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CONSIDERATIONS CONCERNING THE HYDRAULIC YIELD OF IRRIGATION PLOTS UNDER PRESSURE

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ABSTRACT: *The paper analyzes the current state of the irrigation plots with the sprinkling watering regarding the hydraulic efficiency in the transport and distribution of water. Sprinkler irrigation plots have been in operation for about 35-40 years. They present phenomena of wear and aging of the structural components (pipes, fireplaces with hydraulic installations, hydrants, pumping stations, supply channels). Research conducted on a series of irrigation plots in the eastern and southern part of Romania, with various periods of exploitation, has highlighted the complexity of the degradation process of the structural elements. Degradation of the structural components of the irrigation plot causes the formation of water losses, which reduces the hydraulic efficiency. Research has shown the excessive degradation of the supply channels of the pumping stations. The pipes are worn, with cracks and cracks through which there is continuous water loss. Hydraulic installations in fireplaces and pumping stations are worn out and have high water losses. The use of European funds requires the presentation of measures regarding the reduction of water losses.*

Keywords: *channels; damage; hydrants; pipes; water leaks.*

1. Introduction

During the period 1960 - 1989 Romania developed a series of irrigation and drainage systems at a technical level corresponding to the technologies and materials of execution existing at national and international level. The irrigation systems developed during that period supplemented the water reserve for the development of agricultural and horticultural crops under the specific climatic conditions of Romania.

Prior to 1989, different methods of watering were used: sprinkling watering, furrowing watering, bivalent watering, dripping watering, etc. Irrigation systems were customized on relief forms as a way of organizing.

An irrigation system was based on an irrigation plot in which one or two watering methods are applied [Blidaru et al., 1981, Cismaru, 2004].

Beginning in 1990, the irrigated area in Romania was reduced by the abolition of irrigation systems. At present, only a small number of irrigation systems made before 1989 are in operation. The infrastructure of the irrigation systems (water socket, basic pumping and repacking stations, discharge pipes and large transport channels, etc.) is administered by the Romanian state. The irrigation plots are currently in private exploitation system. The research carried out shows that the irrigation systems in operation have degradation processes of the construction structure and of the pumping and water transport installations [Luca, et al., 2016]. The most commonly used watering method is spray watering.

The objective of the work is to analyze the hydraulic efficiency of the irrigation plots by identifying the type of water loss for an old irrigation plot with the sprinkler irrigation currently in operation.

2. The research material and method

The material used in the research is represented by a series of irrigation plots located in Iasi and Vaslui counties. The plots belong to irrigation systems fed from the Prut River, and their location is in the meadow area and terrace area of the river (Fig. 1). The capture of water from the Prut River is done with basic pumping stations (SPB). The water is discharged through pipelines in the meadow area, where the pumping and pressure stations (SPP) of the irrigation plots are taken over.

2015, Luca, 2016]. The documentation analyzed the state of the structural components based on the known and accessible data. The data provided by the technical expertise allowed the analysis of the current state of the construction structure of the irrigation plots in operation after a period of about 40-50 years (Proiect 4824-R, 1987). The networks of pipes and channels related to the irrigation plots have been analyzed based on the data collected from the technical expertise elaborated in the last period of time. Also, a series of plots were conducted field research on the network of canals and pipes.

The research method is the one used to

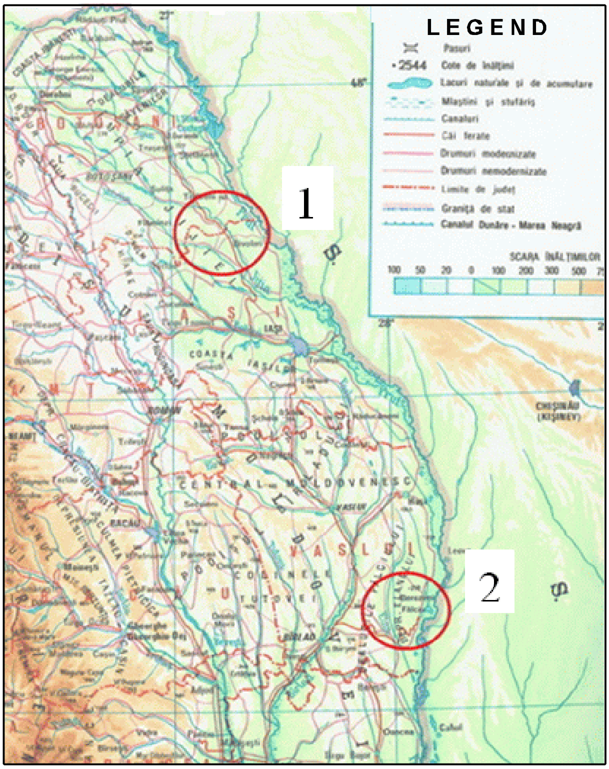

Fig. 1. Research areas
1 - Sud Solone irrigation system; 2 - Albiţa Fălciu Complex Irrigation and Drainage Management.

