FINAL DEMONSTRATION ACTIVITY REPORT

WP 5.3

THE CITY OF ŁÓDŹ
2006-20011

ANNEX 1

Demonstration Project 1:
The Sokołówka River - Restoration of a municipal river for stormwater management and improvement of quality of life

INFRASTRUCTURE CONSTRUCTION

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CITY OF ŁÓDŹ OFFICE

Łódź, 15 April 2011

CONTENT:

1. Introduction

The Sokołówka river is mostly supplied by storm water outlets. The main channel used to be regulated by concrete slabs for the purpose of runoff detention, while the middle stretch of the river valley has still maintained the semi-natural characteristics, which makes it appropriate to be treated as a pilot plot for analyses of the best ecohydrological river rehabilitation options. Reservoirs situated in the Sokołówka River receive nutrient-enriched stormwater, which increases their trophic state. Phytoplankton growth and appearance of algae or cyanobacterial blooms may limit ecosystem services (biodiversity, appearance, recreational values) and if toxic, constitute potential hazard to users as possible carcinogens and tumour-promoters.

The goal of the research and the demonstration was to rehabilitate the municipal river in order to improve its functioning as a stormwater receiver and provide attractive recreational space for the city residents.

The specific goals included:

- reduction of the stormwater flow peaks by construction of a cascade of reservoirs;
- improvement of stormwater quality by adaptation of sedimentary pond and construction of Multi-Chamber Sedimentation Biofiltration System (MCSB);
- improvement of the ecological status of the river by rehabilitation of its stretch in order to increase the quality of water, ecological stability and carrying capacity by instream ecohydrological regulation;
- Increase of quality of life and aesthetic values in the catchment by rehabilitation of the river corridor by establishing Sokołówka Park, and landscape management;
- Ecological education and awareness rising;
- Creation of attractive city spaces for development residential areas.

All the infastructure constructed developed on the Sokołowka River within the demonstration activities of SWITCH in order to meet the above goals are summarized in the graph presented in Figire 1. The graph also includes spin-offs of the SWITCH Project and activities undertaken on the river, which were complementary to the infastructure constructed by SWITCH support.

