Urban River Basin Enhancement Methods

REVITALISATION OF THE LJUBLJANICA RIVER

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INTRODUCTION

The relationship between a developing urban environment and water is manifold. Water is the source of life and a city cannot function properly without a modern and safe water supply. However, water may pose a direct threat to human lives by ways of pollution and floods. Furthermore, water is a major basis for an array of economic civic activities: shipping, sailing, fishing and the use of water force. And importantly, water in built-up city areas provides a means of staying in touch with nature and enables a unique design of man-friendly urban environment.

In spatial planning, a proper solution to crossing the gap between surface water regimes and urbanization is necessary. A water regime with its flow dynamics demands its space; however the city with its own demands of development may want to narrow that very space as much as possible. Simultaneously, urbanisation modifies discharge conditions, which consequently leads to damages imposed on the city during flood events. Ecologically affected water environment fails to provide clear water and friendly environment, bearing an indirect effect on urban life. A modern approach to sustainable development, specified by the Water Framework Directive calls for solutions enabling the development of a safe urban environment and an enhanced development of water regime as well as the possibility of achieving good conditions of water bodies.

The present paper aims at presenting the urban Ljubljanica River from the Ambrož Square to the Špica with the Gradaščica watercourse to the bridge in Riharjeva Street and the Mali Graben, Figure 1, set as case examples of good practice in managing urban watercourse regimes. The Ljubljanica and Gradaščica watercourses were chosen due to their originally beautiful, man-friendly and functionally arranged banks designed by architect Jožef Plečnik. Standing out are the sluice gate, fish market, the Three Bridges and embankment around the Three Bridges, Trnovo Pier and the Gradaščica embankment between the Trnovo church and the bridge on Riharjeva Street. The Ljubljanica water regime on the particular reach is managed by a gate at the Ambrož Square that regulates the low-flow channel. Without the gate, during periods of low flow the flow in the paved channel charged with urban alluvial deposits would have been narrow and shallow. The Mali Graben has been chosen because of its transversal structures that enhance channel wateriness and form river pools and riffles.

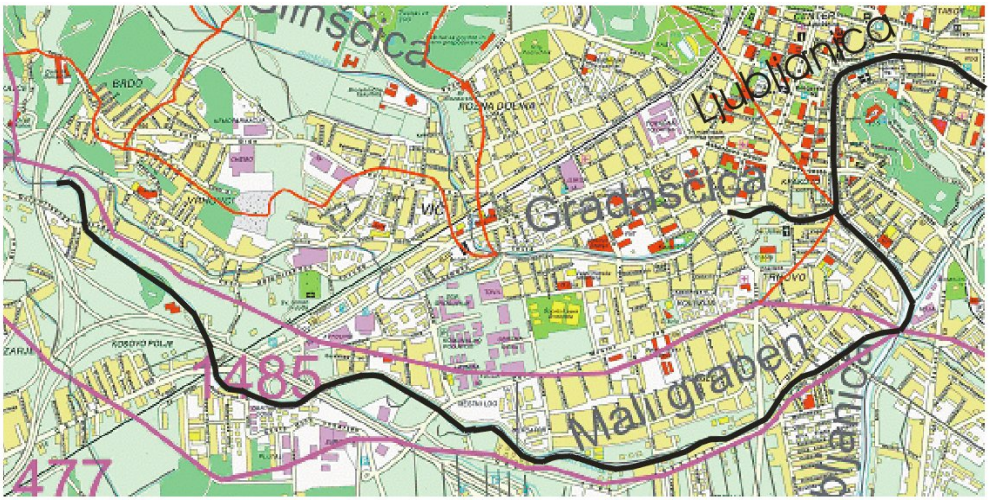

Figure 1. Streams and the surrounding area of the case study site.

HISTORICAL OVERVIEW OF WATER-RELATED ISSUES

The development of the city core of Ljubljana and the Ljubljanica River management dates back to the time of ancient Greece and Rome with the building of Emona, Figure 2. Unfortunately, there are no maps from the time available, however, the position of the city was harmonised with the position and water regime of the then watercourses of the Ljubljanica and Gradaščica that were equipped with structures for navigation and bridges.

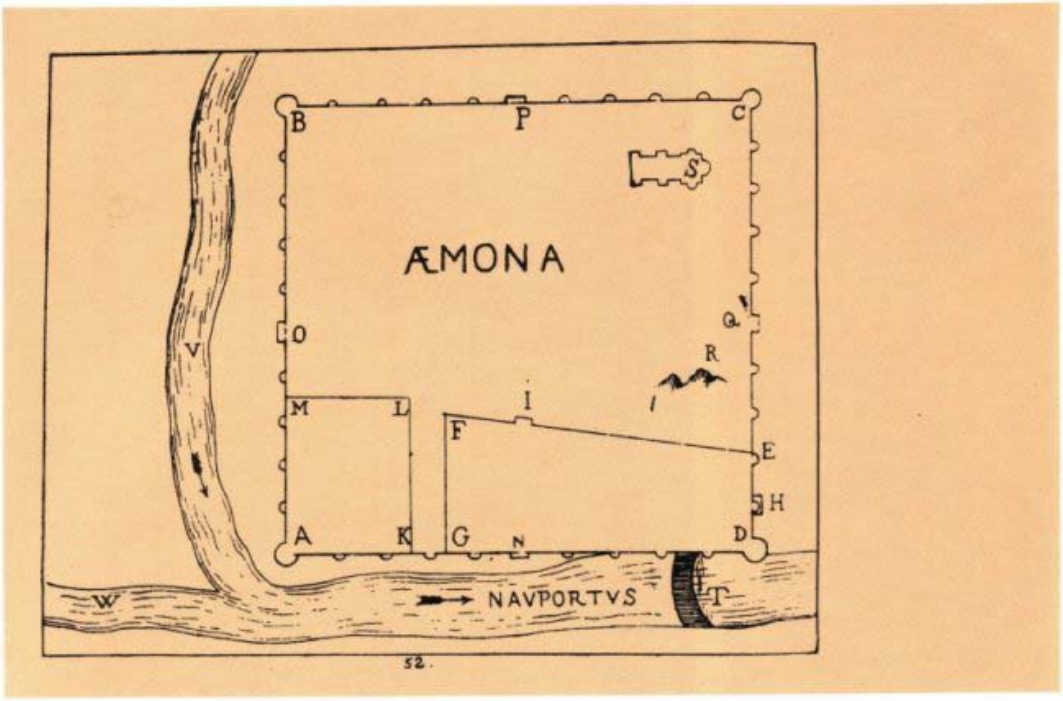

Figure 2. Emona; Source: Korošec (1991).

