THE PARTICULARITIES OF MINIMUM FLOW OF THE RIVERS' WATER FROM SUCEAVA HYDROGRAPHIC BASIN (1981–2005)

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ABSTRACT. The particularities of minimum flow of the rivers' water from Suceava hydrographic basin (1981–2005). Suceava river basin, *suprapus* over the eastern slopes of the Eastern Carpathian and over the Suceava Plateau, is strongly influenced by the climatic characteristics of tis area, such as very low temperatures during winter, creating a long period with *freezing river water.* This is why winter is the main season with low waters, when the river discharge drops below a certain values, threating the water supplying for the settlements in the basin, even the depletion of rivers. As follows, there will be presented these periods in which the river's discharge value drops below a threshold value, specific for low waters using the program HydroOffice. Thiss program helped us better calculating the parameters of low waters, such as their duration, frequency, intensity (severity), minimum discharge, etc. All these will show that this river basin belongs to the Eastern Carpathian water flow regime, with the highest frequency of low waters during winter, followed by autumn low waters.

Key-words: low flow, basin, quantive threshold, sector.

1. INTRODUCTION

The low water fase of the hydrological river flow regime represents the period from a year when the river's discharge and level are way below the multiannual average discharge value. "Low waters in Romania are specific to summer and autumn seasons, because rainfalls are rare and the evapotranspiration is high. Winter is also responsible for the appearance of low waters, because most of the river's water is stored inside the rivefr bed or as ice in the entire basin." (Romanescu, 2009). Low winter waters scarcely appear, especially in the eastern part of Romania, in Moldavia and the Eastern slopes of the Eastern Carpathians, strongly influenced by the climatic Baltic and Continental influences. Low waters in summer and autumn appear especially in the Western and South-Western part of the country, where the invasions of warm air bring high temperatures and very low rainfall values.

Low waters are an indicator for river water depletion.

When time intervals with low waters are very long, they determine the apparition of drought. There are five stages in the evolution of droughts: atmospheric (meteorological) drought, soil drought (when the water reserve from soil comes close to 0), phreatic drought (phreatic reserve is reduced to 0), hydrological drought (river discharge tends to 0), hydraulic reservoir's drought (usable reserve water from lakes tends to 0) (Sorocovschi, 2009b).

From all these five, the hydrological drought appears as a result of low water's appearance on rivers, and "represents the depletion process of streams and rivers, their discharge tending to 0. It depends on the fallen rainfall quantities, on the the soil's properties and on the geological and morphological characteristics of hydrological basins" (Sorocovschi, 2009b, p. 70).

Suceava River Basin is situated on two main relief types – mountains (represented by Bukovina Obcini, as a part of the Carpathian Mountains) and plateau, represented by Suceava Plateau in East (Table 1). At the contact of these two relief types appears a transition are between mountain and plateau, contaning a series of depressions and interfluves (Straja – Marginea – Solca – Cacica Alignment). Because of that, we delineated three main basin sectors: mountain, transition and plateau sector.

2. DATA BASE AND METHODS

The data base used in this article includes hydrological data concerning minimum and average discharge values for the interval 1981 – 2005, obtain from "Siret" Water Basin Administration and Bacău Water Management Service, for eight hydrometric stations, with three on the main course and five on the tributaries (Table 1). From these, data, the discharge values from Iţcani Station are reconstituited, due to the position on the water course, before this station, of the reservoirs Mihoveni, Dragomirna 1, 2, etc.. This is way the discharge values this stationary lower than the normal ones.

Table 1. Hydrometric stations from Suceava River Basin

River	Station	Sector	Basin's surface (km2)	Basin's Aver. Altit. (m)	Station Altit. (m)	Registration Year
SUCEAVA	**BRODINA 2**	Mountain	366	990	587	1956
SUCEAVA	**ȚIBENI**	Plateau	1288	730	334	1981
SUCEAVA	**IȚCANI**	Plateau	2334	629	282	1928
BRODINA	**BRODINA 1**	Mountain	142	989	685	1964
PUTNA	**PUTNA**	Mountain	53	847	566	1965
POZEN	**HORODNIC**	Transition	67	488	387	1969
SOLONEȚ	**PĂRHĂUȚI**	Transition	204	467	305	1952
ȘCHEIA	**ȘCHEIA**	Plateau	33	388	279	1963

The method used in this paper for the interpretation and graphical representation of hydrological data is the method of quantitative threshold (Hisdall and all., 2000), which was calculate using the program package *HydroOffice,* respectively the program *TLM 2.1*.