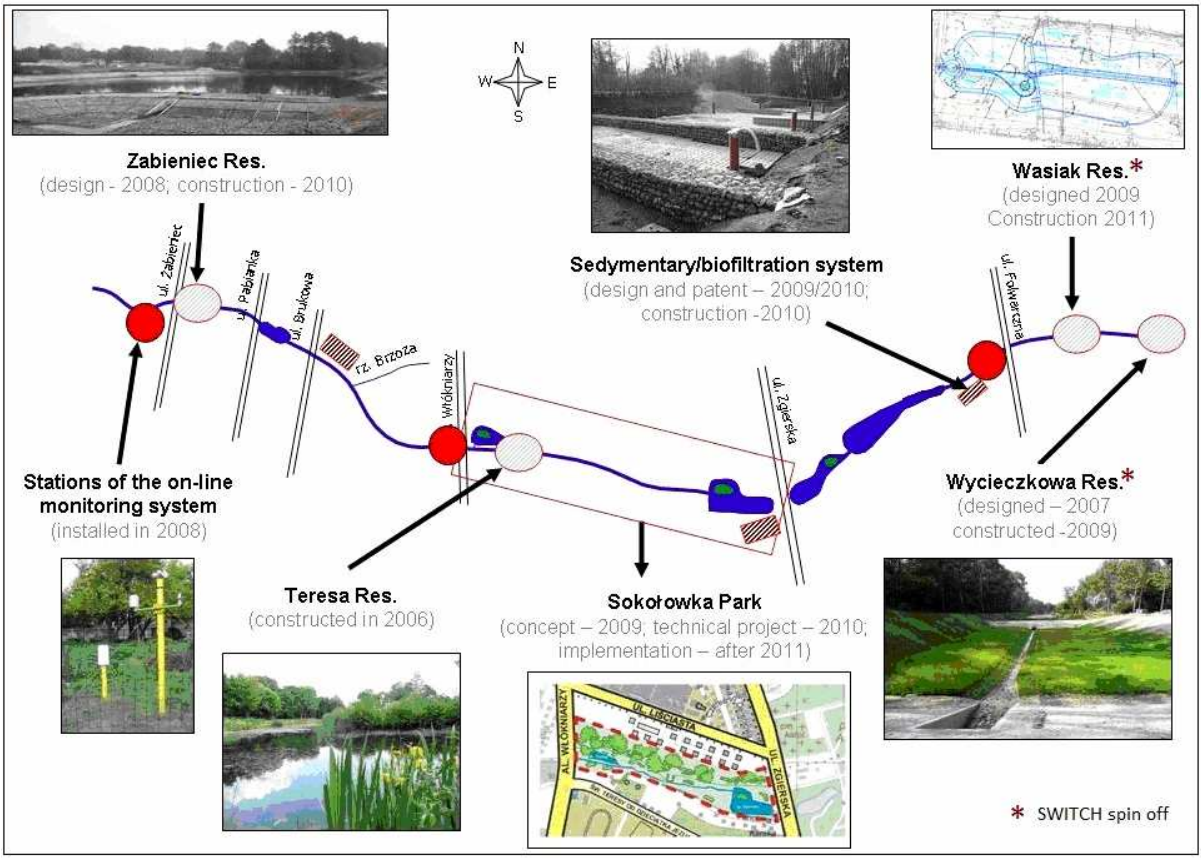

Figure 1. Investments of the Łódź City Office implemented on the Sokołówka under SWITCH project and as a result of the know-how obtained under this project

2. Monitoring systems

2.1. The on-line system of hydrological and meteorological monitoring

In years 2006-2008, an on-line measuring-equipment for hydrological measurements was installed on the Sokołówka River. The flow meters ISCO model 2150 were installed for continuous wave Doppler technology velocity measurements. A sensor transmits a continuous ultrasonic wave, then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow.

Isco 2150 Area Velocity Flow Module were located in three control planes: Folwarczna Street, Lewa Street and Sokolowska Street (Fig.2, Fig. 3).

In cooperation with the University of Łodz Department of Hydrology and Water Management and the City of Łódź, a climate monitoring station - SEBA Hydrometrie MDS-5 was installed near the Deczyńskiego street in the upper part of the Sokołówka river basin (Fig. 4).

