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REVITALIZING SMALL URBAN STREAMS AS AN INSTRUMENT OF URBAN PLANNING IN CREATING RESILIENT CITIES

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Abstract. *Small urban streams are an important element of blue-green infrastructure that is often underused, especially regarding stormwater management. In addition, small streams in dense urban areas often seem to be polluted and devastated, or even buried underground. This paper discusses the problems and challenges that occur in urban areas regarding small streams and creeks, and explores how their revitalization can help in shaping more resilient communities. The study explores two cities, Graz and Oslo, and their best practice examples in revitalizing urban watercourses. As a valuable natural "blue" capital, small streams can reduce the city's risk of flooding from intense rainfall and strengthen the ecosystem. At the same time, small urban streams are cost-effective, proactive and attractive elements of urban landscape. Research identifies the benefits that the process of revitalization of small urban streams brought about to the selected case studies regarding the environment, public health, social interactions, land use and adaptation to climate change. Furthermore, the research establishes urban planning guidelines for revitalization of watercourses that could help in setting up policy framework for adapting inherited urban settings to climate change.*

Key words: *deculverting, renaturation, water quality, flood protection, blue-green infrastructure, recreation*

1. INTRODUCTION

Throughout urban planning history, towns and cities were developed along waterways in order to enable access to drinking water, dispose of wastewater/sewage and provide transportation routes. Aside from large rivers, which are the most visible watercourses, urban areas often have a very rich water potential in small streams and creeks. They are

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vitally important sources of clean water and habitat for wildlife and biodiversity. On the other hand, healthy river ecosystems also provide significant social, economic, and environmental benefits [1]. Even though small urban watercourses represent a very important element of blue-green infrastructure (BGI), they often seem to be polluted, neglected, devastated and forgotten [2]. In some cases, they have even been hidden in culverts and pipes and buried underground, to make way for new developments and expansion of urbanized areas.

This paper discusses the problems and challenges that occur in urban areas regarding small streams and creeks, and explores how their revitalization can help in achieving more resilient communities. Cities around the world are nowadays increasingly attempting to revitalize small urban watercourses and particularly to restore buried streams. The process of deculverting – reopening streams is often referred to as "daylighting". Daylighting consists of exposing some or all of the flow of a previously buried stream by creating a new streambed, and may include the creation of ponds, wetlands or estuaries [3]. Deculverting projects decrease the environmental effects of urbanization by re-establishing natural stream structure and enabling the colonisation of aquatic fauna and flora [4]. Some of the benefits that the overall revitalization of streams brings include reducing flood risk, reducing pollutant concentrations, improving water quality, renewing river ecosystem, improving the ecology and biodiversity of the area, and creating a recreational amenity for the local community. Many cities are exploring possibilities to use small urban streams as a BGI element that would strengthen the ecosystem and reduce the risk of flooding from intense rainfall, and thus improve the resilience of urban areas. In order to better illustrate the benefits of stream revitalization, the paper explores two cities, Graz and Oslo, and their best practice examples in revitalizing watercourses.

The initial hypothesis of this research, which stems from contemporary urban planning theory and practice, is that revitalizing existing small watercourses in dense urban areas can help in increasing the resilience of cities. Therefore, the main goals of this paper are: (1) to determine the benefits that the process of revitalization of small urban streams brought about to the selected sites in Graz and Oslo; and (2) to establish urban planning guidelines for revitalization of watercourses that should help in adapting inherited urban settings to climate change.

2. MATERIALS AND METHODS

This paper explores the process of revitalization of small urban streams in the cities of Graz and Oslo, by using empirical research and literature review. The research methodological framework is conceptualized on description and analysis of the selected cases of stream revitalization, with the synthesis of study findings presented within established key benefits and implementation guidelines.

