Scientific Bulletin of Politehnica University of Timişoara

Transactions on HYDROTECHNICS

Volume 66(80), Issue 1, 2021

CONSIDERATIONS ON LOCAL WATER SOURCES FOR AGRICULTURE. CASE STUDY: MULTIPLE ROLE WATER STORAGE BASINS

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Abstract: Under the current pedoclimatic conditions, identification of local water resources for agricultural purposes must become a priority, to ensure food safety for population and as well for environmental protection. Recent studies demonstrate that the arrangement of local reservoirs on the upper reaches of small permanent and non-permanent watercourses can have various benefits for agricultural purposes, biodiversity and the prevention of natural disasters such as drought or floods. This paper presents the constructive solutions for a water storage basin designed to supply water for a small local irrigation arrangement, but also for fish farming purposes, biodiversity stability and flood prevention.

Keywords: water resources, water storage basins water quality, water for irrigation, aridity.

1. INTRODUCTION

Current specialized studies show that the need to identify local water sources is a global need with various uses in the economy [1]. Thus, in agriculture, in addition to surface watercourses that allow direct supply from the source, groundwater or reused water, the identification of new possibilities for water storage with various uses is a priority especially where the other options are not available or are limited.

Identifying possibilities for arranging local reservoirs with various capacities depending on the need for their use, is a plus from several points of view, including providing water for agriculture, biodiversity prosperity and flood control.

In the high plain areas of the western plain or at the interference of the plain area with the hill area, in the upper basins of the tributaries of watercourses, non-permanent watercourses are created that do not represent cadastral or regularized watercourses. Although these watercourses are irregular, the water supply they provide at certain times of the year, such as the rainy season or melting snow, can be important water sources that can be used in agriculture at other times of the year.

Recent studies show that through careful documentation, in terms of topographic, pedological and hydrological data, landscaping solutions can ensure the availability of water for various uses such as: local irrigation facilities on medium and small areas (10-200 hectares), for field cultivation (cereals, corn) or for localized irrigation (berries, orchards, vegetables), fish farming, recreation but also to avoid natural disasters such as drought or floods.

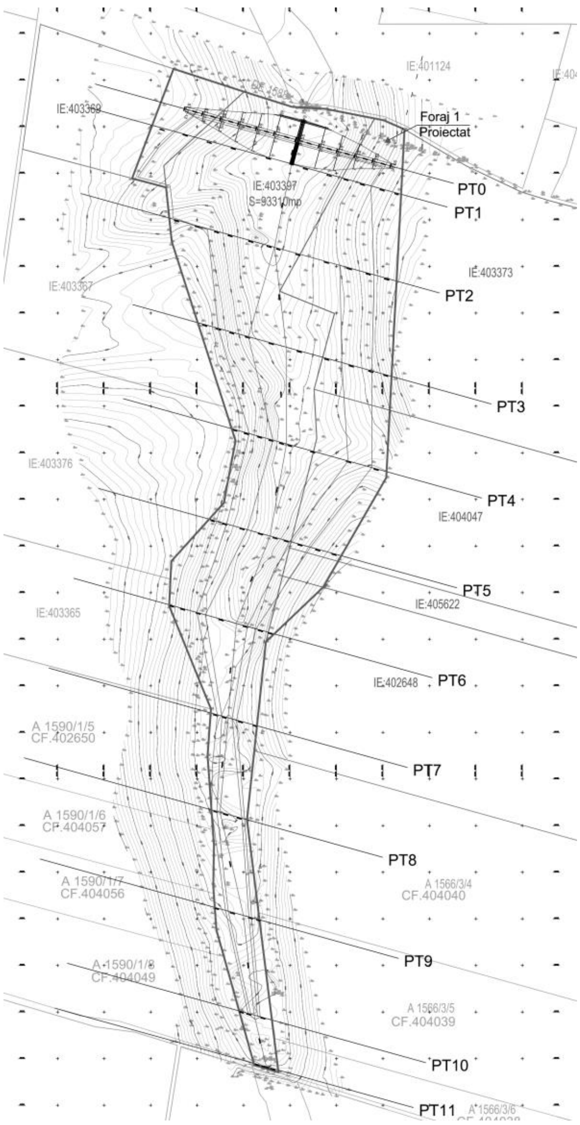

Figure 1. Situation plan with designs of the water storage basin [2]