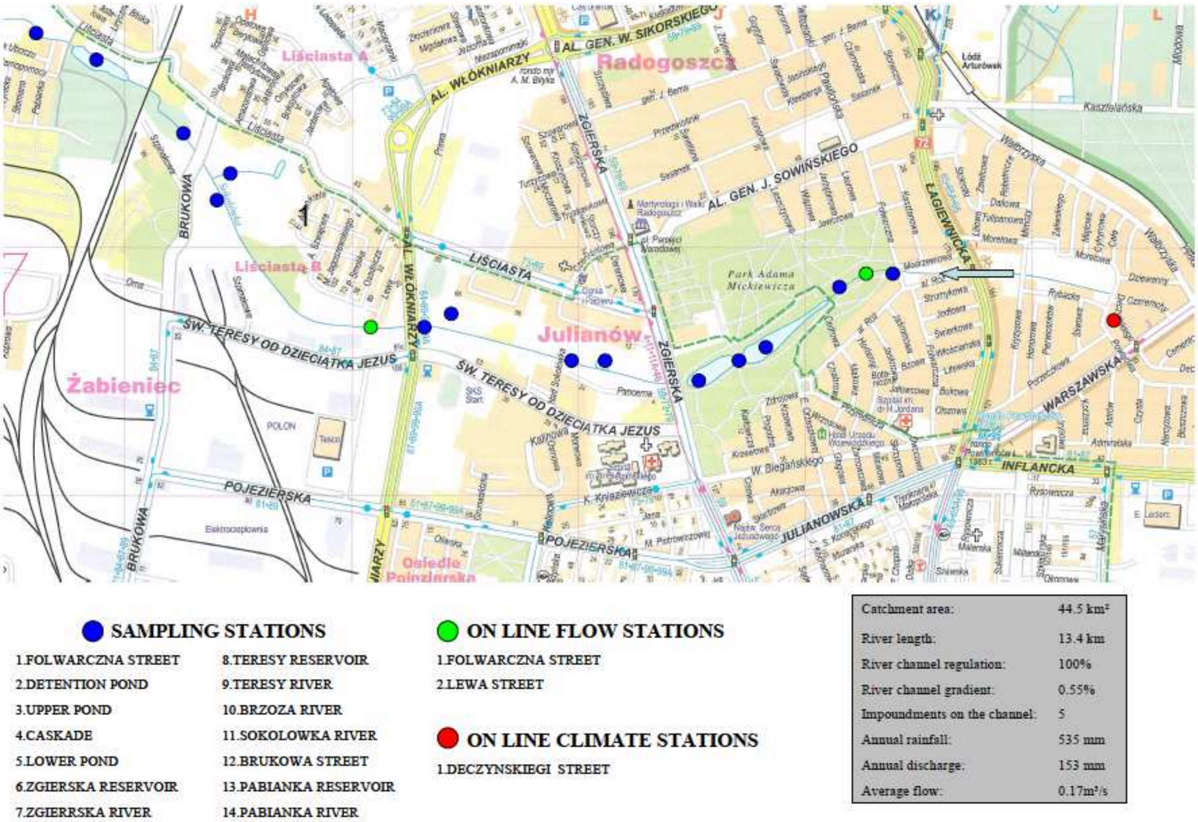

Figure 2. Sokołówka River: Monitoring and sampling stations

Figure 3. On line flow monitoring station on the Sokołówka River

Figure 4. . On line climate monitoring station on the Sokołówka River Valey

2.2. Digital Model of the Sokołówka River

Between 2006 and 2008, under the SWITCH project and with an aid of the SWMM (Stormwater Management Model) software, a digital model of the Sokołówka was developed (Figure 5). It was used to conduct a detailed analysis of the hydrological functioning of the stream. The analysis enabled to record all the processes impacting upon retention and discharges taking place in the river, which assisted in ranking the priorities of the rehabilitation-based measures as to the implementation of which would particularly contribute to improved retention in the catchment and a reduced risk of flooding in the valley. This analysis not only covered the existing status, but also enabled to model any changes in the catchment (it covered variations in such data as river-bed parameters, water structures, catchment characteristics and rainwater drainage systems). The analyses performed with an aid of this model contributed to the following projects:

- Construction of Wasiak Pond Reservoir (table 3) as a priority, on the assumption that Wycieczkowa Reservoir will also function (table 2).
- Ned for the introduction of rainwater retention and infiltration facilities in the middle and upper parts of the catchment in order to resolve the problem of excessive discharge in specific stretches. This finding indicated that the application of BMP's (Best Management Practices), which in the UK are referred to as SUDS (Sustainable Drainage Systems), is particularly important in the process of the Sokołówka River's rehabilitation. The systems that may be used in combination with the conventional piped systems are the best solutions for lowering the run-off from the catchment area.

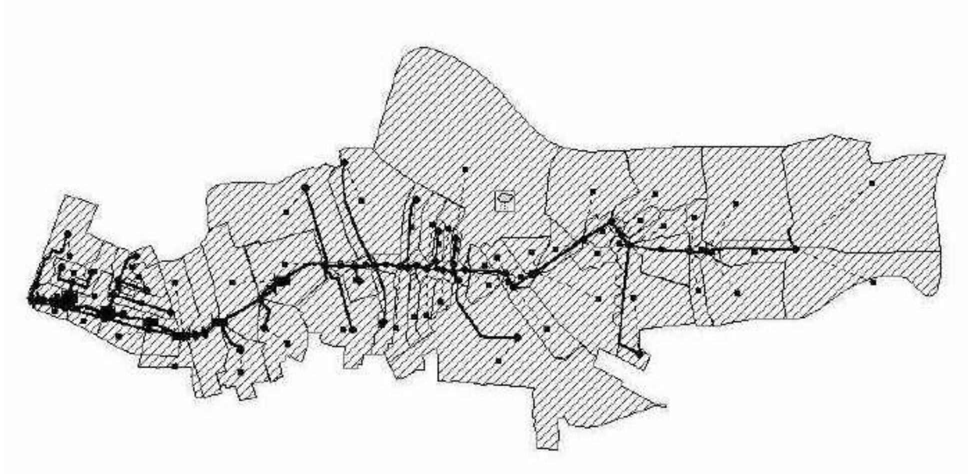

Figure 5. Calculation diagram of the Sokołówka catchment developed for the digital model.

3. Infrastructure constructed under SWITCH

3.1. Modernisation of Folwarczna Sedimentary Tank: construction of Multi-Chamber Sedimentation Biofiltration System (MCSB)

In order to improve quality of the Sokołówka water and provide sustainable protection of its cascade of reservoirs from inflow of pollution from the upper and strongly urbanized Sokołówka catchment of the surface of 5.78 km2, a sedimentary tank of the external dimensions of 65 X 22 m was designed and constructed in 2002 (Fig. 6, 7). It is located on the left bank of the Sokołówka between km 9+258 and km 9+324 in Adam Mickiewicz Park.

Data collected in the research season of 2007 provided the basis for an analysis of balance of nutrients and the total dissolved matter. The analysis covered quality of water inflowing and outflowing to and from the tank. Data collected in two gauge stations located in the inflow and outflow sections, station No 1, i.e. Folwarczna and station No 2, i.e. the sedimentary tank respectively, were used for this analysis. Then two periods, prior to cleaning of the tank and after the cleaning, were compared. In 47% of all the TSS (Total Suspended Solids) samples collected in the season of 2007, the phenomenon of washing out the matter from the sedimentary tank was observed: max. value of 10.05 mg/l inflowed to the tank and 307 mg/l outflowed from it. In 53% of all the TSS samples collected in the season of 2007, the phenomenon of sedimentation was observed: max. value of reduction in suspension 414.9 mg/l (548.0mg/l inflowed, and 133.1mg/l outflowed from the tank). In 22% of all the samples collected, the phenomenon of washing out nitrogen and phosphorus was observed: nitrogen (6.0 mg/l inflowed, 9.3 mg/l outflowed) and phosphorus (0.28mg/l inflowed, 0.57mg/l outflowed). In 78% of the samples collected, the phenomenon of nitrogen and phosphorus accumulation was observed: nitrogen (27.6mg/l inflowed, 5,9mg/l outflowed) and phosphorus (4.94mg/l inflowed, 1.28mg/l outflowed). On the basis of the balance between the matter load and nutrients derived, an operational efficiency of the sedimentary tank in the reduction of the above parameters was calculated.

