ARPHA Proceedings

Proceedings CAUSummit 2025, 0093-0098
doi: 10.3897/ap.9.e0093

10th Anniversary
World Summit: Civil Engineering-Architecture-Urban Planning Congress

Efficiency and Retehnology Works of Irrigation Systems Applied in Local Irrigation Arrangements

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Abstract. The importance of the topic addressed should no longer be questioned, if we only take into account the current state of irrigation systems in Romania, the current decline of national agriculture, a decline aggravated by the droughts of the last decade, the alarm signals raised by local specialists in the field and the need to take the first steps towards functional efficiency, at least of the irrigation systems still usable. Among these are the irrigation systems in the west of the country, the Fântânele – Şag Arad irrigation system, being just one of the systems taken into consideration as an analysed case study.

Keywords: Irrigation systems; functional efficiency; Fântânele – Şag Arad irrigation system; Romania.

Published by CAUSummit and peer-reviewed under the responsibility of "World Summit: Civil Engineering-Architecture-Urban Planning Congress - CAUSummit-2025".

INTRODUCTION

The need for irrigation no longer needs to be argued, but the method and degree of water use resulting from the functional yields of any system are indicators of great importance. The real/current water requirements of crops, the timing of irrigation, water losses from transport and distribution networks are fundamental elements both for the functional efficiency of irrigation systems and for the protection of environmental factors in the spirit of the concept of sustainable development. To achieve these goals, very careful monitoring and appropriate financing are undoubtedly necessary.

In this context, the need to rehabilitate pumping stations, transport and distribution networks and irrigation equipment is correctly addressed, followed obviously by re-technological improvements for economic and financial efficiency.

Based on the system situation plan, the technical condition of each of its components is gradually analyzed. From the base pumping station, to the Fântânele re-pumping station, SPPs (Şag 1, Şag 2, Aradul nou, etc.) to the free-level or pressure transport network (buried pipes). Based on the observations, studies and research carried out, the doctoral student presents the moral wear, degradation and damage of these components or equipment in the composition (pumps, discharge pipe valves, pump-motor pedestals, bank consolidations, floating bodies at the base S.P., etc.). Alongside these, the state of degradation or pollution of the soils within the system is also analyzed.

The situation of the irrigation water user organizations within the Fântânele-Şag Arad irrigation system, reported on the irrigated areas and crop types, recommends the need to re-evaluate the irrigation norms in accordance with the requirements of efficient operation and the protection of environmental factors (soil and subsoil with groundwater) [1].

THE IMPACT OF IRRIGATION ON THE ENVIRONMENT AND ECOLOGICAL BALANCE

The forms and degree of soil degradation in the area caused by the improper application of irrigation norms (erosion, anthropogenic salinization or swamping) are evaluated based on pedological studies and analyses of the evolution of groundwater levels carried out at the boreholes in the system area:

- Arad Foraj 6 N-V, Fântânele commune;
- Arad Foraj 1 N-V, Şag commune;
- Arad Foraj 5 downstream 3 Km S.P. Plutitoare;
- Arad Foraj 7 S-V, Fântânele commune;
- Arad Foraj 1 south Arad Municipality (500 m Aradul Nou Dispatch).

Based on these analyses/studies, conclusions were established on the evolution of groundwater levels in the last decade, presented suggestively in the figure 1. In addition, groundwater samples were analyzed under the aspect of the average concentrations of nitrites, ammonium, phosphates and manganese, but more importantly the fact that pesticides and heavy metals are not found here, and the degree of mineralization is insignificant.

TABLE 1. Evolution of the water table (cm) - ARAD FORAJ 6 N-V of Fântânele commune during 1970–2008.