The quantitative threshold is showing the beginning and end of a period of higher or lower flow rates than the threshold value. Depending on the study objectives, the threshold may be chosen as a fixed values or can be selected multiple values as a threshold for various periods during the year. This threshold value can be set as the average water flow value, as a percentage value from the annual flow or can be set as a fixed value and can function as a value valid for a number of years, for a single year or a season, being able to establish threshold values for each season. This value can vary from one study to another, depending on its needs. Generally, the lower thresholds (90%) are recommended when using time series with short length, while higher thresholds (70% or 80%) are used for analysis in regions where drought can extend from one season to another or even from one year to another. Also, higher threshold values (75-90%) are used for water courses with constant flow, while for rivers with intermittent flow there are being used lower thresholds (70%), such rivers having a low and inconsistent flow (Dina (Toma), 2001). In this paper we used the threshold value of 80% (Q80) used in the literature by Holobâcă, I. (2006) and Dina (Toma) Florentina (2011), to do a comparison between periods with hydrological drought in Transylvania and Oltenia at the same time.

3. RESULTS AND DISCUSSION

Low water parameters depend on river water flow value decrease below a certain threshold, called quantitative threshold. These parameters can be divided into:

3.1. Temporal parameters

Temporal parameters include: **duration** (number of days with average daily flow value below low water threshold; cumulative, maximum values), **frequency** (percentage from the total number of cases when events' duration was within certain limits), **return period**.

3.1.1. Duration of low waters.

The periods with low water in the rivers from Suceava River Basin vary from one case to another. From Table 2 it can be seen that the most common ones are of short lenght (under 10 days), with values between 59.5% at Horodnic Station and 91.8% at Putna Station. The high value recorded at Putna Station is due to the fact that at this station, variations in flow are very fast, discharge values vary widely around the 80% threshold, here being recorded also the highest number of days with low water (329). It follows the duration of 10-20 days, but at long distance (between 5% Putna Station and 20% at Horodnic Station).

Table 2. The percentage of the total number of days with low water (%) for certain periods of time (in days) between 1981-2010 registered at the hydrometric stations from Suceava River Basin

Station	< 10	10 - 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70	70 - 80	80 - 90	90 - 100	> 100	Total (days)
Brodina 2	71,4	12,5	5,4	5,4	0,9	1,8	0,0	0,9	0,0	0,0	1,8	129
Țibeni	67,9	14,3	3,6	6,0	0,0	3,6	0,0	2,4	0,0	0,0	2,4	113
Iţcani	79,2	9,4	4,7	3,4	1,3	0,0	0,0	0,0	0,0	0,7	1,3	180
Brodina 1	72,5	16,7	5,1	2,2	2,2	0,0	0,0	1,4	0,0	0,0	0,0	168
Putna	91,8	5,0	2,1	0,4	0,0	0,0	0,4	0,0	0,0	0,4	0,0	329
Horodnic	59,5	20,2	7,1	4,8	4,8	0,0	0,0	1,2	0,0	1,2	1,2	112
Părhăuți	71,6	13,8	6,9	3,4	0,9	0,0	0,9	0,9	0,9	0,0	0,9	144
Șcheia	80,6	11,2	4,1	1,0	0,0	2,0	1,0	0,0	0,0	0,0	0,0	172

Intervals of more than 70 days are less common in the basin, as they appear only in certain periods of very dry times in terms of hydrology and climate.

If an analysis of uninterrupted periods where the river was under the threshold (Table 3) is made, it can be seen that there is a direct link between the location of the stations and the number of days with low water. Thus, at the stations from the mountain (Brodina 1 - the lowest uninterrupted period of low water = 77 days, and Brodina 2), the number of days is smaller, and overlaps the winter of the years 1983-1984 (November - March).

