DOI: 10.2478/v10025-012-0006-z

JOURNAL OF WATER AND LAND DEVELOPMENT
J. Water Land Dev. 2012, No. 17 (VII–XII): 45–52
PL ISSN 1429–7426

Available (PDF): www.itep.edu.pl/wydawnictwo; http://versita.com/jwld/

Received 30.10.2012
Reviewed 12.11.2012
Accepted 18.11.2012
A – study design
B – data collection
C – statistical analysis
D – data interpretation
E – manuscript preparation
F – literature search

Small water reservoirs – their function and construction

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For citation: Mioduszewski W. 2012. Small water reservoirs – their function and construction. Journal of Water and Land Development. No. 17 p. 45–52

Abstract

Small water reservoirs play important role in rural areas. They used to be very popular, but most of them have been devastated in the last century. It is worth to restore them and to construct new ones. Very small reservoirs (ponds) can be constructed in economical and cost efficient way by individual farmers. In regard to damming below 1.0 m and to reservoirs situated outside protected areas, the permission for construction and the environmental impact assessment is not required. However, one should always keep in mind that even the smallest construction is the work of engineering and should be performed in accordance with the current standards.

The increase of available water resources and improvement of water quality demand various measures including those aimed at reducing and limiting water runoff and pollutants transport from the river basins. One of the methods to improve the structure of water balance and the amount of water in rivers is the construction of a large number of small reservoirs, wetland reconstruction etc. Such reservoirs may be divided to: recreational, floristic and faunistic conservation sites, swimming pools, water quality protection (constructed wetlands) and infiltration reservoirs.

Reservoirs can have many functions of the economic and natural character. If they are designed and constructed properly they can be a valuable element of the natural landscape in rural areas. Basic data for designing of small reservoirs serving mainly recreational (decorative) purposes and those used for water treatment and ground water recharge are given in the paper.

Key words: *small scale water retention, water balance, water quality, water reservoirs*

INTRODUCTION

Changes in the management and use of the river basin and some hydrotechnical works caused the acceleration of water cycles, loss of valuable natural areas and increase of surface and ground water pollution. Therefore, the need of undertaking measures to increase the retention capacity of the basin is obvious. One of the methods to retain rainwater and snow melting water in the catchment is the construction of water reservoirs.

Ponds (small water reservoirs) may be made by water damming on a small stream but there are also dug ponds or small ground depressions filled with water. Small water ponds are the ones that have capacity of less than 100 000 m^3 and damming height not exceeding 1.0 m [MIODUSZEWSKI 2008]. Despite small capacity, such reservoirs have considerable economic, hydrologic and environmental significance. They also improve quality of water flowing into the rivers. They are called “constructed wetlands” if they are built for water quality protection. Experiments that have been carried out show that acceleration of the water cycle and the associated transport of pollutants have an adverse effect on the structure of the water balance and water quality. The increase of available water resources and the improvement of water quality demand various measures including the ones aimed at reducing and limiting water runoff and pollutant transport from the river basins. One of the methods to improve the structure of water balance and the amount of water in rivers is the construction of a large number of small reservoirs, wetland reconstruction etc. Such reservoirs serve various purposes as e.g.: recreational pools, floristic and faunistic conservation sites, swimming pools, water quality protection (constructed wetlands), infiltration reservoirs.

RECREATIONAL RESERVOIRS

Recreational reservoirs (decorative ponds) have been constructed for many years to diversify and enhance the natural and cultural landscape. A pond or a small water course, sometimes with waterfall, used to be the basic element of countryside or manor parks. There is extensive literature on this kind of water bodies [BORCZ, POGODZIŃSKI 1994].

Most of the previously constructed decorative reservoirs (especially in urban areas) have banks reinforced with concrete or wooden palisades (fences). Mainly for this reason, water in such reservoirs is strongly polluted. Today, taking ecological issues into account it is worth promoting the reservoirs covered by vegetation, even in urban areas. In reservoirs reinforced with concrete it is possible to construct small islands or place baskets filled with soil and submerged few inches below water table that can be a good place for aquatic plants. The existing habits do not accept such reservoirs in urban areas. Hence, there is no experience in the rules and ways of exploitation of such reservoirs.

