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# THE INFLUENCE OF THE HYDRO-TECHNICAL SYSTEM ON THE WATER FLOW OF THE SEBEȘ RIVER

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**Summary. The influence of the hydro-technical system on the water flow of the Sebeş River**. Along the Sebeş River was built one of the representative hydro-technical cascade systems in Romania. The significant potential of the river is used primarily to produce electricity at four hydroelectric power stations located downstream of four reservoirs. This system influences the natural runoff, which is controlled at the Petreşti hydrometric station. Based on the reconstruction of the natural flows, two series of parallel monthly flows were obtained: one with flow of water drained into the bed (influenced discharge, what is measured) and another with reconstructed values (obtained from calculations). Based on them, the degree of influence of the natural flow was highlighted. The analyses were performed considering the multi-year average monthly flows, the annual average flows, as well as the extreme monthly average flows. Thus, pertinent conclusions can be drawn regarding the influence of the natural flow on the Sebeş River.

**Keywords.** natural flow regime, influenced flow regime, discharge reconstruction, water use, reservoir, hydroelectric plant, type of influenced flow

## 1. INTRODUCTION

The evolution of human society has left an increasingly strong imprint on the environmental system as a whole and on each individual component. The influence of natural processes manifests itself in three main directions (Pandi, 2011):

- the areas where man influences natural processes increase;
- more and more natural processes are influenced;
- increases the degree of influence of the processes.

Water is one of the most general and vital resources of the human existence. It is not by chance that Earth is called the "Blue Planet", and this century is called the "Water Century". Among the water units, the most used are the rivers. The influence on the water was first manifested quantitatively, then qualitatively. This is how we went from quantitative to qualitative insufficiency regarding water resources.

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Society, understanding at a given moment the dangers generated by its own activity, proceeded to rehabilitate the situation through the temporal and spatial redistribution of natural resources. Thus, the natural flow regime of the rivers is modified, and the influenced flow regimes appear. The most important hydro-technical infrastructures through which the flow is influenced are dams, industrial and building consumer uses, as well as transfer pipes from one hydrographic basin to another (Pandi, 2011).

The importance of knowing the influence of dams on the natural flow regime is also analysed based on the use of Qingting Zuo and Shikui Liang's Indicators of Hydrologic Alteration (IHA) and Range of Variability Approach (RVA) (Qingting & Shikui, 2015).

## 2. SEBEŞ RIVER BASIN

The Sebeş River basin has two distinct units. The southern part is located in the Şureanu and Cindrel Mountains, and the northern part develops in the Secaşelor Plateau. Between the two units, the basin presents a strong necking, which gives it a classic basin format narrowed in the middle sector (Fig. 1).