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The case study presents in the Figure 1 the arrangement of an accumulation basin in Timiș County, Honorici locality, Victor Vlad Delamarina locality on the eastern tributary of the Fața Valley stream, RW 5.1_B4 Surface water body and ROBA18 Groundwater body [2]. The arrangement of the accumulation basin will be made on the surface of approximately 13.90 ha by damming the natural valley and the main works are excavation (modeling) and construction of the dam.

2. MATERIALS AND METHODS

For the analysis of the hydrogeological conditions related to the area, hydrogeological research data were used from a borehole at 80 m depth with a drilling diameter φ 160 mm and it revealed the following information presented in Table 1:

Table 1. Hydrogeological data [3]

Parameter	Unit
Dynamic level d1 (m)	30
Elevation gain s1 (m)	7
Flow Q1 (l / s)	2.22
Spec. Flow q1 (l / s)	0.31
Influenced radius R1 (m)	83
Hydraulic conductivity K1 (m)	1.36
Transmissibility (m^2/day)	43.5

The hydrographic network is generally asymmetrically developed and is tributary to the Timiș River, which receives in the area especially the tributaries on its left side, with temporary courses (Speia Valley, Ştiuca Valley, Oloşag Valley). Hydrological study of maximum flows with a probability of exceeding 2% and 5% revealed the data presented in table no. 2 [5].

Table 2. Hydrological data for the interested sections [3]

Stream	Section	F (km^2)	Maximum flows (m^3/s)	
			2%	5%
Fața	1	0.63	2.01	1.43
Fața	2	0.69	2.10	1.49
Fața	3	2.91	6.19	4.39

In order to establish the design and execution conditions of the foundation, based on the NP074-2014, geotechnical site investigation works on site were performed consisting of two geotechnical drillings with a depth of 6.0 m to identify the stratigraphic sequence (shown in Table 3) and soil sampling and/or groundwater, two 6.0 m deep cone dynamic penetration tests (PDUs) for estimating the physical and mechanical characteristics of the terrain and tests in the geotechnical laboratory [4].

Commonly in traditional irrigation water that is captured in one place is transported, stored and applied in another location, involving a large use of energy and large losses of part of the volume initially collected (through evaporation and/or percolation through deep soil layers) [6].

Table 3. Soil stratification [4]

Soil type	Depth (m)
Vegetal soil	0,00 – 0,40
Clay (dust), brown, thick plastic	0,40 – 0,90
Clay (dusty), brownish-gray, thick plastic, with iron oxides	0,90 – 2,50
Clay (dusty), brown, thick plastic, with small boulder horizons	2,50 – 4,00
Sand (with clay), gray-brown, medium thick	4,00 – 4,40
Clay (with sand), gray, hard, with brown iridescence	4,40 – 6,00

Groundwater was not intercepted in boreholes to a depth of 6.0 m from the natural terrain (CTN).

According to P 100-1/2013, the location is in the area for which ag = 0.15 g, and the corner period TC = 0.7 s and According to NP 112-2014 the frost depth is between 60 and 70 cm.

The topographic field measurements were performed in stereographic 1970 projection system - Black Sea elevation system. The resulting data showed that the length of the earth dam will be approximately 230 m at an elevation of 173.10 m, and with a maximum water gloss elevation of 172.30 m [2].

Calculation of the volume of accumulated water

In order to determine the total volume of water resulting from realization of the dam and the accumulation basin on the natural valley, 11 characteristic cross sections located at established distances were calculated, in the Figure 2 below is presented this type of section.