Flora and fauna conservation sites. Water reservoirs can be constructed as an element of the enrichment of natural landscape values increasing biodiversity or as flora and fauna conservation sites. In many cases the aim of the reservoir construction is to restore the natural condition, including wetlands that had been destroyed due to land drainage or other human activities. Shallow, dug reservoirs with mild sandy slopes form ideal sites for the reproduction of amphibians. On the other hand, small scale impoundments improve water relations in the adjacent areas. The shape, size and water relations (flow, depth) depend on flora and fauna species for the development of which appropriate conditions are meant to be created. From the environmental point of view most of the small reservoirs built for various reasons are valuable aquatic enclaves especially in places where water plants may develop on slopes and in parts of the reservoir. In such sites, rich aquatic flora and fauna develops despite economical or recreational use of the reservoir. In the contact zone between water and land, the so-called ecotone, the most varied forms of life can be observed [ŻBIKOWSKI, ŻELAZO 1993]. Therefore, small reservoirs are one of the most important elements ensuring conservation of the landscape biodiversity which is the fundamental condition of the sustainable development in rural areas.

Decorative reservoirs as well as the ones constructed for the protection of aquatic flora and fauna can be also used for other purposes such as non-commercial fish farming or waterholes.

Non-commercial fish ponds. Even the smallest reservoirs are sometimes used for non-commercial fish farming and fishing. It is believed that in a pond of an area larger than 100 m^2 an extensive fish farming can be economical. It is possible to obtain 100–250 kg of fish per hectare of the pond [GUZIUR 1991]. Such reservoirs can have significant ecological values. Also the drainage ditches with constant water flow can be successfully used for non-commercial fish farming. In many cases the adaptation of a ditch for farming purposes is based on the construction of proper water damming devices.

In reservoirs used for fishing, the bottom is usually diversified (in depth) and small islands or special hiding places for fish are constructed. If net fishing is intended, the slopes of the reservoir should be regular. The most effective depth of the reservoir is greater than 0.8 m on more than 50% of its surface area. Also, the requirements for water quality (mostly for oxygen demand) must be met [GUZIUR 1991; WOŹNIAK 2006].

Watering trough (waterholes). Each water reservoir constructed in the forest area or in the vicinity of a forest can be used by wild animals. There is no need to construct special sites where animals can reach water. It is enough to construct slopes that would be mild but not milder than 1:3.

On the other hand, ponds for domestic animals should be designed in a special way. Usually, such ponds should have mild slopes allowing free access to water. Width of the waterhole (B) is calculated assuming that $B = nb$, where n is the number of animals using the waterhole simultaneously and b is the width foreseen for one animal. It is assumed that b = 0.5–1.0 m per one adult animal and 0.3–0.5 m for the young one. The slope of the reservoir should be 1:6–1:12 and the depth should not be less than 0.35 m.

Ways of construction of this kind of ponds can vary and, in case of large cattle herds, the ponds are sometimes complex hydrotechnical engineering structures. Figure 1 shows a simple construction of waterholes that are suitable for small cattle herd. In case of intensive use, the access to water should be reinforced with concrete boards laid on gravel, fascine (brush wood) or geotextile. It is also possible to strengthen the access route with wooden rods or wired rods arranged on fascine or gotextile. When the intensity of

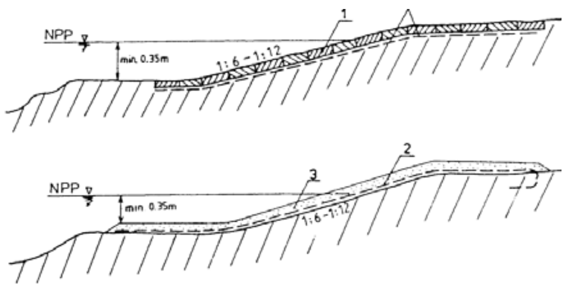

Fig. 1. Examples of a simple watering site construction: *1* – concrete slabs, rods or wooden boards, *2* – geotextiles, *3* – sand

waterhole use is small, piling sand layer 15–20 cm thick on the surface of geotextile is sufficient. Construction of efficient pond to water the cattle is extremely important due to the fact that allowing the animals to the edge of unprepared reservoir can damage the slopes and increase the risk of fecal water pollution. The best solution is to construct a pond at a distance from the reservoir, for example, by making additional small reservoir supplied with water from the proper reservoir with a pipeline or a shallow ditch. Figure 2 provides an original solution for cattle watering site located by the damming reservoir.