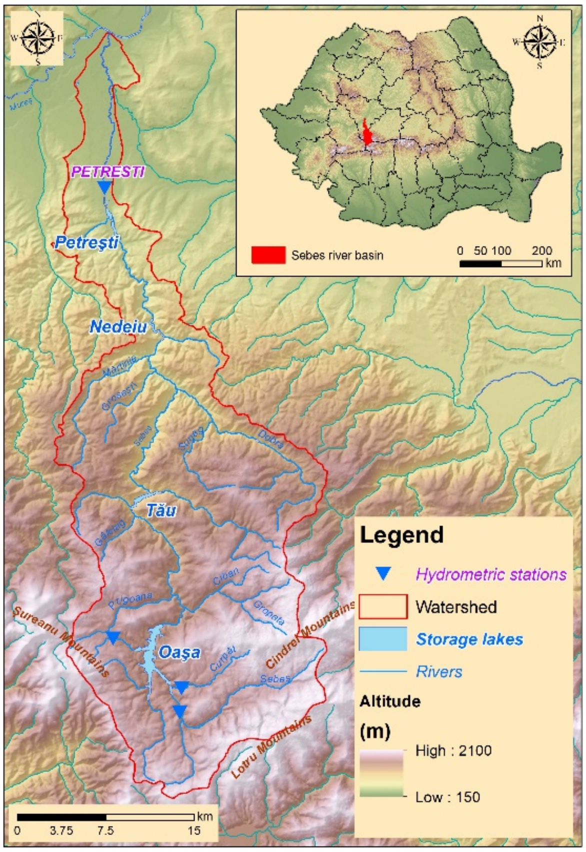


**Fig. 1.** ***Petreşti hydrometric station and reservoirs from the Sebeş river basin***

The mountain area is represented by the crystalline of the Getic sheet, consisting of crystalline schists with a predominance of mica schists, gneisses, amphibolites, quartz rocks and sericite-chlorite schists (Oncescu, 1965). In their contents, lenses of eruptive rocks and some patches of sedimentary rocks appear. In contrast to these, the Piedmont Hills, developed on a small strip at the exit of the river from the mountains and in the plateau area, are made up exclusively of Neozoic sedimentary rocks, where gravels, sands, marls, and clays of Pliocene age predominate. The valleys and terraces are lined with friable Quaternary fluvial deposits, consisting of gravels and sands (Ciupagea & Paucă & Ichim, 1970).

The orography is the mirror of the petrographic constitution and the erosion of the river network. Thus, in the upper basin, the massiveness of the relief, in the form of smooth slabs, is due to the homogeneity and hardness of the rocks, as well as the stages of its modelling. The valleys narrow in the form of gorges when the gneisses are pierced and widen in the crystalline areas (Mihăilescu, 1969). Small depressional basins are characteristic (Frumoasa, Oașa, Tărtăru, Curpăt, Prigoana, Tău, Bistra, Dobra Șugag), which represent areas of hydrographic convergence, with high values of fragmentation density and relief energy. The Piedmont strip is poorly developed and narrow, after which, in the lower basin, there is a characteristic relief of hills with wide valleys. Here the terraces appear much more developed along the collector and on the tributaries.

The hydrographic network in the Sebeș hydrographic basin has an approximately symmetrical shape. Sebeș River, which rises at approx. 2000 m altitude in the Cindrel Mountains, drains this basin in the south-north direction and flows into Mureș River downstream of Alba Iulia. The petrographic and climatic conditions favoured the development of a very rich hydrographic network, especially in the mountainous area with several oro-hydrographic nodes. In the mountains, the density of the hydrographic network reaches 0.7 $km/km^2$, the longitudinal slopes are between 18 – 29 m/km, and the drainage layer is 450 mm (Ujvari, 1972). These characteristics give the upper and middle basin a remarkable hydropower potential.

The steep arrangement of the relief over more than 2000 m, with a wide opening to the north, favours the penetration of the Atlantic air masses, as well as a well-defined stratification of the climatic elements. The average annual temperature drops from 9-10°C in the catchment area, down to 0°C on the highest peaks (www.meteoblue). Atmospheric precipitation is abundant and shows a gradual increase from the depression areas towards the mountain peaks. Annual amounts vary between almost 600 mm in Sebeș and over 1200 mm in the mountains. An essential source of river supply is the snow cover, which exceeds 30-45 cm at high altitudes (ANM.Ro)

## 3. THE HYDROPOWER SYSTEM

Hydro-technical facilities' effects on the downstream hydrological regime can be significant: attenuation of flood waves, increase of minimum flows, and modification of the runoff regime. These effects can have beneficial or detrimental consequences relative to the natural runoff regime. Their quantification helps to evaluate the economic, social, and ecological impact of the developments (Ionescu, 2001) on the water.

The first hydropower development scheme of the Sebeş hydrographic basin was developed by Dorin Pavel, back in 1927. After several resumptions of the project, the development works began in 1972 (Pop, 1996). Today, the Sebeş system includes a cascade consisting of four stages (Fig. 2), each of which includes a reservoir and a hydropower plant (Ştef & Ştef, 2013). At the national level, the Sebeş System represents 2% of hydropower production and 5% of installed electrical power (Hidroelectrica S.A., 2012).

The Oaşa Storage and dam is the system's central unit, having the largest retention capacity (136 mil. mc). Several other rivers increase the tributary water discharge intake. From here, the regularization of water flows along the entire cascade is carried out. The dam that closes the valley is built of rock and provided with a reinforced concrete mask. The next is Tău Storage, where a double-arched concrete dam retains the water. The volume of water retained is significantly lower, only 21 mil. mc. The next two storages - Nedeiu and Petreşti - are significantly smaller and have only the role of flow transit and daily regularization. The city of Sebeş is supplied with water from the Petreşti Lake. The cascade of hydropower plants includes the following units: Gâlceag, Şugag, Săscior and Petreşti.