ARAD FORAJ 6 N-V comunei Fântânele															
Anul	Ian	Feb	Mar	Apr	Mai	Iun	Iul	Aug	Spt	Oct	Noi	Dec	Med	Max	Min
1970	879	751	690	671	696	647	719	798	848	878	894	911	782	607	916
1990	1010	993	993	997	998	995	1000	1005	1019	1041	1018	1041	1009	954	1074
1992	1024	1015	1009	1006	1001	995	997	1003	1009	1016	1017	1024	1010	992	1028
1993	1030	1035	1043	1045	1044	1041	1043	1053	1060	1067	1072	1074	1051	1028	175
1994	1074	1074	1073	1073	1070	1065	1062	1063	1063	1068	1078	1082	1070	1060	1083
1995	1082	1078	1079	1082	1077	1065	1070	1073	1079	1082	1083	1075	1077	1062	1084
1997	936	923	919	897	892	902	910	925	932	940	944	949	922	884	952
1998	957	963	964	903	837	820	813	818	820	824	824	826	864	810	966
1999	827	806	786	822	856	867	877	873	816	871	892	892	849	778	896
2000	885	876	861	838	849	873	887	902	932	942	942	956	895	824	961
2001	965	971	972	983	988	987	982	981	982	982	985	990	981	961	993
2002	998	1002	1001	1004	1008	1013	1019	1016	1018	1018	1018	1019	1011	994	1020
2003	1022	1020	1017	1013	1003	998	1012	1026	1034	1044	1046	1047	1024	997	1050
2004	1051	1047	1020	1002	1000	1006	1000	1005	1009	1012	1017	1016	1015	995	1053
2005	1014	1012	991	862	836	872	875	883	896	911	921	917	916	783	1015
2006	910	894	863	826	804	793	807	829	865	887	910	924	859	773	912
2007	931	939	941	946	952	966	971	973	978	982	977	973	960	922	989
2008	986	990	980	975	978	979	984	990	995	998	994	997	987	970	999

Hence the encouraging conclusion that the Fântânele-Şag Arad irrigation system and the agricultural activity in the area do not significantly pollute the soils and groundwater in the area, and the measure of restoring the rehabilitation works by waterproofing will constitute an additional protection against groundwater pollution in addition to the great advantage of increasing the efficiency of the system's channel network [2].

Regarding the impact of irrigation on soils in the territory of the Fântânele-Şag Arad irrigation system, the soil-plant relationship is studied in natural conditions and under the influence of the impact of irrigation. In this context, it is established, based on information and studies in the specialized literature, that the controlled supply of soil by applying irrigation always has beneficial effects on plants, soil and the atmosphere in the vicinity, therefore on the environmental factors in the area. It is also noted the importance, in irrigated conditions, of the structure and texture of the soil in combination with the types of crops that are potentially eligible. This, obviously, is to maintain an optimal ratio between porosity, usable water and mineral substances for the benefit of plants to obtain safe and stable harvests regardless of the seasonal rainfall regime. In addition, it emphasizes the importance of choosing the watering method depending on the physical properties of the soil in order to protect and preserve its qualities. through a study of the doctoral system, the water requirement is consequently recalculated according to the weather and climate changes in recent years of the crops practiced in the area. The study is based on a calculation method promoted by Manole E., Grumeza N., etc. to cover the deficit of natural precipitation (drought), deficit recorded (in descending order) in the months of July, August, June, September, i.e. the months in which the water requirements are maximum.

WATER LOSSES IN THE FÂNTÂNELE-ŞAG ARAD IRRIGATION SYSTEM (THROUGH INFILTRATION, EVAPORATION AND EXPLOITATION)

The causes of the low system yields caused by water losses in the transport and distribution network from the source (Mureş River) to the irrigated territory. These assessments will also clearly result in the re-engineering measures proposed.

The calculation methods analyzed aim to establish the possibilities of saving water quantities (reducing water losses at the source to the irrigated field), pumping energy (from SPB to SPP) and the method of calculating the minimum or optimal degree of water use in an irrigation system. This last aspect is based on the studies of some long-established specialists in Romania [3].

In order to establish the minimum degree of profitable use of the Fântânele-Şag Arad irrigation system, the need for system rehabilitation and the priority objectives necessary, initially, for rehabilitation and subsequently for the functional efficiency of the system are determined.

Increasing the interest of farmers affiliated to the Fântânele-Şag Arad system in irrigation, the degree of use and the advantages brought by re-technologicalization for the economic efficiency of both the agricultural production of the farms and the irrigation system [4].

