAWPRC). In 2000, these two associations became merged to become the International Water Association (IWA). From the late 1950s to the mid-1980s, many water engineers went for further education to Delft, the Netherlands, and gained the advantage of the best contacts and expertise [59]. Finnish knowhow was also used in export activities and development cooperation while, more recently, the consulting sector has become largely globalized [29] (pp. 196, 210–217).

3.2.3. Water Sources and Treatment

The natural cycle of water services starts from drawing raw water. In Finland, the selection between ground- and surface water for community purposes has been debated for more than a century. In rural areas, groundwater from wells (e.g., drilled boreholes) and springs has been traditionally used for domestic purposes, especially for cattle. Accordingly, the needs of dairy farming promoted the establishment of common piped water supplies. In the early 1900s, Managed Aquifer Recharge (MAR; earlier called artificial recharge) was considered in Helsinki and used in Vaasa to some extent in the late 1920s, promoted by the Swedish expert J. R. Richert and German hydrogeologist G. Thiem [60] (p. 9), [61] (p. 345).

After groundwater investigations lasting several years, in 1920 Tampere decided to give up this option, which likely encouraged other cities to prefer surface water use. Besides, groundwater deposits in Finland are generally fairly small: the average aquifer size being only 1–2 km² and the thickness of the sand and gravel layers around 10 m [62]. After WWII, the use of surface water was further adopted, even in cities with available groundwater resources [63] (pp. 72, 97), [64].

In 1970, the National Water Administration was established, after which the use of groundwater was increasingly promoted [45] (p. 42). That same year, groundwater protection and the wider use of the artificial recharge of aquifers located underground

started gaining popularity. Currently, groundwater use is not necessarily always considered the best option, although it has several advantages in terms of security of supplies. The debate between the selection of surface water or groundwater and MAR is likely to continue [65–68].

In community water supplies, the combined share of groundwater and artificial recharge has increased continuously since the 1930s. In the early 1900s, many cities turned to using surface water, and the share of groundwater declined (Figure 3). By 1970, groundwater use had increased to thirty-one percent, and by 1980 to forty-five percent of the total. From 2014 to 2019, the estimated combined share has been sixty-five percent of community water supply [68]. Groundwater and MAR, in particular, represent nature-based solutions [69].

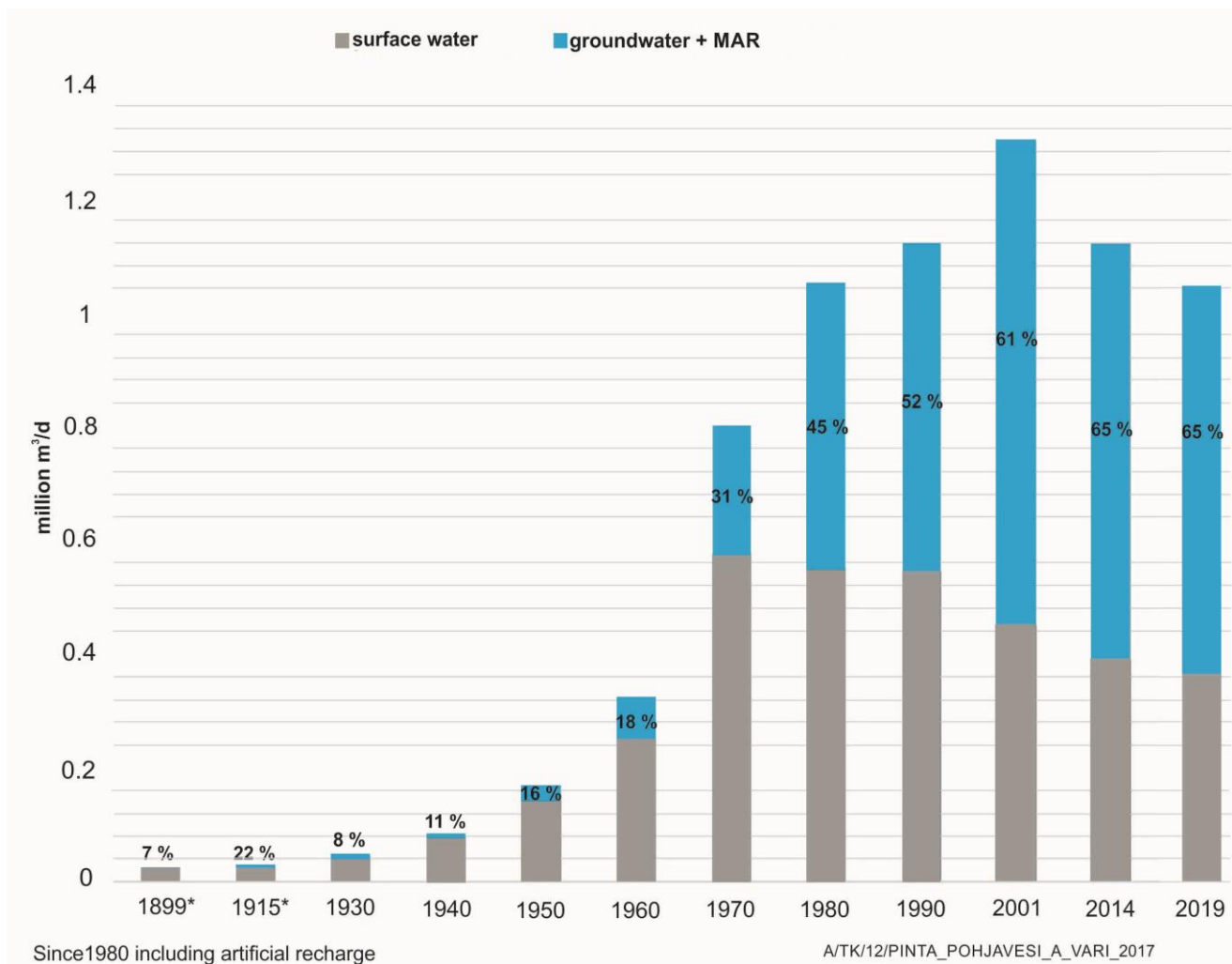


Figure 3. Changes in relative shares of surface and groundwater use of the total pumped volume by water utilities in Finland, 1899–2019 ([29] p. 63, modified).

Another clear change has occurred in per capita water use (specific water use). Until the mid-1970s the forecast was that per capita water use would grow continuously in Finland, and the decline in water use since 1974 came as an unexpected surprise. The energy crisis occurred in 1972, and the Wastewater Fee Act was enacted in 1974. Introduced wastewater fees more than doubled customers' water bills. These two episodes in particular promoted the declining per capita use. Soon thereafter, utilities began to survey water leakages and rehabilitate their networks, and people started to save water as fixtures using

less water came to the market [70]. In the 1990s, similar developments began, e.g., in the Baltic countries [36] (pp. 230–231), [71].

Regarding water treatment and quality, in 2020, as high as 99.98% of tested samples met health-based European Union (EU) water quality requirements of large volume water producers (1000 m³/d or 5000 users [72]). In Finnish conditions, it is often easier, in terms of technology and economics, to treat groundwater than it is to treat surface water. Sometimes the term “organic water” is used to point out that no chemicals are used in the treatment. For surface water treatment, a high flow rate diffused air flotation method, developed in Finland, has gained wide international recognition [73,74]. On the whole, the use of biological methods has increased [45] (pp. 52–53), [75]. Along with the improvement of water treatment methods, it has become more important to monitor water quality in the distribution networks that are aging and facing the challenge of deterioration. In rural areas, the quantity and quality of household well water may still be inadequate [76,77].

3.2.4. Pipeline Networks and Increasing Need for Refurbishment

The earliest existing water and wastewater networks in Finland date back to the early 1900s, although there are some smaller sections originating from the late 1800s. However, the bulk of this infrastructure was constructed after WWII. This means that the need for the refurbishment of urban networks has increased in recent decades and will increase in the future, although the age of the pipes is not a direct criterion for renovation. In rural areas, a similar need is expected to start in the 2030s [78].

Since 1970, the relative share of plastic sewers has continuously increased, and that of concrete ones has decreased. However, for pipes with large diameters, concrete sewers are still more economical than plastic ones [79]. Such a setup of alternatives promotes technology development and competition. In a number of cases, cities often owned concrete factories and thereby they wanted to promote the use of their products.

Unlike in some other countries, in Finland, water pipes, stormwater sewers, and wastewater sewers are installed in the same trench. Due to wintertime and frost in this boreal environment, it would be too expensive and troublesome to have separate trenches with a depth of 2.5 m. However, in areas with snow cover, the trench can be shallower. The four-season climate with sudden temperature changes poses extra challenges, and pipe bursts cannot be avoided.

Finland, Sweden, and France, among others, have a strong tradition of using concrete water towers (elevated reservoirs) made by slip-form casting. Especially with power cuts and pipe bursts, the storage capacity of water towers has proved important, and by modern pumping their use can be optimized. Figure 4 shows the historical development of water towers in Tampere. Their volume has increased, pressure levels have risen in the suburbs, and designs towards mushroom-type towers have appeared. The oldest elevated water reservoir from 1898 is still in use in Tampere [80–82].