Regarding water structures, the medieval Ljubljana boasted a characteristic rake placed transversally to the watercourse among the fortified city walls, Figure 3, Korošec 1991. In addition to the rake, there is a ditch between the castle hill and the Ljubljanica, as seen on the map. Ljubljana spread to both river banks, and consequently, the flood plain area was narrowed with houses, fortified banks, mill dams and fortification objects, Uhlir 1956.

Additionally, owing to occasional flood events, the narrow and shallow channel could not carry the flood water. Major floods were registered in 1190, 1537, and 1599. A first greater intervention into the Ljubljanica water regime in the respective section was the building of the Grubar channel that diverted the flood flow past the city core. The building was accompanied by high costs regarding compensation of purchase of land and unexpected works caused by geological soil composition. The building took place between 1773 and 1780. The preparations and discussions of the variants of possible interventions date back to 1769, when a decree of Empress Mary Theresa was issued, providing the funds for the building. The proposition of demolishing the dams on the Ljubljanica River and expanding the channel in the city failed to receive a proper support of the city and the States. The foreseen changes in the channel of the urban Ljubljanica, otherwise predicted as part of a wide-ranging project, later remained unrealized due to lack of means. The works, i.e. related to dredging and removal of mill

dams, were executed as late as in the period of 1823–27, Uhlir 1956. The position of riparian structures is evident from Austrian army maps dating back to the end of XVIII century (1763–1787), Figure 4.

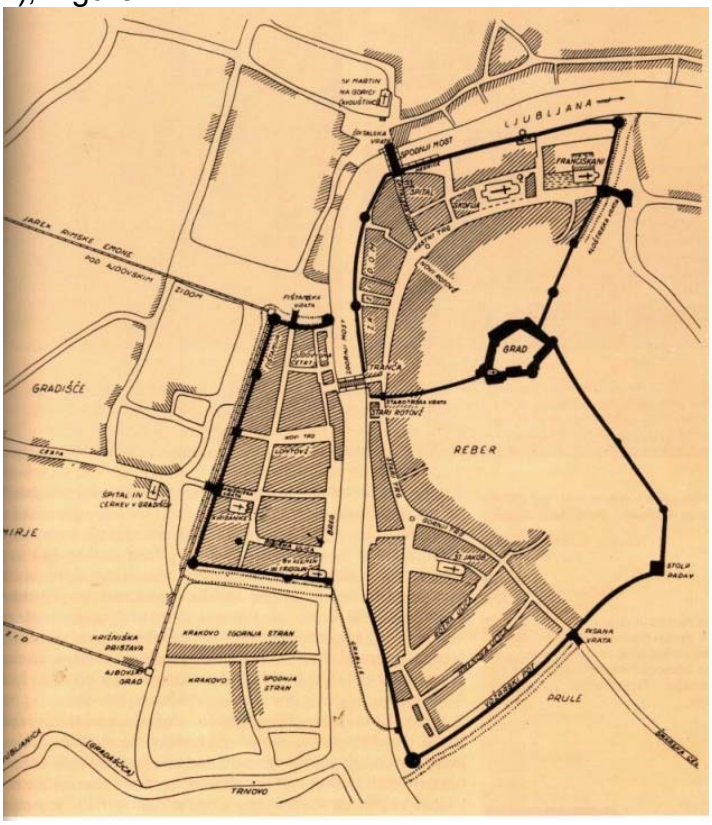

Figure 3. Ljubljana in the 16 th and 17 th centuries; Source: Korošec (1991).

Figure 4. Austrian army map of Ljubljana; Source: Rajšp and Ficko (1996).

Navigation on the Ljubljanica River was essential in the development of the medieval Ljubljana, Figures 5 and 6 (Korošec 1991, Holz 1997). Navigation was first mentioned in 1092, Uhlir 1956. Navigational rights were under princely jurisdiction and an important source of income. With the arrival of railway in the mid-19th century, navigation lost its meaning and in fact died out completely. However, street names in Trnovo (Little and Great Boat St.) and embankment names (Trnovo Pier) still bear witness of the importance of navigation.

Figure 5. Navigation on the Ljubljanica River in the beginning of the 19th century; Source: Korošec (1991).

Figure 6. Illustration of the celebrations on the Ljubljanica River in honour of Crown in 1819; Source: Holz (1997).

The Ljubljana city development was badly interrupted by the 1895 earthquake that caused severe damage but admittedly enabled an urban reconstruction of the city, which gradually transformed from an extended village into a modern European city (Uhlir 1957). Following a successful building of waterworks and several public facilities, the rapidly evolving city came across its first problems owing to the regime of its watercourses. In 1924, there were great floods of the Gradaščica in the Vič area in the Ljubljana suburbs. Due to settlement needs there were extensive works on the Gradaščica regulation, diverting the water into the Mali Graben channel and building levees in the area between the Gradaščica channel and Tržaška Street. The works continued with regulation works on the Ljubljanica. The Ljubljanica River training was additionally enhanced after the 1933 flood that damaged the city core as well. An integral channel fortification encompassed also regulation works of the urban sewage system that put a stop to a free discharge into the channel, causing unpleasant smells with low water level.

Bank training of the urban Ljubljanica was included into the urban plan of the after-earthquake restoration of Ljubljana. The training was dictated by the developing city core in the 19th century and by the completed regulation works. Channel dredging and loading of the excavated material onto the banks formed a deep channel with steep banks. The basic design for the river training with vertical walls was proposed by the Vienna architect Keller in 1913, which followed the example of a similar regulation of the Wienfluss river in the narrow city centre of Vienna. In 1929, architect Jožef Plečnik undertook the design of construction works on the Ljubljanica banks; he managed to change the roughly shaped channel with vertical walls into a friendly and humane environment, Krečič, 1992. Plečnik used every opportunity to enhance the regulation works and improve the contact of man and nature, figures 7 and 8.