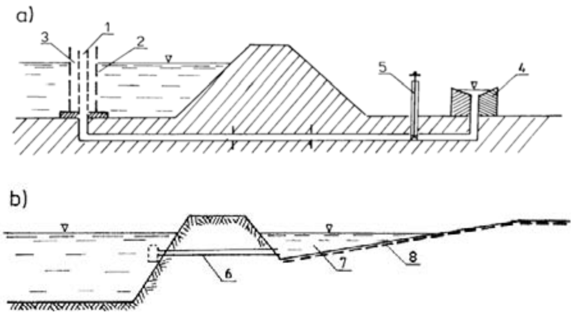

Fig. 2. Water intake from the pond for cattle watering scheme: a) reservoir, b) dug pond; *1* – perforated pipe of 10–15 cm diameter, *2* – perforated pipe of 50–200 cm diameter, *3* – coarse sand or gravel, *4* – drinking site of length depending on the number of cattle, *5* – valve, *6* – metal pipeline with metal stainer, *7* – waterhole, *8* – bottom strengthening such as geotextile

In any case, waterhole should be constructed in a way to protect water from excessive pollution. Animals' access to water should be permitted only within waterhole. The rest of the tank and its banks can be treated as flora and fauna refuge site.

SWIMMING POOLS (NATURAL POOLS)

Construction of the pool, especially the widely available one, should fulfil a number of health requirements. Water quality in a pool is determined by special regulations.

It is also possible to construct swimming pools as dug ponds without special devices to keep water clean. Aquatic plants are used to protect the water quality. In such case, the pond is divided into two parts. One half of the pond is shallow (20–40 cm) and covered with aquatic plants. The other half of the pond of a depth of 1.0–1.2 m is an essential pool. Pools are of varied size but they should not exceed 50 m^2. Banks should be constructed as a sandy or grassy beach with the accompanying devices like a bridge with a ladder.

An exemplary scheme of a small dug pond (natural swimming pool) is presented in Figure 3. The deeper part of the pond (1.0–1.2 m) is used for swimming while the shallow part (ca. 0.3 m) is a natural plant filter ensuring good water quality. This is a concept of a "natural pool" widely used in Europe (Austria, Germany). The shallow part of the pond is separated by a vertical wall (wooden or concrete) from the deep part. The top of the wall is situated ca. 0.1 m below the water table (Fig. 4). Slopes of the deep part of the pond should be trimmed 1:1.5–1:2 and strengthened with a sandy pavement. The more expensive solution is to construct vertical walls of the deep part (similar to the swimming pools). The bottom of both parts of the pond should be covered by loose substratum (gravel, coarse sand). Swimming comfort requires sustaining a constant water level. It is advised to refill the water loss caused by evaporation with ground water from the well. In order to mitigate temperature differences (the shallow part warms faster) and to increase the effectiveness of water purification it is possible to enforce water circulation by pumping it from the deep part to the shallow one.

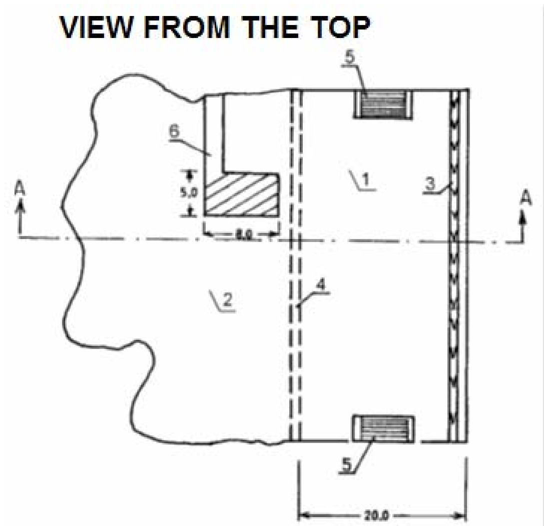

Fig. 3. Plan of the natural swimming pool; *1* – deep part (recreational), *2* – shallow part covered by aquatic plants, *3* – vertical wall, *4* – wall separating the shallow part from the deep one, *5* – stairs going down to the water, *6* – viewing platform