Table 3. Maximum number of uninterrupted days with low waters for the period 1980-2005 at the stations from the Suceava River Basin

Station	Maximum day number with low waters	Registration period
Brodina 2	137	13.11.1983 - 28.03.1984
Țibeni	163	18.06.1987 - 27.11.1987
Iţcani	108	05.11.1986 - 20.02.1987
Brodina 1	77	11.01.1984 - 27.03.1984
Putna	100	09.12.1986 - 18.03.1987
Horodnic	115	14.08.1990 - 06.12.1990
Părhăuți	156	12.07.1990 - 14.12.1990
Șcheia	80	05.01.1999 - 25.03.1999

The stations in the transition sector show higher values (the longest recorded period at Ţibeni Station - 163 days), these periods overlapping the summer and fall of 1986 (Ţibeni) or over the summer and autumn of 1990. At the Şcheia Station there is a special situation, the maximum number of days being recorded in the winter of 1999. It can be said that the two major periods with drought that affected Romania between 1980-2005 had strong damages over the basin, the most dangerous being the low waters that occurred during the summer of 1987 (Ţibeni) and 1990, strongly affecting crops.

Date of appearance of low waters **.**The average appearing date of the low water period is the date in which the value of average daily river flow falls below a pre-stated threshold. Along with the occurrence date of the low water period, it can be established the average end date of the period of low waters and the extreme data of appearance and disappearance of the low water period.

3.1.2.Frequency.

Daily frequency over the period 1981 - 2005 at the stations from the transition and plateau sector presents a decrease, and a more uniform distribution of low water periods throughout the year, especially at Putna, Ţibeni, Horodnic and Părhăuţi stations.

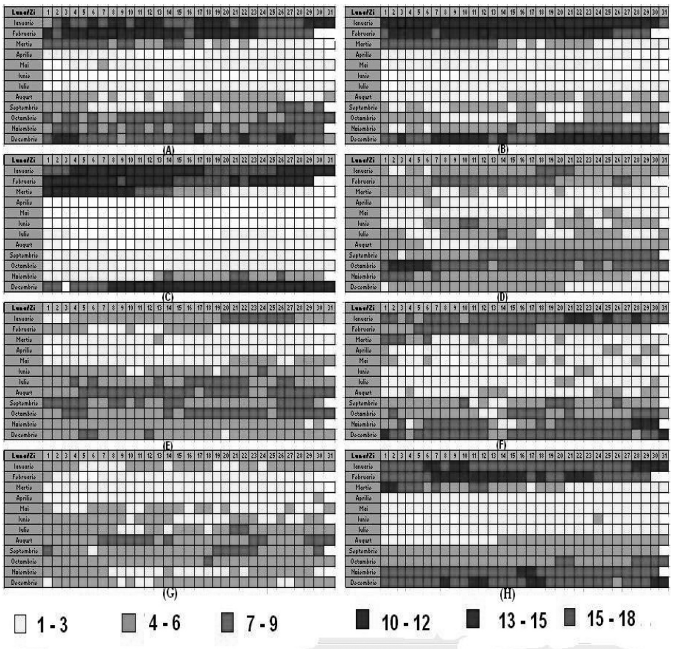

Figure 1. Daily number of cases of days with low waters between the interval 1981-2010 at the stations Brodina 2 (A), Ţibeni (B), Iţcani (C), Brodina 1 (D), Horodnic (E), Părhăuţi (F), Putna (G) and Şcheia (H)

Between 15 and 18 cases/day (from a total of 25 cases) are registered only at one station – Iţcani (January (18-25) and February (9, 15-20, 22) (Figure 2); these values are influenced by the fact that the discharge values from this station are reconstituted. 13 to 15 cases day were registered only at the stations on the main course (Brodina 2 Ţibeni, Iţcani) in January and February, at Iţcani station appearing also in December. This is determined by the fact that the already low water quantities from the river are used on domestic and industrial purposes by industrial units and residents of localities situated on the Suceava River (Suceava, Liteni, etc.). Values between 10 to 12 cases/day are recorded also, in addition to the aforementioned stations, at Brodina 1 (October 2-6), Părhăuţi (January 21-23, 25, 28; November 28 to 30; and December 1st and 31st) and Şcheia stations (January 6-7, 9-10, 28 – 31; February 6-16, 18, 21 – 23; March 1-2; November 16 – 17; and December 8, 11-12, 16-17, 30-31). These stations are located only on tributaries, the many recorded cases at Şcheia Station being determined by the small surface of the basin and the reduced length of this river, which responds more quickly to any change in the climate.