Figure 7. Pedestrian-friendly bank construction made by Plečnik

Figure 8. Three Bridges with river bank access and development made by Plečnik

After World War II works on the gate at the Ambrož Square came to an end and no further alterations followed, with the exception of groundwater discharge from the Cankarjev Dom area, figure 9. The gate fulfill concrete stream channel with water and instead shallow water flow with visible concrete bottom, navigable water course and water body deep more than few meters was established. Volume of the water increases tremendously, figure 8.

Figure 9. The gate on Ambrož Square

The gate on the Ambrož Square is also important with regard to management of surface waters and groundwater regime upstream of Ljubljana moor. The Ljubljana moor, a large flat area with an artesian aquifer covered by 20 meters of unconsolidated clay, is

highly vulnerable to changes in water regime. Lowering the in stream water level of the Ljubljanica river could cause bank slides and instability of the riverbank in the Ljubljana moor area. Lower in stream water level and indirectly a lower artesian groundwater pressure that caused consolidation of the clay layer, subsidence of land surface of the large flood area.

Worsening of water quality in the Ljubljanica due to urbanization and industrialization of the watershed marked the-1950–1990 period. The water failed to meet bathing water criteria and consequently the Špica baths closed down. Additionally, navigation on the river disappeared with the exception of amateur boating.

Additionally, small-sized watercourses at the city edge were polluted; open sewage system had changed them into a site of filth and rats. Thus, a much needed regulation of the urban Gradaščica and Glinščica channels followed in 1974. Today, their channels are narrowed into tight channels made of concrete and rather resemble an open sewage system as opposed to a natural watercourse.

What remained was fishing managed by fishing societies. Owing to the demands and needs of the Dolomiti fishing society, a successful revitalization of the Mali Graben channel with transversal dams was carried out. The dams raised the water level in the channel, increased its volume, and formed several river pools and rapids, and thereby enabled an increase of fish population by 50 %.

After 1990, water quality in the Ljubljanica River started to improve, this being the basic condition for several riparian activities, especially recreational activities. An improved water quality has enabled navigation for tourist needs, which has been developing gradually. The problem remains the insufficient bank regulation and a general disorganization of activities.

3 STATE OF THE LJUBLJANICA, GRADAŠČICA AND MALI GRABEN WATERCOURSES

For the reaches of the Ljubljanica River from the Špica area to the gates at the Ambrož Square an urban regulation of the watercourse is characteristic. The urban regulation has been increasing, following the natural pre-urban river with natural banks and abundance of bank vegetation, park-like setting regulations in the Trnovo Pier area, putting into the foreground the natural watercourse, and finally evolving into a completely urban watercourse with high density of bank built-up areas downstream the Zois Bridge. Photos of presented sections are available on http://ksh.fgg.uni-lj.si/urbemdatasi/.

Plečnik's regulation of the Gradaščica River reaches from the confluence up to the bridge on Grohar Street. The Mali Graben watercourse runs from the weir on Bokalce downstream towards the confluence with the Ljubljanica River in The Špica area, Figure 1.

3.1 ALONG THE LJUBLJANICA RIVER

3.1.1 Špica and Trnovo Pier Sections

The Špica area is intended for mooring of an increased number of river boats. At the section, river banks are grassy or ordered with natural rocks. They reach to the water level and are equipped with walking paths and benches. The left bank has been arranged as a tree-lined promenading path.

The Trnovo Pier is a major feature of urban planning and a constituent part of the green system of Ljubljana. It boasts a characteristic avenue planted with trees on the left bank, while the opposite bank is grassy with a pathway. At the ending section, the urban Gradaščica flows into the Ljubljanica River. The Trnovo Pier was regulated by architect Jožef Plečnik in 1932 and presents an extraordinarily beautiful, friendly and functional spatial arrangement. The wide steps enable a direct access and contact with water, as well as the possibility of spending time on the river banks and a pleasant way of having a rest or walk. High trees give an additional protection against sun and are of enjoyable nature.

3.1.2 Urban Ljubljanica Section

The urban Ljubljanica section downstream of the Zois Bridge differs from the Špica and the Trnovo Pier in having a distinctive concrete river bed with high walls. In the first section, the highly regulated watercourse beds are still grassy and equipped with tree-lined arrangements and benches. Along the left and right banks, respectively, there are pavements and traffic ways.

In the Cobblers' Bridge area, there are no more high grassy watercourse banks. The concrete channel walls terminate as a fence, on the left and right banks there are tree-lined arrangements all the way to the Three Bridges that finishes off on the right river bank with the colonnade of the Ljubljana market. The concrete walls are decorated with rock materials, and intermittent terraces were built that enable the growth of decorative plants and provide a cover-up for the grey concrete walls. Restaurants built into the walls of the banks and set-up floating pontoons enable further contact between the city and river.

The market is of exceptional beauty. Plečnik put the fish market into the vertical bank and lowered it to the water level. The visitors are given a fine view of the by-passing river.

Downstream of the Dragon Bridge the channel and grassiness of the banks are similar to the ones of the Zois and Cobblers' Bridges. Somewhat lower walls of the concrete channel were revitalised with grassy banks, tree-lined arrangements and benches. Similar is the situation downstream of the Ambrož Bridge gates.

A study entitled "Arrangement of the riparian space of the Ljubljanica River from the Barje marshes to the Sava River" (LUZ d.d., 1997) has included for the Špica area, Trnovo Pier, and the urban Ljubljanica River an overview of proposals for arrangements and use, a complex analysis of riparian space and a description of main characteristics of the river reaches under consideration. On the basis of identification of problems (maintenance, planning, and arrangements, deterioration of riparian space, river as public good), conditions for implementation of programmes into riparian space, and professional bases for an integrated planning the study proposed suggestions for planning the riparian space. It gives mapping resources, including the problem map (inaccessible watercourse banks, disconnectedness of the river corridor, low amenity value of the hinterland, disuse, improper public utilities, and ecologically and spatially degraded space of the river corridor).