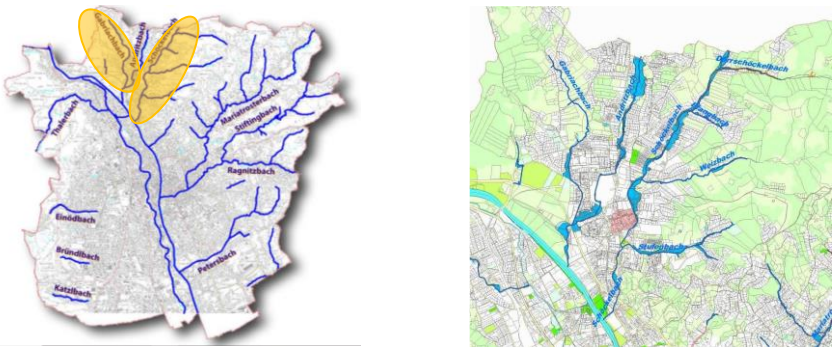
The cities of Graz and Oslo were selected as study areas because they are currently implementing comprehensive programs and various projects for the restoration of their urban watercourses, in an attempt to address climate change challenges, such as Streams of Graz Program in Graz, Oslo Reopening Waterways Project and Urban Ecology Program in Oslo. Four small urban streams were analyzed: Schöckelbach and Gabriachbach in Graz, and Hovinbekken and Alna in Oslo. These particular watercourses were chosen based on two criteria: (1) extensive revitalization works along the stream already completed, so that

their effects can be evaluated; and (2) size of watercourse catchment area 10-100 km^2, so that they are considered small urban streams according to the size typology of the Directive 2000/60/EC [5].

3. Learning from Best Practice Examples

3.1. Streams of Graz Program

The City of Graz has 52 streams and numerous small channels and ditches, with a total length of about 270 kilometres [6]. Out of that, 125 km of small urban watercourses are located within the urban area, with approximately 70 km^2 catchment area lying within the city (Fig. 1A). With development of the municipal sewer system in Graz, streams were mostly encased, piped or fed into the sewers in central city areas. On the outskirts these streams remained largely open, thereby creating a mix of naturally flowing sections and concrete channels. Densification of urban area brought about new developments along small urban streams, thus narrowing their riverbeds and increasing the risk of flooding. Urban area of Graz was flooded by small urban streams several times in the last 50 years. Discharge measurements performed in 1997 showed that more than 1000 buildings in the urban area of Graz would be endangered in the event of a flood with a return period of 100 years [6]. A particularly dramatic flood event occurred in August 2005, resulting in vast damage to populated areas that amounted to 5 million euros [7].



A. Streams in Graz urban area, with the position of Schöckelbach and Gabriachbach. *https://docplayer.org/79587336-Das-sachprogramm-grazer-baeche-hochwasserschutz-fuer-die-stadt-graz-ein-integraler-ansatz.html*

B. Schöckelbach and Gabriachbach with floodplains. *https://geodaten1.graz.at/WebOffice/synserver?project=baeche*

Fig. 1 Waterways in Graz.

These floods have led to the creation of a special program Streams of Graz, a project of the Federal Ministry of Agriculture and Forestry, Environment and Water Management, the Provincial Government of Steiermark and the City of Graz. The program was designed to run for a period of ten years (2006-2015), with three main goals to be achieved [6]: (1) provide flood protection for endangered zones in Graz based on a catalogue of measures, coordinated with spatial planning; (2) improve the ecological quality of streams; and (3) turn the streams and their adjacent space into recreational areas for the population, in order

to improve their quality of life. Flood protection measures involve: linear measures, such as widening of the streambed, raising the embankment or the adjacent terrain, removing discharge obstacles and pruning streamside vegetation; and retention measures, which imply the construction of retention structures.

The implementation of actions envisioned in the program on how streams and their catchment areas can be improved to prevent flooding, is illustrated in the examples of two streams, Schöckelbach and Gabriachbach (Fig. 1B). Relevant data on the selected streams, including stream characteristics and main issues of concern regarding the stream and flood events, is provided in Table 1.

Table 1 Schöckelbach and Gabriachbach streams datasheet

	Schöckelbach	Gabriachbach
General data	▪ catchment area 34km2; ▪ llength 12km (4,8km in urban area); ▪ flows into the River Mur.	▪ catchment area 2,6km2; ▪ length 6,8km; ▪ flows into the Andritzbach stream.
Main issues	▪ buildings and high-value infrastructure developed close to the stream, no available space to safely retain the floodwater; ▪ partly elevated stream bed aggravates the floodwater to flow back into the channel.	▪ along the stream there are more than 30 residential buildings at risk of flooding.
Flood events	▪ flooded the district centre of Andritz in 2005, 2009.	▪ flooded residential buildings along the stream in 1989, 1996, 1998 and 2005.

