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WATER TRANSFER BETWEEN SIRET TO BAHLUI

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Abstract. The drought of 2015 in Moldova region has sharpened the lack of water in the area. Even in normal years, in terms of precipitation there is a shortage of water. The article describes a solution for increasing the volume of water in Iasi region by taking it from Moldova and Siret rivers . The water will be transferred from the catchment basin of the Siret in Bahlui river by utilizing existing waterways and the shortest route for the underground headrace required. Level difference between basins will be used to produce hydroelectric power. The water transfered in Bahlui will be used including after storage in tanks located on hillsides with pumps using the water hammer effect.

Keywords: water transfer between river basins, low impact water intake, underground adduction, RAM pumps

1. Introduction

Iasi County is located in one of the driest areas in the country. The existing water sources (rivers, groundwater), estimated at 140 millions m^3 per year, ensure approx. 20% of the water needed for agriculture (Blidaru et.al, 2013). Given this situation, *the solution* adopted so far was to create numerous ponds to retain water in order to use it when needed. However, the water quantity from the Bahlui and Jijia catchment areas is not sufficient for the agricultural lands in the area. Retaining water in ponds, even if the salubrious flow downstream is provided, leads to the shaping of a poor hydrographic network (Minea, 2012).

The solution for supplementing the amount of water for Iasi can be found in the two major rivers flowing at the eastern (Prut) and western (Siret) boundaries of the county. The Prut river bed has an elevation which is inferior to the county’s territory and should be pumped. The best solution would be to bring water from the Siret river bed which has a higher elevation than that of Iasi County’s territory.

Concerns regarding the water transfer between the Siret basin and the Bahlui basin existed even before the year 1900, given the emphasis of the difference in elevation of approx. 100 m between the two river beds. The most consistent contributions in addressing this issue belong to prof. Blidaru and his collaborators (2013). These solutions stipulate, beside water headrace, also storage capacities for its usage at the appropriate moment.

To derive a quantity of water from Siret to Bahlui, two scenarios are possible:

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- the completion of the Pascani accumulation and the ensuring of a constant flow towards Bahlui

- the derivation of a variable flow in accordance with the duration curve of the Siret flow, given the absence of the Pascani accumulation. In this scenario the flow must be supplemented by taking a quantity of water from the Moldova River.

The amount of water that can be transferred from Siret to Bahlui depends on the restrictions of the Siret River Basin Plan. Considering the headrace route (canal and underground headrace) the flow must be relatively constant (given the high costs of underground headrace, the partial use of the flow section is not justified).

Previous studies have advanced flows of up to 25 cubic meters/s and different routes for the headrace, considering several parameters (headrace length, existing accumulations, free flowing or pumping)

The chosen solution shall be an optimum to meet several requirements:

- a route as short as possible
- using the difference in elevation to produce electricity
- using the existing river beds for headrace
- using the water for complex usages (irrigation, recreation, electricity production, etc.)
- the accumulation of water in order to use it when needed
- considering a flow intake from the Moldova river

2. Proposal for the water flow derivation from Siret river into Bahlui basin

2.1. Previous achievements and conditioning

The total natural water resources of the Siret hydrographic basin (ABA Siret 2010, 2014) amount to 6.868 mil m^3, of which:

- surface resources - 5.800 mil m^3
- underground resources- 1.068 mil m^3

Out of these resources, an average of 2.655 mil. m^3/year is usable thereby

- surface resources - 1.955 mil. m^3
- underground resources - 700 mil. m^3

In 2013, the water volume from surface resources that was used (ABA Siret 2014) amounted to 129 mil. m^3. During the precedent years (2011, 2012) the volume of used water was approximately the same.

Therefore, 6.5% of the surface water volume from the Siret basin is used. The used water volume does not include the water processed by hydropower plants. Hence, a vital resource for the land it passes through is being used in an insignificant amount.