3.2 ALONG THE GRADAŠČICA

Plečnik's regulation of the Gradaščica reaches from the confluence up to the bridge on Grohar Street. The lower section from the confluence to the Trnovo Church is strongly fortified with a concrete channel and vertical walls. Peculiar are the walking zone in Eipprova Street at the right bank lined with chestnuts.

The walking path on the left bank of the Gradaščica from the Trnovo Church to the bridge on Grohar Street is an example of a simple and friendly arrangement, enabling a direct access to the water. The water quality has gradually enhanced, and a revitalisation of the stream, including the removal of concrete lining, has been foreseen.

3.3 ALONG THE MALI GRABEN

3.3.1 Kozarje Section

The Mali Graben watercourse runs from the dam on Bokalce downstream towards Dolgi most passing the areas of Kozarje and Češminj. In the respective section, the watercourse is fairly wide, this being due to open space surrounding it, and is not limited by built structures and infrastructure connections in its proximity. Land use of riparian areas along the Mali Graben watercourse in the Bokalci–Dolgi most section is fairly agricultural. Upper riparian vegetation is well preserved and in mature condition. Here and there the riparian vegetation develops into a belt of hinterland vegetation. The banks of the watercourse are in their natural condition overgrown with riparian vegetation (in sections overgrown completely). In Bokalce in certain sections downstream they are fortified with massive rocks. The streambed is natural. Mud and large particles of alluvial deposits prevail. Water management measures in the form of

stone weirs are noticeable that were carried out in the course of stream stabilization. In some sections, watercourse banks are due to dense riparian vegetation hard of access.

3.3.2 Dolgi Most Section

In the Dolgi most area the Mali Graben watercourse is crossed by three anthropogenic (man-made) corridors: the south Ljubljana ring, the regional road Ljubljana–Vrhnika and Ljubljana–Koper railway. From the crossings downstream along both banks of the Mali Graben corridor, a residence area has been under development. The watercourse corridor is substantially narrower, upper riparian vegetation is removed completely. The banks are grassy and overgrown with low riparian vegetation. The preserved hinterland vegetation is in mature state. Downstream the watercourse corridor is widened again; the overgrowth is extensive in both banks. River bottom is in natural condition, mud is in prevalence. There are some rocky ground thresholds. The corridor is crossed in the respective section by two street corridors, Lipan Street and the south ring. Watercourse banks are partly accessible via fishing paths and stands.

3.3.5 Mestni Log Section

In the Mestni log area of the Bonifacija, Murgle and Sibirija settlements the Mali Graben corridor is narrower. The riparian areas of the left and right banks take up open space and built structures, mainly individual residential buildings and traffic infrastructure. Along the left bank at Bonifacija there is in the immediate proximity of the watercourse of the major town planning features, a constituent part of the green system of Ljubljana and a prominent recreational area of the local inhabitants, namely the “pot” (Path of Remembrance and Comradeship). The bank boasts along the Path of Remembrance and Comradeship well-developed riparian vegetation, overgrowing the watercourse channel. Hinterland vegetation was removed during the building of settlements on both watercourse banks. The stream has natural mud bottom, in parts reinforced with transversal ground thresholds. Due to its dense riparian vegetation, the watercourse is hard of access and only in places functionally connected to the Path. The watercourse corridor widens once more downstream from the Murgle, where the dense vegetation of mature state partly overgrows the watercourse. Hinterland vegetation is well spread as well. In places, the hinterland and partly the riparian vegetation is intermittent due to land plots of individual residential objects, otherwise the riparian areas are mostly in the process of overgrowing. The banks are unmanaged, poorly accessible and left to natural succession.

The Path of Remembrance and Comradeship. Not so much hidden as impossible to take in at a single glance, this 30 km circuit of marked trails threading through Ljubljana's outskirts is both a reminder of history and a living recreational area. Numerous signposts and plaques reading "POT" (as in *Pot spominov in tovarištva*) mark the place where Ljubljana's World War II Italian occupiers erected a barbed wire barrier, intending to cut the city off from the outside world and choke its resistance movement. Now a very popular promenading and cycling path, the POT encompasses important sights like Žale Cemetery and Fužine Castle, the green slopes of Mostec and Golovec, suburban-industrial areas, and broad tracts of scenic countryside.

3.3.3 Trnovo Section

For the Mali Graben flow in the south ring section into the city centre towards the Mali Graben flow into the Ljubljanica a narrower river corridor with dense riparian vegetation is characteristic. Land use of riparian areas involves settlements of individual residential houses with private gardens reaching to the watercourse bank and disconnecting

riparian vegetation. There is hardly any hinterland vegetation in the section with the exception of the Mesarica area, which boasts well developed small allotments. The river bottom is natural and mostly muddy, the banks are grassy and partly overgrown with riparian vegetation. Watercourse access in the section is mostly limited by private ownership of land.

3. 3. 4 State of Water Body after Implementation (according to Water Framework Directive)

According to the EU directive, evaluation of the ecological state of a specific water body calls for determination of the biological state, taking into account characteristic living structures in water ecosystems, namely in phytoplankton, macrophytes, phytobenthos, ground invertebrate fauna, and fish communities. The project included the valuation of the biological state in the Ljubljanica in urban environment and in the Mali Graben, and that after the measures carried out in certain sections of the watercourses. The state of the Ljubljanica River was assessed as poor according to its ecological status, considering biological, physical, and chemical as well as hydromorphological parameters. The microbiological parameters and parameters needed for estimating the bathing water criteria are even poorer and fall into the lowest category (3), failing to meet bathing water criteria altogether. In comparison to the Ljubljanica, the ecological state in the Mali Graben is one level higher, and demonstrating partly changed ecological status (moderate after revitalisation).

By way of a detailed analysis of living structures in the mentioned water bodies it can be established that the state of phytoplankton, macrophytes, phytobethos and fish communities is fairly good, however changed (i.e. moderate) in ground invertebrate fauna. Due to unfit hydrological conditions, there is no typical phytoplankton community in the Mali Graben, while other communities demonstrate a good state of water body.