These results provided grounds for a decision to modernize the sedimentary tank and construct the Multi-Chamber Sedimentation Biofiltration System (MCSB). It has led to elaboration of a concept of modernization of a structure in which improvement of physical,

biogeochemical and biological efficiency in reducing biogenic compounds and suspension occurs due to the following:

- use of additional processes of adsorption and biofiltration in the process of pre-treatment of rainwater with the use of functional zones;
- intensification of processes occurring in the individual zones;
- stabilisation of discharge parameters at the inlet and outlet of the sedimentary tank
- developing guidelines for the system of maintenance.

The developed sequential method of water biofiltration to be used in the process of rehabilitation of semi-natural streams involves a regulated discharge of water through a three-level system of improvement of biophysical parameters, which uses processes of hydrodynamically intensified sedimentation, intensive biogeochemical processes and intensive biofiltration. Ultimately the treated water is sent to the outlet channel.

Between 2008 and 2011, the sedimentary tank at Folwarczna Street was modernized by dividing it into three functional zones:

1. ***The zone of hydrodynamically intensified sedimentation,*** which is 26 metres long and its surface covers 344 m^2 . Its end section will be equipped with a lead-in pier with the dimensions of 1x1x1m filled covered with stones that will collect solid pollution drifting in water. In order to stabilize it, the bottom of the tank will be filled with IOMB slabs placed on non-wove geotextile fabric, and 20 cm draining layer of coarse gravel in which draining pipes connected to gravitation wells will be placed in order to dry the bottom of the tank and remove sediments deposited. In order to disperse water energy during violent flood waves and direct jets of low water to the inlet section of the tank, a barrier made of concrete elements will be constructed. A portable structure of a multi-stream sedimentary tank (lamellas) has been installed in the central section of the zone to intensify sedimentation processes. In the course of its operation, it will be possible to move this device to a different location or change the angle of lamellas.
2. ***The zone of intensive biogeochemical processes,*** the so-called process intensifier (differs depending on the season) is responsible for improvement of water biological parameters (reduction of nitrogen and phosphorus compounds in water leaving the sedimentary tank). A cover of thick-fraction limestone and two revision chambers with the system of ground water drainage arranged in 20 cm layer of coarse gravel in the bottom of the zone.
3. ***The zone of intensive biofiltration of sediments,*** which is 27 metres long and its surface covers 325 m^2 . It has been designed to intensify the process of removing biogenic compounds from the water leaving the sedimentary tank. Vegetation layer will be used to facilitate this process. The system has been designed to enable its operation in the following configurations:

- free water surface constructed wetlands with emerget macrophytes
- horizontal subsurface flow constructed wetlands
- vertical subsurface flow constructed wetlands

This solution will enable to use the sedimentary tank during low temperature periods, i.e. it will improve the tank's operational efficiency also during the non-vegetation seasons.
The following flora species are planned for planting in this zone: *Phragmites Australis*, *Schoenoplactus lacustris*, *Iris pseudacorus*, *Acorus calamus*, *Typha latifolia* and *Sagittaria sagittifolia.* They will be planted in the sand bed of 0.5-2mm fraction,

and a 20 cm layer of gravel will be arranged at the bottom, which will be equipped with drainage ended with wells to regulate discharge and rinse the deposits. The aquatic plants will additionally limit release of internal load of the tank to the reservoirs located in the stream below the tank.