Monthly frequency. At the stations in the upper mountain sector (Brodina 1 Brodina 2), the month with most periods of low water is January, followed by December and February, with over 60% of cases, reaching even a maximum of 84% in December to Brodina 2 Station (table 4). This phenomenon is caused by the lower temperatures in the winter months. A similar situation occurs at Iţcani Station, where the water is regulated by the reservoir located upstream of this station. At the stations from the transition and plateau sector, the month with most cases is January.

Table 4. Monthly frequency (%) of cases with low water at the stations from Suceava River Basin

Station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Brodina 2	80	88	52	0	0	0	0	16	12	20	48	84
Ţibeni	52	32	24	20	28	36	48	48	44	44	32	44
Iţcani	72	64	44	8	20	20	16	32	32	44	48	68
Brodina 1	72	76	56	16	16	12	20	24	32	32	60	76
Horodnic	80	52	52	32	40	28	24	36	52	48	60	72
Părhăuţi	48	44	36	24	24	40	48	40	44	40	36	28
Putna	60	56	44	12	24	24	28	20	32	32	44	60
Şcheia	52	36	28	16	32	40	44	40	36	36	44	52

The difference between stations is given by the percentage of the summer months, with lower values in the mountain sector (up to 20%), even lacking at the Brodina 2 Station (April-July). At the stations from the trasition and plateau sectors, the periods with low water occur more often during the summer, due to the drier climate in these sectors. The month with the lowest values is April, at all stations, being the month in which high waters have the highest frequency.

Seasonal frequency. In the Suceava River Basin, periods of low water occur mostly in *winter* (Figure 2), when rainfall is low and very low air temperatures help to the appearance of lower quantities of water drained, due to the appearance of frost.

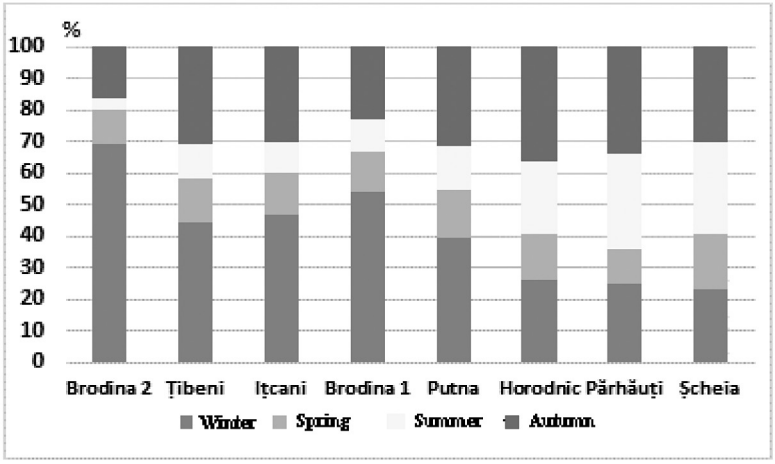

Figure. 2. Seasonal frequency of days with low waters at the stations from Suceava River Basin

In this situation, the rivers are supplied only by underground water reserves, leading to the emergence of low waters. 69.3% of the total number of days with low water are registered at Brodina 2 Station in the period 1981-2005 in this time of year, while at Brodina 1 Station there were registered 54% of the cases, at these two stations being registered 40% of the total cases of low water during this season. On the transition and plateau sectors of the basin, the values recorded in this season decline, reaching a low at Şcheia station, of 22.8%, due to higher amounts of precipitation and higher temperatures recorded in these sectors, making the rivers freeze to occur less frequently, thereby increasing the discharge of water drained on these rivers. If it is made an analysis of the total number of days with low waters by season recorded in the basin, it can be noted that in the 25 years of analysis, the station Brodina 2 were recorded 1,200 such days, followed by Brodina 1 to 987 days, the less days occurring in Şcheia station - 353 (Table 5). But the station where occurred most days with low water in a year is Țibeni station, with 90 days in 1986.