In Finland, and in other developed economies in particular, aging infrastructure and distribution networks are likely to form the biggest challenge of water services over the coming 20 to 30 years, although this is not yet necessarily recognised everywhere. In sewerage, the challenge is leakage reduction, which becomes more important with expanding systems. In network refurbishment, no-dig methods should be used, if possible. Even the 120-km raw water tunnel from Lake Päijänne to Helsinki had to be renovated in 2001 and 2008. Water towers have also been increasingly restored [29] (pp. 96–99), [83–87].

In 1938, Helsinki introduced separate sewers for sewage and stormwaters, followed by other Finnish cities after WWII. Because urbanization occurred in Finland later than in many other European countries, combined sewers are currently in use in the central areas of bigger cities only. In Helsinki’s central areas, nine percent of the total sewers are combined, whereas in Turku it is six percent, and in Tampere it is five percent [88–90].

Solving the challenges of aging water infrastructure is necessary, and it will require more appropriate institutional arrangements and strong commitments from var-

ious stakeholders. Without additional efforts regarding refurbishment, the backlog in maintenance/repair will persist and vulnerability will continue to increase.

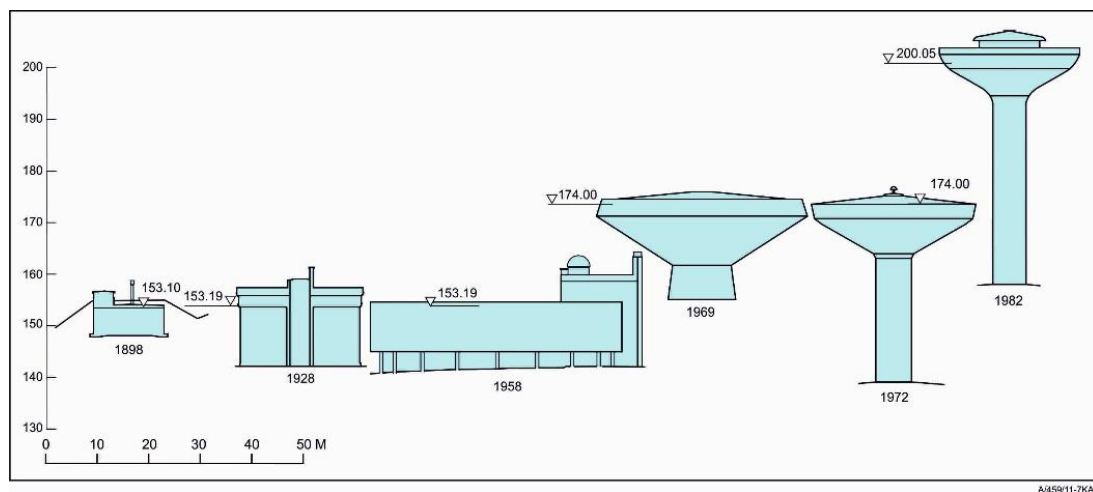


Figure 4. Silhouettes of elevated water reservoirs and towers in Tampere. From left: the “cellar” on Pyynikki ridge from 1898, the old “crown” of Kauppi from 1928, the new “ice-hockey puck” of Kauppi from 1958, and the mushrooms: “*Gomphidius glutinosus*” of Tesoma from 1969, “*Rozites caperata*” of Peltolammi from 1972, and “*Tricholoma virgatum*” of Hervanta from 1982 ([42], p. 28).

3.2.5. Water Pollution Control

Based on voluntary action and the felt need to do something about polluted waters and shoreline, the first wastewater treatment plants in Finland were constructed in 1910 in Lahti and Helsinki. As early as the first years of 1900s, the Hämeenlinna city plan took into account the locations and directions of gravity sewer flows, which later made it possible to start wastewater treatment [36] (p. 64), [91] (p. 43).

Between 1910 and 1961, approximately 20 wastewater treatment plants were constructed on this voluntary basis, driven by the acute need to promote water pollution control. WWII stopped the planned construction of wastewater treatment facilities until the 1950s [92] (p. 71).

Figure 5 summarizes the diffusion of urban wastewater treatment in Finland from 1879 to 2009, elaborated by major acts and decrees. The Health Decree of 1879 and the Water Rights Act of 1902 were the first weak signals of emerging water pollution control. The major driving forces for pollution control covered the acceptance of flush toilets around 1900, the Health Decree of 1928, the construction of the first separate sewers in 1938, and EU membership in 1995. The following three acts were very important strategic decisions, because they included concrete requirements: Water Act of 1962 (wastewater treatment), Wastewater Fee Act 1974 (finance), and the Water Services Act of 2001 (upgrading treatment). Furthermore, the Water and Wastewater Utilities Act of 1977 promoted the integration of water and wastewater utilities, which has proved to be feasible in most cases [93].

Large scale modern water pollution control in Finland started in 1962 when the Water Act came into force. For the first time, communities and industries had to apply for a permit to discharge their wastewaters. These requirements became stricter as technology developed over time, although some additional requirements might still be coming, such as the removal of plastics and pharmaceutical compounds. The diffusion was quite rapid in the 1960s and 1970s. Within two decades, the country had gained modern wastewater treatment, in most cases including biological and chemical methods. The number of urban wastewater treatment plants, as shown in Figure 5, was at its highest in 1990.

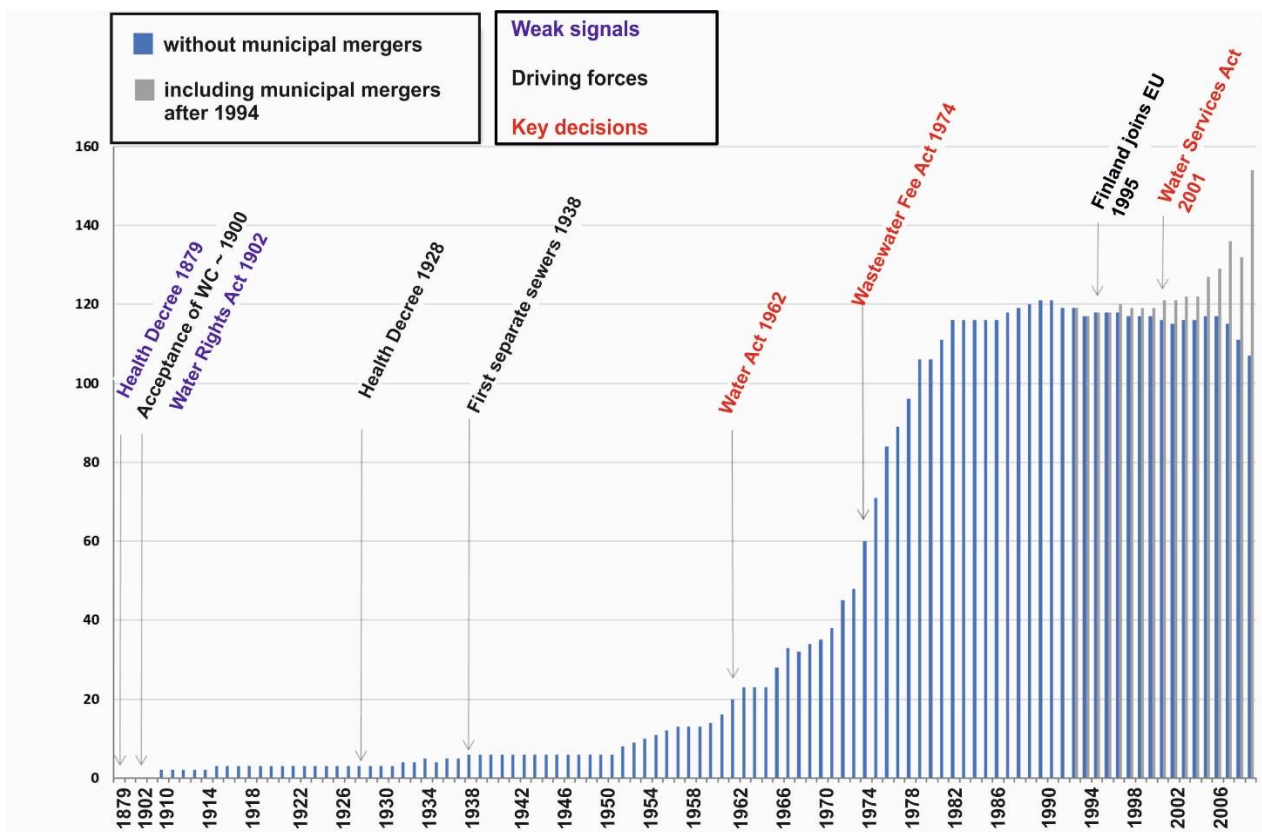


Figure 5. Total number of urban wastewater treatment plants in 1910–2009, number located in the 102 cities in existence in 1994 and those including municipal mergers since 1994, with related key legislation ([29], p. 105; modified).