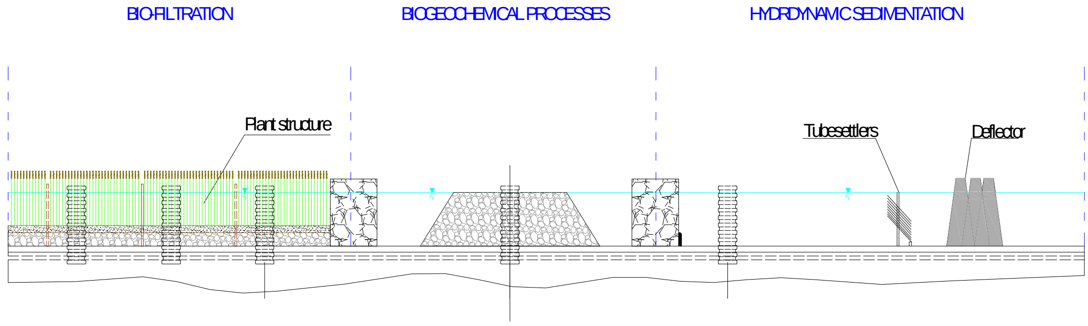

Figure 6. Cross-section of the sedimentary tank

Figure 7. 2010: Construction of the MCSB System

3.2. Zgierska Reservoir and Teresa Reservoir

The final work with regard to the building of Teresa Reservoir (Table 1), including the ground work, the installation of the reservoir construction and the planting of vegetation, were completed in 2006. The use of the phytotechnology concept (UNEP, 2003) was an innovative measure implemented in Teresa Reservoir, and also in Zgierska Reservoir (Table 2), which was constructed before SWITCH. The planting of macrophytes was to improve the aesthetics of the reservoirs on the one hand, and contribute to improved water quality on the other. The planting took place in 2007 (Fig. 8, 9).

Table 1. The key parameters of Teresa Reservoir

Teresa Reservoir				
1	Length		7+726	km
2	Surface of the catchment in the section of water uptake to the reservoir		7.87	km^2
3	Retention level			
		NPP	197.00	m asl
		Max PP	197.48	m asl
4	Capacity			
		Within the bank line	0.62	ha
		Within the water-table	0.44	ha
5	Capacity			m^3
		at NPP	3.165	m^3
		at max PP	5.678	m^3

Table 2. The key parameters of Zgierska Reservoir

Zgierska Reservoir				
1	Length		8+200	km
2	Surface of the catchment in the section of water uptake to the reservoir		7.21	km^2
3	Retention level			
		NPP	201.50	m asl
		Max PP	202.60	m asl
4	Capacity			
		Within the bank line	1.86	ha
		Within the water-table	1.52	ha
5	Capacity			m^3
		at NPP	24.094	m^3
		at max PP	48.299	m^3

a)  b) 

Figure 8. Vegetation in Teresa Reservoir just after being planted (a) and in 2010 (b)

In 2007, hydrophyte plants covered the banks and islands of the reservoirs. The planting undertaken in 2007 facilitated several sound decisions concerning additional plantings at these reservoirs and confirmed the choice of vegetation for other reservoirs. The following species have been planted**:** *Acorus calamus (240), Scirpus lacustris (240), Iris pseudoacorus (240), Sagittaria sagittifolia (240), Phragmites communis (100), Nymphaea (32) and Numphar lutea (16).*

Thanks to the planting of aquatic vegetation, suitable conditions for self-treatment processes have been provided, which directly contribute to the improved water quality in these two reservoirs. Collecting the biogenic substances and enclosing them in an inaccessible pool also reduced the risk of the occurrence of toxic blue-green algae blooming. Refuges for many fauna species, fish in particular, have also been developed, which positively impacts upon the condition of the ichtiofauna in the reservoirs.