Schöckelbach stream revitalization project. Schöckelbach stream is located in the north of Graz, in the Steiermark province. Its lower course has a small capacity, which often results in flooding of nearby areas (Fig. 2A). Main aims of the revitalization project were to maintain or extend the existing retention spaces/floodplains, and to improve the capacity of flood discharge downstream, by implementing linear and retention flood protection measures. Project activities involved the renaturation stream of the segment from Andritzer Maut tram stop to Rotmoosweg road (2013), and the construction of a flood retention basin Weinitzen 2 Höfbach outside of the urban area (2012) [8]. Future actions that are now in the planning stage include the linear expansion of a 2 km section of the stream from Rotmoosweg road to city limits, as well as the construction of one additional flood retention basin Weinitzen 1 outside of urban area of Graz.

Revitalization of the 2,7 km long stream section Andritzer Maut – Rotmoosweg was implemented in three phases and involved widening the stream bed (Fig. 2B) and raising the terrain and embankment level. A variety of actions were implemented in the project [7]. Suitable native trees and shrubs were planted along the stream and a flower meadow was sowed in order to create to create a colourful habitat. In the zone where the stream's bed has been widened a children's playground was built, and the stream was allowed to develop its own channel. New habitats for fish, insects and birds were created in the stream itself, by using elements such as wood and rocks.

Retention basin Weinitzen 2 Höfbach has a capacity of 215.000 m^3. It is supposed to reduce the incoming flood discharge peak of Schöckelbach stream by almost 50% [9]. After the retention basin was completed, renaturation measures were carried out, including planting

the embankment areas with site-specific greenery (Fig. 2C), planting riparian wood fringes and developing wet areas.

Besides active flood control measures, the following planning activities were also conducted [7]: (1) developing water management plans; (2) developing flood forecast models, warning and alarm plans; and (3) developing residual risk analyses and contingency plans. Accompanying procedural measures included negotiations with land owners regarding purchasing their land [8]. Revitalization project also engaged the local community, with the following goals [7]: (1) informing the local population of different projects; (2) raising awareness on the significance of the stream; and (3) introducing personal responsibility of each individual who might be affected and promoting protective measures, such as constructing flood adapted buildings, using mobile flood-protection measures, preparing personal contingency plans and buying flood protection insurance.

A. Flooding of Schöckelbach in Andritz district, Graz in 2005. *https://www.wetterzeugen.at/hochwasser-in-graz-andritz-2005/*

B. Widening the stream bed in the area of the Gasthof Pfleger. *http://www.freiland.at/de/hws_schoeckelbach/*

C. Retention basin Weinitzen 2 Höfbach.*https://www.graz.at/cms/dokumente/10278073_8028812/dccbe8b0/Fotodokumentation%20RHB%20Weinitzen%202.pdf*

Fig. 2 Schöckelbach Revitalization Project.

Gabriachbach stream revitalization project. Gabriachbach is a very small stream that is also located in the north of Graz, in the Steiermark province. Despite its size (Fig. 3A), the stream can reach a water level of several meters in just a few hours during heavy storm events. Therefore, the risk of flooding nearby areas is severe. Main aims of stream revitalization were to address protective water management, landscaping and ecological issues, and to create a recreation area along the watercourse [7]. Revitalization project involved the construction of two flood retention basins Untere Schirmleiten and Am Eichengrund (2007), and renaturation of the stream in the Schleppgleistrasse area (2014) [8]. Linear expansion of about 0,8 km of the stream along Hoffeldstrasse road is planned for the third construction phase.