In 2017, there were approximately 450 wastewater treatment plants in Finland, each serving at least 50 people. As an average they removed organic (BOD) by close to 98%, phosphorus by 96.5%, and nitrogen by 66% [94].

In Finnish water bodies of mainly lakes, phosphorus is often the so-called limiting factor that causes eutrophication. After 1990, wastewater treatment started to become more centralized, which required longer transfer sewers. The main options for upgrading existing systems were to regenerate an existing plant with possible expansion or to build a new one. Since 1995, large tourist resorts in Lapland have been a special case in terms of modern water services, with an accommodation capacity in 2017 of over 100,000.

In 2014, approximately eighty-five percent of the population was connected to a centralized sewerage system. Regarding organic (BOD) and phosphorous (P) loadings of communities, it seems that even with the current technologies we can achieve “zero loadings”—reflecting that the share of outlet loadings is zero-point-something [95].

In the economic development of Finland, forest industries have been very important and still are. Because these industries are located mainly along water bodies and many of them are in inland areas closer to the forest resources, water pollution became a major and clearly visible problem. From 1950 to 2007, the production of paper and paperboard in Finland grew roughly 20-fold, while the production of pulp grew almost 10-fold. From 2008 to 2020, the production of paper and paperboard has declined by one third, whereas that of pulp has remained more or less the same. Along with this, the organic loading and suspended solids discharged by the industry increased until the early 1970s, whereafter water protection started to develop [96].

In the 1970s, the production of one ton of pulp required approximately 250 m³ of water, while in 2020 it required between 5 and 15 m³. In producing one ton of paper for newsprint, the water use has declined from 100–150 down to 7–15 m³ per ton [97].

Although the pollution of water bodies close to forest industries was first officially recognized by a Senate committee [98] as early as 1909, forest industries introduced modern wastewater treatment approximately 20 years later than communities. Due to their strong position in the Finnish economy, they were able to postpone their investments for an unfairly long amount of time, even though this would have increased the price of a ton of paper and pulp by only an estimated one percent.

After the raw water tunnel for the Helsinki metropolitan area was completed in 1982, the political and social pressure forced the forest industries to start treating their wastewaters properly in 1984 [96,99]. However, in mining and in dispersed rural areas as well as non-point loadings, major challenges remain. It is, in many respects, more difficult to gain control over non-point loadings [100].

In Sweden, urban water systems started up 20–30 years earlier than in Finland. In Sweden, a major part of wastewater treatment plants were funded by government grants [101], as was the case in the USA, whereas in Finland they have, to a large extent, been funded by consumer fees. In Sweden and Norway, municipal utilities of various types produce water services, while they do not have actual water cooperatives. Finland has approximately 1400 water cooperatives in rural townships and dispersed areas [102], while Denmark has 2400 [103]. Regarding these issues, institutional development of water services in Finland will be explored in more detail.

3.3. Institutional Development

3.3.1. Organizational Diversity

As a framework of institutional development, water services development is viewed by using the soccer analogy of D.C. North, a Nobel Laureate: institutions are the “formal and informal rules of the game”, while organizations are the “players” [104]. Each player should find a suitable role, while above all it is a question of good team play.

In fact, institutional and organizational diversity is a major characteristic of the development of Finnish water services. They are managed at four different levels by various modes: on-site systems, cooperatives (water user associations), municipal utilities, and various types of inter- and supra-municipal arrangements. Furthermore, these four levels are often interconnected by various means. This diversity of organizations and the multiple levels of governance of Finnish water services are a special feature—a strength as well as a challenge [105]. The distinction of provision and production is important, as argued by Ostrom [106] (p. 31) and Oakerson [107] (pp. 7–18). In most countries, including Finland, legislation requires municipalities to provide the services which are produced by utilities or cooperatives [108].

Over time, the operational environment of water services has changed and is continuously subject to change. More recently, organizational structures have evolved: municipal water and wastewater works have largely transformed into commercial enterprises; supra-municipal systems of various forms have been created; water and wastewater utilities have increasingly become merged; and, outside planned areas, new cooperatives have been established. So far, the ownership belongs to municipalities or cooperatives.

In January 2020 the city of Jyväskylä planned to sell a share of its public water utility to an international private investor. This created a debate and a citizen initiative against privatization of water services, which was soon signed by approximately 90,000 people. On 8 September 2021, the parliament accepted the initiative unanimously, and thereby the council of state will start preparing legislation that will guarantee that publicly-owned utilities will remain in municipal ownership and control. This action will not concern water cooperatives, though. This was the first time that such an initiative was passed unanimously by the Parliament.

A recent, conventional argument to improve water services is the idea of increasing utility size (e.g., [109,110]). However, several studies indicate that the institutional diversity of water services is rather a strength in a large country such as Finland, with 337,000 km² and 5.5 million people, out of whom a remarkable share live in the countryside, and

approximately ten percent are also likely to stay out of the networked systems in the future (e.g., [66,111]).

In his classical book “Small is beautiful”, Schumacher [112] (p. 70) noted that “for different purposes man needs many different structures, both small ones and large ones, some exclusive and some comprehensive. Yet, people find it most difficult to keep these two seemingly opposite necessities of truth in their minds at the same time.” Examples on this are, e.g., the headline in professional magazines where “the best form of organization” is searched for water services. Further, according to Schumacher [112] (p. 70), “for every activity there is a certain appropriate scale, and the more active and intimate the activity, the smaller the number of people that can take part. However, the appropriate scale depends on what we are trying to do.”

Increasing the size of utilities should indeed be only one option to improve efficiency. The economic transparency of water utilities in Finland also needs to be increased; the rate of return on capital required by larger cities [113] from their water utilities should be more reasonable, and the financial position of smaller utilities ought to be improved. From vulnerability and resilience points of view, this diversity can be considered a strength. Thus, the appropriate size of the systems depends on local conditions: utilities may be large, medium, or small.

The biggest challenge of water services in Finland is most likely that most water utilities do not have adequate resources nor an interest in developing their operations and the rate of refurbishment. Since 2007, the State of the Built Properties [109] in Finland has been prepared biannually by using the school rate (scale from 4 to 10) and assessed by experts. In 2007, the rate was 8, declined to 7 in 2011 and 2013, and was $7\frac{1}{2}$ in 2021 [84] (p. 31). Since 2011 and 2013, the need for increasing refurbishment of networks has been much on the agenda. The use of digitalization is progressing, e.g., in distance reading of water meters [84].

The need for network refurbishment and investments is still growing, and the pace of renovation needed has not been kept up. However, there are clear developments in the asset management of a number of water utilities. For example, the eight water utilities involved in the Vepatuki research cluster have been investing in refurbishment for years [114].

The state of the infrastructure has also been explored in countries such as Norway [115], and the U.S.A. [116].

As for safeguarding future services produced currently by Finnish cooperatives, there are several options. Bigger cooperatives are often strong enough, whereas smaller ones in dispersed rural areas will face challenges in the case of migration and aging population. However, solutions to these constraints need to be considered case by case. These options may include increasing cooperation of various types with other cooperatives or municipal utilities in small steps avoiding unnecessary bureaucracy, developing operational services with local entrepreneurs, or shifting responsibilities to municipal bodies [117].

It has also been argued that fragmentation of the water sector would be a major constraint. This may be partly true. However, it would not be useful if we would concentrate water matters under a single ministry as was done in many developing economies. If and when water is a sector and a connector [9] (pp. 1–17), water is, by definition, fragmented. Would it, therefore, be much more feasible to guarantee smooth collaboration between the involved stakeholders? Water services management is typically a challenging problem that is difficult or impossible to solve because of its complexity: its incomplete, contradictory, and changing requirements [118].

On the whole, a sound institutional framework has developed continuously and dynamically in Finland, and hopefully this will also be the case in the future. This is not to deny the current challenges of the country. In particular, we have to have better rules of the game and more resources on Research, Development, and Innovations (RDI) activities in the future. We are turning to an era of “additional refurbishment” where such efforts will be particularly required.

In recent years, the Finnish educational system—as well as our water sector—have ranked very well in various international comparisons. However, concerning water education and research, it seems strange how the current focus in Finland and elsewhere is on water resources and much less on water services. In the latter, educational programmes concentrate on treatment technologies, which is important. However, approximately eighty percent of the assets are connected to the networks and their management. The current focus on natural sciences and treatment technologies is not able to give any answers to wider management, institutional, policy, and governance issues, such as appropriate pricing and feasible asset management. Awareness and understanding of historical development are also needed. These should not be left merely to continuing education and on-the-job training.

3.3.2. Co-Operation and Inclusion

Finland is often referred to as the promised land of voluntary non-profit organizations (VOs). In 2010, the country had approximately 120,000 VOs with 15 million members. VOs play an important role in water services, e.g., through the networking of experts. Helping to build up and share expertise, the first Swedish-speaking engineering society dates back to 1880, and that of a Finnish-speaking society to the late 1890s [29] (pp. 56–57).