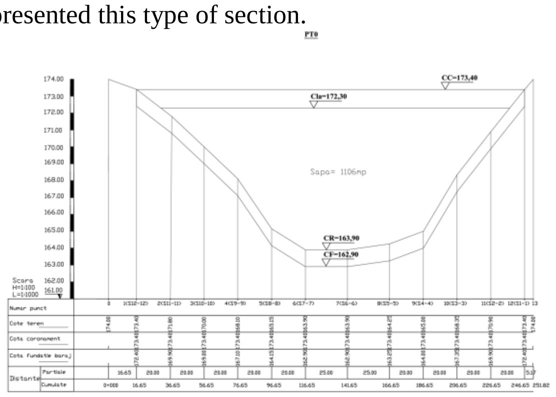

Figure 2. Characteristic cross section through the water storage basin [2]

The volume of water was obtained by reshaping the natural valley of the land, presented in Figure 3. Thus, between sections 2 and 7 the natural slope was reshaped at a slope of 1: 5 and between sections 8 and 10 the natural slope was reshaped at a slope of 1: 3 [2].

Lined reservoirs can be constructed in a wide range of ground conditions but the lining (usually geomembrane) adds significantly to the costs. It is therefore advisable to first look for sites where the reservoir could be lined with clay. Most land owners will be aware of the location of clay sub-soils within their own land but it is well worth considering other nearby locations where a shared, unlined reservoir might offer a more cost effective alternative [7].

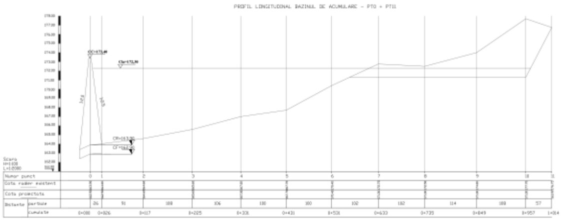

Figure 3. Longitudinal profile through the water storage basin [2]

<u>Calculation of the filling volume for the body of the earth dam</u>

Starting from the characteristic sections 1-12, the body of the dam was divided into 12 distinct parts that were assimilated to prisms with a trapezoidal base presented in the Figure 4. The elevations of the land were extracted from the sections and an average elevation of it was calculated (with the vegetal layer that was calculated at stripping). The difference between the projected elevation of the dam crest and these average elevations of the land resulted in the height of the dam in each section. With this height $h_{mediumdam}$ and together with the slopes of the slopes, m_1 and m_2, the large base B in each section was calculated. By averaging the areas of two adjacent sections and multiplying by the distance between the sections we found the volume of fillings required in each section. Cumulating the volumes in all sections resulted in the total filling volume.

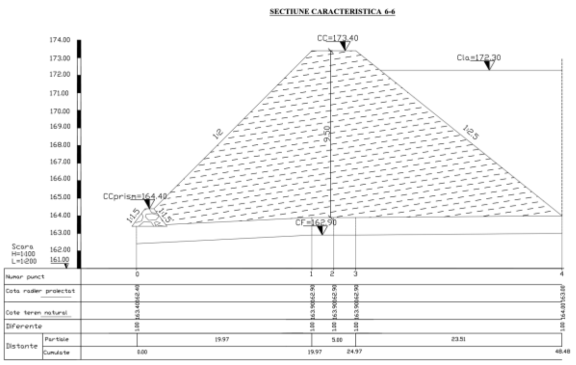

Figure 4. Characteristic cross section through the earth dam [2]

The filling volumes of the basin delimitation dam are determined by applying the following relations:

$$B_i = b + m_1 \cdot h_i + m_2 \cdot h_i = b + h_i \cdot (m_1 + m_2) \quad (1)$$

$$Si = \frac{(B_i + b_i) \cdot h_{i\,mediumdam}}{2} \quad (2)$$

$$Vol_i = Si \cdot Li \quad (3)$$

$$Vol_{TOT} = \sum_{i=1}^{16} Vol_n \quad (4)$$

<u>Calculation of the volume of the vegetal layer for the construction of the dam foundation</u>

It was calculated from the total excavation volume of the dam foundation which is dug to a depth of 1 m from the surface. The average thickness of the vegetal layer according to the geotechnical study is 40 cm resulting that the volume of soil represents 40% of the total excavated volume, the rest of it being used for filling of the dam.