In the first phase of the project, flood retention basins Untere Schirmleiten and Am Eichengrund were built, with a total capacity of 40.000 m^3, and a section of the stream of about 120 m was opened. The retention basin Am Eichengrund is particularly interesting because it is located in a landscape protection area. Therefore, the project activities were accompanied by a nature conservation expert [9]. When designing the retention basin, special attention was given to planning, in order to keep the interference in the bank vegetation of the Gabriachbach low. Landscaping involved planting of 1200 woody plants, which are native and suited to the site. Also, the emphasis was placed on keeping the visual axes of the valley free, while natural vegetation along the brook was largely preserved and retained all the way to the dam [7]. Dam slopes were kept as gentle as possible and connected to the surrounding terrain (Fig. 3B). The project created a wet

biotope at its lowest point, thus providing a habitat to numerous plant and animal species [7]. Food retention basin is replenished permanently with drainage water.

The second phase implied linear expansion of 0,6 km of the stream in the Schleppgleistrasse area, from mouth to the Andritzbach stream to Andritzer Reichsstraße. Ecological upgrade of the stream was carried out, involving the removal of former concrete half-shells and the creation of a meandering low water channel with wooden pilots (Fig. 3C). An accompanying footpath and cycle path with drainable special surface and new lighting were also provided. Diverse bank planting included 20 new tree locations and 600 riparian trees, thereby creating a natural zone along the stream [10]. Recreation zone with greenery and seating was established, and a suitable stream access for children was enabled. This comprehensive renaturation project enabled a connection to the Andritzbach stream at the same riverbed level, which allowed unimpeded migration for aquatic organisms, particularly fish [7].

Accompanying activities involved negotiating with land owners regarding redemption, securing funding through grants from the federal and state governments, and conducting necessary tender procedures [8]. A very important aspect of the project was educating the young population on the significance of urban streams. When planting the retention basin Am Eichengrund, pupils of the local elementary school were engaged, thus educating them on water ecology.

A. Gabriachbach stream before revitalization. *https://www.graz.at/cms/dokumente/10278073_8028812/4ae10ab1/Pressemappe_Gabriachbach.pdf*

B. Retention basin Am Eichengrund. *https://www.wasserwirtschaft.steiermark.at/cms/beitrag/10857450/4570277/*

C. Meandering low water channel. *https://www.graz.at/cms/dokumente/10278073_8028812/4ae10ab1/Pressemappe_Gabriachbach.pdf*

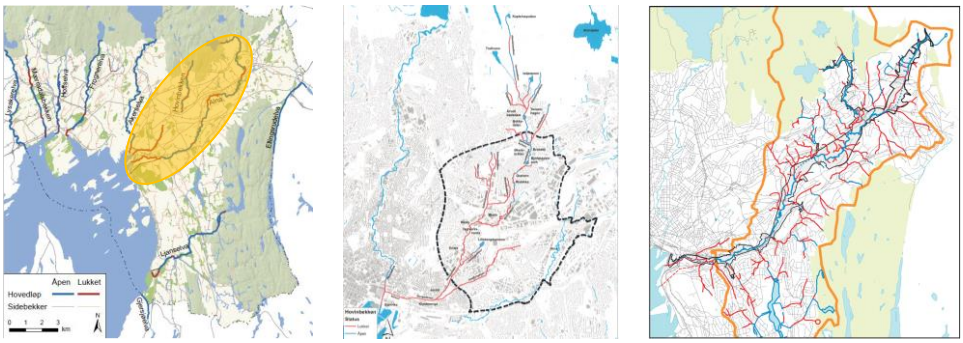
Fig. 3 Gabriachbach Revitalization Project.

3.2. Oslo Reopening Waterways Project

The City of Oslo has ten main waterways in the urban area, which have numerous tributaries (Fig. 4A). Total length of rivers and streams amounts to 354 km [11]. Many watercourses in Oslo area were diverted underground during “the big closing” of rivers in 1879, and remained largely in culverts and pipes until the late 1990s. Until the 1980s, rivers and streams were considered problematic due to leakages from the sewage system and heavy pollution, and were viewed as an impediment to urban development and efficient use of land. Culverted watercourses have limited capacities to manage water, which can cause urban flooding problems in extreme weather events.

