"BABEȘ-BOLYAI" UNIVERSITY CLUJ-NAPOCA
GEOGRAPHY FACULTY
GEOGRAPHY DOCTORAL SCHOOL

PHD THESIS

STUDY OF URBAN HYDROLOGY IN THE MUNICIPALITY OF SATU MARE

- SUMMARY-

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Summary

CHAPTER I. INTRODUCTIVE ASPECTS

I.1. Geographical position and limits of Satu Mare municipality

Satu Mare is located in the north-western extremity of Romania, at the intersection of the 47°47'30" north latitude with the meridian of 22°52'30" east longitude. It developed in the central sector of the Someș Plain, at an average altitude of 125 m (NMN).

From the administrative point of view, the city is the residence of Satu Mare County (Fig. 1), belonging to the North-West Development Region. The low plain of Someș, on which the city of Satu Mare was crafted, occupies an area of about 1800 km^2 with a slight inclination from the east to the west.

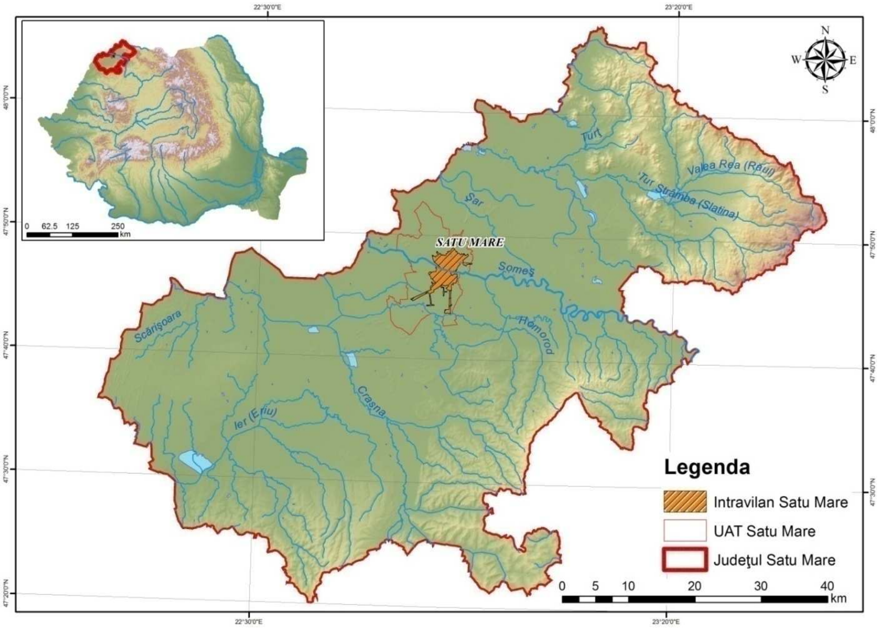


Fig. 1. Geographical position of Satu mare municipality in the Romanian territory and in the county

From a physico-geographical point of view, Satu Mare municipality (UAT) overlaps the Someș' meadows and terraces, extending spatially along both river banks. The city is situated at a distance of about 13 km from the internal border of the European Union with Hungary towards west and about 28 km from the border of the European Union with Ukraine towards north.

Hydrographically, the city is located in the lower section of the Someș River, about 15 km upstream of the river's exit from Romanian territory and about 40 km upstream of its confluence with Tisa River. The northern municipality sector grafted on the right bank, has grown around the old urban medieval nucleus, and the southern sector, more recently, has developed over the last 60 years. The municipality of Satu Mare is administratively delimited by the communes: Dorolţ, Vetiş, and Doba to the west; Lazuri to the north; Viile Satu Mare, Terebeşti and Ardud City, to the south; Odoreu, Botiz and Păuleşti, to the east. The physico-geographical limits of the urban area are difficult to trace due to the uniformity of the natural frame characteristics.

The emergence of the incipient nucleus and the subsequent development of the municipality was favored by the collaboration of several factors, among which the *relief*, favorable through its flatness, *the fertile soils, the presence of Someș River* as an important hydrographic axis, and *the convergence of the communication routes* in the region.