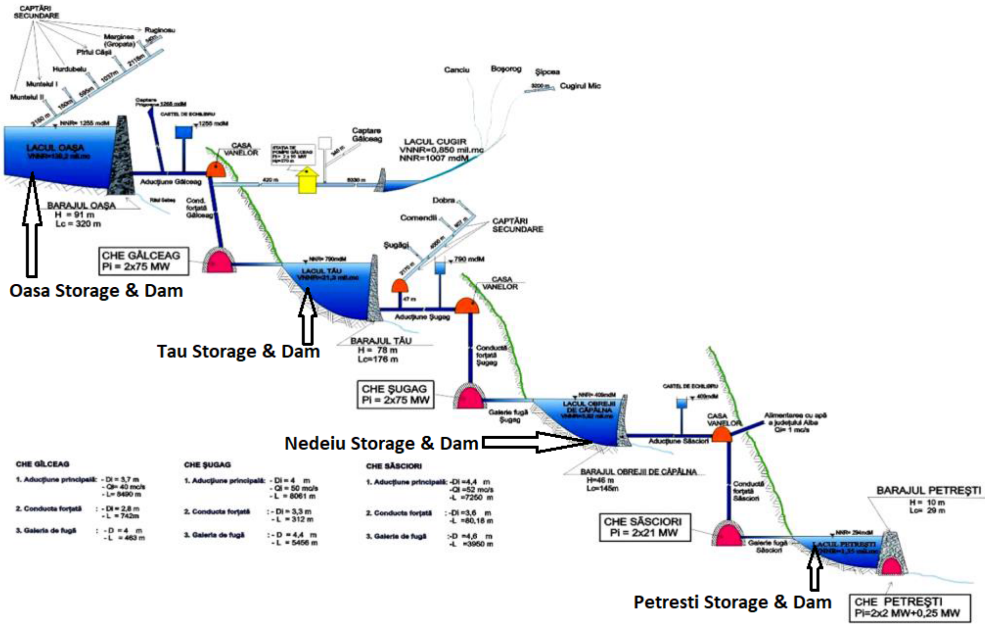


**Fig. 2.** ***The structure of the hydropower system (Paraschivescu, 2008)***

## 4. DATA AND METHOD

The closing section of the hydropower system is at the Petrești Hydrometric Station, located downstream of the last reservoir (Fig. 1). The area of the related basin is 695 $km^2$, the average altitude is 1249 m, and the length of the upstream river is 84 km (Ujvari, 1972).

The hydrometric control of the hydro-technical objectives is carried out at each reservoir. The natural flow downstream of each reservoir can be reconstructed with the formula:

$$Q_{rec} = Q_{mas} \pm \Delta Q \quad (1)$$

where: $Q_{rec}$ is the natural flow in the section of the dam being reconstructed;
$Q_{mas}$ is the flow that comes out through the dam's evacuators;
$\Delta Q$ is the variation in the volume of water in the lake, converted into flow:

$$\Delta Q = \Delta V / \Delta T \quad (2)$$

During accumulation, $\Delta Q$ is positive, during de-accumulation $\Delta Q$ is negative. The calculation is performed for the average flows of a time period $\Delta T$, usually for a month.

To express the degree of influence on the natural flow, it is necessary to reconstruct the series of flow rates.

The degree of influence of the natural flow can be expressed in absolute values and/or in relative values, using the formulas (Pandi & Stoica, 2015):

$$\Delta Q = Q_{nat} - Q_{infl} \qquad (mc/s) \quad (3)$$
$$\varepsilon = (Q_{nat} - Q_{infl}) / Q_{nat} * 100 \qquad (\%) \quad (4)$$

The graphs $\Delta Q = f(T)$ and $\varepsilon = f(T)$ express the deviations of the reconstituted (natural) multiannual average monthly flows compared to the drained ones (influenced / measured). Of course, the deviations of the respective annual averages can also be expressed on their basis. The characteristics of extreme monthly average flows can also be analysed.