The City of Oslo decided to reopen closed rivers and streams wherever possible, as an integral part of climate change adaptation plan to make the city resilient to flood risk [11], and started the project Oslo Reopening Waterways in 2002. Relevant municipal

agencies have, in collaboration, developed a management document that outlines the principles for reopening projects, including a list of prioritised projects [12]. In an attempt to achieve a green profile, the City has developed "Urban Ecology Program 2011-2026", which defines the goals for improving both the quality of life and the ecology of urban environment. These goals include deculverting as many streams as possible, creating blue-green corridors and preventing pollutants from entering waterways [13]. In line with this, 2.810 m of streams were already reopened, while long-term plans envision opening up of additional 8 km of waterways [11]. Today, the City of Oslo's main goal is to create blue-green corridors throughout the city, where living rivers form a city web, binding everything together into an organic, logical, functional and attractive whole [14].



A. Ten main waterways in Oslo, with the position of Hovinbekken and Alna. *https://rm.coe.int/16806f5e75*

B. Hovinbekken with tributaries. *https://hovinbekken.org/2015/02/12/innspill-til-strategisk-plan-for-hovinbyen-fra-hovinbekkgruppen/*

C. Alna with tributaries. *https://docplayer.me/docs-images/39/19839266/images/6-0.png*

Fig. 4 Waterways in Oslo.

Some of the principles for the projects of reopening waterways in Oslo that are outlined in the program are illustrated in the two examples of Hovinbekken stream and Alna River (Fig. 4B and Fig. 4C). Relevant data on the selected streams, including stream characteristics and main environmental issues of concern regarding the stream and flood events, is provided in Table 2.

Table 2 Hovinbekken stream and Alna River datasheet

	Hovinbekken	Alna
General data	▪ catchment area 10km2; ▪ length 8,5km; ▪ flows into Akerselva river.	▪ catchment area 69km2; ▪ length 17km; ▪ flows into the Oslo Fjord.
Main issues	▪ one of the most culverted streams in Oslo; ▪ poor water quality, with high nutrient levels and organic load.	▪ large sections of the river are culverted; ▪ highly polluted river, used as a sewer drain to receive runoff from the sewer and traffic areas.
Flood events	▪ increased risk of flooding due to the increase in rainfall, increase in population density and intensive urbanisation along the stream.	▪ increased risk of flooding due to paved surfaces of the third of the catchment area, and completely/partially closed tributaries; ▪ flooded Kværnerbyen area in 2015.

Hovinbekken stream revitalization project. Hovinbekken is one of the most culverted streams in Oslo (Fig. 5A). The stream was gradually hidden until the 1960s, in order to hide pollution, to expand the city and make way for new infrastructure and housing. Nowadays, the stream is being reopened throughout urban area, thereby connecting the forest with the fjord, and linking different parts of the city. The restoration project was initiated with the main goal to improve the water quality downstream, by implementing natural self-purification of water through planted wetlands and pools [13]. Secondary aims included adapting to a changing climate, strengthening urban ecology, increasing possibilities for recreation and improving public health [15]. Reopening of the Hovinbekken and creating a more "natural" look involved the following completed projects of various stream segments [16]: Bjerkedalen Park (2013), Teglverksdammen (2015), and the segments in the neighbourhoods Ensjø (2019) and Jordal (2020). Reopening of the stream is also planned for the stretches in Oslo's parks Klosterenga and Grønlandspark.

Bjerkedalen Park is situated along Hovinbekken stream in Bjerke neighbourhood, in the middle of a residential urban area that used to have few public spaces. Restoration project involved reopening of 300 m of the formerly culverted stream, with the main aim of improving water quality, preventing floods and creating new green areas [15]. Several elements of blue-green infrastructure were implemented in park design. Native trees and plants were planted along the river, and open grassy areas and trees were provided on the slopes of the park. Bjerkedalen Park features 36.000 m2 of natural meadows, perennial flower beds, and paths made of permeable material [17]. Blue features such as the stream, canals and pond were also installed. Habitats for various aquatic and land species were provided. This park adjacent to the waterway plays an important role in stormwater management, since it functions as a retention basin during extreme weather events. These actions improved the overall urban landscape and created an attractive recreational area with various facilities for outdoor activities, hiking trail, bathing pond, small stage, café and playground. The project also brought about social and health benefits to the residents, such as the improved access to urban green space, increased opportunities for social interaction and gained amenities for recreation and exercise [15].