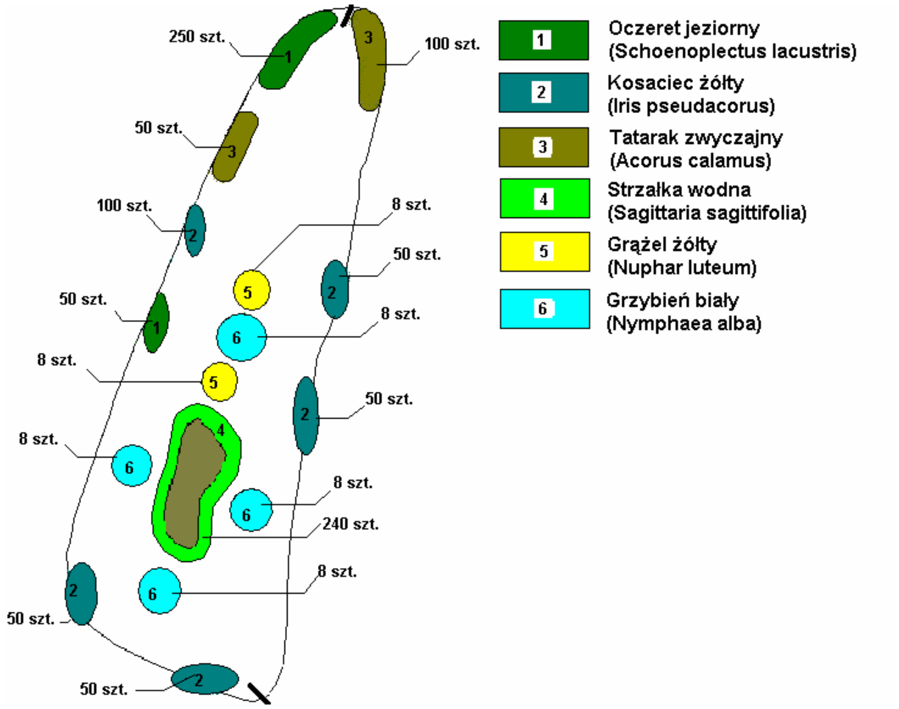

Figure 9. The project for plantings in Teresa Reservoir

As a result, ecotone zones have been created. On the one hand, they reduce the speed of water discharge, and on the other, contribute to the elimination of general suspensions. They also significantly improve local retention and reinforce the banks, thanks to well-developed root systems. Relatively shallow roots were exhibited by the plants at Zgierska Reservoir, whereas much deeper roots were observed at Teresa Reservoir (photo 3). The shallow roots could be also due to the major fluctuations in the water-table noted at Zgierska Reservoir, which occurred in the weeks following the planting. In the future, further work will be implemented in order to select plant species that will ensure a high level of efficiency in purifying Zgierska Reservoir.

Between 2006 and 2010, standard annual maintenance work was conducted at Zgierska and Teresa Reservoirs. At Teresa Reservoir, self-sown plants were removed and, in particular, the tank containing the hydrophytes was cleaned during their most intensive stage of

development. The regular removal of macrophytes during the autumn is a procedure that is necessary to reduce the risk of blooming. It enables the removal of biogenes trapped in the macrophyte biomass in the reservoir and prevents the system from internal recharging, a result of the autumn and early-spring decomposition of tissues. Trees and lichens were also removed from the island, which is a refuge for wild birds that nest in the area.

3.3. Żabieniec Reservoir

The technical documentation for the construction of Żabieniec Reservoir was developed under the SWITCH project in 2008. It included guidelines based on the scientific research conducted, which resulted in the use of a gabion lead-in pier while building this reservoir. The construction started in 2010 and is now being under completion (2011). Location of the Żabieniec Reservoir links with the historical aspects of water in Łódź, i.e. it is built in the vicinity of a compensation reservoir of a former mill, whose old foundations can still be seen on the right bank of the river.

Table 3 The key parameters of Żabieniec Reservoir (AQUAPROJEKT, 2008)

Żabieniec Reservoir				
1	Length		5+078	km
2	Surface of the catchment in the section of water uptake to the reservoir		14.6	km^2
3	Retention level			
		NPP	187.50	m asl
		Max PP	187.94	m asl
4	Surface			
		Within the bank line	1.18	ha
		Within the water-table	1.04	ha
5	Capacity			m^3
		at NPP	10.333	m^3
		at max PP	15.098	m^3

The reservoir is located within the stretch of the Sokołówka from 5+043km to 5+206km; it is rectangular, 150m long and between 60m and 100m wide (Fig. 10, 11).

Żabieniec Reservoir will retain water by flattening the culmination waves caused by torrential rains, contribute to improved water quality, and become the next stage in the Sokołówka's rehabilitation due to its landscape values, which will enhance the attractiveness of the adjacent areas as recreational and walking areas.

The reservoir is not very deep, therefore, it was decided that no channel, not even a shallow one, would be constructed in the bed to facilitate water run-off during the reservoir's cup maintenance. The bottom has been shaped in such a way so as to provide it with a gentle longitudinal slope as well as transverse slopes to facilitate water outflow towards the damming and sluice structures. At the inlet section of the river-bed, leading to the reservoir itself, a lead-in pier made of 3 gabion baskets, which will be responsible for distributing the stream of water in order to avoid water stagnation, has been installed. Within the zone of anticipated fluctuations in the water-table, caused by changes in discharge and waving, the reservoir scarp will be reinforced with light and environment-friendly materials in the form of geocells Above the reinforcements, those scarps that are above the water level will be made of

geo-grid and the edge of the reservoir will be covered with a layer of humus and sown with grass seeds. The mild tilt of the scarps will facilitate and accelerate the growth of the aquatic vegetation planted on the edge zone.

Water in the reservoir will be dammed by the front dike, which will also form the surface overflow. Damming water to the NPP level will be facilitated by two culverts. Guides and log-stops facilitating the regulation of the water-level in the reservoir and its emptying have been installed at the inlets to these culverts. Between the surface overflow and the retaining wall, which constitutes the front of the existing pipe culvert under Żabieniec Street, a stilling-basin was formed. In order to maintain the natural characteristics of the reservoir, the plates were made of field stones.