I.2. Metodology and data base usrd in the thesis elaboration

I.2.1. Research

The subject of the study was carried out on several stages and main research directions: the stage of documenting and collecting the necessary informative material; stage of field research and documentation; the data processing stage, graphic and cartographic materials as well as the documentary observations and research carried out; the stage of elaboration, analysis and interpretation of the obtained results.

The research was carried out starting with the identification of the spatial geographical particularities of the Satu Mare (UAT) municipality. We used a series of research methods: the method of analysis (statistical analysis of data strings, cause-effect analysis); the comparative method (comparative analysis of the spatio-temporal differences of the manifestation of the climatic geographical elements); observation method (significant phenomena and processes for the analyzed geographic area - observed and photographed); synthesis method (analysis and interpretation of processed data); statistical method (calculation of statistical indicators of the climatic, hydric, demographic parameters; territorial balance, water balance, etc.); the method of data diagrams used.

I.2.2. Data base

Several types of data were used for the elaboration of the thesis: meteorological, hydrological, cartographic, geospatial, demographic, historical and socio-economic data.

Cartographic database. For mapping of the present study, topographical maps (1:25000), vegetation and land use maps (processed under the Corine Land Cover project), the EU-DEM geospatial database, thematic maps and sketches based on which were developed spatial reconstruction of the urban territory and hydro-technical works (https://maps.hungaricana.hu, Satu Mare County Museum, Satu Mare National Archives and Satu Mare County Council), maps of the floodplains in the Someş basin (SGA SGA, County Council Satu Mare), maps of the evolution of surface waterproofing (https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness), maps of the spatial distribution of the water supply and sewerage network (APASERV SA), etc.

Climate database. Data were recorded by the Satu Mare metrological station, the Satu Mare hydrometric station and the Turulung pluviometric stations, Supuru de Jos, Dara, Hrip and Micula. Climatic data from the meteorological station Satu Mare were processed according to the ROCADA program gridded daily climatic dataset over Romania (1961-2013) for nine meteorological variables, 2015.

Hydrological database. Primary hydrological and hydrogeological data were obtained from SGA SGA. Hydrogeological data were used in the project: *NATO-SQUASH PROJECT Quantitative and Qualitative Hydrogeological Study of the Alluvial Aquifer of Someș-Szamos, Romania-Hungary, 2004*. The hydrological parameters of the Someș river used in the present study are quantified by the Satu Mare hydrometric station. The primary hydrogeological data was processed after the observation drills of SGA SGA located in the localities Amaţi, Atea, Ruseni and Botiz.

Demographics database. The demographic data on the numerical evolution of the Satu Mare population were obtained from the Satu Mare County Statistics Department, the Satu Mare County Museum and the database http://statistici.insse.ro.

Socio-economic database. Primary data on the territorial structure of the investigated urban area were obtained from the City Hall of Satu Mare Municipality and the Satu Mare County Council. Data obtained from the National Archives of Satu Mare were used. Data bases related to the structure and temporal-spatial evolution of capture, feeding, sewage and treatment systems were obtained from APASERV S.A. Satu Mare. The data provided by SGA Mare SGA were used for water risk analysis.

Photographic database. The photographic images used in the thesis were taken from the personal photo archive, the personal photo archive of Dr. Pop Ovidiu Tiberiu, the photo archive of the Satu Mare County Museum and https://portalsm.ro.

I.3. Geographical particularities of Satu Mare municipality

I.3.1. Particularities of the substrate and the geomorphical characteristics

Among the major fractures in the studied region are the Ardud rise, which is a *horst*-like structure reaching some 500 m deep and the sinking of Satu Mare, a symmetrical and longitudinal gravel structure of the Someș River (Ţenu, 1981). In the area of Satu Mare, there are higher chalk deposits represented by micaceous limestone sandstone in alternations with marsh and shaley shrimp clays (Pelin et al., 1969, quoted by Miklos, 2005). Sedimentation of the compartments continued in the paleogene. The petrographic composition corresponding to the series, contains paleogenic sediments represented by alternations of black clays, polygonal conglomerates, eocene and oligocene sandstones and marches, with thicknesses varying between 400-600m. The mio-pliocene layer has about 1000 m thick and large varieties of facies, revealing different stages of the plain's evolution.