The Finnish Water Utilities Association (FIWA), originating from 1956, represents utilities and promotes enabling policies and a favourable economic and operational environment for its members. The FIWA collaborates with its Nordic and European sister organizations. In 1969, Water Association Finland was created to promote professional and scientific cooperation between various water sectors. In 2009 the Finnish Association of Water Cooperatives was also established to represent the smaller water service producers in Finland [29] (pp. 195–99), [119–121].

As the broader operational environment has changed, Finnish companies have also been able to become more international or have merged with foreign enterprises. In 2009, the Finnish Water Forum was established to promote international cooperation and export. In the Baltic region environmental cooperation, wastewater management was a major field of activity during the period 1991–2012. In development cooperation, water supply and sanitation have played an important role, and good results have been achieved [29] (pp. 204–237), [122,123]. In spite of possible limitations, national and international activities in water services can support each other through the motivation of experts and the expansion of views and competences.

4. Discussion

The variety of water organizations over time has developed simultaneously and presented institutional diversity. However, the majority of them, in terms of production, are municipal—rather than state—dependent [124]. As discussed earlier, water services are strongly path dependent. Sometimes, such as in raw water selection, the paths may be reversible.

Water services, as well as Finnish society as a whole, have developed quite fast. This development is here elaborated by two historical episodes from rural water supplies. First, “in Parainen, on the south coast of Finland, a young girl had to lower herself into a well in the 1920s in winter, and hack the ice-cover in order to be able to scoop water into her bucket” [125]. In 1952, Finland hosted the Summer Olympic Games, and around that time, Finnish women still walked a total of 400,000 km every day, or the distance from Earth to the Moon, carrying water from wells to cowsheds and homes [126]. These episodes can be compared to the current availability of operative water services 24 hours a day for approximately ninety percent of the population, the rest being supplied by on-site systems in dispersed rural areas [29] (p. 242).

Instead of answering directly to the research questions, though “diffusive penetration” throughout the overall history of water services of Finnish water services is assessed by using the PESTEL framework below.

4.1. Political Factors

The development of water services in urban and rural areas of Finland has, to a large extent, been based on trust. In addition to professional competence, this has required political will. In the long-term, the requirements of citizens and expectations for decision-making have increased. In recent years, the autonomy of municipal utilities has increased, emphasising the owner's role and policy.

Historical experiences from the late 1800s in Finland and elsewhere, as well as those from the 1990s internationally, clearly indicate that municipalities should hold on to the ownership of their water utilities, while goods and services can be bought from the private sector, safeguarding adequate competition. Water services are invaluable; they cannot just be replaced. Water services are also a key component of critical infrastructure, the national security of supply, and community safety.

4.2. Economic Factors

In 1951, the first act on funding of water services came into force, influenced by the Committee for Rationalization of Households [127], with eight influential women as members. The share of central government funding for water services was approximately two percent in the 1950s and increased gradually from eight to nine percent by the late 1980s. In the 1990s, it was sixteen percent, but the figures also included loan support. Thus, over the years, the actual support has remained at less than ten percent [128] (pp. 306–307). This support has promoted groundwater surveys and the planning and investments of inter-municipal cooperation, in particular. After Finland joined the EU in 1995, the share of public support may have been higher, in cases such as holiday resorts in Lapland in the 1990s and early 2000s.

In 2003, the level of government support was ten percent, but since then has started to decline [129]. The overall water strategy of the MoAF for the period 2011–2020 shifted government support from water services towards the control of flood risks and the renovation of water bodies [79]. Since 2017, Governmental support for water services network investments has practically ceased. However, some support has been directed, for example, to the development of nutrient recycling and use related to community wastewaters, as well as some special purposes in rural areas [130].

From the very beginning, the cost of water supply in Finland has mostly been covered by consumer fees, and since 1974, also those of wastewater services. Prior to 1974, wastewater services were partly paid by municipal tax funds, whereas since 2001 the utilities have been obliged to fully cover their costs. While the major cities may expect more than reasonable rates of return from their utilities, smaller utilities are not always able to cover their costs by fees.

Affordability of water services is currently generally not a problem, because these services cost less than one percent of the annual household expenses of an average Finnish family of four [131]. This is quite low compared to many other services. When water use per capita declines, utilities have to restructure their tariffs to be able to foresee future investments, including refurbishment. In 2017, FIWA published a recommendation that, for better balancing the income flow, water utilities should increase gradually the share of their basic charges up to fifty percent of their total income. Such a tariff structure would better fit with the challenge of refurbishment but would still remain the control of metering [132].

4.3. Socio-Institutional Factors

Diversity is likely one reason for the success of Finnish water and sanitation systems. The country has applied several organizational and institutional options for these services at various scales. Local and regional variations have been taken into account, and one organizational model has not been applied in all conditions.

Along with the acceptance of biological and cultural diversity, institutional diversity, shortened to “insdiversity”, should also be remembered [133]. In most Finnish cities and townships, water and wastewater utilities are integrated in a single entity. How-

ever, separate organizations may be justified in supra-municipal systems due to different operational areas.

Another issue is the need to raise awareness on the fundamental role of the invaluable water services in society and improve citizen orientation. Wider collaboration among the many stakeholders of water services is also required. While some urban centres and regions are growing, other areas are faced with a declining population. At the same time, higher expectations on water quality and services have emerged by users.

4.4. Technological Factors

As shown earlier, since 1974, the water use per capita has declined. Thanks to overdesign, this decline has made it possible to expand the systems and also make renovations by no-dig methods and relining. Simultaneously, water quality problems have partly transferred to the networks.

Gradual centralization and expansion of water supply and wastewater systems have brought technical and economic benefits, including underground wastewater treatment under undisturbed weather conditions. Accordingly, Finland hardly needs to decentralize its existing operational systems. However, it needs to be reconsidered to what extent it is feasible to expand the current systems in a country with a quite dispersed population needs to be reconsidered. Furthermore, for on-site systems, non-water borne sanitation should be seriously considered. In any case, the great majority of the costs, approximately eighty percent, come from the networks, not from treatment plants.

Due to path dependence, it is difficult to dramatically change water infrastructure networks. Information technology has made it possible to expand the systems, pump raw water from distant sources, and manage wastewaters by remote control. These systems, however, also have their limitations considering their vulnerability and resilience. In developing technologies, enterprises and individual “Gyro Gearloose” inventors have excelled.

4.5. Environmental Factors

Wastewater treatment plants have often been the major environmental investments of municipalities. Except for some early experiments, effective wastewater treatment could begin when construction of separate sewers gradually started in the 1930s. After the Water Act in 1961, cities and townships built their wastewater treatment plants over the course of two decades. Forest industries introduced modern wastewater treatment in the mid-1980s, some 75 years after pollution of water bodies by such industries had been noted. Thus, it took time for the required corporate social responsibility to develop.

The importance of wastewater treatment and water protection became clear after the collapse of the Soviet Union and the later environmental cooperation in the Baltic region, which was also supported by the Finnish Government. The latter promoted wastewater pollution control in communities and by industries and produced good results in a relatively short time in the region.

4.6. Legislative Factors

The role of legislation and related control has proved to be largely successful, especially in water pollution control, and it has included some major reforms. On the other hand, “continuous and dynamic development” has been the leading principle in Finnish water services legislation and policy.

In the European Union, directives are transposed into the laws of member states such as Finland. One of the cornerstones of water services is the principle of subsidiarity—management at the lowest possible level—as stated in the Maastricht Treaty in 1992 and the Dublin Statement on Water and Sustainable Development in 1992, as well as the Charter of the European Union in 2000. However, the categorical nitrogen removal requirement from wastewaters everywhere—without taking into consideration the nature of water bodies and the minimum factor [29] (pp. 108–109)—indicates that the variety of natural conditions

in Europe is not necessarily adequately understood, and any harmonization should have a sound scientific basis.

In public policy discussion, the argument is sometimes heard that there should be less regulation. If and when the operational environment grows more and more complex, this argument can be questioned. It would be more appropriate to talk about the renewal of regulations to meet the changing operational environment and future challenges.

4.7. Major Development Phases and Paradigms over Time

The evolution of water services in Finland in the last 150 years is largely connected with the overall socio-economic development and change from an agricultural society to a post-industrial country. Water services in urban and rural areas have been promoted with varying motives: in urban areas to protect against fire, to ease thirst, and for better health and in rural areas to promote cattle farming in particular. Over the previous decades, inter- and supra-municipal cooperation has progressed well.

As elaborated by the typology in Table 1, the overall development of water services by their nature is complex and challenging. The ways of water services management have developed over a long time based on many decisions and various requirements. Thus, it is not feasible to think that by a single decision or principle all the prevailing challenges, even in one country, could be solved, nor would such solutions be applicable everywhere.

Table 1. Major development phases, paradigms, and foci in Finnish water services evolution, 1860–2020 and beyond.