Previous achievements

Together with the arrangement of the accumulation on Siret, at Bucecea, they also created the derivation towards the Sitna River on which the Catamarasti accumulation is built, nearby Botosani. This derivation (ABA Prut Barlad) works gravitationally, it is 17 km long and includes underground and over ground pipes, as well as a tunnel with a diameter of 1,6 m. The annual water volume to be transported in order to supplement the water volumes necessary for irrigation in the hydrographic basin of the Jijia River is estimated at 40 mil. m^3.

Conditioning

Considering the water used currently, from the point of view of the available water volume, there are no quantitative limitations for the water usage.

One of the conditions which must be considered is the existence of an accumulation that would allow the adequate distribution in time of the accumulated volume.

Given the lack of an accumulation, the water quantity that can be derived is limited by the shape of the flows' duration curve. In this situation, the available quantity of water in Siret must be supplemented by a volume taken from the Moldova River.

The derivation must work gravitationally. The land configuration suggests that underground headrace is necessary. It is necessary to correlate the digging technology with the diameter of the headrace.

The difference in elevation between the basins must be used for producing electricity.

2.2 The description of a solution for water headrace from Siret into Bahlui

We looked for an optimal solution considering a few criteria:

a) the shortest route for the underground headrace. We traced transverse profiles in various locations resulting in a route, 7 km long, under the Helesteni village from Ruginoasa commune.

b) the gravitational flow. This criterion is easy to be achieved given the land configuration.

c) the underground headrace must operate at full section, at all times. To comply with this criterion *the stabilization of the derived flow* is necessary.

The main usage of the water is the irrigation of agricultural lands. The amount of water necessary for irrigation is of minimum 2000 m^3/ha per year. The surface of agricultural land that might be irrigated is of approx. 100 thousand hectares.

The water treatment plant from Iasi City will send towards the emissary (Bahlui), in 2017 (according to APAVITAL Iasi) a flow of 4.2 m^3/s. The multiannual average flow of Bahlui is of approx. 3 m^3/s. During winter, the average flow is of 1.6 m^3/s. Although the water is conventionally clean when treated, it is better that the flow of the emissary should be at least at the level of the treated water flow (dilution degree of minimum 1). The flow of the emissary is $Q_{95\%}$= 0.08 m^3/s, with a confidence interval of 95%.

From the need to ensure the dilution degree downstream of Iasi, results a volume of water on Bahlui of approx. 100 mil. m^3. Given these aspects, the annual volume necessary in the Bahlui basin is of 300 million cubic meters.

Moreover, the underground part of the headrace is important. The land in the area of the tunnel to be created is a clayey land. Modern digging technologies are of two types:

- excavations with the tunnel boring machine and support with pushed concrete tubes
- tunnel boring machine and support with concrete blocks

The first method is applicable for diameters of the excavation of up to 3m.

The free level water flow requires a less expensive coating for the underground gallery.

The free level flow must be realized in a low flow regime so as the occasional obstacles will not lead to the rise of the water level (within certain limits). Given these aspects we took into consideration a diameter of the gallery of 2.5m with an excavation diameter of 2.90m. For this section, the flow is of 10m^3/s. Given this flow, the annual volume of transited water is of approx. 315 million m^3.

If the Pascani accumulation is completed, the 10cbm/s flow can be ensured without any problem.

If the accumulation is not completed, the current flow of the Siret river cannot provide the 10cbm/s derivation in a continuous manner. A flow intake from the Moldova River is necessary.

The most appropriate solution to derive an amount of water from the Moldova River into the Siret River basin, is the one imagined by Blidaru et al. (2013), by creating an underpinning on the Moldova River, in the Malini area, and a headrace to the river basin of the Somuzul Mare River, through the river basin of the Bradatel creek and onward to Siret. According to the flow duration curve of Moldova River,(fig. 2) there can be taken a flow of

$3m^3/s$. By adding these to the $7m^3/s$ from Siret(fig. 1) , we reach the $10m^3/s$ flow, ensured in a proportion of 90%.

The average multiannual flows within the underpinning areas (downstream of Gura Humorului for Moldova and downstream of Pascani for Siret) are of 18.1 m^3/s, respectively 36.5 m^3/s. A total average multiannual flow of 54.5 m^3/s is reached, out of which 10 m^3/s are derived into Bahlui river.