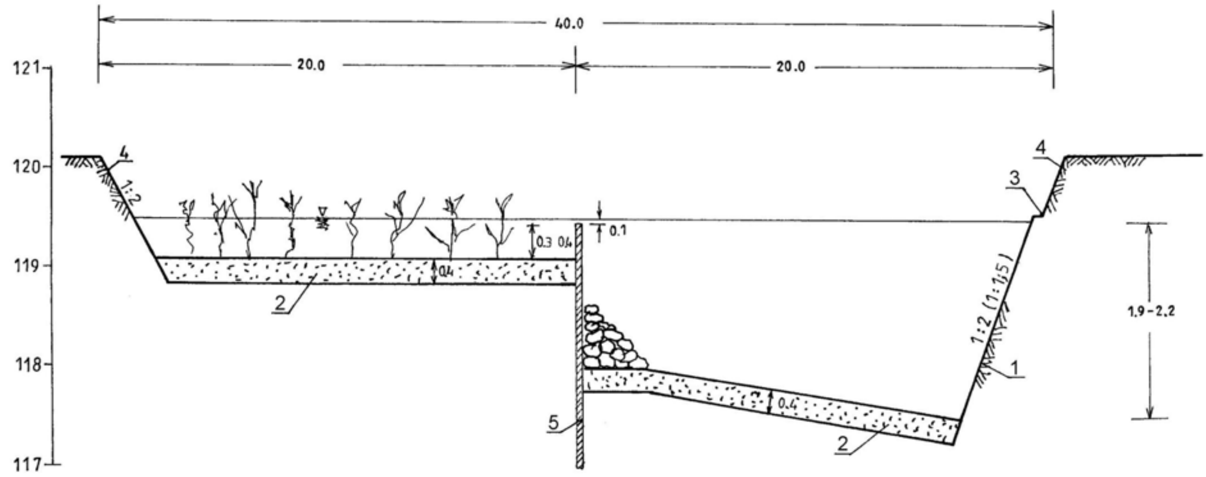

Fig. 4. A schematic cross section through the natural swimming pool; *1* – slope of the deep part of the pool, *2* – bottom (gravel, coarse sand), *3* – bench allowing a walk over the water table, *4* – slope covered by grass, *5* – wall separating the deep part of the pool from the shallow one

Groundwater input to the pond to refill water losses and to sustain circulation between both parts of the pond can be formed as a small fountain. The output of pumps for ponds of a size as that presented in Figure 4 is estimated at 20–30 l per hour. At such low flow rates it is possible to use pumps powered by solar cells or wind energy.

The pond (swimming site) should be secured against the direct inflow of surface waters as they are usually polluted by nitrogen and phosphorus. Aquatic plants should be cut down before the onset of the winter season. It is allowed to keep fish but only for decorative purposes as they help in limiting the population of mosquitos. It is also recommended to carry regular chemical and microbiological water analyses.

Ponds constructed as public swimming ponds must fulfil sanitary standards and it is necessary to obtain permission for the construction before start of the ground works. Size of the pond depends on the expected number of users. The maximum number of people per 1 ha of the pond is 500. Periodical water quality tests are required.

PROTECTION OF WATER QUALITY

Surface waters flowing to rivers in rural and in urban areas are often polluted. Runoff of these waters to rivers and lakes contributes to the excessive pollution including a meaningful load of pollution transferred to the Baltic Sea. Construction of water treatment plants and implementation of clean technologies in agriculture are not able to eliminate the emission of pollutants completely. Therefore, measures to intercept and purify the polluted waters are implemented. One of the most effective methods of limiting the transport of pollutants, especially from diffuse agricultural sources, is the construction of small reservoirs.