The Miocene begins with the Badenian represented by volcanic tuft intersections from the Oaș-Gutâi chain eruptions. Sarmatian is represented by sands, carbonate clays and conglomerates (Posea, 1997). The Panonian has appreciable thicknesses of over 1,000 m, being represented by sands, gravel, sandy marls, volcanic tuffs and muddy clays. The sedimentary series ends with a quaternary fluvial alluvia and wind deposits. The upper pleistocene is represented by alternations of pebbles, sands and marshes that cantonate aquifers. The stratigraphy of the area reveals a cover made up of clays, sands and gravel of inferior Holocene age and disseminated upper pleistocene loessoid deposits with a depth of up to 150 m **(Figure 2)**. Along the Someş Valley there appear higher Holocene deposits, consisting of a pile of sand, gravel and clay with a thickness of up to 10 m that belong to the river bed. In the formations of sand and gravel, important aquatic streams have been set up, which supply Satu Mare with drinking water.

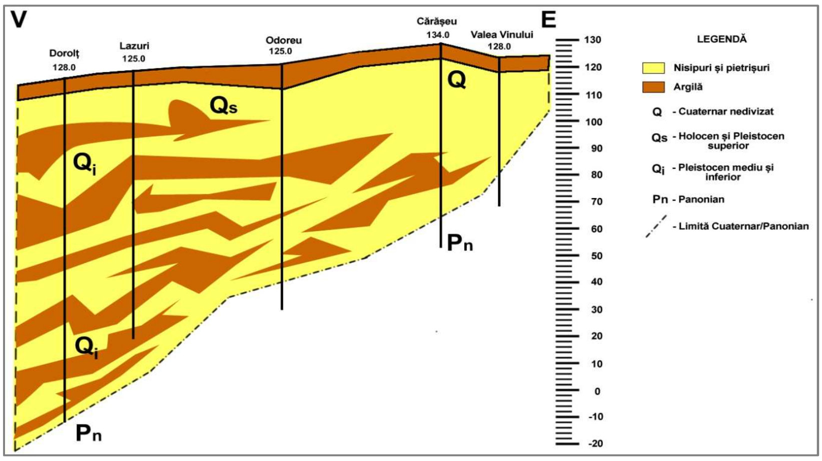


Fig. 2. East-west geological section in Satu Mare municipality.
(Source: after NATO-SQUASH PROJECT Quantitative and Qualitative Hydrogeological Study of the Alluvial Aquifer of Someș-Szamos, Romania-Hungary).

The territory of Satu Mare is crafted on three sub-units of the Someş Plain, namely the *Micula Plain, Someş-Homorod Plain and the Ecedea Plain* **(Figure 3)**.

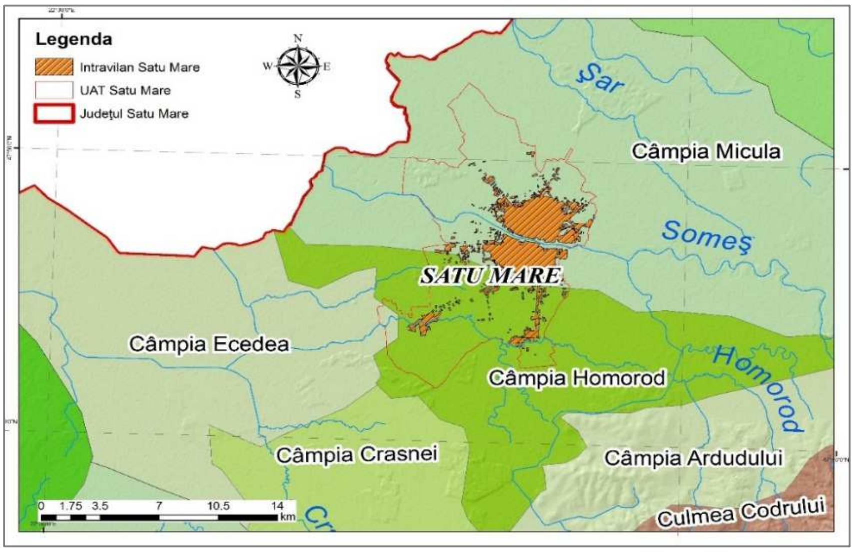


Fig. 3. Subdivisions and relief units that characterize the geographical space of Satu Mare municipality.
(Source: after Posea, 1997; http://www.geo-spatial.org/download/romania-seturi-vectoriale#limita_unitati_relief).