For each objective studied, a documentary study was carried out. A series of irrigation plots have been technically expertises for the analysis of the structural and functional state [Luca, 2012, Luca, achieve the technical expertise for irrigation systems and irrigation plots with pumping stations. Field research has taken material samples, tested resistance and taken photographic surveys and video images. For some irrigation plots, the updated topographic plans of the irrigation systems in use were used; In parallel, the initial topographic plans were used. It is worth mentioning that much of the technical documentation of the irrigation plots analyzed is no longer available during the current period. Data processing followed the methodology used in the technical and scientific analyzes elaborated for irrigation systems with networks of channels and pipes.

The primary data collected were processed through specialized programs in the field of irrigation, hydraulics, resistance, etc.

3. Results and discussions

The irrigation systems built before 1990 were structured on the following components: water capture, pumping stations that raised water to different levels, water transport and distribution channels, pressure stations in irrigation plots, canal networks and pipes for water distribution, protection and control installations, watering equipment, etc. (Blidaru et al., 1981, Cismaru, 2004). The canal and pipeline network was executed between 1975 and 1982, so that the operating time is exceeded. The pipe and channel network has high water losses and has a low hydraulic yield in operation.

Irrigation plots with sprinkler and mixed watering (sprinkler + furrows) were made in the years 1970-1980 based on well-developed type projects (Project no. 4824-R 1987). The irrigation plots in Romania were designed for watering an area of 500 - 2500 ha. The plot pipeline network is powered by a pressure pumping and pumping station (SPP), or a number of monofilament pumping stations (SPPM). The pumping station is supplied from a channel or pipe belonging to the irrigation system. The irrigation plot is integrated into the infrastructure of the irrigation system, or can be made individually for small areas.

Field research was carried out in Iasi and Vaslui counties. In the field the current state of some irrigation plots was analyzed with sprinkling. The plots belong to irrigation systems fed from the Prut River. The irrigation plots are located in the meadow area (research area 2), on the first and second river terraces (research area 1) (Fig. 1).

The irrigation plots are fed through channels or pipes, being equipped with pressure pumping stations (SPP), or with monofilament pumping stations (SPPM). The plots have a network of pipes made about 40-50 years ago, which are currently in a state of advanced degradation (Luca, 2012, Luca, 2015).

The yield of the irrigation system (h) represents the degree of water use, being determined by the relation (Stăncescu et al., 1984):

$$\eta = Qu / Qbr \qquad (1)$$

where: Qu is the useful flow used by plants (m^3/s);
Qbr - the captured gross flow (m^3/s).

The hydraulic yield of the irrigation network formed by pipes or channels is determined by the relation (Pleşa and Burchiu, 1986):

$$\eta_r = \frac{Q_i - Q_p}{Q_i}\ 100\ \% \qquad (2)$$

where: Qi is the network flow;
Qp - the lost network flow.

Using the relationship requires measuring the flow of water introduced into the network and the lost flows.

The total / global yield of an irrigation system (hg), respectively irrigation plot, results by multiplying the efficiency of the network (hr) with the yield of watering in the field (hu), according to the relation [Pleşa and Burchiu, 1986]

$$\eta g = \eta r \cdot \eta u\ (\%) \qquad (3)$$

The flow rate of the irrigation plot served by a pumping station (SPP) is calculated with the relation [Blidaru et al., 1981]:

$$Q_{SPP} = Sq_{u,pond}\frac{1}{\eta_c}\frac{1}{\eta_r}\frac{24}{t}\ \text{(l/s)} \qquad (4)$$

where: Q_{SPP} is the sizing flow of the pressure pumping station (l/s);

S - irrigated area (ha);

$q_{u,\ pond}$ - the weighted hydromodule (l/s ha);

ηc - yield of watering in the field;

ηr - the yield of the network downstream of the pumping station;

t - number of actual hours of operation of the watering equipment (hours/day).