All kinds of small reservoirs are regulators of water and matter circulation [DOLL 1996; Stormwater... 2000] and are called “constructed wetlands” if built for improving water quality. Reservoirs that are meant to be biofilters are dammed or dug and are constructed by extending the bed of a watercourse. Such reservoirs are usually shallow and the depth of prevailing area of each reservoir is 0.3–0.6 m. It allows the development of vegetation covering largest part of the reservoir. Water purification is based on sedimentation of particulate matter, denitrification and the uptake of nutrients by vegetation [Stormwater…, 2002]. Size and capacity of each pond should be calculated so that the average water flow is not greater than $0.15\ m^3 \cdot s^{-1}$. Many studies showed that a decrease of N load in such reservoir is ca. $1\ g \cdot m^{-2}$ of the reservoir area per year. A nomogram that allows to determine the approximate minimum size of the reservoir depending on the average water inflow and N concentration in the inflow is presented in Figure 5. The nomogram was developed assuming that the average depth is 0.5 m and the effectiveness of pollutants elimination is over 90%. If the size of a pond is smaller than that defined from the nomogram, the effectiveness of N elimination will be lower.

Examples of biofilters (constructed wetlands) are presented in Figure 6. Constructed wetlands can vary in shape – from very simple single-chamber ones (Fig. 6a) to two and multi chamber wetlands with a preliminary trap (Fig. 6c) and enforced water circulation (Fig. 6b) to expand the flow path. Ditches can also be used to purify water (Fig. 6d).

Increased pollution holding capacity is possible when the bottom of the reservoir is covered by submerged and emergent aquatic vegetation and the shore zone and slope are covered by reed, wicker, etc. It is recommended to cut down the vegetation during the winter season and to remove it outside the reservoir.

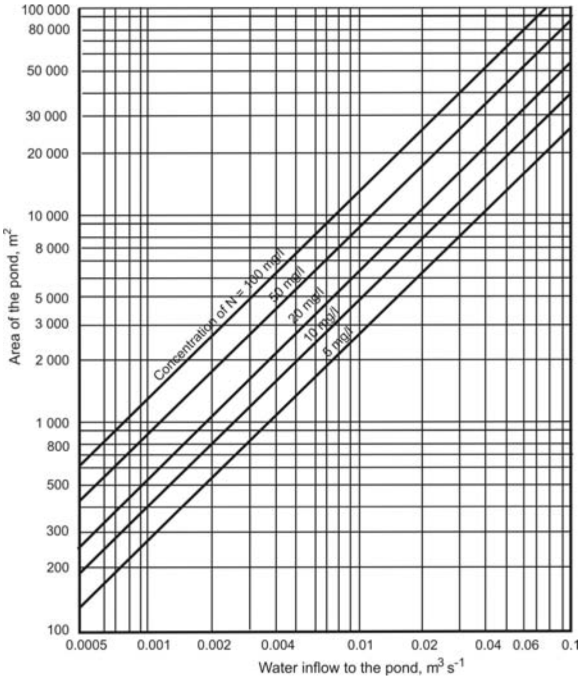

Fig. 5. A nomogram for determining the minimum size of the pond for water purification from nitrogen (average depth of 0.5 m)

In many cases the removed vegetation is used for compost production, bedding of livestock or as an energetic material. Biofilter reservoirs are valuable as a transition zone prior to the disposal of surface water, water from intensively exploited fishponds or the run-off from urban areas to recipient waters (rivers, lakes).

Purification of rain water is necessary to protect rivers and lakes. Also, during the collection of rain-water for economical purposes (e.g. irrigation) it is recommended to preliminarily purify it before its in-flow to the reservoir. Surface runoff from agricultural lands usually contains large amount of nutrients (nitrogen, phosphorus). Therefore, economic use of reservoirs recharged by these waters is limited. If rain water is collected for recreational or economic purposes it is necessary to develop the surroundings of the reservoir in a way to limit mudding and improve recharge water quality. Exemplary solutions allowing partial purification of surface runoff are presented in Figure 7. These are very shallow reservoirs constructed on the flow path of the surface runoff water and covered by vegetation.