The plain has a slight slope from the southeast to the northwest, with two steps in relief: the eastern plateau in the east and the western plains, separated by a line connecting the towns of Porumbeşti, Micula, Satu Mare and Mădăraş (Roșu, 1973).

The *Micula Plain* extends north of Someș, on the right bank of the river, which is bounded north of the Tur Plain. The eastern part of the plain overlaps with the high meadow and the western part overlaps with the low meadow. The *Someş-Homorod Plain* extends south of Someș, on the left bank of the river, as a result of Someș's action and of some valleys, such as Homorod Valley and Bălcaia Valley. The weak fragmentation of the relief is due to the presence of small valleys like Homorod, or drainage channels. The *Ecedea Plain*, is a plain appeared on the former Ecedea swamp. The relief of this field is dominated by the elevations with the appearance of blurred beams, small alluvial depressions (formerly abandoned courses) and drainage channels. The absolute elevation of the urban perimeter is between 118.8-130.8 m, descending to 115-118 m in the small Someș bed, the Homorod Canal, and the main drainage channels.

I.3.2. Climatic particularities

The analysis of non-periodic variations over a period of 53 years, between 1961 and 2013, reveals an average annual temperature of 9.6°C at the Satu Mare meteorological station. The graphical representation reveals an alternation between the cooling periods and the heating periods, having slight thermal oscillations. The trend of annual average growth is evident, especially since 1995, when the average annual temperature passes in some cases by 11°C **(Figure 4)**.

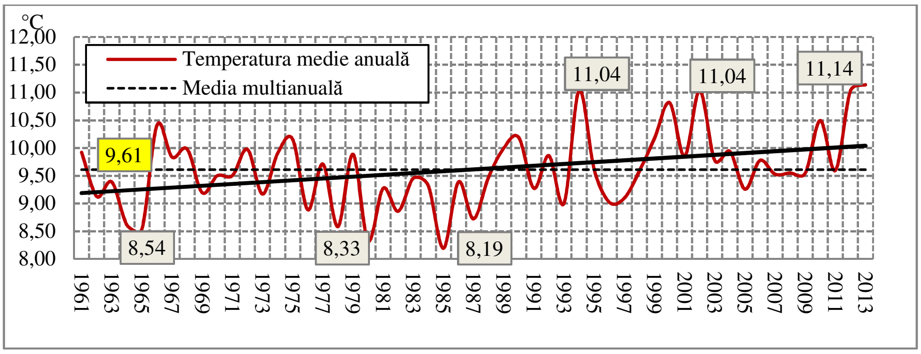


Fig. 4. Variation of annual average temperatures and the evolution trend at the Satu Mare meteorological station, in the interval 1961 – 2013.
(Source: Dumitrescu, Bârsan, ROCADA: a gridded daily climatic dataset over Romania (1961–2013) for nine meteorological variables, 2015).

The pluviometric regime in Satu Mare is influenced by a dominant western air circulation due to the oceanic influence. The 1961 - 2013 range has a multi-annual average of 615 mm of atmospheric precipitation. For the municipality of Satu Mare, 1974, 1980, 1998, 2008 and 2010 are noted as rainy years with precipitation exceeding 800 mm / year, and 1961, 1969, 1971, 1973, 1975, 1976, 1992 with low precipitation below 500 mm/year.

The pluviometric fluctuations are due to the alternation of the years in which cyclonic and convective activity was manifested more markedly with years in which the blocking circulation and the anti-cyclonic regime persisted. The maximum value of the period was recorded in 2010 with a cumulative rainfall value of 995.6 mm. The minimum value was recorded in 1961 with only 378.1 mm, a value well below the multiannual average of the studied territory **(Figure 5)**.