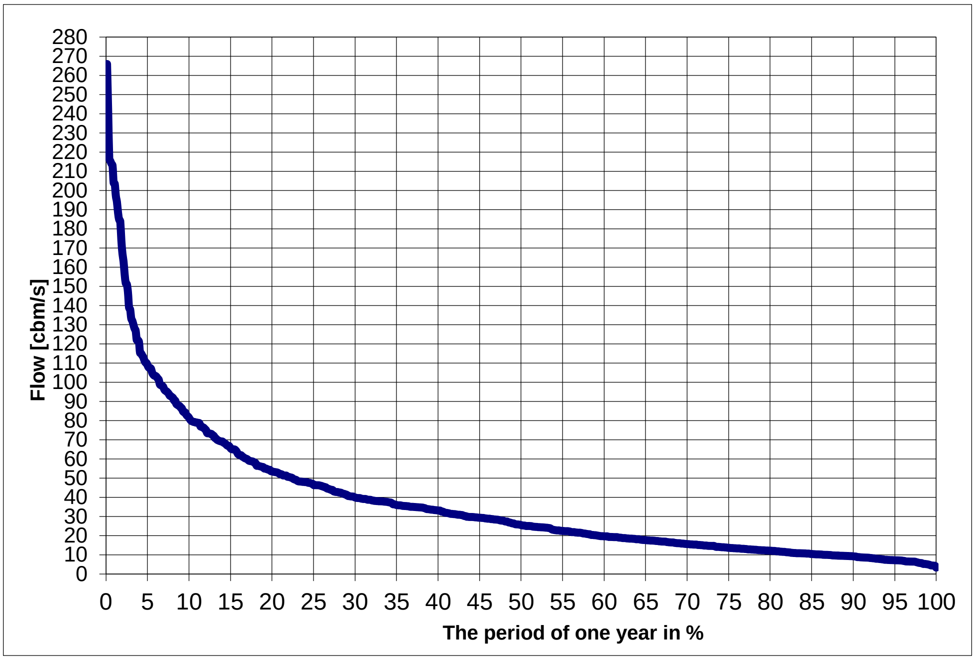

Figure 1: Flow duration curve for Siret river at Lespezi

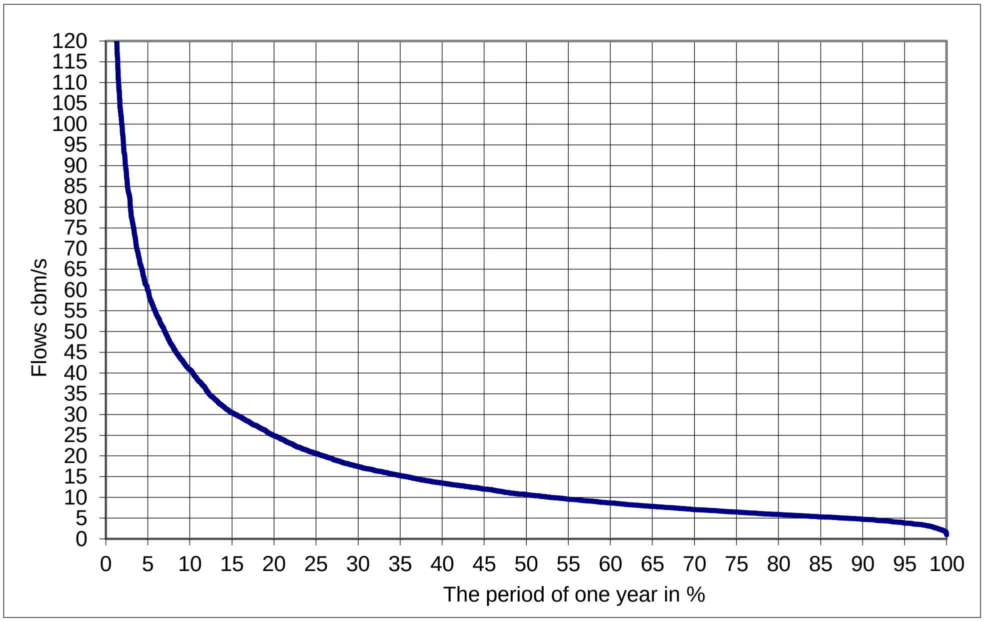

Figure 2: Flow duration curve on Moldova river at Gura Humorului

By analysing the two duration curves,(fig.1 and fig. 2) one can observe that the cumulated flow Siret + Moldova is of 15 m^3/s, with a confidence interval of 90%,.

3 Works necessary for creating the derivation

The derivation shall include the following works (fig.3 and fig.4):
3.1. Water intake from Siret, located downstream of Pascani
3.2. Headrace canal, L=3km
3.3. Free level headrace gallery and downstream loading room, L=7 km
3.4. Penstock L=1.7 km
3.5. 7MW small hydropower plant
3.6. Canal on Rediu creek, recalibrated for the derived flow
3.7. Canal on Bahluiet River, recalibrated for the derived flow
3.8. Arrangement of the Bahlui river bed for the derived flow
3.9. Accumulations for storing the flow during the period in which there is no consumption for agriculture (irrigation). These accumulations can be arranged either in the Bahlui river bed, or there can be introduced a special exploitation regime of the polders. There can also be arranged accumulations on the slopes at altitudes of 50-60m above the river bed's elevation. The water can also be pumped into these accumulations with pumps relying on hydraulic impact (RAM pumps). Approx. 100.000 m^3 of water can be pumped at a height of 50-60 m with a pump station, during one month. One station would consume $1m^3/s$. There can be arranged a maximum of 5 stations downstream of the existing arrangements (Podu Iloaiei dam, polder) or the proposed ones (T. Vladimirescu weir), or there can be arranged new accumulations.
3.10. Arrangement of the Bahlui recreational area on Iasi territory