From the analysis of the relationship, we can see the presence of the pipeline / channel network yields and the field watering efficiency.

The hydraulic yield of the components of the irrigation plot intervenes in the operation of the following structural components: feed channels, pumping stations, pipeline network, watering equipment. The yield is variable in time, by decrease, being influenced by the wear of the components and the value of the water losses on each structural component. The value of hydraulic efficiency is particularly influenced by the volume of water losses.

The yield of the pipeline network for the case of current operation can be determined with the relation [Stăncescu et al., 1985]:

$$\eta_c = \frac{\alpha\ Q_{inst} T_1 - \sum p_i\ T}{\alpha\ Q_{inst}\ T_1} \cdot 100\,\% \qquad (5)$$

in which: *α* is the ratio between the average daily flow achieved and the flow installed at the SPP;

Q_{inst} - SPP installed flow;

p_i - the sum of the losses during the irrigation period, established as a percentage of the total volume of pumped water;

T_1 - number of days of operation of the SPP;

T - the duration of the irrigation campaign in which the network was filled with water.

The yield of the pipeline network is not currently evaluated by the irrigation platoon services.

The appearance and evolution of water losses in irrigation systems are generated by a number of natural and anthropogenic factors. The factors are generated throughout the life of the structural components of the system and come from the following characteristics [Chirica, 2019; Luca, 2016, Luca and Chirica, 2017]:

- the quality of the design studies (topographic, geotechnical, hydrogeological, seismic, etc.);
- the professional quality of the technical system design team reflected in the design stages: analysis of geo-physical conditions in the site, system design, definition of flows and pressures in the network of pipes and channels, choice of execution materials and technologies, etc.;
- the professional quality of the execution team, evidenced by the technologies used in the realization of the system (conditions of installation to the pipes, the quality of the joints, the technology of waterproofing of the channels, etc.);
- the professional quality of the operating team, through the operating mode of the system, correlating the intervention measures with the nature of the phenomena encountered in the site, etc;
- user management through the characteristics of the process of exploitation, rehabilitation and modernization of the components of the irrigation system.

Pipeline networkers from the irrigation systems are made with materials conditioned by the characteristics of the site (external loads, the aggressiveness of the land), the parameters of the transported water (with alluviums, clean) and the hydraulic parameters (flow rates, speeds, pressures). The type of pipe connection is a major factor in the formation and evolution of water losses. The components of the joints, which structure and realize the tightness of the pipe, support in time mechanical actions, phenomena of degradation and aging. These actions cause dislocations and the expulsion of the jointing and waterproofing materials.

The water losses allowed by the operating rules of the sprinkler irrigation plots are limited to the following values [Stăncescu et al., 1984]:

- A - the characteristics of the irrigation plot:
  - branch pipe network (CP, CS, CT - antennas):
  - pressure station type SPP;
  - watering equipment for sprinkling.
- B - allowed values of water losses:
  - in the pipeline network 5%;
  - in the supply channel lined with waterproof clothing 5%;
  - 10% watering in the field.

The studies and research carried out within the irrigation plots SPP 16 Berezeni, SPP7 Doniceasa - Fălciu and SPP O etoaia, components of the "Albiţa - Fălciu Complex Management" highlighted significant water losses in the network of canals and pipes (Luca, 2015, Luca 2016). The irrigation plots in the meadow area are fed through one or two distribution channels. The structural state of the channels has a high degree of degradation, an aspect highlighted by the field research carried out in the period 2011 - 2019. The channels are executed in the well and are protected with a layer of reinforced concrete slabs, where the joints are filled with cement mortar. This process reduces water leakage through infiltration into the foundation land. The degree of degradation of the concrete slab lining is variable along the channel length, from 30 - 40% on central sections, to 80 - 100% in the area of the pumping stations (Fig. 2).

Studies and researches carried out within the irrigation plot SPP1b Sud - Soloneţ, Iaşi

Fig. 2 - State of the supply channel of SPP Oţetoaia, year 2019, Vaslui county
a - degraded reinforced concrete slabs and mortar joints; **b** - reinforced concrete slabs totally degraded and displaced from the slope in the SPP area (Photo Luca, 2019)

Water losses on the watering equipment (qeu, m3/s) are produced by the emission of water at the joints (flanges, sockets), valves, sprinkler (sprinkler lock) when the system is emptied. The spray watering efficiency is about 90% if water losses are kept within permissible limits. The main loss of water is when draining the watering equipment.

county, a degradation of the surface protected by concrete slabs. The slabs are degraded by cracking and cracking, by expelling the mortar from joints, by breaking them and sliding on the slope (Fig. 3). Research has shown the production of significant water losses in the network of canals and pipes [Luca, 2012].