In the case study; analyzing the influence of the degree of use on the system's operating efficiency, it is found that in order to obtain the maximum performance of the system (yields η_s >45%) in its current state, it must be used for a period of 3-4 months with the net volume Vor ≥ 2250 m^3/ha x 7154 ha ≅ 16,1 million m^3 of water distributed in the active soil layer of all crops that occupy the entire surface of the system. At a system efficiency η_s >47% it results that a gross volume of at least 38,3 million m^3 must be introduced into the system, returning to a gross irrigation rate of 5353 m^3/ha and year; in order to ensure a yield η_s >40% at a duration T=3-4 months it is necessary to have a water requirement from the beneficiaries at a utilization rate G=0.8-1.1. This means an irrigated (contracted) area of 5700 – 7200 ha irrigated on which the irrigation rate $M_o^{50\%}$=2250 m^3/ha and year is distributed; at utilization rates G<0.7 (irrigated area < 5000 ha) the system efficiency decreases from 39% to 7%, meaning that water losses are 61%-93% values with dramatic effects on environmental factors and considerable economic losses of the system's activity. Taking into account the current state of the national economy and the world experience, it can currently be accepted that there is a minimum degree of technical use of this system Gt ≥ 0.8 to ensure a water use efficiency η_s = 40%. To eliminate these negative effects, only rehabilitation-modernization works are performed to reduce water losses from the intake to the soil reservoir of agricultural crops.

From the case study, regarding water savings, this varies depending on the water loss reduction options (for 0.5≤G≤1.6 and 1 month ≤T≤5 months): the minimum water savings result from rehabilitation measures solutions in interior design, between 12% and 23% of the current volumes taken at the system intake (Vpa); the maximum water savings are obtained when all rehabilitation measures solutions are applied, being 40%-57% of the current volume taken at the system intake (Vpa); rehabilitation measures in the hydrotechnical network ensure a saving of 16%-45% of the current volume (Vpa), resulting in a water saving with which 3300 ha can be irrigated.

Regarding the economy of electricity in the system, as an effect of the rehabilitation modernization works, it results that by applying all the rehabilitation modernization solutions to obtain the maximum water economy, it determines an energy saving of 31%-88% with an average of 52,6% by reducing the volumes of water circulated by the station that are lost on the area served by it; the application of the rehabilitation modernization solutions aimed at reducing the specific energy consumption of the stations, determines an energy saving of pumping of 24%-86% with an average of 47.5%; the maximum saving of pumping energy is 33%-88% with an average of 54% in the case of applying all the rehabilitation modernization solutions aimed at reducing consumption of water and energy, the average specific power consumed in the system being reduced from 0.8 kW/ha to currently 0.45 kW/ha after the execution of the rehabilitation - modernization works.

The strategy for approaching the rehabilitation - modernization works in this system can be established in this way, if financial resources are limited, the variant with the water usage in the system has priority because the water use works in the system can ensure both water (35%) and energy (52.6%) savings; if financial resources are greater, the variant with with the water usage and electricity economy in the system is the most efficient, as it ensures water savings (35%), energy savings (54%) and protection of environmental factors.

The minimum degree of profitable operation (Gpo) of the Fântânele-Şag Arad system, thus at the current stage, the average value of the minimum degree (Gpo) of this system is 82%; and which decreases as the duration of the system's operation increases: from 92% for T≅1 month to 82%, and for T≅4 months it results that the profitability of crops decreases with the increase in the degree of profitable operation (Gpo) as follows: corn Gp= 38 – 49%; wheat

+ soybean + sunflower Gp > 50%. Thus, the efficient operation of the system can be achieved by annual optimization of the structure of the crop plan and increasing the real degree of use of the system that did not function due to the lack of requests for water delivery for irrigation, the non-coverage by the beneficiaries from their own income of the operating, maintenance and repair expenses. It should be noted that the minimum degree of profitable operation of the Fântânele-Şag Arad irrigation system (Gpo) was imposed by the need to establish the minimum value of the water requirement of the beneficiaries in the system, from which the effect of applying irrigation generates profit by increasing agricultural production. Applying the degree establishment model (Gpo), after carrying out the expected rehabilitation-modernization works, I note as important and correct the following conclusions established by the doctoral student:

- for the same duration of continuous operation, the classification of irrigated agricultural crops in the profitability groups of the current stage is maintained;

- the degree of efficient use (Gpm) of the system depends on the possible rehabilitation-modernization options of this system, namely: the effect of the total works to reduce water losses, expressed by increasing the efficiency of water use in interior design (ηai) and the efficiency of water transport on the hydrotechnical network (ηt), determines a degree of efficient use of the system between 73% and 44% depending on the operating duration T= 1...4 months/year, with an average of 53%; the works to increase exclusively the operating efficiency of the pumping stations determine a degree of efficient use between 86% and 24% depending on the operating duration T= 1...4 months/year, with an average value of 48%; The total effect of the rehabilitation-modernization works aimed at increasing both the efficiency of water use and electricity in water pumping determines a degree of efficient use between 77% and 32% depending on the operating duration T=1...4 months/year, with an average value of 47%. Thus, the rehabilitation-modernization works have very favorable effects, lowering the minimum degree of profitable operation from 82% to 47%, in the case of the most efficient measures proposed.