Years	Development Phase	Major Paradigm	Major Focus	Nature of Change (PEcSTEnL)
1860–1875	Initiation	exploring urban and rural responsibilities; industrialisation	rejection of private concessions, public responsibility	P, Ec, S, T, L
1875–1900	Rise of first systems	firefighting; drinking water; miasma theory; bucket system	municipal legislation; networking of experts; abandoning of lead pipes; flush toilets	P, Ec, S, T, En, L
1900–1939	Diffusion	expanding access	from ground- to surface water; early WWT plants; Water Rights Act; early separate sewers	P, Ec, T, En, L
1939–1945	WW II	survival	secure basic operations	P, Ec, S, L
1945–1960	Reconstruction	social and political will; structural change; WS for cattle farming	peace; knowledge transfer; plastic pipes; institutional development; starting export activities	P, Ec, S, T, En, L
1960–1980	Rapid expansion	WPC as forerunner in environmental protection; post-industrialism	Water Act; Wastewater Fee Act; decline in SWU; inter-municipal systems; HRD; development cooperation	P, Ec, S, T, En, L
1980–2020	Balanced growth	extending services and interconnecting and systems; institutional diversity	MAR expansion; centralization of WWT; rural WSS; promotion of water cooperatives; integration of water and wastewater	P, Ec, S, T, En, L
2020–	Challenging futures	safeguarding operations; resilience, management, institutions, policy and governance issues; SDGs	refurbishment of aging infrastructure; adopting to climate change; improving resilience; better awareness; stakeholder cooperation; land use planning and water	P, Ec, S, T, En, L

Ec = economic; En = environmental; EU = European Union; HRD = human resources development; L = legislative; MAR = managed aquifer recharge; P = political; S = socio-institutional; SDGs = Sustainable Development Goals; T = technological; SWU = specific water use (/l/cxd); WPC = water pollution control; WSS = water supply and sanitation; WWT = wastewater treatment.

Within our timeframe, we have identified eight major development phases and related paradigms and foci in Finnish water services evolution. The nature of changes indicate how almost all the phases are subject to all the PESTEL dimensions. However, over time, each of these dimensions have emphasized the topical issues of the particular development phase. For instance, environmental issues due to water pollution first occurred locally but with population and industrial growth gradually became national issues in the 1960s.

On the whole, the original megastudy implies some general principles, well promoted in the Finnish experience, that could potentially be applicable in water services all over the world [128] (p. 264), modified. These include (i) appropriate pricing as a fundamental factor, (ii) sound institutional arrangements where various partners play roles that support each other, (iii) the principles of good governance, including fighting corruption, (iv) the need for long-term visionary and strategic thinking, and (v) proper organization and management of the systems.

In 2017, a web-based questionnaire survey was conducted to explore the views of experts regarding the future challenges of Finnish water services. The respondents ($n = 40$), widely covering the sector actors, assessed the major challenges over the next 20–30 years. In 2008, a similar survey ($n = 48$) was carried out. In both surveys the most urgent themes were noted: aging infrastructure; vulnerability and risk management; and human resources and know-how as well as education and research [83,134]. In a wider framework, the major challenges are thus related to water services governance, institutions (rules of the game and players), and management of the systems.

The recent vision and roadmap of FIWA up to 2030 includes six strategic goals: (i) secured operational requirements of water utilities; (ii) recognition of the social importance of water services; (iii) water services as an attractive sector; (iv) water services as a forerunner in bio- and recycling economy; (v) customer experiences guiding the development of operations; and (vi) water services under continuous renewal through wide collaboration between partners [135]. Considering the nature of the challenges above, we can note that three out of five can be measured by single benchmarking figures. The latter are important in analysing the development of, e.g., an individual utility, but are not adequate to explain the wider development within the PESTEL framework.

Another sign of the felt priorities by Finnish water utilities are the themes of the Vepatuki research cluster, phase II for 2022–2027, as follows:

- (i) Water services leaderships and development;
- (ii) Regulation of water services;
- (iii) Governance of large-scale water and wastewater projects;
- (iv) Management of stormwaters;
- (v) Future challenges and opportunities of water utilities.

Along with the aforementioned we need to remember the challenges of small scale rural and on-site systems. Even in many European countries we have a remarkable share of citizens that are relying on community or cooperative based small systems, or are permanently outside the networked systems including free-time housing.

In water services nature-based solutions are used particularly in raw water source selection, some treatment processes such as MAR and in finding most suitable sites of water bodies for the disposal of final effluents. In land use planning it is important to take into account water services at an early stage bearing in mind safeguarding water sources for the future needs and protect groundwater resources. The links to stormwater management, excluded in this article, need to be remembered as well. In the current fashion of condensing the urban structure based strongly on economic arguments, we should remember to safeguard adequate open space for recreation, parks and forests and stormwater infiltration areas, particularly in a country with large areas of forests and other unplanned areas.

5. Concluding Remarks

There are several lessons to learn from the long-term development of water services in Finland which are also relevant for the problems of today and the foreseeable future. In order to achieve a wide understanding of the overall development of water services in Finland over 160 years, it proved to be beneficial to use the PESTEL framework in spite of the changes of strategies and foci over time.

The aging infrastructure is currently a problem in both Finland and worldwide, due to the urban growth after WWII. In safeguarding good raw water sources for the future, groundwater protection in connection with land use planning is a continuing challenge. In terms of environmental protection, wastewater purification plants have often been the biggest investments in human settlements. In the rural areas of Finland, the tradition of consumer involvement and engagement still has many advantages, although this might not be that evident in the future.

During the last 50 years, Finland has experienced dramatic changes and development in many respects. The country has turned from an agricultural society to a developed, post-industrial economy, which has required much effort at various levels of society. Education at various levels and its development has been one of the basic requirements for developing water services. Earlier, the required knowledge had to be gained from abroad, and later by developing national universities and their programs.

Instead of ad-hoc reforms, a sound institutional framework for water services has developed continuously and dynamically. Improving collaboration between the stakeholders will probably bring the best results, also for future challenges. Clearly, we need to have better rules of the game and additional resources on Research, Development, and Innovations (RDI) activities in the future. In Finland, and elsewhere in developed economies, the focus is turning to an era of “increased refurbishment” where such efforts, in particular, are needed.

Regarding the future challenges of aging infrastructure and the acute need to invest substantially more in refurbishment of the networks, it is good to remember this: in January 1974, the wastewater Fee Act came into force, which more than doubled the price of water for most customers. Everybody could see that the Finnish lakes and rivers had become polluted next to communities due to wastewaters from both the communities and forest industry. Furthermore, no complaints on this environmentally innovative regulation could be found in the literature. Such lessons should be remembered and used to raise awareness of the refurbishment needs in Finland and in other countries.

The development of water services in Finland to a high level has required long-term and systematic work that has required appropriate social policies and political decisions. In the future, it will be worth exploring to what extent, especially analogical lessons from water pollution control, could possibly be used in climate change adaptation and carbon-free policy development.

Author Contributions: Conceptualization, T.S.K.; data collection and analysis, T.S.K., P.S.J., R.P.J. and E.J.N.; investigation, P.S.J., R.P.J., T.S.K. and E.J.N.; writing—original draft preparation, T.S.K.; writing—review and editing, P.S.J., R.P.J., T.S.K. and E.J.N.; visualization, R.P.J., T.S.K. and E.J.N.; project administration, T.S.K.; funding acquisition, T.S.K., P.S.J. and R.P.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: The support from VEPATUKI Research Cluster is acknowledged.

Conflicts of Interest: The authors declare no conflict of interest.