Reopening of the second section of Hovinbekken in Hasle neighbourhood called Teglverksdammen involved deculverting 650 m of the stream. Teglverksdammen is both a large-scale biological cleaning system and a spectacular recreational space [18] (Fig. 5B). In order to achieve water purification for the downstream section, a natural cleaning system to filter incoming waters was designed and developed. It consists of several sedimentation basins, a small lake Teglverksdammen, three dams, streams with rapids, and high-density native vegetation in shallow waters [11]. Native plants also act as a wetland. Within this system, the sediments settle and the water is filtered through rocks and vegetation. The City of Oslo monitors water quality at Teglverksdammen after reopening the stream, and the results indicate the potential for purification [13]. Long-term monitoring should determine how the natural system matures and develops, in order to enhance the knowledge database and provide insight into how future projects may be improved. This restoration has enabled the development of a clean habitat to native species and rejuvenation of biodiversity. Consequently, the naturalization of urban landscape resulted in an appealing recreation zone with a park environment. A pedestrian trail was placed along the restored stream segment.

Restoration of the part of Hovinbekken stream in Ensjø neighbourhood was initiated within urban regeneration of this area, with the goal to improve water quality in the newly

created residential zone. Former industrial area Ensjø, located at the margins of Oslo's inner city, was redeveloped with an emphasis on high residential density, high frequency transit services, and path improvements to encourage walking and cycling. Reopening of the third section of Hovinbekken covered 400 m of stream along Gladengveien Street, until the newly created Ensjø Square. Streambed is a 4 m wide concrete duct, which was filled with stone, earth and plants in order to create a nature-like creek [18] (Fig. 5C). Access to the stream was improved with stairs leading to the water itself. Seating facilities were placed along the sidewalk, thereby creating an appealing linear setting. The burble from the stream helps to curb traffic noise and makes it more attractive to stay, exercise, and rest along the city street [18].

Reopening of 600 m of Hovinbekken stream in Jordal neighbourhood occurred with the construction of a new Jordal amphitheater. The Municipality of Oslo has created a new Jordal Sports Park that is open to everyone and has organized seating. New trees were planted along the stream and in the park, while more activities on naturalization and beautification of open space are expected in the future [19].

A. Culvert of Hovinbekken under the subway at Risløkka. *https://hovinbekken.org/vandring/*

B. Teglverksdammen project. *https://commons.wikimedia.org/wiki/Category:Teglverket_skole*

C. Hovinbekken in Ensjø. *https://arkitektur-n.no/prosjekter/gjenapning-av-hovinbekken-hasle-ensjo*

Fig. 5 Hovinbekken Revitalization Project.

Alna River revitalization project. Alna River is the longest watercourse in Oslo. On its flow towards the fjord, the river formed a biological and blue-green spine of the Grorud Valley [14]. This valuable natural resource was endangered by culverting the stream until the 1980s (Fig. 6A). Alna is the most polluted river in Oslo, as it runs through industrial areas Groruddalen and Alnabru, and is also affected by recent urban densification. After the turn of the Millenium, the Municipality acknowledged this issue and developed plans to restore the Alna as a central element of Oslo landscape. Main aims of reopening the river were reducing the risk of flooding and improving water quality through nature's own self-cleaning processes. Reopening and environmental enhancement of Alna River was implemented at various sites, in two phases along the watercourse: Hølaløkka Waterpark (2004) and Grorud Valley, which encompassed creating the Alna Trail (2011) and the Grorud Park (2013).

Hølaløkka Waterpark is a site located between an industrial business park and a housing estate, where a 300 m section of formerly culverted Alna River was reopened. The aim of the project was to combine a technical water management system, where ecological and hydrological needs are met, with a design that maximizes the potential of an appealing outdoor space [20]. The newly created riverbed of Alna is widened at one point to create a natural settling basin in a corner of the park. Then, the river moves

through small waterfalls and flows into an open swimming pond, which holds back flood waters. In the middle of the park a water mirror is located (Fig. 6B), with the adjacent meadow serving the double purpose of an informal relaxing area and a flood meadow [20]. A new wetland with detention capacity is developed in the eastern park zone, to treat polluted stormwater from traffic and industrial areas. This run-off is first conveyed via surface drainage to a cleansing biotope, before the water is released to wetland area for final cleansing. Water management concept implies directing rainwater into an open canal, returning water to the surface, cleansing it and releasing back into the Alna [20].