If the Pascani accumulation is not completed, the following works shall be necessary:
3.11. Water intake on the Moldova River, in Malini area, for $Q=3m^3/s$
3.12. Headrace pipe to Bradatel creek's river bed, L=5 km, D=1.5m
3.13. Arrangement of Bradatel creek's river bed for the flow of $3m^3/s$

4. Description of the works with a major technological and environmental impact

4.1. Water underpinning on Siret, downstream of Pascani

Downstream of Pascani, the Siret River has a flow of 2060 cbm/s, with a probability of 1%. The arrangement of a catchment area within the river bed usually implies the need to protect the residents from the afflux produced by the catchment weir. Considering the configuration of the river bed and the flow regime, we have identified a way to create the catchment so that it does not produce any backwater. This structure is explained below.
The constant flow of water into a canal (river) with a rectangular section, given the existence of a thalweg step, is done as follows:

- if the flow regime from upstream is critical ($h<h_c$), after the step the water level rises
- if the water flow regime from upstream is slow ($h>h_c$) the level of water after the step falls. The maximum height of the step, so that the water level upstream would not be affected by its presence is $\Delta z_{\max} = E_1 - E_c$ (fig. 6)

Elevating the step over this level implies reducing the energy specific to water (E_c). On the other hand, the critical flow regime means minimum specific energy, thus reducing the specific energy is not possible.
If we raise the level of the step over Δz_{max} the flow will decrease if the level upstream remains constant, or the level upstream rises to increase the specific energy and ensure the flow.
h_c = critical depth
.