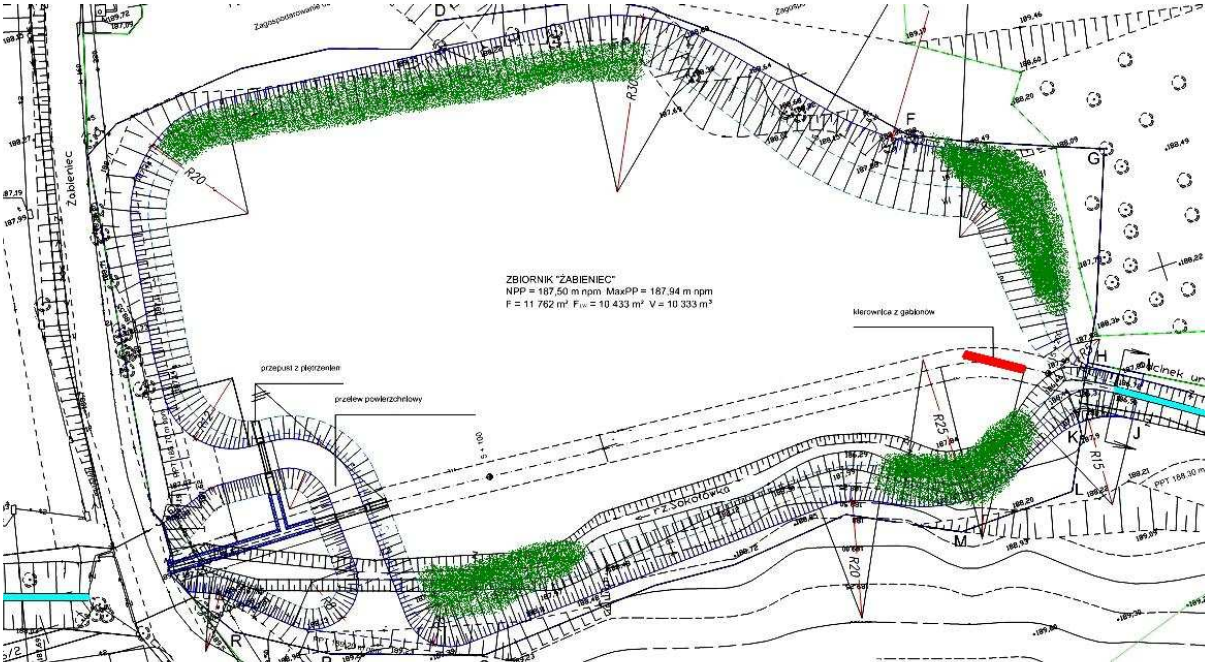

Figure 10. Design of Żabieniec Reservoir, 2008.

Figure 11. Żabieniec Reservoir during the implementation of the investment, 2010, with a view of the front dike of the reservoir.

4. Spin-offs and complementary infrastructure

4.1. Wycieczkowa Reservoir

In 2009, Wycieczkowa Reservoir (Table 4), which is located in the upper-most stretch of the Sokołówka River, was constructed. This was delivered under the Small Retention Programme and is a SWITCH spin-off, which benefitted from the knowledge and experience generated in the course of the project's implementation, and complements the functioning of the other reservoirs constructed under the SWITCH project. It was financed with funds provided by Łódź City Office and the Regional Fund of the Environmental Protection and Water Management in Łódź.

The objective is to intercept flood waves from the upper part of the Sokołówka River catchment in order to limit the discharge within the reconstructed covered stretch located below the reservoir, leading to "Wasiak Pond" Reservoir. The construction of this reservoir permitted the reduction of the dimensions of a planned closed channel, which will contribute to reducing the cost of this investment. It has also improved the quality of the water in the river and stabilized its hydrological regime, which is of critical importance in the context of the river rehabilitation that is planned for the middle stretch of the river. In the years prior to the investment, numerous inundations and flooding of the areas located above the covered river channel were recorded. After the reservoir became operational, torrential rains have not produced any flooding in this region. Wycieczkowa Reservoir is a dry retention facility composed of a cascade of 6 sub-reservoirs (Fig. 12, 13). The original dimensions of this reservoir have been modified (its surface was reduced by approximately 25%), mainly to protect the abundant and self-maintaining tree and shrub vegetation at the request of the local community.

Table 4 The key parameters of Wycieczkowa Reservoir

Wycieczkowa Reservoir				
1	Length		11+773	km
2	Surface of the catchment in the section of water uptake to the reservoir		1.73	km^2
3	Bank line surface		0,93	ha
4	Capacity	at Q10%	7.156	m^3
		at Q100%	2.925	m^3

Figure 12. Design of Wycieczkowa Reservoir, 2008 (1,2,3,4,5,6 – sub-reservoirs ; green colour – greenery to be kept, brown – greenery to be removed)

Figure 13. Wycieczkowa Reservoir, 2010

4.2. Wasiak Pond Reservoir

In 2011, in the upper stream of the Sokołówka, the construction of the Wasiak Pond Reservoir (Table 5) will be finalised. This is also implemented under the Small Retention Programme.