References and Note

1. Juuti, P. Kaupunki ja vesi. Ph.D. Thesis, Acta Electronica Universitatis Tampereensis 141, Tampere University, KehräMedia Oy, Finland, 2001. (Summary in English). Available online: <https://trepo.tuni.fi/handle/10024/67155> (accessed on 22 January 2022).
2. Pacey, A. Technology is not enough: The provision and maintenance of appropriate water supplies. *Aqua* **1977**, *1*, 1–58.
3. WHO; UNICEF. *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020: Five Years into the SD*; WHO: Geneva, Switzerland, 2021.
4. McDonald, R.I.; Green, P.; Balk, D.; Fekete, B.M.; Revenga, C.; Todd, M.; Montgomery, M. Urban growth, climate change, and freshwater availability. *Proc. Nat. Acad. Sci. USA* **2011**, *108*, 6312–6317. [[CrossRef](#)] [[PubMed](#)]
5. World Economic Forum. *The Global Risks Report 2016*; World Economic Forum: Geneva, Switzerland, 2016. Available online: <https://www.weforum.org/reports/the-global-risks-report-2016> (accessed on 30 January 2022).
6. Sadoff, C.W.; Hall, J.W.; Grey, D.; Wiberg, D. *Securing Water, Sustaining Growth: Report of the GWP/OECD Task Force on Water Security and Sustainable Growth*; University of Oxford: Oxford, UK, 2015.
7. Hukka, J.J.; Castro, J.E.; Pietilä, P.E. Water, Policy and Governance. *Environ. Hist.* **2010**, *16*, 235–251. [[CrossRef](#)]
8. UNESCO. Water for People, Water for Life. World Water Development Report (WWDR). The United Nations: Executive Summary. 2003. Available online: <http://www.unesco.org/water/wwap/wwdr/index.shtml> (accessed on 24 January 2022).
9. Grigg, N.S. *Integrated Water Resources Management, An interdisciplinary Approach*; Palgrave/MacMillan: London, UK, 2016.
10. Jiménez-Cisneros, B.; Alexander, O.; Doria, M.d.F.; Arduino, G.; Salamé, L.; Demuth, S.; Mishra, A.; Aureli, A. Water Security through science-based cooperation. UNESCO’s International Hydrological Programme. In *Free Flow. Reaching Water Security through Cooperation*; UNESCO, Tudor Rose Digital: Paris, France, 2013; pp. 12–17. Available online: <https://unesdoc.unesco.org/ark:/48223/pf0000222893> (accessed on 22 January 2022).
11. Ferriman, A. BMJ readers choose the ‘sanitary revolution’ as greatest medical advance since 1840. *BMJ* **2007**, *334*, 111. [[CrossRef](#)]
12. International Law Association. *The Berlin Rules on Water Resources*; Fourth Report, 20; Vital Human Needs: Berlin, Germany, 2004; pp. 10, 12, 22–24, 43.
13. Birkett, D.M. Water Critical Infrastructure Security and Its Dependencies. *J. Terror. Res.* **2017**, *8*, 21. [[CrossRef](#)]
14. Heino, O.; Takala, A.; Jukarainen, P.; Kalalahti, J.; Kekki, T.; Verho, P. Critical Infrastructures: The Operational Environment in Cases of Severe Disruption. *Sustainability* **2019**, *11*, 838. [[CrossRef](#)]
15. Juuti, P.; Katko, T.; Rajala, R. Vesihuollon haasteet Suomessa—Saneerausvelka ja tutkimusresurssien puute ongelma. *Vesitalous* **2019**, *60*, 58–61.
16. Brown, C.; Boltz, F.; Freeman, S.; Tront, J.; Rodriguez, D. Resilience by design: A deep uncertainty approach for water systems in a changing world. *Water Secur.* **2020**, *9*, 100051. [[CrossRef](#)]
17. Inha, L.M. Developing Policies for Resilient Water Services. Ph.D. Thesis, Tampere University, Tampere, Finland, 2021. Available online: <http://digital.tudor-rose.co.uk/free-flow> (accessed on 22 January 2022).
18. UNEP. *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*; A Report of the Working Group on Decoupling to the International Resource Panel; Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Sewerin, S., Eds.; Paris, UNESCO & Earthscan: London, UK, 2011. Available online: <https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth> (accessed on 30 January 2022).
19. Sedlak, D. *Water 4.0. The Past, Present, and Future of the World’s Most Vital Resource*; Yale University Press: New Haven, CT, USA, 2014.
20. Marin, P.; Tal, S.; Yeres, J.; Ringskog, K. Water Management in Israel. In *Key Innovations and Lessons Learned for Water-Scarce Countries*; World Bank: Washington, DC, USA, 2017. Available online: <https://openknowledge.worldbank.org/handle/10986/28097> (accessed on 22 January 2022).
21. Sullivan, C. Calculating a Water Poverty Index. *World Dev.* **2002**, *30*, 1195–1210. [[CrossRef](#)]
22. Wendling, Z.A.; Emerson, J.W.; de Sherbinin, A.; Esty, D.C. *Environmental Performance Index*; Yale Center for Environmental Law & Policy: New Haven, CT, USA, 2020. Available online: <https://epi.yale.edu/> (accessed on 30 January 2022).
23. Sahlberg, P. *Finnish Lessons 2.0: What Can the World Learn from Educational Change in Finland?* Teacher’s College Press: New York, NY, USA; London, UK, 2014.
24. Transparency International. Corruption Perceptions Index. 2021. Available online: <https://www.transparency.org/en/cpi/2021> (accessed on 25 January 2022).
25. Sachs, J.D.; Kroll, C.; Lafortune, G.; Grayson, F.G.; Woelm, F. *Sustainable Development Report 2021; The Decade of Action for the Sustainable Development Goals*; Cambridge University Press: Cambridge, UK, 2021.
26. Sustainable Society Foundation. Sustainable Society Index. 2020. Available online: <http://www.ssfindex.com/> (accessed on 30 January 2022).
27. Social Progress Imperative. 2021 Social Progress Index. Available online: <https://www.socialprogress.org/> (accessed on 20 January 2022).
28. Happiest Countries in the World 2021. Available online: <https://worldpopulationreview.com/country-rankings/happiest-countries-in-the-world> (accessed on 22 January 2022).
29. Katko, T.S. *Finnish Water Services—Experiences in Global Perspective*; Finnish Water Utilities Association: Helsinki, Finland, 2016; Co-Published E-book, IWA Publ.: London, UK, 2017.
30. Leppälä, K. Miten tekniikkaa oikein tieteellisesti tutkitaan? *Tiedepolitiikka* **1998**, *23*, 25–30.

31. Hughes, T.P. Human-Built World. In *How to Think about Technology and Culture*; The University of Chicago Press: Chicago, IL, USA; London, UK, 2004.
32. Statistics Finland. Population. Available online: http://www.stat.fi/til/vrm_en.html (accessed on 20 January 2022).
33. Hjerpe, R. *The Finnish Economy 1860–1985. Growth and Structural Change*; Bank of Finland: Helsinki, Finland, 1989.
34. Climate Elements s.a. Finnish Meteorological Institute. Available online: <https://en.ilmatieteenlaitos.fi/climate-elements> (accessed on 22 January 2022).
35. *Vesihuolto-Opas*; Vesiteknillinen Insinööritoimisto Oy Vesto: Helsinki, Finland, 1953.
36. Juuti, P.S.; Katko, T.S. (Eds.) *Water, Time and European Cities. History Matters for the Futures*. Printed in EU. 2005. Available online: <http://www.watertime.net/> (accessed on 22 January 2022).
37. Renko, T.; Luukkonen, H.; Sänkiäho, L. *Julkisoikeudellisen Hulevesimaksun Määrittäminen*; Suomen Kuntaliitto: Helsinki, Finland, 2015.
38. Juuti, P. *Suomen Palotoimen Historia*; Sisäasiainministeriö: Helsinki, Finland, 1993.
39. Suikkari, R. *Paloturvallisuus ja Kaupunkipalot Suomen Puukaupungeissa—Historiasta Nykypäivään*. Ph.D. Thesis, University of Oulu, Oulu, Finland, 2007. Available online: <http://jultika.oulu.fi/files/isbn9789514286995.pdf> (accessed on 30 January 2022).
40. Herranen, T. 125 years of life with water. In *The History of Water Services in Helsinki*; Helsinki Water: Helsinki, Finland, 2002.
41. Katko, T.S.; Juuti, P.S.; Hukka, J.J. An early attempt to privatise—Any lessons learnt? Research and technical note. *Water Int.* **2002**, *27*, 294–297. [CrossRef]
42. Katko, T.S.; Juuti, P.S. *Watering the City of Tampere from the Mid-1800s to the 21st Century*; Tampere Water & International Water History Association: Tampere, Finland, 2007. Available online: https://www.tampere.fi/material/attachments/vesi/vesi/8ibh6dM3H/Watering_the_City_of_Tampere1.pdf (accessed on 22 January 2022).
43. Juuti, P.S.; Mäki, H.R.; Rajala, R.P. Private initiatives in Finland and South Africa: Proposals for waterworks by von Nottbeck and Marks. *Water Hist.* **2010**, *3*, 29–43. [CrossRef]
44. Tampere City Archives, minutes of magistrate 18.10.1865 §2, 22.11.1865, 11.12.1865§8:1, 28.9.1874 Ca:55 and minutes of Tampere city council 24.2.1875 §6 CI:1.
45. Katko, T.S. *Water!—Evolution of Water Supply and Sanitation in Finland from the Mid-1800s to 2000*; Finnish Water and Waste Water Works Association: Helsinki, Finland, 1997.
46. Brown, R.R.; Keath, N.; Wong, T.H.F. Urban water management in cities: Historical, current and future regimes. *Water Sci. Technol.—WST* **2009**, *59*, 847–855. [CrossRef] [PubMed]
47. Katko, T.S. The use of wooden pipes in rural water supply in Finland. *Vatten* **1997**, *53*, 267–272.
48. Wäre, M. Maaseudun yhteiset vesi- ja viemärijohdot. *Maanvilj. Vuosik.* **1951**, 82–88.
49. Mäkelä, U.O. Painevesijohdoista Toholammilla. *Maanvilj. Vuosik.* **1944–1945**, 113–127.
50. Peräkylä, O. Kairattujen puuputkien käyttö vesijohtoina. *Maa- ja vesirakentaja* **1953**, *1*, 175–185.
51. Laakkonen, S. Vesiensuojelun synty. In *Helsingin ja sen Merialueen Ympäristöhistoria 1878–1928*; Gaudeamus: Helsinki, Finland, 2001.
52. Bakker, K. Privatizing water. In *Governance Failure and the World's Urban Water Crisis*; Cornell Univ. Press: Ithaca, NY, USA; London, UK, 2010.
53. Kaivo-oja, J.Y.; Katko, T.S.; Seppälä, O.T. Seeking for Convergence between History and Futures Research. *Futures J. Policy Plan. Futures Stud.* **2004**, *36*, 527–547. [CrossRef]
54. Melosi, M.V. Path Dependence and Urban History: Is a Marriage Possible? In *Resources of the City: Contributions to an Environmental History of Modern Europe*; Schott, D., Luckin, B., Massard-Guilbaud, G., Eds.; Ashgate: Hampshire, UK, 2005; pp. 262–275.
55. Rajala, R.P. *Long-Term Development Paths in Water Services—The Case of Finland*. Ph.D. Dissertation, Tampere University of Technology No 818, Tampere, Finland, 2009.
56. Lillja, J.L.W. *Helsingin Kaupungin Vesijohtolaitos 1876–1936*; Otava: Helsinki, Finland, 1938.
57. Masten, S.J.; Davies, S.H.; McElmurry, S.P. Flint Water Crisis: What Happened and Why? *J. AWWA* **2016**, *108*, 22–34. [CrossRef]
58. Fredrickson, W.J. The Economic Recovery of Finland since World War II. *J. Political Econ.* **1960**, *68*, 17–36. [CrossRef]
59. UNESCO–IHE Alumni from Finland (Online). Personal communication, 29 March 2012.
60. Johansson, B. Frisk vatten och rena sjöar. In *Från VAV till Svensk Vatten 1962–2002*; Svenskt Vatten: Stockholm, Sweden, 2002.
61. Nygård, H. *Bara ett Ringa Obehag? Avfall och Renhållning i de Finländska Städernas Profylaktiska Strategier 1830–1930*. Ph.D. Thesis, Åbo Akademi förlag, Turku, Finland, 2004. Available online: <http://www.doria.fi/handle/10024/4126> (accessed on 30 January 2022).
62. Groundwater in Finland s.a. Available online: https://www.ymparisto.fi/enus/Waters/Protection_of_waters/Groundwater_protection/Groundwater_in_Finland (accessed on 22 January 2022).
63. Juuti, P.; Katko, T. *Ernomane Vesitehdas—Tampereen vesilaitos 1835–1998 (Marvellous Water Factory—Tampere Water Works 1835–1998)*; Tampere City Water Works: Tampere, Finland, 1998; (Summary in English and Swedish). Available online: <https://trepo.tuni.fi/handle/10024/66324> (accessed on 22 January 2022).
64. Katko, T.S.; Lipponen, A.M.; Rönkä, E.K.T. Groundwater use and policy in community water supply in Finland. Report. *Hydrogeol. J.* **2006**, *14*, 69–78. [CrossRef]
65. Gagneur, B. Om grundvattenförhållanden. *Teknikern* **1910**, *20*, 377–383.