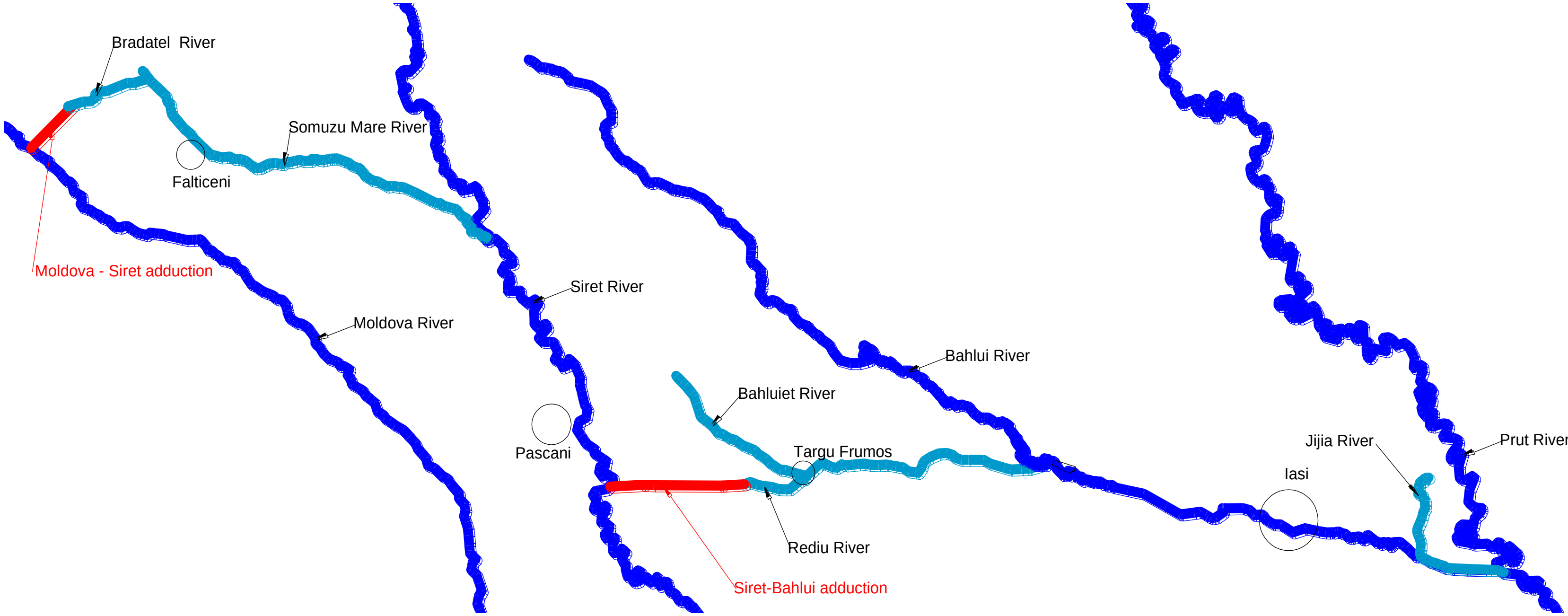

Fig. 3 Site plan

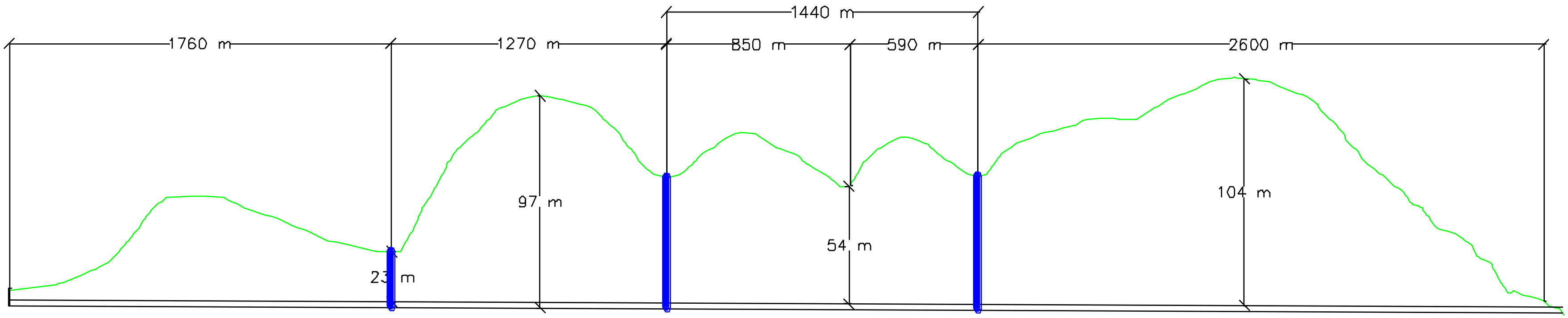

Figure 3: Longitudinal profile through the underground adduction gallery Siret-Bahlui