<u>Calculation of the excavation volume in the accumulation basin</u>

In order to have as much water as possible and to use efficiently the land destined for accumulation basin, the valley wire it was reshaped, between sections 2 and 7 a reshaping of the valley with slopes of 1: 5 and between sections 8 and 10 a reshaping of the valley with slopes of 1: 3 [2].

<u>Calculation of the earth dam</u>

In this case, it was chosen a variant of dam with a homogeneous body based on a waterproof layer, without berm and without foundation spur. Dam calculations were performed according to NP 130-2013 "Norm on the establishment of loads and load groups for hydrotechnical retention constructions".
The main calculations performed were for the height of the dam, slope stability, large water discharger, increase level from precipitation, slide verification, wave pressure on hydrotechnical constructions with smooth slopes. The values resulted are shown in the Table 4.

Table 4. Initial data for dam design [2]

No.	Parameters	Value
1	Surface HB, F_b, [Ha]	2.91
2	Slope surface roughness coefficient (concrete) K1	1.25
3	The elevation of the trough at the base of the dam $▼_{talv}$, [mSL]	163.90
4	The elevation of the valley floor at the tail of the dam lake $▼_{talv}$, [mSL]	171.30
5	Upstream load $_{Hapa}$, [m]	8.40
6	Downstream load, H_{apaav}, [m]	0
7	Maximum wind speed v_{max}, [m/s]	27.77
8	Length of gloss in the direction of the wind L_{luc}, [m]	940
9	The angle between the gloss axis and the wind direction α, [º]	30
10	Dam permeability coefficient k [m/zi]	3
11	The width of the dam crest b_{cor}, [m]	5.0
12	Upstream slope indices m_1, [-]	2.5
13	Downstream slope indices m_2, [-]	2
14	Upstream slope consolidation	grass

Auxiliary installations of the accumulation basin - hydrotechnical installations

It was selected a hydrotechnic - type installation provided with water level adjustment valves and which also has the role of bottom emptying described in the Figure 5, designed using the data shown in Table 5 . The access of the water is made through the lower part of the installation, this having established the level of adjustment by modifying the vanes.

A frontal spillway located central in the body of the dam was provided for the evacuation of large levels of water.

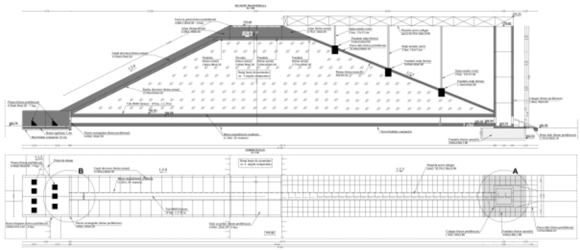

Figure 5. Hydraulic dischargers of the water storage basins [2]

Table 5. Initial data for hydrotechnical installations [2]

No.	Parameters	Value
1	Flood flow, Q_v, [m^3/s] with a probability of exceeding 5%	4.39
2	Depth of water in the basin at the base of the dam, h_p, [m]	8.4
3	Depth of water in the basin at the level of the vertical screed, h_{rad}, [m]	8.4
4	Vertical body height at the spillway ridge, h_c, [m]	8.88
5	Maximum height of the spill blade, h_{dv}, [m]	0.48
6	Dam height, H, [m]	9.50
7	The clear height of the dam, $h_{1,}$ [m]	1.10
8	Horizontal body length, L, [m]	47.75
9	Depth of drainage channel in the overflow basin, $h_{dr,}$ [m]	1.50
10	Horizontal pipe section (1 φ600), *S*, [m^2]	0.282
11	Wet perimeter, P,[m]	1.88
12	Real section of the damping basin, A_1, [m^2]	2.25