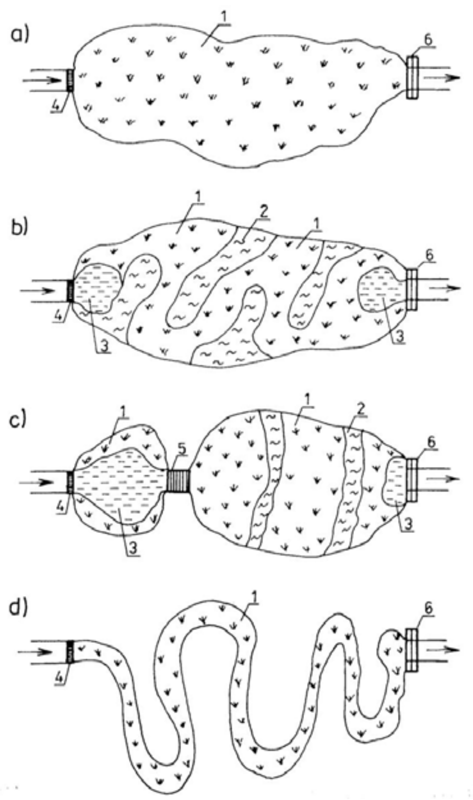

Fig. 6. Schemes of reservoirs (biofilters) for the purification of polluted water; a) one-chamber reservoir, b) reservoir with diverse surface, c) two-chamber reservoir, d) channel (ditch); *1* – surface of the reservoir covered by aquatic plants or grass, *2* – elevated areas of the reservoir or areas covered by higher vegetation, *3* – reservoir filled with water, *4* – inlet construction, *5* – rapid flow channel (cascade), *6* – outlet construction; source: CAMPBELL, OGEN [1999]

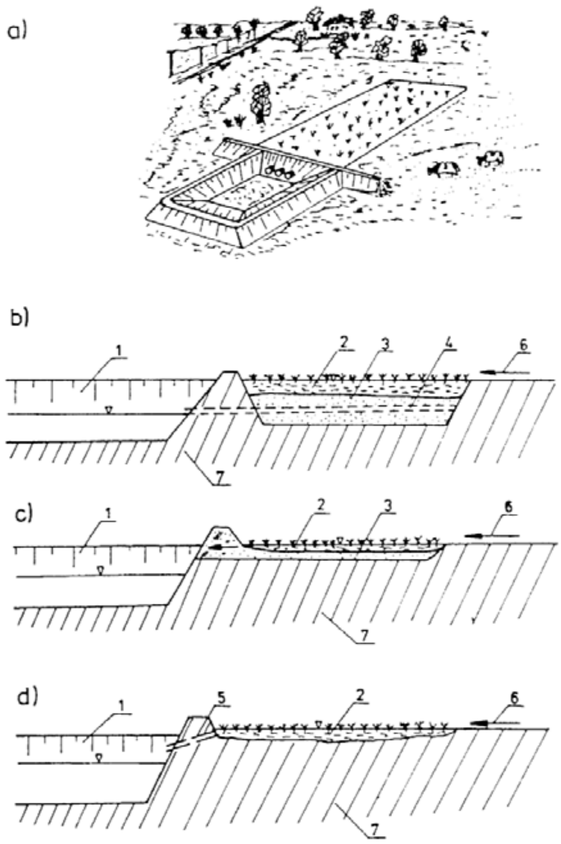

Fig. 7. A scheme of reservoir for preliminary surface runoff water purification: a) general view of the reservoir, b), c), d) cross sections of different types of reservoirs of verified construction; *1* – pond, *2* – initial pond (biofilter) of 20–30 cm depth covered by plants, *3* – filtration material (sand), *4* – drainage, *5* – pipeline draining water (or space in the crown of the dike), *6* – water flow direction, *7* – poorly permeable substratum

Water discharged from the drainage system is very often discharged directly to a water course. That water usually contains substantial amounts of nitrogen and phosphorus. Therefore, such waters should be preliminarily purified in a small and shallow reservoir as it is presented in Figure 8, although the best solution is to retain waters and use them for irrigation.