Input data Siret river at Pascani are given by
$Q_{1\%}$=2060 m^3/s
n=0,035
B=100 (river width)
S=0,5‰ (0,0005)
water depth in the canal with rectangular section (y=1/6) is given by eq (1)

$$h = \left(\frac{Q \cdot n}{B\sqrt{S}} \right)^{\frac{3}{5}}$$

h_1=7,05m
critical depth is given by eq (2)

$$h_c = \sqrt[3]{\frac{\alpha Q^2}{B^2 g}}$$

h_c=3,51m
hydraulic energy is given by eq (3) (Chaudhry 2008)

$$E_1 = h_1 + \frac{v^2}{2g}$$

E_1=7.48 m

$$E_c = h_c + \frac{v_{cr}^2}{2g}$$

E_c= 5.27m
The difference of energy between sections
E_1 –E_c = d = 7.48 – 5.27 = 2.21 m

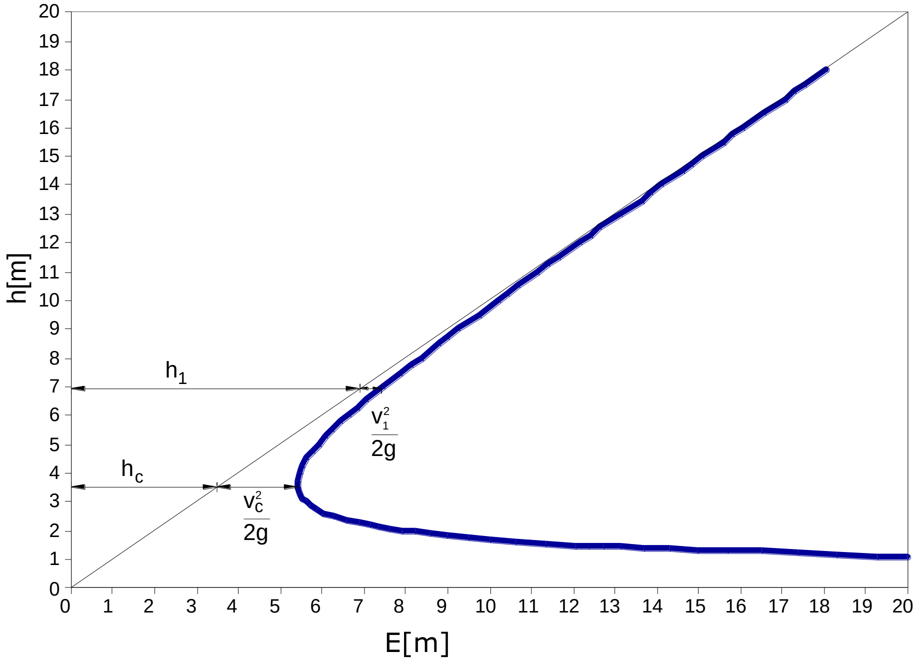

Figure 4: Graphic representation of the hydraulic energy E=H=f(h), for determining h_c

Figure 4 represents the ecuation (4)

$$E = H = h + \frac{\alpha v^2}{2g} = h + \frac{\alpha Q^2}{2gA^2} = h + \frac{\alpha Q^2}{2g(Bh)^2}$$

The difference of depth between sections is

h_1-h_c=7.05 – 3.51 = 3.54 m

The meaning of terms:

h_c= critical depth in the river bed

E_1 = hydraulic energy upstream of the step

E_c = hydraulic energy in the step's (weir) section, given a critical flow regime