3. RESULTS AND DISCUSSIONS

The main characteristics resulting from the calculations of the water storage basin are the following:

- Total area S = 13.90 ha;
- Volume of accumulated water: V ≅ 392534 m^3;
- Natural land elevation CR = 163.90 m in PT 0 and CR = 171.30 m in PT 20;
- Maximum retention level Cla = 172.30 m;
- Characteristics of the basin earth dam:
  - Crest elevation of earth dam CC = 173.40 m;
  - H max = 9.5 m;
  - Dam crest width = 5.00 m;
  - Width at the base of the earth dam is variable between a minimum of 13.59 m in section 11 of the dam and a maximum of 47.75 m in section 6 of the dam;
  - Outside slope: 1: 2;
  - Inner slope: 1: 2.5;
  - Interior facing protection: grassing;
  - Exterior facing protection: grassing;
  - The height of the drainage prism hd = 1.0 m;
  - Slope upstream prism drainage m_3 = 1.5;
  - Slope upstream prism drain m_4 = 1.5;
  - Drainage prism crown width = 1.00 m.

Results for the total volume of water are shown in the Table 6:

Table 6. Maximum storage volume [2]

Section No.	Surface (m^2)	Medium surfaces (m^2)	Partial distance (m)	Partial volume (m^3)
PT0	1106	-	-	-
PT1	1141	1123.5	21	23594
PT2	1050	1095.5	91	99691
PT3	924	987	108	106596
PT4	585	754.5	106	79977
PT5	324	454.5	100	45450
PT6	107	215.5	100	21550
PT7	27	67	102	6834
PT8	34	30.5	102	3111
PT9	26	30	114	3420
PT10	11	18.5	108	1998
PT11	0	5.5	57	314
PT0	1106	-	-	-
TOTAL			1009	392534

Results of the calculation of the volume of embankments for the execution of the foundation of the dam and of the body of the dam are presented in the Table 7:

Table 7. Volume of embankments for the dam construction [2]

Parameter	Unit
Cumulative distance (m)	230
Total filling volume (m^3)	29388
Total excavation volume (m^3)	7126

Results of the calculation of the volume of embankments for the valley correction are presented in the Table 8:

Table 8. Volume of embankments for the valley correction [2]

Section	Distance (m)	Volumes of embankments (cm)	Elevation (m)
PT0	-	-	163,90
PT1	21	0	164,00
PT2	91	16198	164,60
PT3	108	40446	165,60
PT4	106	34980	167,00

PT5	100	27250	167,70
PT6	100	19000	170,40
PT7	102	8007	171,30
PT8	102	4794	171,30
PT9	114	8322	171,30
PT10	108	13662	171,30
PT11	57	4161	176,75
Total	1009	176820	/

The hydrotechnical installations consists of an atypical prefabricated rectangular fireplace with internal dimensions of 1.50 mx 1.50 mx 2.45 m, with a wall thickness of 0.2 m and a screed thickness of 0.2 m, which continue at the top with three prefabricated rectangular rings of internal dimensions 1.50 mx 1.50 m x 2.45 m. The sealing of the three bodies is done with raw rubber band with a section of 30 x 30 mm. The entire rectangular construction and ring assembly sits on a 4.00 m x 4.00 m x 1.00 m deep monolithic concrete foundation. The lower body is provided towards the downstream side with a plug connecting the reinforced concrete pipes with DN = 600 mm that make up the horizontal body of the hydrotechnical installations and upstream the lower body is provided with a circular gap with a diameter of 750 mm for water access to the installation. To stabilize the pipe and reduce the risk of infiltration at joints or near the pipe wall, it is surrounded by a concrete with dimensions of 1.20 m x 1.20 m.