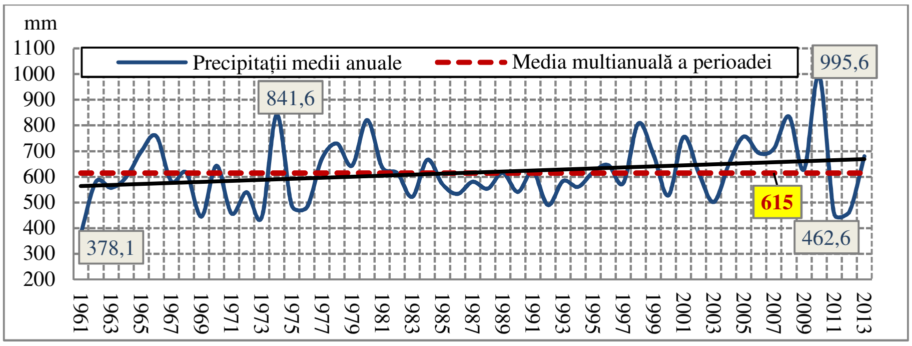


Fig. 5. The variation of annual average rainfall quatities compared to the multiannual averageand the their evolution trend at Satu Mare meteorological station, in the interval 1961 – 2015.
(Source: Dumitrescu, Bârsan, ROCADA: a gridded daily climatic dataset over Romania (1961–2013) for nine meteorological variables, 2015).

In order to establish a pluviometric region in the Someş Plain area and the impact on the amount of precipitated rainfall, we carried out a comparative study between the pluviometric stations Supuru de Jos (southern compartment), Satu Mare (Central compartment) and Turulung (Northern compartment) **(Figure 6)**.

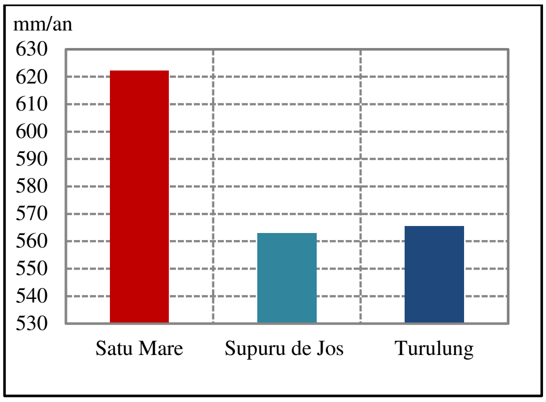


Fig. 6. The distribution of multiannual rainfall quantities in Someş Plain at the Satu Mare, Supuru de Jos and Turulung, pluviometrice stations in the interval 1965 – 2016.
(Source: SGA Satu Mare Archive)

I.3.3. Hydrographic particularities

The hydrographic network of the territory of Satu Mare includes all the hydrographic units that transit through the area, represented by the *Someş River*, the alohton river that crosses, in the east - west, the town and a series of small valleys, among which *the Homorod* that crosses over a length 2.5 km of Satu Mare and *Bălcaia Stream* **(Figure 7)**. **The Someş River** is an altohton river but it is remarkable as a significant hydrographic axis of the perimeter studied. The river basin of Someş is extended on an area of 15740 km^2 of which 15217 km^2 on the territory of Romania. The total length of Someş is 427 km, of which 376 km in Romania and 51 km in Hungary. The annual spill has large variations from one year to the next depending on the variability of climatic factors. Changes in annual average flow over multiannual average flows show significant positive and negative deviations. High values of annual average flows with a positive deviation of more than 50 m^3/s from the multiannual average were recorded in 1970 (242 m^3/s), 1974 (185 m^3/s), 1980 (200,4 m^3/s) 1981 (185 m^3/s), 1998 (197.3 m^3/s), 1999 (197 m^3/s), 2006 (191.7 m^3/s) and 2010 (215 m^3/s) (76.3 m^3/s), 1961 (53.8 m^3/s), 1963 (78.1 m^3/s), 2003 (79.4 m^3/s), 2012 (70.0 m^3/s) **(Figure 7)**.