The general chemical state in the Mali Graben is one level better than the one in the Ljubljanica (poor). Due to unregulated communal water treatment there are high contents of organic material in the water, especially critical in the Ljubljanica are some heavy metals in sediments and, according to the specific synthetic conditions, their state is considered bad. None of the chosen water bodies meets bathing water criteria needs, since the parameter values are exceeded; the inadmissible microbiological parameters stand out considerably, namely the high E. coli index, physical and chemical parameters and other substances indicating pollution, namely heavy metals and other pathogens.

A detailed overview of the state of communities in the Ljubljanica River may show the following: in the community of major water invertebrates, there is a prevalence of indicators of organic pollution, therefore – as mentioned before – the state of the Ljubljanica is moderate regarding invertebrates. Characteristic taxa are *Polycelis* sp., *Lumbriculidae, Naididae, Tubificidae, Enchytreidae, Eiseniella tetraedra*, some *Ephemeroptera*, and *Trichoptera* as well as a frequent occurrence of *Chironomidae*, among them *Orthocladinae* and genus *Chironomus*. The riverbed is overgrown by typical tree species, among them the frequent *Alnus* sp., *Salix* spp. and humid vegetation of *Iris pseudacorus*, *Sagittaria sagitifolia*, *Myosotis palustris*. There is an abundance of submerse vegetation communities, including filamentous algae e. g. *Cladophora* sp. and macrophytes, respectively. The most frequent among them are *Batrachium* spp., *Berula erecta*, *Callitriche* sp., *Lemna minor*, *Nuphar luteum*, *Potamogeton* spp., *P. natans*, *Lemna minor*, *Elodea canadensis*, *Hippuris vulgaris* etc.

3. 3. 4. 1 Fish Species Found in the Mali Graben

The regulation works in the Mali graben were carried out between 1984 and 1986. There were several thresholds built in the river, however no walls made of concrete were built and the living conditions remained favourable, bringing but a few changes for fish species. Table 1 lists the fish species found in the Mali Graben today. Table 1. Fish Species in the Mali Graben.

Class/Order	Common name
Barbus barbus	barb
Barbus balcanicus	
Carassius carassius	crucian carp
Chondrostoma nasus	nase
Cottus gobio	sculpin
Cyprinus carpio	common carp
Esox lucius	northern pike
Eudontomyzon mariae	Ukrainian brook lamprey
Gobio gobio	gudgeon
Hucho hucho	Danube salmon
Lepomis gibbosus	pumpkinseed sunfish
Leuciscus cephalus	chub
Oncorhynchus mykiss	rainbow trout
Perca fluviatilis	European perch
Phoxinus phoxinus	minnow
Rutilus rutilus	roach
Rutilus pigus virgo	Danube roach
Salmo trutta m. *fario*	brown trout
Scardinius erythrophthalmus	rudd
Thymallus thymallus	graylin
Tinca tinca	tench
Cobitis elongatoides	Danubian loach
Vimba vimba carinata	
Abramis brama	common bream
Alburnoides bipunctatus	chub
Hypochthalmychthis nobilis	
Lota lota	burbot
Rhodeus sericeus amarus	bitterling
Stizostedion lucioperca	pike-perch
Silurus glanis	Wels catfish

The catch of the nase (*Chondrostoma nasus*) and of the Danube roach (*Rutilus pigus virgo*) is presented (Figures 10 and 11). Both species are frequent in the total catch and of high interest. The catch prior and after the regulation is shown.

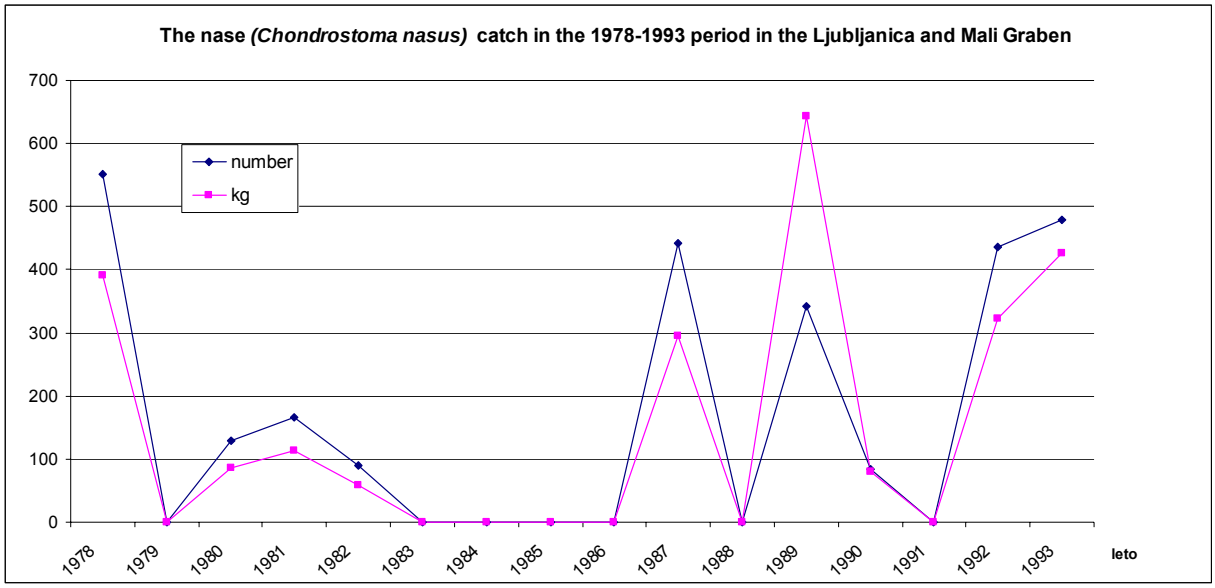

Figure 10. Catch of the nase fish population in the Mali Graben.