The frontal spillway located central in the body of the dam for the evacuation of large levels of water is rectangular in shape with an opening b = 3.6 m and a free height h = 1.5 m of monolithic reinforced concrete.

Verification calculation of flow and height of the water at the entrance to the spillway is presented in the Table 9:

Table 9. Flow and height of the water at the spillway [2]

Water height (m)	**B (m)**	**Area (m^2)**	**Q (m^3/sec)**
0,1	3,6	0,36	0,352676
0,2	3,6	0,72	1,082035
0,3	3,6	1.08	2,058735
0,4	3,6	1,44	3,223761
0,48	3,6	1,728	4,265698

Optimization is required for the application of some practices that involve a large number of possible combinations and for strategies such as deficit irrigation that aim at balancing water productivity, the economics of production, infrastructural and irrigation system requirements [8].

An analysis of the global costs of the investment reveals that a water accumulation can be arranged with relatively low costs for the positive impact it has in the multiple roles it can play in the process of agricultural, fish farming or environmental protection.

Improving the irrigation performance requires a variety of measures and practices, acting together on the design and operation of the systems. Increasing concerns about water scarcity have promoted the adoption and diffusion of irrigation technologies, such as drip irrigation, which allow farmers to use water in a more efficient way, while saving water resources [9].

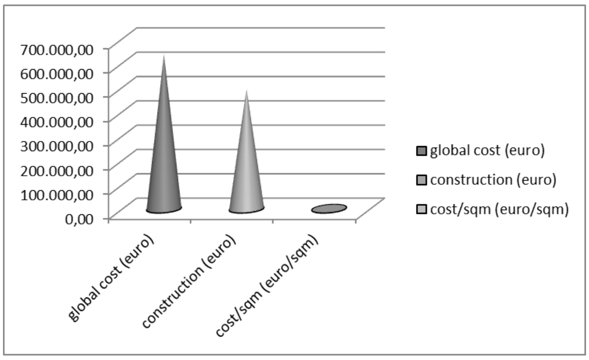

Figure 6. Global cost, construction cost and cost per square meter

Although there are several factors that need to be considered in the execution of such an accumulation basin, ground conditions play the most important role. From the arrangement cost per square meter of approximately 4.58 euro/sqm, 2.84 euro/sqm represents the cost of embankments and 0.42 euro / sqm represents the cost of hydrotechnical installations represented in Figure 6.

Renewable water resources are defined as the water resources that can be withdrawn from aquifers and surface water bodies without causing either groundwater depletion or loss of environmental flows—the stream flows that need to be maintained to preserve aquatic habitats. Farmers can either practice sustainable irrigation without completely meeting the crop water requirements or meet these requirements through unsustainable irrigation practices at the expenses of environmental flows and/or groundwater stocks [10].

Intensified land use is undeniably the main cause of biodiversity loss, there is an increasing expectation that productive agricultural landscapes should be managed to preserve or enhance biodiversity [11].

4. CONCLUSIONS

Local water resources to ensure agricultural production or only to protect them, diversification of rural activities, environmental protection by protecting biodiversity, but also against natural disasters such as drought or floods can be ensured by arranging such reservoirs on the upper reaches of small permanent and non-permanent watercourses.

The natural terrain conditions in the western part of Romania allow the arrangement of such reservoirs in the high plain area or at the interferences between the plain area and the hill, areas where climate change is beginning to feel its effects through the accentuated aridity manifested in recent years.

The costs of arranging such works are relatively low, compared to the lack of water resource or other solutions such as extracting water from the aquifer, and the benefits can be multiple so that the profitability on such an investment is ensured from the start.

The Romanian legislation provides that for obtaining the building permit for such works the need to obtain others specialized documents such as obtaining the water management permit and the environmental agreement, the design and execution works being necessary to be carried out by authorized companies in the field of land improvements and water management, thus ensuring the safety, operation and environmental conditions.

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