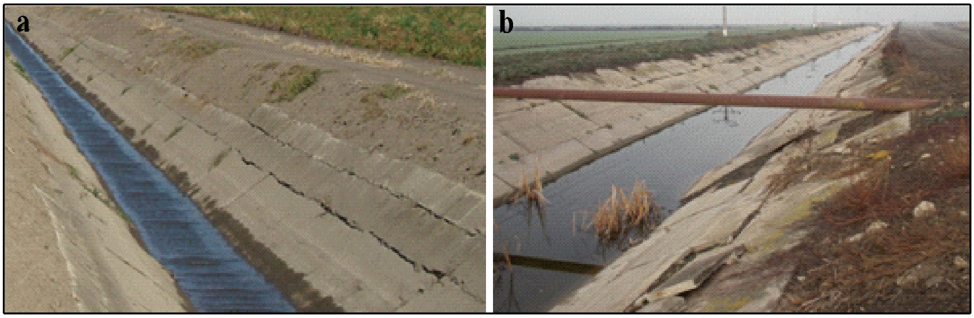

Fig. 3. The state of degradation of the supply channel of SPP1b Sud Soloneţ, Iaşi county
a - cracked slabs and mortar removed; **b** - reinforced concrete slabs totally degraded and displaced from the slope (Luca, 2012)

The main pipes in the irrigation plots equipped with SPP are made of reinforced concrete tubes (PREMO type) and steel pipes. The research carried out in the field (SPP1b Sud - Soloneţ, SPP16 Berezeni, SPP7 Doniceasa Fălciu, SPP Oţetoaia etc) showed the degradation by chemical corrosion of the main pipes made of steel. The replaced pipe sections showed the total non-functional state of the main pipes with a diameter of 500 - 600 mm made of steel sheet (Fig. 4).

Secondary pipes are generally made of blast pipes. Pipes of this type are greatly degraded by accidental pressure variation in the system (hydraulic shock). Most faults occur in the area of the jacks and bypasses. The aging of the rubber gasket determines the appearance of local and diffuse water losses, an aspect highlighted in the plot SPP16 Berezeni (Fig. 5) [Luca, 2015].

A case study was prepared for the SPP1b Irrigation Plot South Solonet System (Fig. 6), regarding the hydraulic efficiency of the pipeline network. The existing pipeline network consisted of the following components [Luca et al., 2012]:

Fig. 4. Condition of the main pipe (Dn 600 steel) at SPP Oţetoaia, year 2019, Vaslui county
a - section of pipe replaced; b - detail regarding the structural degradation of the steel pipe (Photo Luca, 2019)

Exceeding the service life of the pipes and degradation of the inner and outer protection layer favoured the formation of holes and cracks in the pipe walls. This situation led to large water losses, which led to the reduction of the hydraulic efficiency of the main pipe.

– main steel pipe, Dn 800 mm, Pn 10; Secondary pipes from asbestos cement Dn 400 - 200 mm; tertiary pipes made of asbestos cement and PVC with Dn 200-125 mm;

Fig. 5. State of distribution pipes (abasement) from plot SPP16 Berezeni, Vaslui county, year 2015
a - changed degraded pipes; **b** - damage by breaking the plug (photo Luca M.)