66. Kurki, V.; Pietilä, P.; Katko, T. Assessing regional cooperation in water services: Finnish lessons compared with international findings. *Public Work. Manag. Policy* **2016**, *21*, 368–389. [CrossRef]
67. Kurki, V.; Takala, A.; Vinnari, E. Clashing coalitions: A discourse analysis of an artificial groundwater recharge project in Finland. *Local Environ.* **2016**, *21*, 1317–1331. [CrossRef]
68. Juuti, P.S.; Juuti, R.P.; Katko, T.S.; Lipponen, A.M.; Luonsi, A.A.O. Groundwater option in raw water source selection and related policy changes in Finland. *Public Work. Manag. Policy*, 2022; *accepted*.
69. Oral, H.V.; Carvalho, P.; Gajewskac, M.; Ursino, N.; Masi, F.; Hullebusch, E.D.V.; Kazak, J.K.; Exposito, A.; Cipolletta, G.; Andersen, T.R. A review of nature-based solutions for urban water management in European circular cities: A critical assessment based on case studies and literature. *Blue-Green Syst.* **2020**, *2*, 112. [CrossRef]
70. Katko, T.; Juhola, P.; Kallioinen, S. Declining water consumption in communities: Sign of efficiency and a future challenge. *Vatten* **1998**, *54*, 277–282.
71. Rajala, R.P.; Katko, T.S. Household water consumption and demand management in Finland. *Urban Water J.* **2004**, *1*, 17–26. [CrossRef]
72. Zacheus, O. *Yhteenveto suurten Vedenjakelualueiden Talousveden Valvonnasta ja Laadusta Vuonna 2020*; Finnish Institute for Health and Welfare: Helsinki, Finland, 8 December 2021.
73. Jokela, P.; Vaahtera, M.; Vuori, T.; Meriluoto, J. The Effect of Iron and Aluminium Chemicals in Humic Water Treatment by High-Rate Dissolved Air Flotation. In *Chemical Water and Wastewater Treatment IX*; Hahn, H.H., Hoffmann, E., Odegaard, H., Eds.; IWA Publishing: London, UK, 2007; pp. 221–229.
74. Suutarinen, O.; (Insinööritoimisto Oy Rictor Ab., Helsinki, Finland). Personal communication, 11 December 2015.
75. Tanhuala, T. Vedenkäsittelyn kehitys Suomessa. Master's Thesis, Tampere University of Technology, Tampere, Finland, 1994.
76. Mattila, H. The role of public acceptance in the application of DESAR technology. In *Decentralised Sanitation and Reuse—Concepts, Systems and Implementation*; Lens, P., Zeeman, G., Lettinga, G., Eds.; IWA Publishing: London, UK, 2001; pp. 517–533.
77. Szabo, H.M.; Kaarela, O.; Tuhkanen, T. Finnish well water quality in rural areas surrounded by agricultural activity. *Vatten* **2009**, *65*, 27–35.
78. Berninger, K.; Laakso, T.; Paatela, H.; Virta, S.; Rautiainen, J.; Virtanen, R.; Tynkkynen, O.; Piila, N.; Dubovik, M.; Vahala, R. *Tulevaisuuden Kestävä Vesihuolto—Ennakointi, Ohjaus ja Järjestäminen*; Valtioneuvosto: Helsinki, Finland, 2018; Selvitys- ja tutkimustoiminnan julkaisusarja 56.
79. MoAF (Ministry of Agriculture and Forestry). Vesitalousstrategia 2011–2020. Helsinki, Finland, 2011. Available online: https://mmm.fi/documents/1410837/1516651/Vesivarastrategia_esite_lores.pdf/d2f18f53-9d94-4012-8d86-259bb05b1c5f/Vesivarastrategia_esite_lores.pdf.pdf (accessed on 22 January 2022).
80. Asola, I. *Vesitorni—Yhdyskunnan Maamerkki (Water Tower—Landmark of the Community)*; RIL: Helsinki, Finland, 2003; (Partly in English).
81. Nagler, B.E. Elevated Concrete Reservoirs in Finland. *J. AWWA* **1966**, *58*, 1429–1445. [CrossRef]
82. Sunela, M.I.; Puusti, R. Real-Time Whole-Cost Optimization of Water Production and Distribution. In Proceedings of the Computing and Control for the Water Industry CCWI2017, Sheffield, UK, 5–7 September 2017; p. F38. Available online: <https://ccwi2017.figshare.com/> (accessed on 22 January 2022).
83. Heino, O.A.; Takala, A.J.; Katko, T.S. Challenges to Finnish water and wastewater services in the next 20–30 years. *E-Water* **2011**. Available online: <http://www.ewa-online.eu/e-water-documents.html> (accessed on 22 January 2022).
84. Katko, T.S.; Hukka, J.J.; Juuti, P.S.; Rajala, R. Rehabilitation of Aging Urban Water Systems: Strategic Thinking Required. *Geosciences* **2018**, *8*, 230. [CrossRef]
85. Cutler, B. Identifying the Gaps between Water and Wastewater Operators and Market Partners. *WaterWorld* **2019**, *1*, 18–19.
86. Hukka, J.J.; Katko, T.S. Resilient Asset Management and Governance for Deteriorating Water Services Infrastructure. 8th Nordic Conference on Construction Economics and Organization. *Procedia Econ. Financ.* **2015**, *21*, 112–119. Available online: <https://www.sciencedirect.com/science/article/pii/S2212567115001574> (accessed on 22 January 2022). [CrossRef]
87. Taipale, P. Pääkaupunkiseudun vesi Oy. Päijänne-tunnelin peruskorjaus valmistui. *Kuntatekniikka* **2009**, *63*, 58.
88. Elo, P.; (Turku Water, Turku, Finland). Personal communication, 26 January 2020.
89. Lukka, A.; (HSY, Helsinki, Finlanda). Personal communication, 11 February 2019.
90. Laakkonen, P.; (Tampere Water, Tampere, Finland). Personal Communication, 10 February 2019.
91. Manner, V. *Hämeenlinnan Kaupungin vesijohto- ja Viemäriulaitos*; Suomalainen Kirjapaino Oy: Helsinki, Finland, 1910.
92. Juuti, P.; Rajala, R.; Katko, T. Metropoli ja Meri: 100 vuotta jätevedenpuhdistusta Helsingissä; HSY, Julkaisu 6/2010, Helsinki, Finland. Available online: <https://trepo.tuni.fi/handle/10024/65422> (accessed on 22 January 2022).
93. Katko, T.S.; Kurki, V.O.; Juuti, P.S.; Rajala, R.P.; Seppälä, O.T. Integration of water and wastewater utilities: A case from Finland. *J. AWWA* **2010**, *102*, 62–70. [CrossRef]
94. Lapinlampi, T. (Ed.) Vesihuoltolaitokset. In *Vesilaitokset 1970–2014*; SYKE Raportteja 22/2021; Suomen Ympäristökeskus: Helsinki, Finland, 2021.
95. Kallio, J.; (SYKE, Velvet, Helsinki, Finlanda). Personal communication, 31 January 2019.
96. Katko, T.S.; Luonsi, A.A.O.; Juuti, P.S. Water Pollution Control and Strategies in Finnish Pulp and Paper Industries in the 20th century. *Int. J. Environ. Pollut.* **2005**, *23*, 368–387. [CrossRef]