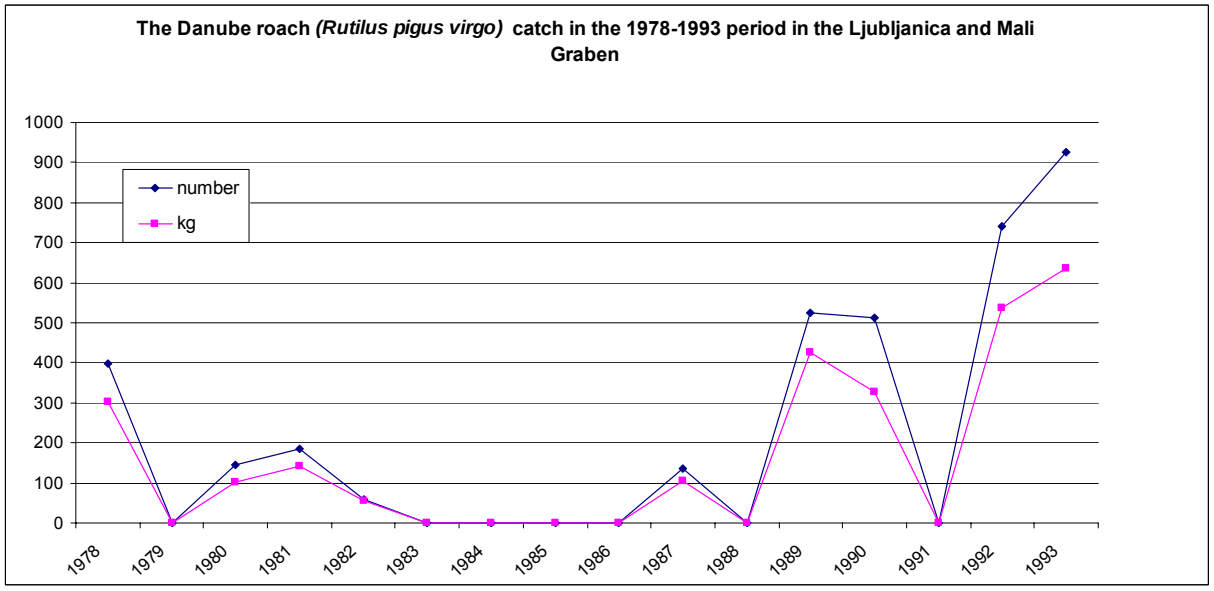

Figure 11. Catch of the Danube roach fish population in the Mali Graben.

4 SEWAGE SYSTEM DEVELOPMENT IN LJUBLJANA

In the area of Ljubljana, the first water supply was managed by the Roman city (*castrum*) of Emona. Water supply needs to be considered in an integrated manner, i.e. with regard to the water source – distribution system – as well as drainage and wastewater treatment, and it can be established that Emona was a well managed city. The water source was located in Rožnik outside the building area without the influence of urban activities, the drainage was channelled into the Ljubljanica (by way of *cloaca* sewers) without exceeding the self-cleansing ability of the river.

Figure 12. Sewage System of Emona; Source: Kolar (1983).

Regarding water supply, the medieval Ljubljana was poorly managed. Water was gained from the wells situated in courtyards where waste water was also discharged. Diseases were common. Exceptions are the remains of the Roman aqueduct, the Hercules well in the Levstik Square of today, which had water directed from Golovec (Volovec), as well as the well in the garden of the Benedictine monastery in what is today Congress Square, also the well at Castle Road is worth mentioning.

In 1890, when the Ljubljana water system was built (much of it is still in function today), the city had 900 houses and about 30,000 inhabitants. The more important citizens, in charge of decisions regarding development, were schooled in Prague and Vienna, and they brought back ideas of broader scope. Admittedly, water supply was one of the first meticulously inspected and executed development decisions. Namely, groundwater pumping of the plain Ljubljansko polje was one of the six alternative solutions based on observations, measurements and analyses carried out in the course of 10 years.

According to merit, the most deserving were the then mayor of Ljubljana Ivan Hribar, Prof. Dyonis Stuhr, who reviewed the design of the Ljubljana plumbing system, and architect Janez Vladimir Hrasky.

Ivan Hribar was mayor of Ljubljana between 1896 and 1910. His contribution was of high importance due to the development of the city that somehow coincided with the general restoration works following the 1895 earthquake of catastrophic proportions.

His inspiration came from the travels he made in his youth and his wish was that the city and its inhabitants would fit into the west European space. During his term, Ljubljana got its own plumbing system, gas piping, power plant, electric power railway, first public swimming pool, and Dragon Bridge.

He proposed several initiatives for development of education and pursued the establishment of a Slovenian university.

Figure 13. Ivan Hribar (1851–1941); Municipal Museum of Ljubljana.

The ingenuity of the created plumbing system enabled city growth by expanding the network and by increasing the number of wells until 1953 when a new pumping station of Hrastje had to be built in the eastern part of the city. In the water station, the same water source is used as in the Kleče water station, which made it possible for the quickly developing, mainly industrial areas of the city, to supply water from the new water station, and to increase the capacity of the Kleče water station and build essential transport piping system. The Šentvid water station was included into the supply system in 1955, the Brest water station in 1981, and the Jarški Brod water station in 1982.

As mentioned above, the first regulated discharge of water in the area of Ljubljana was in Emona. The *cloaca* – man-made channels – were placed in the west/east direction draining into the Ljubljanica.

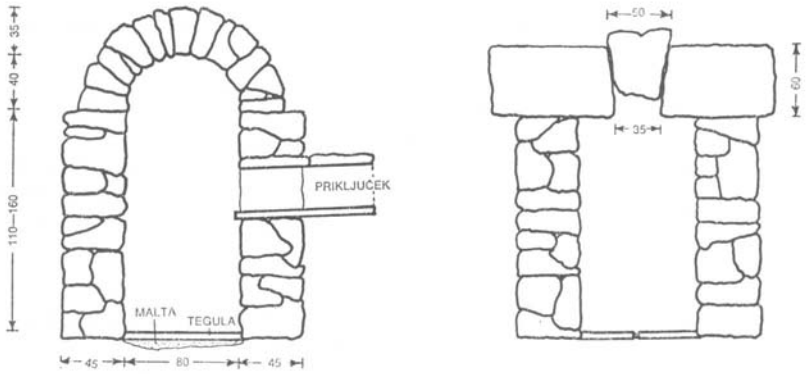

Figure 14. The Emona sewage system – channel cross sections; Source: Kolar (1983).