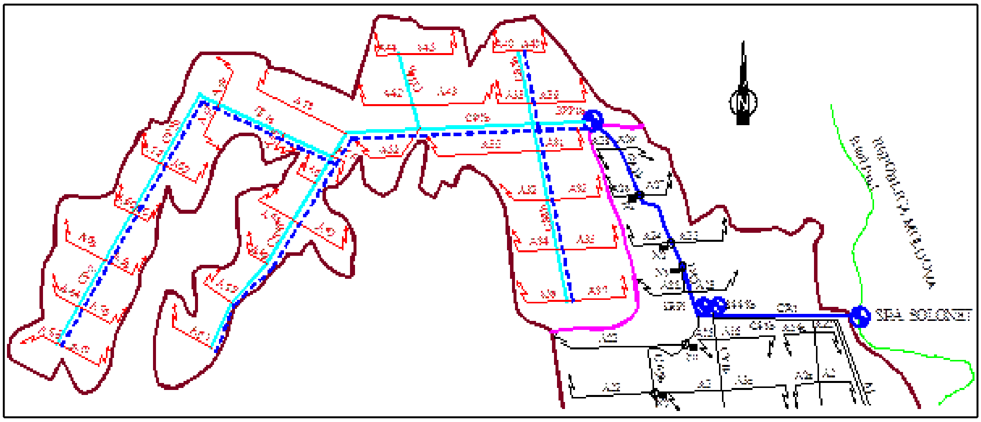

Fig. 6. Initial scheme for the irrigation plot SPP1b Sud Soloneţ
continuous line - high pressure pipelines; dashed line - medium pressure pipelines (Luca, 2012)

- bypass chambers with hydraulic steel pipe and cast iron valves; homes for emptying, ventilation; massive anchors;
- underground and overpasses of roads and channels made of steel pipe;
- irrigation hydrants of different diameters depending on the watering equipment served.

The structural state of the pipeline network was during the degraded research period, a situation that causes numerous water losses through the repeated failures.

The condition of the hydraulic installations in the fireplaces, as well as the hydrants was influenced by the degree of wear and the absence of maintenance and rehabilitation works (Fig. 7).

The hydraulic efficiency of the pipeline network was greatly diminished over a series of sections, where the values were about 60 - 70%.

Within the SPP1b South-Soloneţ irrigation plot, research was carried out over a period of three years, which showed that the pressure pipe network was degraded by 60-70% (Luca, 2012). The pipe network is of branched type (Fig. 8) and has the following structure:

- the main pipe CP2b with the length 8955 m is made of PREMO tubes (Dn 800, Dn 600 and Dn 400) and supplied by SPP1b; the pipe is worn and degraded by 60%;
- four secondary pipes (CS2, CS3, CS4 and CS5) with a total length of 8565 m made

Fig. 7. The state of degradation of the hydraulic installations from irrigation plots
a - the state of the ventilation installations on the main pipe in the plot SPP1b, South-Soloneţ Iasi county, year 2012; **b** - status of hydrants in plot SPP7 Berezeni, Vaslui county, year 2015 (photo Luca M.)

from PREMO tubes Dn 400, AZBO Dn (350-200); the secondary pipes are fed from CP2b and have a variable degree of degradation (50-80%);

– 38 tertiary irrigation pipes (A30b… A67b) with a total length of 23,128 m made of AZBO, PVC, steel pipes (in high pressure areas); tertiary pipes have diameters of 250-100 mm and are supplied from CS; the tertiary pipes have a variable degree of degradation (50-75%);

– hydrants for supplying manual and mechanized moving watering installations; hydrants have diameters Dn 100 and 125 mm; the degree of wear of the hydrants is accentuated until the total degradation, which causes water losses at the closing device;

– constructions on the network: bypass shelters, ventilation sheds (Fig. 7a), massive drainage sheds, anchorages, sub-crossings, etc .; the fireplaces with hydraulic installations were made of reinforced concrete and concrete pipes, which favoured their degradation over time; the hydraulic system has the period of operation exceeded, and its components are degraded in a proportion of 70-80%.

The pipeline network of irrigation plots SPP1b was put into operation in 1981.

The research revealed significant water losses starting from the pumping station

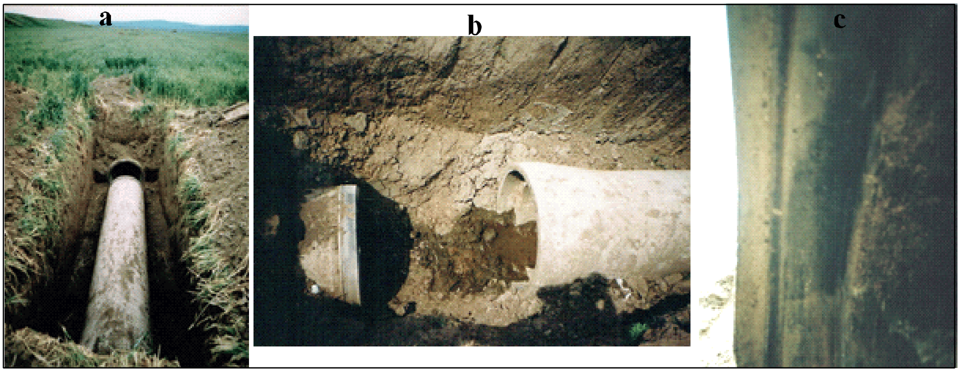

Fig. 8. Analysis of the degradation state of the PREMO tubes mounted on pressure pipes
a - tube Dn 800 unscrewed; b - detail regarding the state of the tube joint; c - detail regarding the trace related to the rubber gasket pressed unevenly in the tube socket (photo Luca M., 2012)