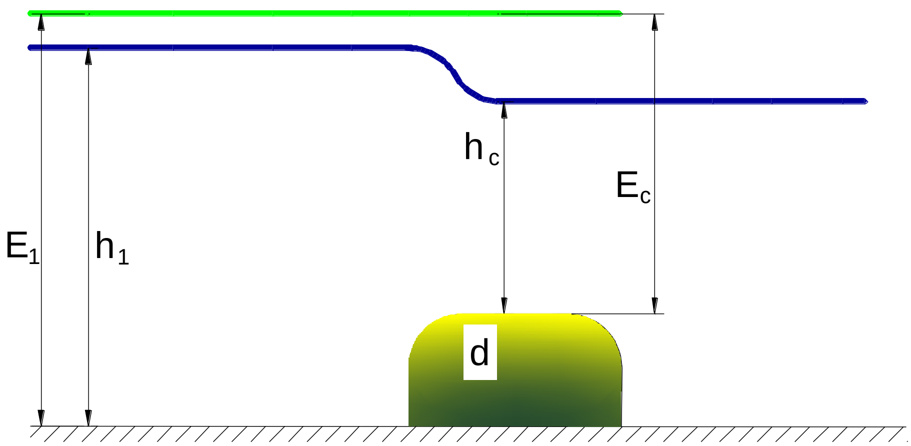

Figure 5: Water level in Siret river intake section

4.2. Underground headrace gallery

The interior diameter of the gallery will be of 2.50 m. The lining shall be made of reinforced concrete (Chapman 2010). The excavation technology for the gallery will be the following (fig. 6). Three wells (marked with a thick, blue line on the longitudinal profile) will be dug.

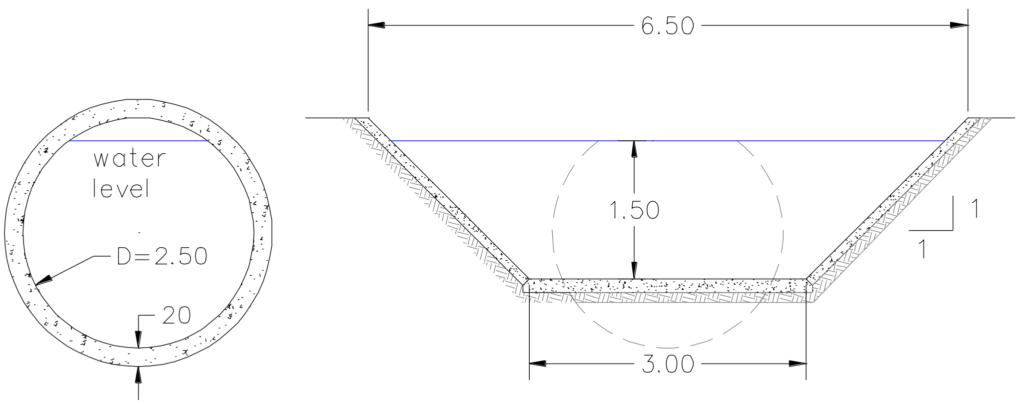

Figure 6: Sections through the Siret-Bahlui headrace; on the left the free level underground gallery; on the right headrace canal before the entrance into the gallery

In each well there shall be introduced a tunnel boring machine. The boring machine (shield) shall advance with the help of hydraulic cylinders supported by concrete blocks (Pipe Jacking Association 1995). Each advanced step (1m) means the installation of a 1 m long reinforced concrete precast (fig.6left).

Considering the configuration of the land (the big distance between the wells intermediate stations for pushing (advancing) the digging machine and the coating will be needed.