In the medieval Ljubljana, waste water was discharged through drenches and built channels into the river, and in shingle terrain the waste water infiltrated downwards. In May 1895, there was a major earthquake in Ljubljana, which destroyed many buildings and affected almost every building to some extent. 145 houses needed to be pulled down, amounting to 10 % of all houses in the then Ljubljana. In the following five years, international aid helped build more than 500 houses and facilitated the restoration of the same number. The city was restored according to the accepted regulation plan (today's urban plan). In 1899, it was prepared by Janez Vladimir Hrasky, later on other city architects aimed at participating in the urban planning, such as Maks Fabiani and Jožef Plečnik, respectively.

A basic element of the urban plan is – besides outlining the building areas and designing city outlook – municipal water supply management, discharge and waste water treatment. And not only waste water management, the precipitation water as well, since in sustainable management the water discharge is essential.

The Hrasky regulation planning also foresaw building of reservoirs in the left and right banks of the Ljubljanica, as well as building of a water treatment plant in Kodeljevo and alternatively in Fužine. After World War II the revised version according to Roth was realized, encompassing tow reservoirs with a discharge into the Ljubljanica behind the gate. Today, the treatment plant has not been built.

Figure 15. water sewage system dating to 1906; Source: PF (JP) VO-KA archives.

In comparison to the water piping system that was put into use in its original scope on an entrepreneur basis, the sewage system was for many years only considered as plot and road facilities and in its management there was no self-development trend identified. For a long time, the Ljubljanica served as the main discharge reservoir and its contamination/pollution was a significant put-off for the inhabitants. In the years of substantial growth, in the course of building reservoirs, an independent company Kanalizacija emerged. It was established in 1951and dealt with the development, planning, building and system maintenance. By way of illustrating the city growth, the numbers with regard to city inhabitants speak for themselves. In Emona, there were only 3,000 inhabitants, in Ljubljana in 1896 37,000, by the end of World War I 51,000, in 1940 88,000, and in 1953 as many as 138,000.

The sewage system of Ljubljana (mixed system and waste water sewage system) developed with the dynamics shown in Table 2 and Figure 9.

Table 2. Sewage system of Ljubljana.

Year	Length (km)	Channelled area (km2)	Sewage system density (km/km2)
1917	28	4,97	5,63
1945	105	10,76	9,76
1971	300	24,63	12,18
1985	593	45,61	12,99
2001	755	65,76	11,48

4. 1 CURRENT SITUATION – AN OVERVIEW

The sewage system of Ljubljana is mainly mixed (60 % of the system), however there are individual subsystems for waste water only (20 % of the system) and for precipitation water only (20 % of the network maintained by JP VO-KA Ljubljana).

The discharge and waste water treatment system is complex and needs to work without obstructions with regard to discharge and treatment and in all ratios of discharge of waste water and precipitation water, respectively. According to the conditions in the mixed sewage system, the flow at the discharge site from the main reservoir in periods of dry and wet weather, and especially during rain showers, may change to a level that makes it impossible to ensure a reliable treatment process (3.200–9.600 m3/h), therefore both reservoirs (in the right and left banks) have relief flows through which flows a diluted waste water into the Ljubljanica River. Therefore, a general solution of the sewage system that was worked out in cooperation with the Danish Hydraulic Institute in December 1996 provides for several measures (mainly regulating the overflow edge and building reservoir facilities), which are from the viewpoint of reducing environmental pollution as significant as waste water treatment plant building.

Suburbs that are at a larger distance from the reservoirs, have their own sewage systems and treatment plants. There are 14 of them: Črnuče, Dobrova, Gameljne, Horjul, Ig, Kamnik pod Krimom, Matena, Notranje gorice, Pirniče, Polhov Gradec, Smodinovec, Škofljica, Vižmarje - Brod, Zadvor.

Given are some main data related to the current state of the sewage system of Ljubljana:

Table 3. Current features of the Ljubljana sewage system.

Sewage system area	6,576 ha
Length of the sewage system (without sink hole connections):	1,011 km
– mixed channels	497 km
– waste water channels	258 km
– precipitation channels	256 km
Sewage user connections	22,603
Wells	30,662
Road sink holes	25,504
Relief system in mixed channels (into the conduits)	57
Water pumping stations (capacity of 10–320 l/s)	46
Local treatment plants	14/22,000 PE