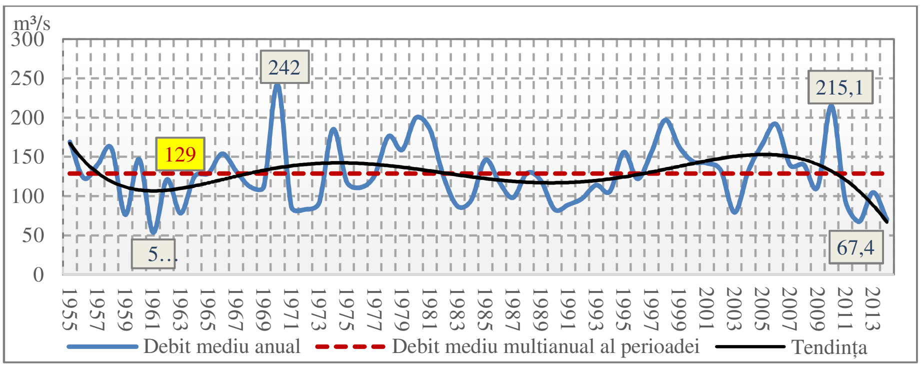


Fig. 7. The variation of annual average discharges compared to the multiannual average discharge of Someş River at Satu Mare hydrometric station and their trend in the interval 1955 – 2014.
(Source: SGA Satu Mare Archive).

The graphical analysis **(Figure 8)** of the evolution of the annual maximum flows reveals years with high values (1962, 1964, 1970, 1974, 1978, 1981, 200 and 2001), with the year 1970 being noticeable. 1959, 1960, 1961, 1990, 2012 and 2014, years in which maximum flows did not exceed 300 m^3/s.

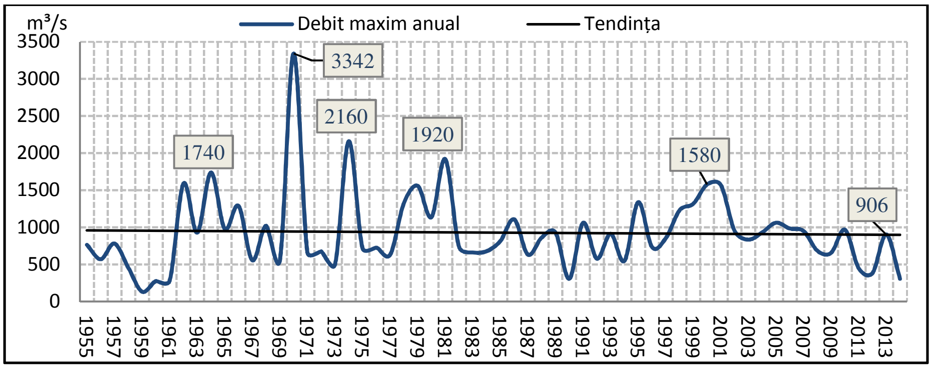


Fig. 8. The repartition of annual maximumdischarges on Someş River and their evolution trend at Satu Mare hydrometric station in the interval 1955 – 2014.
(Source: SGA Satu Mare Archive).

The annual variation in minimum flows shows oscillations due to the evolution of the meteorological phenomena in the basin. It is worth mentioning the years 1961, 1967, 1972, 1983 and 1986 with annual annual flows below 10 m^3/s as years of water shortages. With high annual flow rates above 50 m^3/s the years 1981 and 2010 are highlighted **(Figure 9)**.