The rehabilitation of the Fântânele pumping station in the Fântânele-Şag Arad irrigation system consists of replacing the floating pumping station with a fixed pumping station, equipped with submersible electric pumps mounted in steel pipes with Dn 1000 mm located on the slope of the left bank of the Mureş River in a 300 inclined plane. The basic equipment of the station consists of 6 submersible electric pumps that provide a flow rate of 950-1000 l/s each at a height of approximately 26 mCA. Rehabilitation of the Fântânele pumping station in the Fântânele-Şag Arad irrigation system through repair works: at the suction and discharge basin; for the basic equipment, for two pumps it is necessary to replace the complete rotating assembly, the housings of the two pumps on which the intervention is being carried out will be rehabilitated by sealing the corroded areas; the basic hydromechanical equipment requires rehabilitation; an electric motor needs to be replaced N=630 KW, U=6000 V, n=750 rpm, f=50 Hz; relays and equipment require rehabilitation and in some cases replacement; the rehabilitation of the low-voltage installation consists of replacing the old equipment with new modern equipment.

The rehabilitation measures aim to increase the network performance, reduce pressure losses and energy consumption at SPPs. An important problem in the current plots is the lack of hydraulic independence of each beneficiary, requiring that, through appropriate modifications to the distribution networks, the supply be achieved, mainly of agricultural holdings with large areas, through a single supply point that is provided with a flow meter.

For the case study of the Fântânele-Şag Arad irrigation system, a hydraulic calculation regarding the closure of the Aductţiune I irrigation Channel with a metallic structure (tubes) made of corrugated steel sheet that can support a load, over a length of 1677 m. Analytical calculations were performed for various proposed pipeline variants and for the existing paved canal: determination of the transport capacity of the Aducţiune I Channel and determination of the transport capacity of the studied pipelines.

Starting from the theoretical foundations, analytical calculations were performed for:

-determining the transport capacity of the Adduct I canal in the current situation

-determining the transport capacity of the studied pipes by creating the diagrams Q=Q(h); A=A(λ); B=B(λ) to be used for piping:

a) Corrugated steel sheet metal structure pipe

b) High-density polyethylene pipes (HDPE).

The analysis of the diagrams presented in Figure 1 and 2 led to some possible construction variants with the mention of some advantages and disadvantages.

From the topographic studies it results that the slope of the land i = 0.000205882353 is a very small slope that affects the transport capacity of the pipes. The graphs presented in the paper as key curves (calculation nomograms) are made for a slope of 0.01 resulting in much higher transport capacities than in the case study carried out.

In the case of the conclusions at this hydraulic stage, it is shown that the choice of a variant can only be made after using an economic calculation to minimize the total cost.

The high roughness of corrugated steel pipes leads to low water transport capacities in the case of long pipes, making them well suited for bridges or underpasses with short lengths.

The polyethylene pipe (PIED) having much lower roughness than the existing channel, can be a piping solution, along with other types of pipes with roughness similar to polyethylene, e.g. PREMO, PAFSIN or ductile iron pipes, which however have much higher purchase prices.