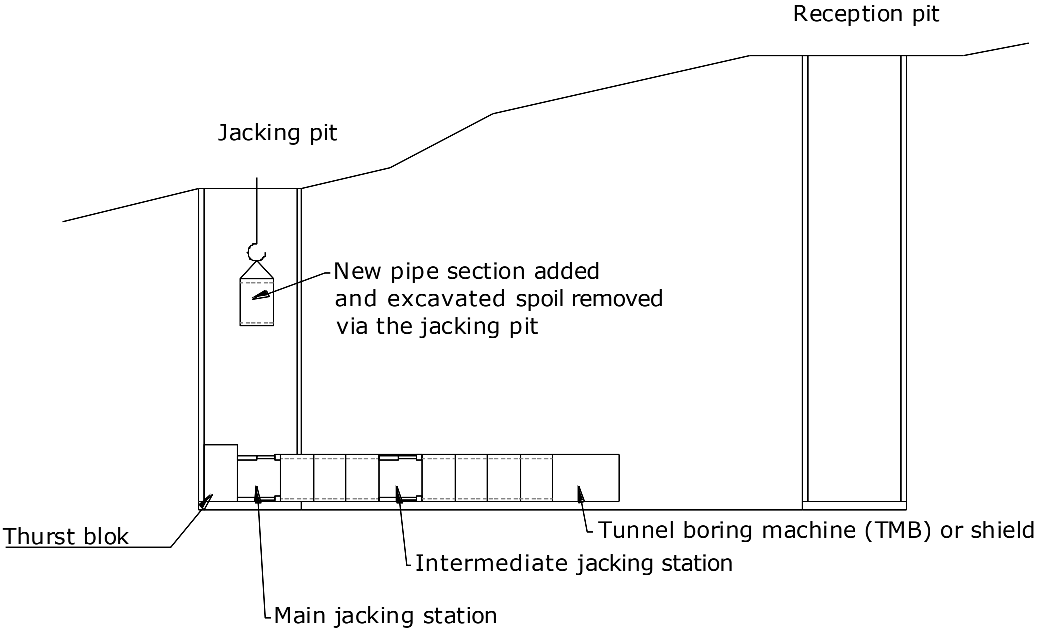

Figure 7: Underground headrace gallery technology

Such technology has already been used in Romania for a sewage collector in Bucharest, with the diameter of 2,40m.(Kanaby 2010).

4.3. Storing water for future usage

The 10 m^3/s flow which shall pass through the river beds of Bahluiet and Bahlui represents a hydraulic energy whose use cannot be neglected. This quantity of water is and must be used along the way. At least 4-5 m^3/s must pass through Iasi City to create an optimal dilution for the treated waters of the city. The most appropriate solution is the use of RAM pumps which rely on the use of the hydraulic impact produced when handling the valves of a hydraulic circuit.

A RAM pump is a pumping system (Watt 1974) which uses a small water fall to rise a part of the available quantity of water at a higher altitude; for example, it uses the bigger quantity of water flowing through a small opening and it rises a smaller quantity of water which will flow through an opening located at height. The main quality of this type of pump is that its only moving parts are two valves and is, from a mechanical point of view, very simple. This quality provides it with reliability, minimum maintenance requirements and a long lifetime.

The operating scheme can be the following:

The RAM pumps need a small fall (h) and a big flow (Q) in order to rise to a big height (H) a small flow (q) according to the relation(5)

$$q = \frac{Q \cdot h}{H} \eta$$

where: η is the pump efficiency (0,6-0,7)

For example, if in the pipe which enters the pump the flow is Q=1cbm/s, the fall at the entrance into the pump is of 3 m and the height to which the water must be elevated is H=50m, the flow to be pumped is

$$q = \frac{1 \cdot 3}{50} 0,7 = 0,042 \ mc/s = 42 \ l/s$$

During one month, the volume of water that will be pumped is V=108.864 m^3

This amount of water is pumped with no energy consumption.

Considering these aspects, it is reasonably to create on the slopes nearby the accumulations from the Bahluiet and Bahlui river beds, basins that will store water and provide it gravitationally for various usages.

One location that can be used is the right side of the lake from Podu Iloaiei on the Bahluiet. Here, the existence of the lake provides a fall of minimum 8 m for setting up the RAM pumps. Another location can be the temporary accumulation on Bahlui, downstream of Podu Iloaiei, where a fall of 3 m can be used. Also, there can be used the designed location of the dam on Bahlui, in Iasi, from Tudor Vladimirescu bridge where there is a fall of 2.2 m which can be used for setting up the RAM pumps.

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