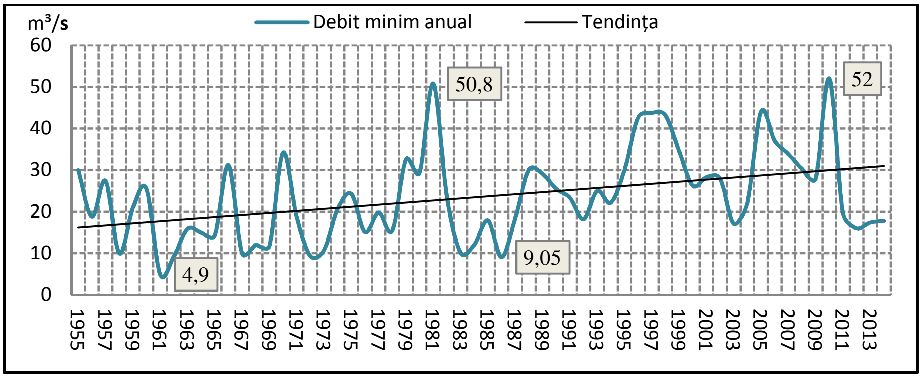


Fig. 9. The repartition of annual minimumdischarges on Someş River and their evolution trend at Satu Mare hydrometric station in the interval 1955 – 2014.
(Source: SGA Satu Mare Archive).

Underground waters. After genesis and hydrogeological conditions, groundwater falls into: ***phreatic waters and deep water***. ***The phreatic waters*** are located in the poroscopic permeable, Holocene-Pleistocene age deposits in the alluvial cone development area of the Someş River to a depth of approximately 25-30 m. The aquifer consists of sands mixed with pebbles and boulders, whose granulation decreases from east to west, with lentiliform interlayers or sandy and clayey stratiforms. The phreatic aquifer is continuous, with thicknesses varying between 5 and 15 m, rising from east to west. In the perimeter of Satu Mare, the phreatic waters are located at relatively low depths, namely 2 - 3 m on the left bank of the Someş, especially in the Balta Blondă and Curtuiuş area, and at depths of 3 - 45 m, on the right bank of the river. The intra-annual variation of the piezometric surface of the observation drills in the proximity of Satu Mare municipality is shown in **Figure 10 a, b, c, d**.

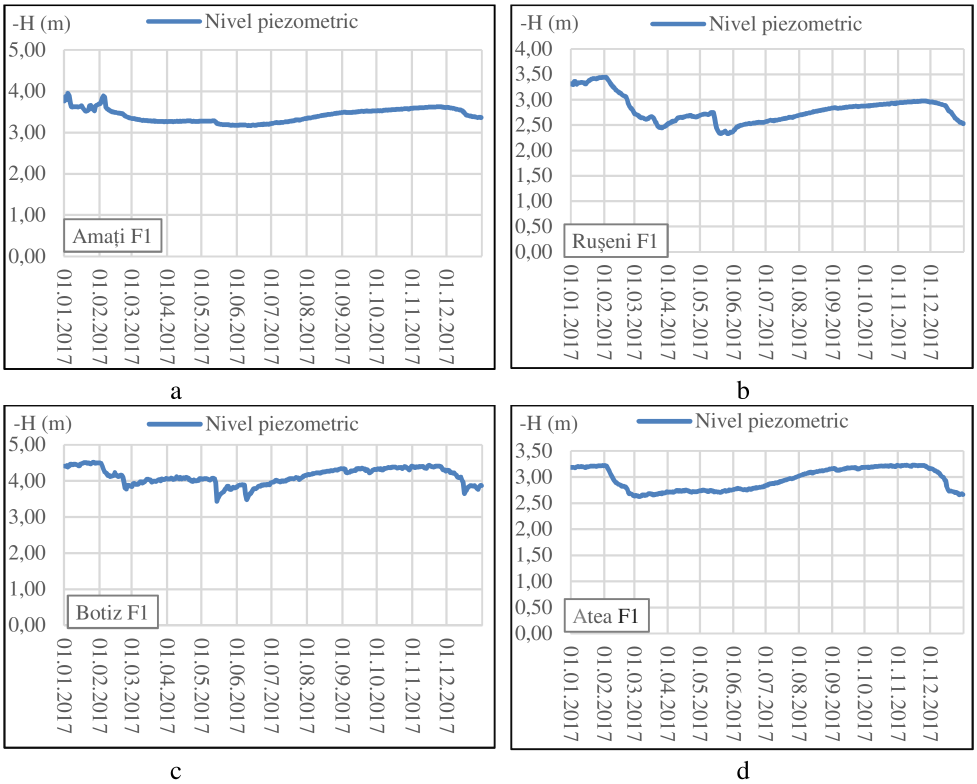


Fig. 10. Intraannual variation of phreatic piezometric level around Satu Mare municipality on the left (a, b) and right bank (c, d) Someș. (Source: Archive SGA Satu Mare).