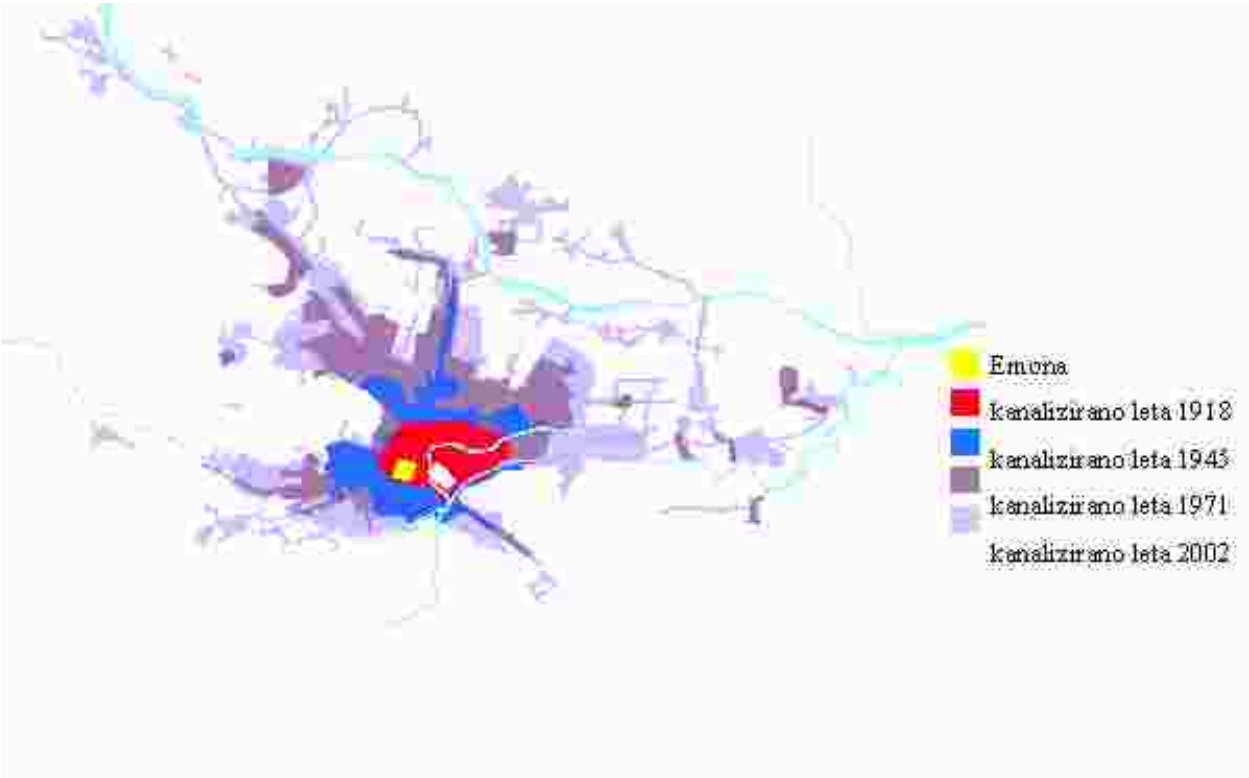

Figure 16. Historical development of the Ljubljana sewage system.

Annual volume of waste water discharged to the sites of treatment plants amounts to approx. 47.6 x 10^6 m^3, out of it 48 % of municipal waste water from households and

industry. Currently, stage 2 of building of the Central Treatment Plant of Ljubljana is underway with a capacity of 360,000 PE that will enable a quality treatment of waste water and consequently a better water quality in the Ljubljanica from the class III/IV of today to class II. The final constructions of the central Treatment Plant is predicted by 2006 and will enable upgrading the sewage system of Ljubljana by connecting several peripheral areas from neighbouring municipalities (Škofljica municipality, Vodice, Medvode). The features of several parameters at the inflow area, and allowed outflow concentrations are illustrated in the table below:

Table 4. Current inflow at the CTP Ljubljana and border allowed outflow values.

parameter	inflow	border values
BPK_5	207 mg/l	< 20 mg/l
KPK	425 mg/l	< 100 mg/l
Ammonium nitrogen	31.7 mg/l	< 10 mg/l
Undissolved particles	160-291 mg/l	< 35 mg/l

The two settlements in Ljubljana, namely Rakova Jelša and Sibirija, that have developed outside the urban planning system in the south part of the city at the edge of the marshes of Ljubljansko barje will be addressed by building the local pressure depression system and local treatment plant with a capacity of 8.500 PE.

Building the missing parts of the sewage system is underway in accordance with Slovene legislation, which has been harmonized with the environmental legislation of the European Union. According to the predicted deadlines, the entire sewage system will have been built by 2017.

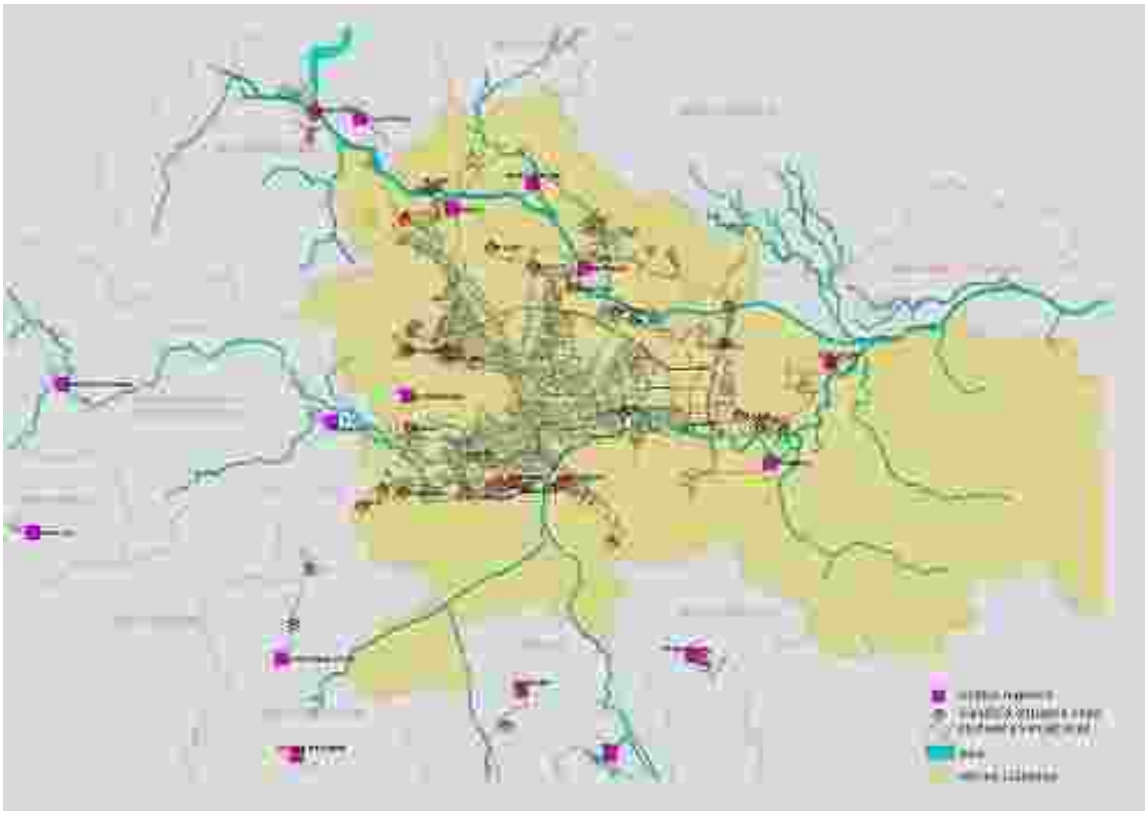

Figure 17. Ljubljana sewage system.

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