97. Metsäteollisuus ry. Metsäteollisuus on Onnistunut Vesiensuojelutyössä Erinomaisesti. 1 July 2019. Available online: <https://www.metsateollisuus.fi/uutishuone/metsateollisuus-onnistunut-vesiensuojelutyossa-erinomaisesti> (accessed on 30 January 2022).
98. Sulfaattikomitea. *Komitean Mietintö, 1909:1*; Sulfaattikomitea: Helsinki, Finland, 1909; pp. 48–57.
99. Konttinen, E. *Päijänne Puhtaaksi–Reittivedet Raikkaammaksi*; Publication No. 57; University of Jyväskylä, Department of Sociology: Jyväskylä, Finland, 1994.
100. Mattila, H. Appropriate Management of on-Site Sanitation. Ph.D. Thesis, Tampere University of Technology, Tampere, Finland, 2005. Available online: <https://trepo.tuni.fi/handle/10024/114828> (accessed on 22 January 2022).
101. Swedish Environmental Protection Agency. *Wastewater Treatment in Sweden in 2018*; Swedish Environmental Protection Agency: Stockholm, Sweden, 2020. Available online: <https://www.naturvardsverket.se/om-oss/publikationer/8800/wastewater-treatment-in-sweden-2018> (accessed on 30 January 2022).
102. The Association of Finnish Water Cooperatives s.a. Available online: <https://svosk.fi/svosk-3/the-association-of-finnish-water-cooperatives/> (accessed on 22 January 2022).
103. Association of Danish Water Supply s.a. Available online: <https://stateofgreen.com/en/partners/association-of-danish-water-supply/> (accessed on 22 January 2022).
104. North, D.C. *The Role of Institutions in Economic Development*; Discussion Paper Series No. 2003.2; United Nations Economic Commission for Europe: Geneva, Switzerland, 2003. Available online: https://unece.org/DAM/oes/disc_papers/ECE_DP_2003-2.pdf (accessed on 25 January 2022).
105. Hukka, J.J.; Katko, T.S. *Towards Sustainable Water Services: Subsidiarity, Multi-Level Governance and Resilience for Building Viable Water Utilities*; Tampere University, CADWES Publications: Tampere, Finland, 2021. Available online: <http://www.cadwes.com/publications/others/> (accessed on 22 January 2022).
106. Ostrom, E. *Governing the Commons; The Evolution of Institutions for Collective Action*; Cambridge University Press: Cambridge, UK, 1990.
107. Oakerson, R.J. *Governing Local Economies: Creating the Civic Metropolis*; ICS Press: Oakland, CA, USA, 1999.
108. Katko, T.S.; Hukka, J.J. Social and Economic Importance of Water Services in The Built Environment: Need for More Structured Thinking. 8th Nordic Conference on Construction Economics and Organization. *Procedia Econ. Financ.* **2015**, *21*, 217–223. Available online: <https://www.sciencedirect.com/science/article/pii/S2212567115001707> (accessed on 22 January 2022). [CrossRef]
109. ROTI s.a. Rakennetun Omaisuuuden Tila; RIL: Helsinki, Finland. Available online: www.roti.fi (accessed on 30 January 2022).
110. Vahala, R. *Vesihuolto Vuonna 2050*; Vesivision Tulevaisuusseminaari 29.8.2017; Pirkanmaan ELY-keskus: Tampere, Finland, 2017.
111. Takala, A.; Arvonen, V.; Katko, T.; Pietilä, P.; Åkerman, M. The evolving role of water co-operatives in Finland—Lesson learnt? *IJ Co-Oper. Manag.* **2011**, *5*, 11–19.
112. Schumacher, E.F. *Small Is Beautiful. A Study of Economics as if People Mattered*; Blond & Bridge: London, UK, 1973.
113. Vinnari, E.M.; Näsi, S. Creative Accrual Accounting in The Public Sector: Milking Water Utilities to Balance Municipal Budgets and Accounts. *Financ. Account. Manag.* **2008**, *24*, 97–116. [CrossRef]
114. VEPATUKI, s.a. Available online: <http://www.cadwes.com/vepatuki/> (accessed on 22 January 2022).
115. Rådgivende Ingeniørers Forening. *State of the Nation–Norges Tilstand*; Rådgivende Ingeniørers Forening: Oslo, Norway, 2019. Available online: <https://rif.no/wp-content/uploads/2019/08/Vann-Avl%C3%B8psanlegg.pdf> (accessed on 30 January 2022).
116. ASCE (American Society of Civil Engineers). *America’s Infrastructure Report Card 2021*; ASCE: Reston, VA, USA, 2021. Available online: <https://infrastructurereportcard.org> (accessed on 22 January 2022).
117. Arvonen, V.; (SVOSK, Konnevesi, Finland). Personal communication, 19 January 2022.
118. Head, B.W. Wicked Problems in Public Policy. *Public Policy* **2008**, *3*, 101–118.
119. FIWA (Finnish Water Utilities Association), s.a. Available online: <https://www.vvy.fi/vesilaitosyhdistys/in-english/> (accessed on 22 January 2022).
120. SVOSK, s.a. (The Finnish Association of Water Cooperatives). Available online: <https://svosk.fi/> (accessed on 30 January 2022).
121. Water Association Finland s.a. Available online: <https://www.vesiyhdistys.fi/briefly-in-english/> (accessed on 30 January 2022).
122. MFA (Ministry for Foreign Affairs). *Finland’s Support to Water Supply and Sanitation 1968–2000*; Evaluation of Sector Performance: Helsinki, Finland, 2001.
123. MFA. *The Finnish Development Cooperation in the Water Sector*; Evaluation Report 2010:3; MFA: Helsinki, Finland, 2010.
124. van Dam, P.J.E.M.; van Cruyningen, P.; van Tielhof, M. A Global Comparison of Pre-Modern Institutions for Water Management. *Environ. Hist.* **2017**, *23*, 335–340. [CrossRef]
125. Skyttä, K. Personal communication, 7 January 2016.
126. Wäre, M. *Maaseudun Vesihuolto*; Mitä-missä-milloin, kansalaisen vuosikirja **1953**, *3*, 216–219; Otava: Helsinki, Finland, 1953.
127. Kotitalouden rationalisointikomitea. *Maaseudun Vedenhankinta- ja Viemäriolojen Parantaminen*; Mietintö No. 1.: Helsinki, Finland, 1950; 73p.
128. Katko, T. *Vettä! Suomen Vesihuollon Kehitys Kaupungeissa ja Maaseudulla*; Vesi- ja viemäriulaitosyhdistys: Helsinki, Finland, 1996.
129. Hanski, M. (MoAF, Helsinki, Finland). Personal communication, 30 March 2007.
130. Kallio, J. (MoAF, Helsinki, Finland). Personal communication, 26 January 2022.
131. FIWA (Finnish Water Utilities Association). Presentation at the Kuntamarkkinat-Fair, Helsinki, Finland, 14–15 September 2016.
132. FIWA. *Vesihuoltolaitosten Maksuja Koskevat Ohjeet ja Suositukset*; FIWA: Helsinki, Finland, 2017.

133. Ostrom, E. *Understanding Institutional Diversity*; Princeton University Press: Princeton, NJ, USA, 2006.
134. Juuti, P.; Mattila, H.; Rajala, R.; Schwartz, K.; Staddon, C. Resilience is the key for sustainable water services. In *Resilient Water Services and Systems: The Foundation of Well-Being*; Juuti, P., Mattila, H., Rajala, R., Schwartz, K., Staddon, C., Eds.; IWA Publishing: London, UK, 2019; pp. 1–7.
135. FIWA. *Vesilaitosyhdistyksen Strategia: Visio 2030 ja Tiekartta 2021–2030*; FIWA: Helsinki, Finland, 2021. Available online: <https://www.vvy.fi/ajankohtaista/uutiset/vesilaitosyhdistyksen-strategia-visio-2030-ja-tiekartta-2021-2030/> (accessed on 26 January 2022).