## 5. RESULTS

### 5.1. Degree of runoff influence

The graphs in Fig. 3 and Fig. 4 illustrate the deviations of multi-year monthly averages. They have, as is normal, a similar allure and keep the same sense of deviation every month. The largest positive deviations are recorded in the months of April and May: 6.08 mc/s and 9.53 mc/s, respectively 42% and 50%. The deviation values are close to zero in March and September. The biggest negative deviations were at the beginning and end of the year: January -2.60 mc/s and 51%, December -1.99 mc/s and 33%.

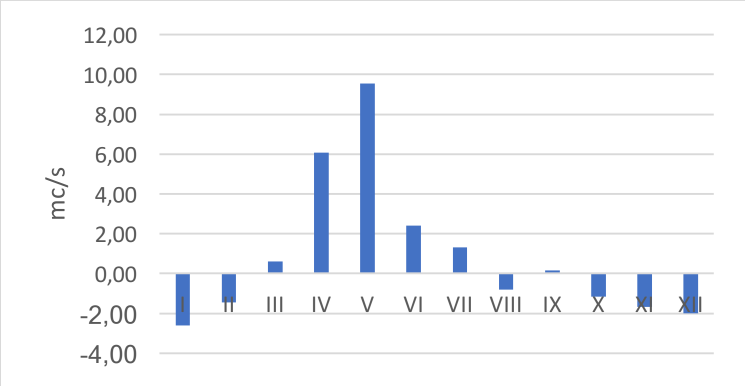


**Fig. 3.** ***Absolute deviation of monthly flows***

The variation of the annual average flows is relatively pronounced, both for the reconstructed values and for the influenced ones (Fig. 5). This illustrates that water use was consistent with annual resources.

The richest years were 1998, 2005 and 2008, with flows above 12.0 mc/s, and the poorest 1993, 1994, 1996, 2001 and 2003 with flows below 8.00 mc/s. It should be noted that, in general, in years with abundant runoff, the differences in reconstituted flow - runoff are smaller than in poor years. Such surplus years are: 1995 (-0.08 mc/s), 2004 (-0.32 mc/s), 2008 (-0.62 mc/s), 2005 (+0.92 mc/s). The characteristic deficit years are: 1994 (+1.98 mc/s), 1996 (+3.41 mc/s), 2001 (+2.45 mc/s).

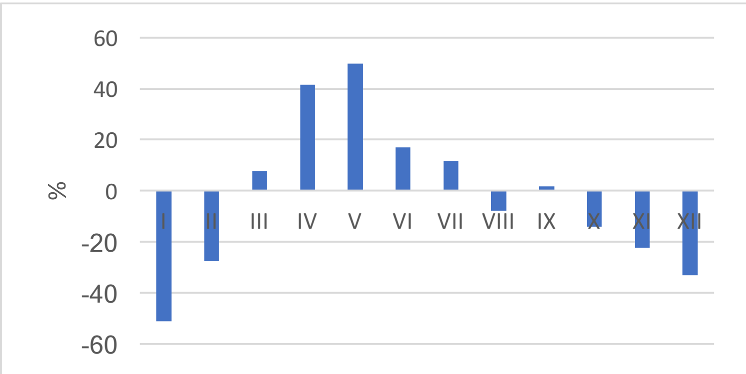


**Fig. 4.** ***Relative deviation of monthly flows***

The graph of the variation of the reconstructed multiannual average monthly flows has an allure consistent with the legitimacy of the runoff in our climatic zone (Fig. 6).