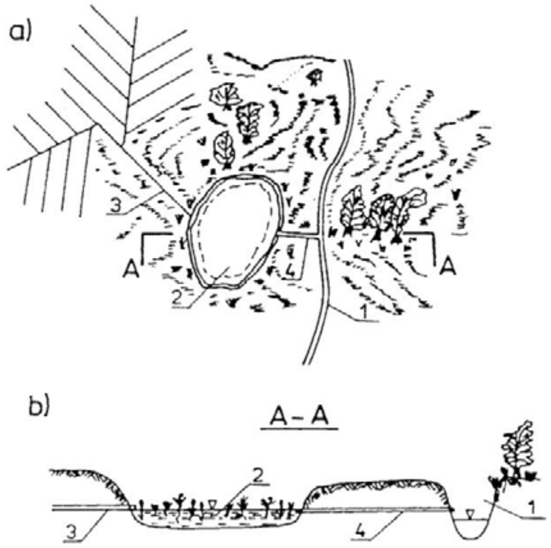

Fig. 8. A scheme of the biofilter located in the vicinity of a drainage water recipient: a) situation plan, b) A–A section; *1* – water course (drainage water recipient), *2* – dug pond covered by vegetation, *3* – outlet of the drainage water, *4* – discharge of purified water to the water course (open ditch or pipeline)

INFILTRATION RESERVOIRS

Fast drainage that occurs especially in urban (sealed) areas is unfavourable due to limited ground water recharge and progressive lowering of ground water table. One of the ways to limit such adverse effects is the construction of reservoirs that retain rain water and allow its infiltration.

Reservoirs recharged by waters from the surface runoff are usually very valuable due to environmental reasons. Not only they create good conditions for the development of flora and fauna species (especially the reservoirs constructed in agricultural areas) but also contribute to the reduction of diffuse pollution and thus, to the protection of ground and surface waters.

Rain water from streets and markets, including rural areas, is usually polluted and its discharge to rivers is not recommended. In order to impede the rapid runoff from the catchment it is recommended to recharge lower situated geological layers by waters from the sealed areas. However, these waters should be purified before. As shown in Figure 9, infiltration reservoirs can be used for this purpose. The reservoirs can be of a dug type (Fig. 9a) or may have the additional filtration layer (Fig. 9b). If water carries a substantial load of particulate matter and chemical compounds it is recommended to construct the doubled reservoir. Sedimentation of soil particles and preliminary purification occur in the first reservoir (biofilter reservoir with sealed bottom). After preliminarily purification, water flows to the second reservoir from which it infiltrates to the ground. Due to the fact that the reservoirs are recharged only in wet season or after snow melting, they are less vulnerable to silting (especially the reservoirs where growth and development of aquatic plants is possible).

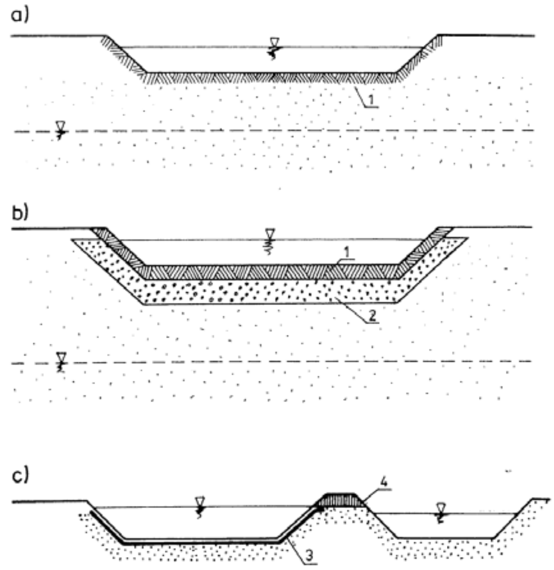

Fig. 9. Schemes of infiltration reservoirs: a) natural basin, b) filtration layer, c) infiltration reservoir with preliminary settling; *1* – soil, *2* – filtration layer, *3* – plastic sealing, *4* – overflow (pipeline)

A more complex construction of the reservoir is presented in Figure 10. Such reservoirs can be constructed on impermeable grounds with very low capacity for water conduction.