(SPP1b) on the main pipe (CP2b), favoured by the high and continuous pressure on the secondary pipes. Pipes made from PREMO tubes show significant water leakage at the socket due to aging of the rubber gasket. The same phenomenon also occurs in pipes made from azure cement tubes, where the socket is degraded by pressure variations. PVC pipes are degraded by the appearance of cracks and cracks in the wall of the tube caused by exceeding the period of exploitation of the material.

The use of pipes for a limited time (irrigation season), when their section is full, favours the degradation of the gaskets. The pipes are drained outside the irrigation season, which causes an asymmetrical action on the rubber lining: maximum pressure at the bottom of the socket and no pressure at the top. This situation causes a change in the behaviour of the gasket over time.

Water losses on each type of pipe occur during the service life and contribute to reducing the hydraulic efficiency of each type of pipe and implicitly the pipe network. The measurement of water losses implies a methodology that requires metering on each type of pipe (CP, CS, A), a situation difficult to achieve given the relatively large diameters of the pipes. The flow measurement is performed only at the water outlet from the pumping station with the flow meter mounted on the discharge pipe / main pipe.

The correct solution of the water losses involves rehabilitation, refurbishment and modernization works, an efficient use of the volumes of water at all the components of the irrigation system and a modern monitoring of the structural and functional parameters (Chirica et al., 2018, Tabesh and Saber, 2012).

All irrigation plots are required to be equipped with flowmeters on the discharge pipes in the pressure stations.

The reduction of water losses is achieved through three main directions:

– rehabilitation of the pipeline network with the use of materials and technologies that reduce the formation of water emissions through the wall and joints;
– flow metering and comparison with those distributed by the watering equipment to obtain hydraulic efficiency on pipeline network sectors in operation;
– water loss management must be carried out in a similar way to that of the local water supply systems; the main cause of the loss of water is the pressure variation in the pipes, therefore, an adequate management of the pressure in the network must be ensured (Cunha, 1999).

Irrigation systems face the phenomenon of "water loss" throughout their life. The main problem is monitoring the losses and keeping the values within permissible limits. Pipeline networks made of multiple joint pipes (asbestos cement, PVC, Pafsin, cast iron) are easily damaged by pressure variation, or when moving the ground. Pipes with continuous sections (steel, PE), with end-to-end joints, can be moved to variations in pressure, the room deformation actions of the land, situation in which the damages are reduced.

Water loss detection can be done by classical and modern methods. Among the modern methods that can be used in irrigation plots are the Georadar and sonar. The use of these methods requires the presence of a team of specialists equipped with the specific equipment for investigation, data retrieval and processing of results.

The rehabilitation of the pipeline network of the irrigation plot is carried out on the basis of a technical expertise and a technical project approved by a project verifier in the field of land improvements. The technical project may provide for partial or total change of the piping forming the pipeline network. The hydraulic installation in the fireplace must be completely changed, because its operating time is exceeded.

4. Conclusions

• Sprinkler irrigation plots have an unsatisfactory structural and functional status, given the high operating or conservation time, the exceeding of the life of some materials, the absence of maintenance and repairs, a situation in which the hydraulic efficiency is greatly reduced.

• The smallest hydraulic efficiency occurs on the network of transport and distribution channels, where there are the largest water losses (about 40-60% of the water volume), given the absence of rehabilitation work in the last 30 years.

• Partial rehabilitation of the pressure pipes from the irrigation plots by sprinkling contributed to the reduction of water losses by about 10-15% at the researched objectives.

• The use of modern watering equipment has contributed to the reduction of water losses, where they only reached 5-15%, and the hydraulic efficiency has improved significantly.

• The rehabilitation of the components of the irrigation plots by sprinkler helps to reduce water losses and increase the hydraulic efficiency of the network of canals and pipes.

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