Grorud Valley Project was developed for a 10-year period (2007-2016) in cooperation of the National Government and the City Government. Roads, industrial areas and railway lines represented some of the main barriers for pedestrians and cyclists in the Grorud Valley. The main aim of the project was oriented towards sustainable urban development, environmental upgrades and improvement of the quality of life [14]. Blue-green measures in redevelopment area of Alna River had the priority in realization of project activities.

Within the Grorud Valley Project, Alna Trail was developed as part of the efforts to strengthen Alna River and provide options for recreation in the river landscape. One of its segments is a 900 m long section through the Svartdalen nature area. A unique feature of this project is a 250 m long boardwalk bypassing the geological phenomenon of Ekeberg escarpment [14]. Prior to the construction of the trail, the area was inaccessible and littered. By the Nygård waterfall, one of the biggest waterfalls in the Alna, the trail crosses a new suspension bridge, and creates opportunities for a close encounter with nature (Fig. 6C). The construction of the 40 m long underpass Haugen Gate beneath the railway lines has enabled strolling along the Alna Trail. Leir Waterfall, one of Alna's biggest waterfalls, which used to be hidden behind a concrete dam, was also reopened, and the access to it was significantly improved. Alna Trail now represents the longest stretch of inter-linked walking trails and green spaces along the course of Alna River.

A. Culvert of Alna at Kvaernerfossene. *https://www.skiforeningen.no/marka/bilder/?poi_id=1912*

B. Hølaløkka Park. *http://www.alnaelva.no/nyhet094.php*

C. Suspension bridge along Alna, Svartdalen. *https://no.wikipedia.org/wiki/Svartdalen#/media/Fil:Alna.jpg*

Fig. 6 Alna Revitalization Project.

Grorud Park was inserted into the existing green corridor along reopened Alna River. The park is designed around a swimming pond close to the Grorud sports grounds, with seating facilities established near the river. Now, the entire path system along this section of Alna creates a nature and parkland area of high quality. A lighting plan was created for the entire area, with the goal of improving public safety and enabling the recreation after dark. The water in the park is being treated through sedimentation, detention, infiltration and cleansing before it reaches the Alna River, and also creates good biotopes for animals and plants [21].

4. Discussion and Conclusion

Cases of revitalization of small urban streams that were examined in this paper point towards a very important role that watercourses play in urban landscape, particularly regarding the resilience of cities. In line with the first research aim, it can be stated that the revitalization of small urban streams brought numerous benefits to Graz and Oslo, thus providing valuable contribution to the environment, public health, social interactions, land use and adaptation to climate change.

In Graz, a holistic planning approach to stream revitalization resulted in these key benefits: (1) *flood remediation of settlement areas*, by implementing both linear and retention measures, thereby preventing million costs in flood damage; (2) *improvement of stormwater management* to the current integrated approaches that implement BGI elements and wetland areas, and thus relieving the city's sewer system; (3) *restoration of the streams' ecological function*, by planting native, site-specific vegetation and creating new habitats for fish, insects and birds; (4) *improvement of the quality of life* of urban residents, by creating nearby recreational areas and strengthening the connection with nature; (5) *enhancement of the watercourses' positive image* in people's consciousness, by raising awareness on the significance of streams, improving the experience of users and enhancing the safety for the population.

In Oslo, extensive reopening of culverted watercourses provided the folowing main benefits: (1) *flood mitigation*, by developing sustainable solutions for stormwater management, and thus decreasing pressure on the city watershed, reducing the risk of flooding and preventing damages; (2) *improvement of biodiversity*, by developing BGI, planting native vegetation and creating new aquatic and terrestrial habitats for flora and fauna; (3) *provision of new recreational space*, including parks, walking/hiking trails and playgrounds, which represent valuable amenities for the community and improve public health; (4) *improvement of water quality*, by developing natural cleaning systems with self-cleaning processes, which include sedimentation basins, water rapids and shallow waters with dense vegetation for filtering pollution from the water; and (5) *improvement of urban landscape*, by adding aesthetics of water surfaces and attractive greenery.