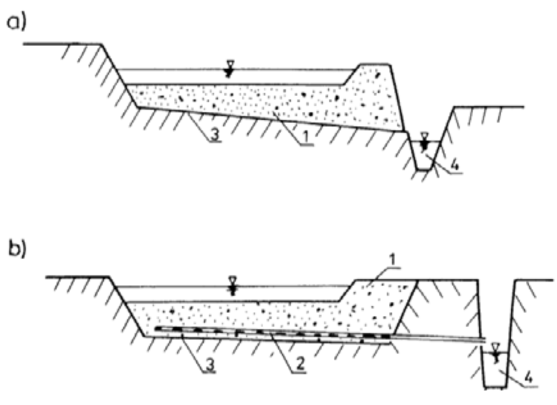

Fig. 10. Schemes of filtration basins: a) simple basin, b) drained basin; *1* – filtration material, *2* – drainage with a filter cover, *3* – natural bottom (impermeable or poorly permeable) or sealed with plastic, *4* – infiltrating water recipient (water course, pond, channel, pipeline, etc.)

Instead of typical reservoirs, the linear ones (drainage ditches) can be constructed. A scheme of infiltration ditches is presented in Figure 11. This kind of ditches can be constructed to allow infiltration and accelerate outflow from the infiltration reservoir in the areas of low permeability.

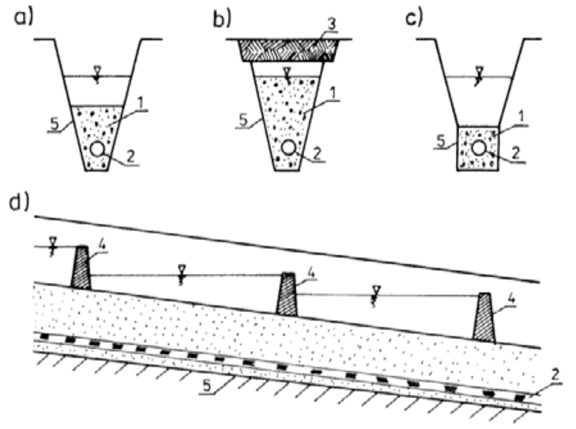

Fig. 11. Infiltration ditches scheme: a), b), c) cross sections, d) longitudinal section of the ditch a) and c); *1* – filtration material (gravel, stones), *2* – pipe drainage with filtration cover, *3* – turf, *4* – overflows, natural bottom (poorly permeable or impermeable) or sealed with plastic

CONCLUSIONS

The aim of the paper was to present the role of small water reservoirs based on the literature and own experience. Small water reservoirs are valuable elements of rural and urban landscape. They are a valuable part of both, agricultural and urban, landscape. Small water reservoirs improve the structure of water resources and increase biodiversity in areas used by humans while they can be used for commercial purposes at the same time. This wide variety of functions of small water reservoirs should be used as often as possible. It is advisable to establish programs aimed at financial and substantive support for people undertaking the construction of such reservoirs.

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Waldemar MIODUSZEWSKI

Małe zbiorniki wodne – ich funkcje i konstrukcje

STRESZCZENIE

Słowa kluczowe: *bilans wodny, jakość wody, mała retencja, zbiorniki wodne*

Zmiany zagospodarowania i użytkowania zlewni, a także niektóre prace hydrotechniczne spowodowały przyspieszenie obiegu wody w przyrodzie, zanik wielu cennych przyrodniczo obszarów, zwiększenie zanieczyszczenia wód podziemnych i powierzchniowych. Konieczne jest więc podjęcie działań w celu zwiększenia pojemności retencyjnej zlewni. Jedną z metod zatrzymania wód opadowych i roztopowych w zlewni jest budowa wszelkiego typu zbiorników wodnych, zarówno gromadzących wodę na powierzchni terenu, jak i zasilających wody podziemne.

Celem artykułu było, na podstawie dostępnej literatury i doświadczeń własnych, wykazanie roli małych zbiorników wodnych. Stanowią one cenny element zarówno w krajobrazie rolniczym, jak i zurbanizowanym. Przyczyniają się do poprawy struktury zasobów wodnych i zwiększają różnorodność biologiczną terenów wykorzystywanych przez człowieka, a jednocześnie mogą być wykorzystywane do celów gospodarczych. Ta duża różnorodność funkcji małych zbiorników powinna być możliwie często wykorzystywana. Celowe jest ustanowienie programów mających na celu pomoc finansową i merytoryczną dla osób podejmujących się budowy takich zbiorników.