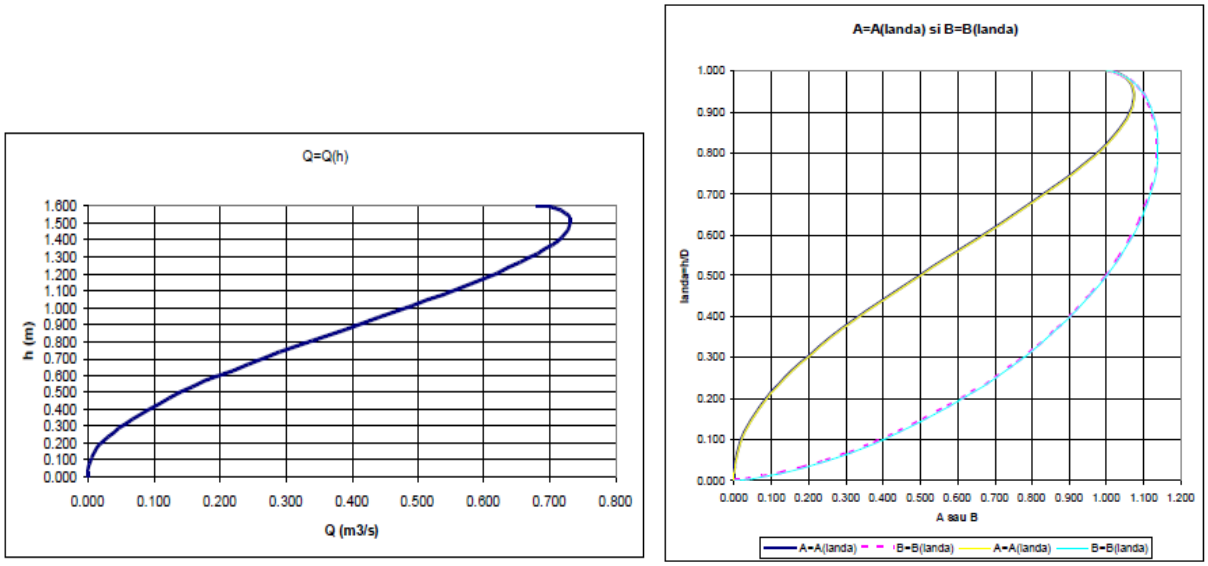

FIGURE 1. Variation of flow rate depending on height for determining the transport capacity of pipes with a metallic structure made of corrugated steel sheet.

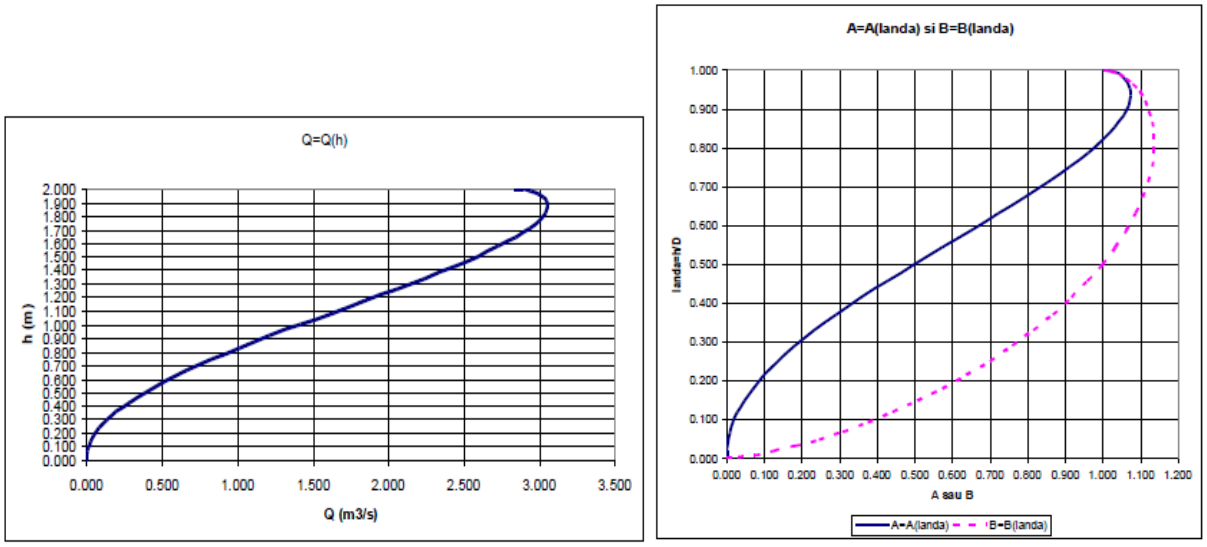

FIGURE 2. Variation of flow rate depending on height for determining the transport capacity of pipes with a metallic structure made of HDPE.

CONCLUSIONS

The conclusions regarding the rehabilitation-modernization works are:

1. The requirement to update the net irrigation water requirement using a series of climatic data consisting of precipitation and temperature values as well as establishing the specific net flows for the analyzed irrigation system;
2. Establishing the technical parameters of the operation of the hydrotechnical system for irrigation at the current stage and after the implementation of the rehabilitation and modernization works;
3. Estimating water losses on the hydrotechnical network, in the interior landscaping network and when applying irrigation in the field, to determine the efficiency of irrigation water use;
4. Evaluating the effects of the rehabilitation-modernization works on water and energy savings for pumping water in the studied irrigation system;
5. Determining the minimum degree of profitable use, respectively the minimum water requirement that economically justifies the commissioning of the system, both under current conditions and after the progressive introduction of rehabilitation - modernization solutions.

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