Table 5. Total, average and maximum seasonal number of days with low waters and the year of … of minima for the interval 1981-2005

Station	Winter				Spring				Summer			
	Total	Average	Max	Year	Total	Average	Max	Year	Total	Average	Max	Year
Brodina 2	1200	48	86	1984	191	7,64	29	1984	62	2,3846	24	1987
Țibeni	768	30,72	90	1986	246	9,84	56	1986	188	7,2308	51	1987
Iţcani	768	30,72	88	1990	217	8,68	57	1990	161	6,1923	56	1987
Brodina 1	987	39,48	82	1984	231	9,24	36	1990	195	7,5	77	1994
Putna	622	24,88	69	1987	242	9,68	54	1991	223	8,5769	60	1993
Horodnic	414	16,56	67	1983	227	9,08	72	1987	368	14,154	92	1987
Părhăuți	422	16,88	63	1991	181	7,24	69	1990	507	19,5	80	1995
Şcheia	353	14,12	55	1995	279	11,16	80	1996	447	17,192	75	1995

	Autumn				Total			
Stație	Total	Average	Max	Year	Total	Average	Max	Year
Brodina 2	278	11,12	75	1994	1749	69,96	165	1987
Țibeni	541	21,64	91	1990	1817	72,68	299	1987
Iţcani	498	19,92	91	1990	1814	72,56	278	1990
Brodina 1	416	16,64	84	1987	1803	72,12	204	1994

Spring is the season in which there have been recorded, on average, the fewest days with low water, this being due to the large, constant quantities of rainfall in this season, but also to the gradual melting of snow, which maintained rivers water supplies at higher values. The frequency of low water periods during the spring ranges between 10.7% at Părhăuți Station and 18% at Şcheia Station, where they reached a total of 279 days with low water. The highest values were recorded also at Şcheia Station - 80 days in 1996, while the lowest values (29, respectively 36 days) occurred at stations of the mountain sector – Brodina 2, respectively Brodina 1.

In summer, low water have low frequency values, close to those of spring, but the values vary greatly at the stations in the entire basin. Stations on the main course and from the mountain sector (Brodina 2 Țibeni, Iţcani, Brodina 1) present values lower than 10%, with a minimum of 3.6% to Brodina 2 Station, here having a much higher percentage the low waters from winter. In the mountain sector fall heavy rainfall quantities during summer and lower than the national average temperatures for this month keep the evaporation at low levels, resulting in a smaller frequency of low waters in this area during summer. Rivers from the transition and plateau sectors are strongly affected by the high temperatures during summer, by the increased evapotranspiration and by the agricultural activities from these sectors; they present very high frequency frequency values of low waters during this season, with a 30.1% maximum Părhăuți Station, and a total of 507 days. The highest number of days with low water in one year was recorded at the Horodnic Station – 92 days in 1987, in this year being recorded only 24 summer days with low water at Brodina 2 Station.

The values recorded during summer on the tributaries from the plateau and transition sector are even higher than in autumn, causing a secondary minimum.

Autumn is the second season with low water after winter; this is due to the higher temperatures, determining higher evaporation rates, and lower rainfall this season, which reduce the amount of water in rivers. The frequency ranges from 16% at Brodina 2 Station (278 days) to 36% at Horodnic Station (578 days), more than 30% of the total being recorded at all stations in the transition and plateau sector, they increasing from the mountain to the plateau sector. At three of the stations in the basin - Țibeni, Iţcani and Părhăuți – has being reached a maximum of 91 days (full season) during 1990.

3.1.3 Return period

Frequency analysis of extreme hydrological event contains several items related to the likelihood of an event. Period of return (recovery) (T) of an event is the period (in years) when an event of a certain intensity may occur in the basin.

The analysis of the frequency of an event was calculated based on the daily flow analysis using log-normal law of probability at a confidence level of 95%. The size of the estimated number of hazard on the basis of the period of return quantiles (xT) (Holobâcă, I, 2006).Quantiles were analyzed for the return periods of 2, 5, 10, 20, 50 and 100 years (Table 6).