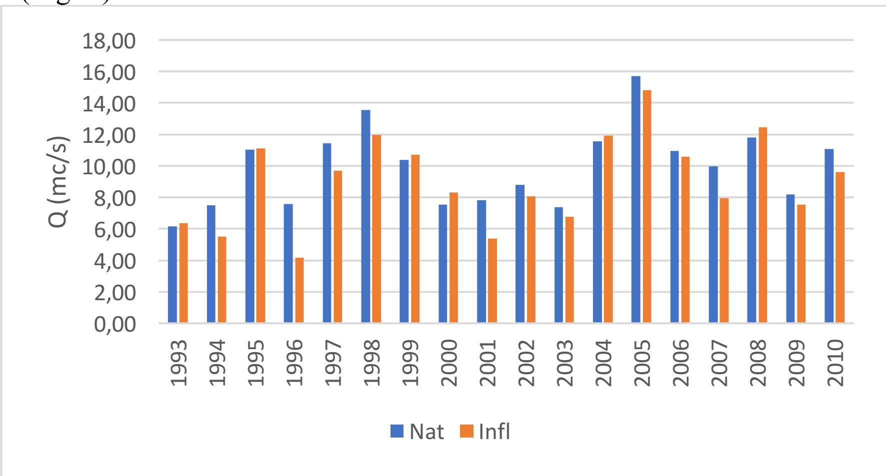


**Fig. 5.** ***Variation of average annual flows***

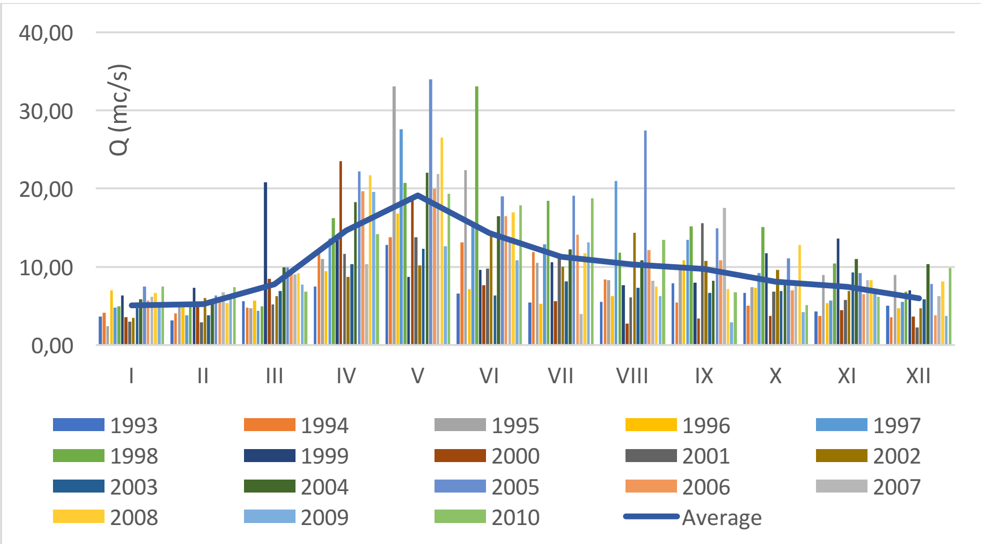


**Fig. 6.** ***The variation of the reconstituted multiannual average monthly flows***

The richest months of the runoff are April, May and June, and the minimum runoff was recorded in the winter months, due to the watershed's location in the mountainous area with strong frosts. The difference between the maximum and minimum multiannual monthly average flow is 14.05 mc/s.

In comparison, the chart of past multi-year average monthly flows has a much-faded look (Fig. 7). Richer runoff occurs during the summer period, but with significantly lower values than the reconstructed runoff (maximum of 11.87 mc/s versus 19.14 mc/s).

On the other hand, in winter, although the values are lower than in summer, they exceed those of the reconstructed runoff (in February 6.71 mc/s compared to 5.26 mc/s).