Regarding the second research aim, several elements of urban design and key planning activities can be identified as those that enhance the retrofitting of small urban streams into the existing urban fabric, and contribute to creating resilient communities. Certain guidelines for the urban planning framework that are established in this research are summarized below, around the following crucial points:

(1) *Flood protection*. Implementing linear and retention measures along the stream; Deculverting enclosed/piped streams; Implementing contemporary integrated stormwater management approaches, along with elements of blue-green infrastructure; Developing wetlands and parks in retention basins.

(2) *Strengthening urban ecology*. Creating new habitats in revitalized watercourses and adjacent urban green spaces; Planting native, site-specific vegetation and introducing new aquatic species; Developing natural self-cleaning systems, where natural soils and plant life improve water quality by filtering pollution.

(3) *Creating recreational areas*. Developing nature-like zones for both active and passive recreation for all user categories; Providing adequate lighting to enable recreation in the evening; Enabling easy access to the stream itself; Creating opportunities for social interaction by implementing various amenities for outdoor activities.

(4) *Appealing urban landscape*. Improving the overall aesthetics of space to enhance the experience of users, by creating a park environment; Implementing diverse types of greenery within meadows, open grassy areas, flower beds and parks, as well as a variety of water features such as lakes, ponds, dams, canals, rapids and waterfalls.

(5) *Sustainable mobility*. Developing bicycle and pedestrian pathways made of permeable material along the streams in order to promote healthy transportation options, and inter-linking them to the city transportation network.

(6) *Community engagement.* Raising awareness on the significance of the streams, along with creating a positive image with the local population; Educating local population on different projects; Promoting healthy lifestyles, such as walking, cycling, exercising and establishing a contact with nature, along the revitalized streams; Designating streams as potential research polygon for local schools.

(7) *Risk management*. Performing risk analyses, developing forecast models and early warning plans, and integrating them into urban planning documents; Promoting protective measures based on personal responsibility; Enhancing the safety for the population.

It can be concluded that rivers and streams must be given a new strategic significance in urban planning, within a holistic planning approach that includes spatial, functional, social and environmental aspects of revitalization. Only the open watercourses with natural character that are integrated into a dynamic blue-green web can indeed serve as a planning instrument in adapting inherited urban settings to climate change.

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REVITALIZACIJA MALIH URBANIH VODOTOKA KAO PLANSKI INSTRUMENT U KREIRANJU OTPORNIH GRADOVA

Mali urbani vodotoci su važan element plavo-zelene infrastrukture koji je često nedovoljno iskorišćen, posebno u pogledu upravljanja atmosferskim vodama. Pored toga, potoci u gusto izgrađenim urbanim područjima su često zagađeni i devastirani, ili čak zakopani pod zemljom. Ovaj rad razmatra probleme i izazove koji se javljaju u urbanim sredinama u vezi sa malim vodotocima i istražuje kako njihova revitalizacija može pomoći u oblikovanju otpornijih zajednica. Studija istražuje dva grada, Grac i Oslo, i njihove primere dobre prakse u revitalizaciji urbanih vodotoka. Kao vredan prirodni „plavi" kapital, mali potoci mogu da smanje rizik od poplava u gradu usled intenzivnih padavina i ojačaju ekosistem. Istovremeno, mali gradski vodotoci su isplativi, proaktivni i atraktivni elementi urbanog pejzaža. Istraživanje identifikuje benefite koje je proces revitalizacije malih urbanih vodotoka doneo odabranim studijama slučaja u pogledu životne sredine, javnog zdravlja, socijalnih interakcija, namene zemljišta i prilagođavanja klimatskim promenama. Osim toga, istraživanje uspostavlja smernice urbanističkog planiranja za revitalizaciju vodotoka koje bi mogle pomoći u uspostavljanju okvira javnih politika za prilagođavanje klimatskim promenama nasleđenih urbanih područja.

Ključne reči: *otvaranje kanala, renaturacija, kvalitet vode, zaštita od plavljenja, plavo-zelena infrastruktura, rekreacija*