Table 5. The key parameters of Wasiak Pond Reservoir

Wasiak Pond Reservoir				
1	Length		10+064	km
2	Surface of the catchment in the section of water uptake to the reservoir		5.34	km^2
3	Surface	In the bank line	2.08	ha
		Lower part	0.77	ha
		Upper part	1.31	ha
4	Capacity	max. in the bank line	21.740	m^3
		at Q10%	4.688	m^3
		at Q100%	2.690	m^3

Wasiak Pond is a dry retention reservoir (Fig. 14). It is intended to intercept excessive rainwater from the upper part of the catchment and reduce discharge in the stretch between the planned reservoir and the ponds in A. Mickiewicz Park. This reservoir in particular will retain water from the Sokołówka catchment below Wycieczkowa Reservoir. Its surface area will be 3.61 km^2. Limiting the discharge will favourably impact upon the efficiency of rainwater treatment in Folwarczna Reservoir's sedimentation tank, which is located above the upper pond in the park. It will also indirectly contribute to better water quality throughout the cascade of reservoirs and in the river.

Due to a periodic lack of discharge, the reservoir was designed as a dry facility. In its lower section, a small pond with a bank line surface of 956m^2 and a capacity of 248m^3 was established (Fig. 14). It has a decorative function and is reminiscent of the fish pond which used to exist in the past. The ground water-table is at the level of the pond's bed, and thus the water required to fill it is the same as the pond's capacity.

It is anticipated that the same water-table will be maintained in the pond throughout the year. In the summer the pond will be a decorative feature, and in the winter it may be used as an ice-rink. The pond will be emptied only in order to maintain it and remove alluvial deposits.

The reservoir's bed will be at two levels. The flood wave occurrence probability, p = 100 %, and p = 10 %, will be accommodated in the lower section of the reservoir, thus statistically its upper section will not be flooded more often than once every 10 years. A mild tilt of the external scarps and the scarp that separates the upper section of the reservoir from the lower was adopted. The edges and cap of the reservoir, both in the upper and lower sections, will be used as green areas for walking and recreational purposes.

The southern edges of the pond will have rush cover with aquatic vegetation, while a round island with a surface area of approximately $80m^2$ is to be planted with Salix sepulcralis and other vegetation. The experience gained from the SWITCH-related developments that have been implemented so far will be used for the purpose of this design.

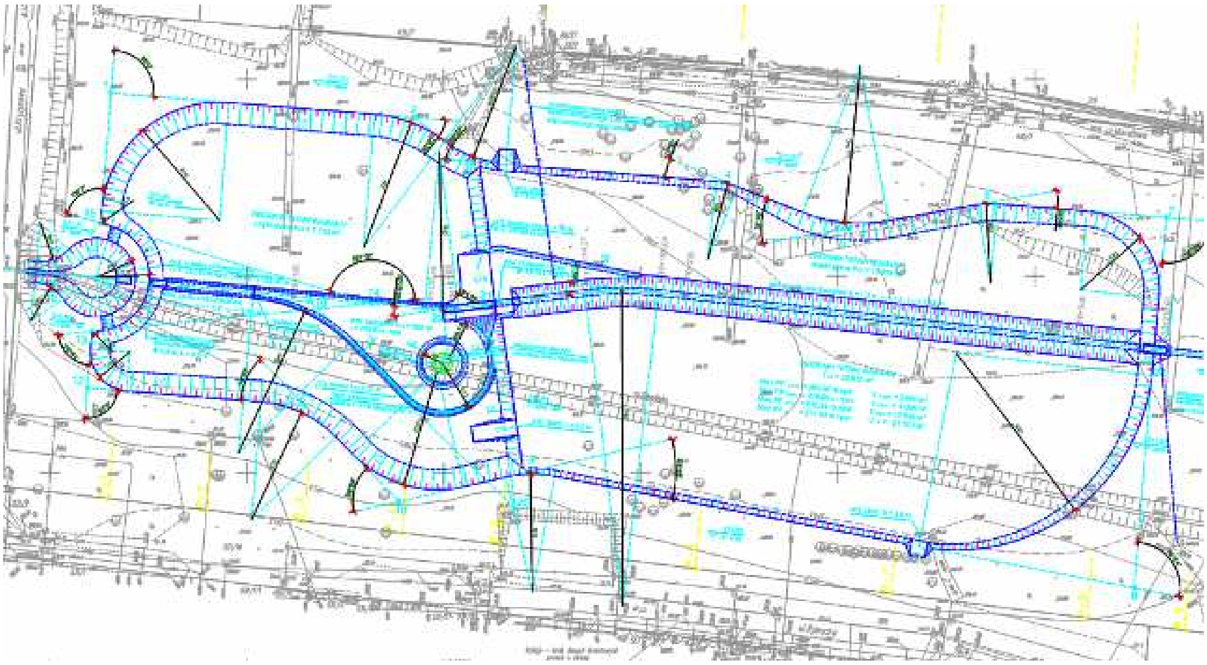

Figure 14. Design of Wasiak Pond (2010)