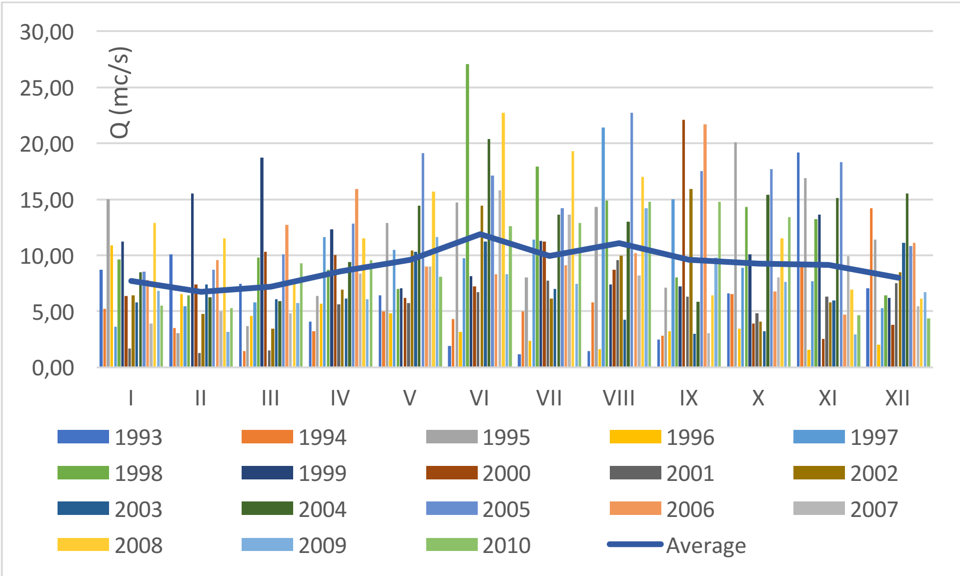


**Fig. 7.** ***The variation of the influenced multiannual average monthly flows***

If the average extreme monthly runoff is analysed, it is found that the maximum values for reconstituted are over 30.00 mc/s, and for drained ones over 20.00 mc/s (a single case over 25.00 mc/s).

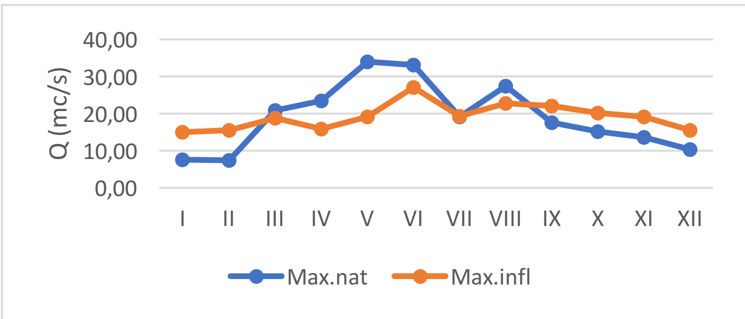


**Fig. 8.** ***The variation of the average monthly maximum annual flows***

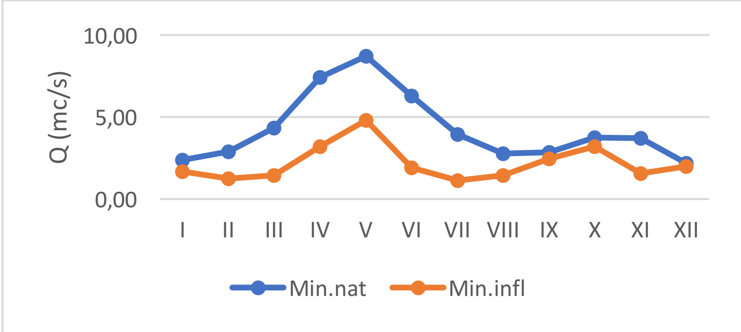


**Fig. 9.** ***The variation of minimum annual average monthly flows***

Meeting the water needs of the reservoirs has led to a much more balanced runoff, where the differences between the extreme values are significantly smaller.

The degree of runoff influence also results from the analysis of extreme flows (Fig. 8 & 9). In the case of the maximum multiannual monthly averages during the rich runoff period, the natural runoff values are higher than the influenced runoff (e.g. May: 34.00 mc/s versus 19.10 mc/s). On the other hand, during the autumn-winter period, the natural values are lower than the previous one (e.g. January: 7.49 mc/s compared to 15.00 mc/s).

At minimum multiannual average monthly flows throughout the year, the natural runoff values are above the drained flows. In the spring-summer months the differences are greater (May 8.71 mc/s and 4.80 mc/s, June 6.30 mc/s and 1.90 mc/s) than in the autumn-winter months (September 2.86 mc/s and 2.46 mc/s, December 2.20 mc/s and 2.00 mc/s).

## 6. CONCLUSIONS

The hydrographic basin of the Sebeş River has rich water resources with appreciable energy potential. The hydropower system significantly influences natural runoff.

The analysis of the degree of influence of the discharge at the Petrești Hydrometric Station shows absolute deviations of over +9.00 mc/s and over -2.00 mc/s, which in relative values means deviations of ±50%.

The variation of the annual average flows is relatively pronounced, both for the reconstructed values and for the influenced ones.

Plots of multi-year average monthly discharges show a much fainter pattern for the induced runoff than for the natural runoff. Obvious differences are also observed when analysing extreme monthly average flows.

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