Table 6. Quantiles x_T for the return periods of 2, 5, 10, 20, 50, 100 years for minimum daily discharges

River	Station	T2	T5	T10	T20	T50	T100
Suceava	Brodina 2	2.65	5.93	9.05	12.8	19	24.6
Suceava	Țibeni	5.7	13	19,8	30	39	54,7
Suceava	Iţcani	8.8	20	30.6	43.6	65	84.7
Brodina	Brodina 1	0.96	2.14	3.24	4.57	6.73	8.71
Putna	Putna	0.36	0.81	1.23	1.74	2.56	3.32
Horodnic	Horodnic	0.35	0.62	0.85	1.1	1.46	1.76
Soloneț	Părhăuți	0.69	1.46	2.15	2.97	4.27	5.43

3.2. Quantitative parameters

Quantitative parameters include*:* **severity of low water** (volume necessary to regularize at the level of average daily flow threshold), **minimum discharge**.

3.2.1. Minimum volume

Hydrological drought severity is determined by flow deficit, meaning the amount of water necessary to regularize a river at the average daily flow threshold (Holobâcă, 2006). For this water basin there were analyzed the *average severity of low water* over the period 1981-2005 and the maximum severity recorded during this period (Table 7).

Table 7. Some parameters of low flow in Suceava River Basin

Station	Q min.	Year	Average Cumulated Deficit	Maximum Cumulated Deficit	Year	Mximum deviation
Brodina 1	0.14	1991	0.08	1.13	1987	-0.31
Brodina 2	2.12	2001	0.38	6.86	1984	-0.89
Putna	0.027	2002	0.02	0.75	1987	-0.14
Horodnic	0.088	1987	0.05	0.72	1987	-0.13
Țibeni	0.01	1987	1.54	46.31	1987	-2.69
Părhăuți	0.103	1990	0.11	2.48	1990	-0.31
Ițcani	0.2	1995	1.06	26.72	1990	-3.78
Șcheia	0.03	1987	0.15	0.55	1999	-0.08

It can be seen that the highest values of minimum volume are in direct correlation with the average flow of the river, with the highest values recorded on the main water course. However, it can be noted that the values at Țibeni and Ițcani stations, located on the Suceava River in the plateau sector, are pretty close, which is determined by the high population degree of these sectors in the bed of the main course, but also by the presence of the city of Suceava as county capital, which by its economic needs, resulted in the construction of Mioveni mobile dam and of other chain of lakes, which reduce the volume of water drained on the main river downstream of the Mioveni Dam.

The maximum severity was assessed based on the aggregate volume during low water periods, registered under the 80% threshold. These distinct peaks occur in two years (1987, 1990), which represented the most severe drought years when in the basin in 1987 recorded most cases. This was the most severe drought in the basin, being a widespread drought across the country (Table 7).

3.2.2. Daily minimum discharge

Daily minimum discharge recorded in the period 1981 - 2005 at the stations from Suceava River Basin is closely correlated with the maximum deviation from the threshold value (80%) considered above. The largest deviations were recorded at Ițcani and Țibeni stations, where appeared the longest periods of low water. It can be seen that the driest periods in this hydrographic basin were concentrated in the winter, with the exception of stations in the plateau, where they appear in the autumn, with a minimum in

The maximum deviation is directly correlated with the maximum discharge, representing the deviation from multiannual discharge registered to a certain station. Compared to the maximum deficit, it can be seen that the maximum deviation is the largest at Ițcani Station, and not at Țibeni Station, showing the influence printed

by the presence of Mioveni movable dam and of the chain of lakes on the River Dragormirna held around the city of Suceava, showing the anthropic nature of the regime at this station.

CONCLUSIONS

If we look at the whole period 1981 - 2005, it can be seen that most years with low water were 1983-1987, when were recorded the highest maximum values during winter, summer and autumn, especially in 1987 and 1990, years with strong droughts throughout Romania. The 1986-1987 winter was the poorest in drained water flow at Țibeni Station, Suceava River drying out surprisingly between 12/02/1986 - 25/03/1987 (the flow occurred in three days, during 22-24.02.1987). Also, in the same year, the stations on the smaller rivers in the transition and plateau sectors (Horodnic, Părhăuți, Șcheia) attained lower discharge values, close to zero. This caused big problems in the water suppling of cities and a very drastic reduction of agricultural crop in 1986, 1987 and 1990.

The years 1995 - 2000 were evidenced by a reduction in periods of low water, the smallest values being registered in 1999, when, at Țibeni, Iţcani, Horodnic and Părhăuți stations there were registered no day with low water and at Brodina 1 and Putna stations there were registered 9, respectively 5 days with low water.

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