Medium size underground waters are located at depths between 30 m and 50 m in the eastern part and between 30 m and 120 m to 130 m in the western extremity. (by: NATO-SQUASH PROJECT Quantitative and Qualitative Hydrogeological Study of the Alluvial Aquifer of Someș-Szamos, Romania-Hungary, 2004). The general direction of groundwater flow is: east - west with infiltrations of hydroisoises of up to 2 m, determined by the influence of the capture fronts Mărtinești - Micula and Doba **(Figure 11)**.

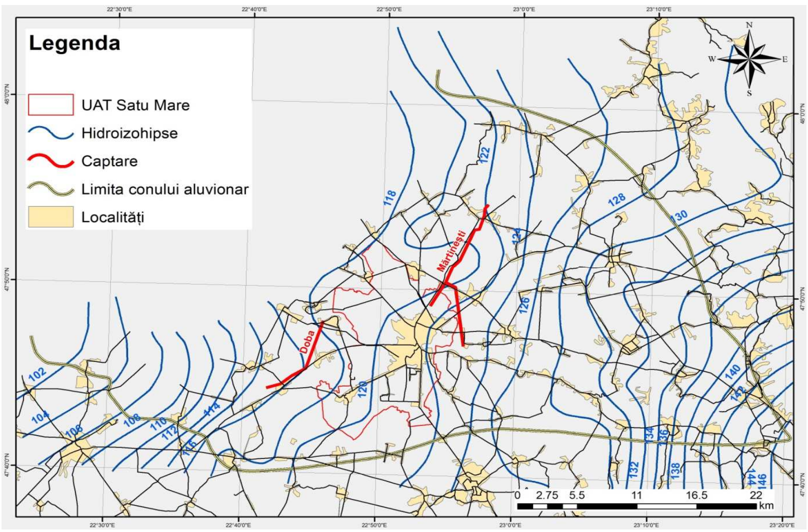


Fig. 11. The distribution of hydro-izohypse in the medium depth aquipher of the Someș River alluvial cone. (Source: after NATO-SQUASH PROJECT Quantitative and Qualitative Hydrogeological Study of the Alluvial Aquifer of Someș-Szamos, Romania-Hungary, 2004).

Deep thermal waters develop in the permeable formations of the lower Pontian, with some probable passages in the upper part of the Pannonian. From a lithological point of view, the complex consists of a series of permeable psamics interchanges alternating with fine sandy clays and clays. Permeable intersections are either in the form of layers or lenses, or in the form of sandy bodies in bundles resulting from conjugations and local effillations (Țenu, 1981). The aquifer has a slow dynamics of filtration speed of up to 0.5 m / year. The geometric values of the thermal aquifer complex are shown in **Table 1**.

Table 1. Geometric values of the Pontian thermal complex in the Satu Mare urban area.
(Source: after Țenu, 1981).

Drilling indicative	Absolute elevation of drilling (m)	Complex's depth (m)	Number of aquipher strata	Individual thickness of individual strata (m)	Q/m³	H (m)
4747 Satu Mare	$\frac{121}{1551}$	**692-1327**	**16**	**5-12**	**432**	**1446**
4748 Satu Mare	$\frac{124,4}{1497}$	**695-1298**	**13**	**5-18**	**449**	**1437**
4749 Noroieni	$\frac{126}{1431}$	**837-1384**	**22**	**1.5-4**	**216**	**1399**

I.3.4. Biopedogeographical particularities

The tabular plain with altitudes of 100-150 m, on which the city of Satu Mare was crafted, falls within the silviculture field (Rosu, 1973). Miklos (2005) frames the area at the boundary between the deciduous forest and the sturgeon forest. In the past, the forest vegetation was widespread, but anthroposis led to radical transformation of natural vegetation. Classification of soils in Someș Plain was carried out by Asvadurov and Boeriu, (1983) and by Miklos (2005). The spatial distribution of soils in the Satu Mare urban area is shown in **Figure 12**.

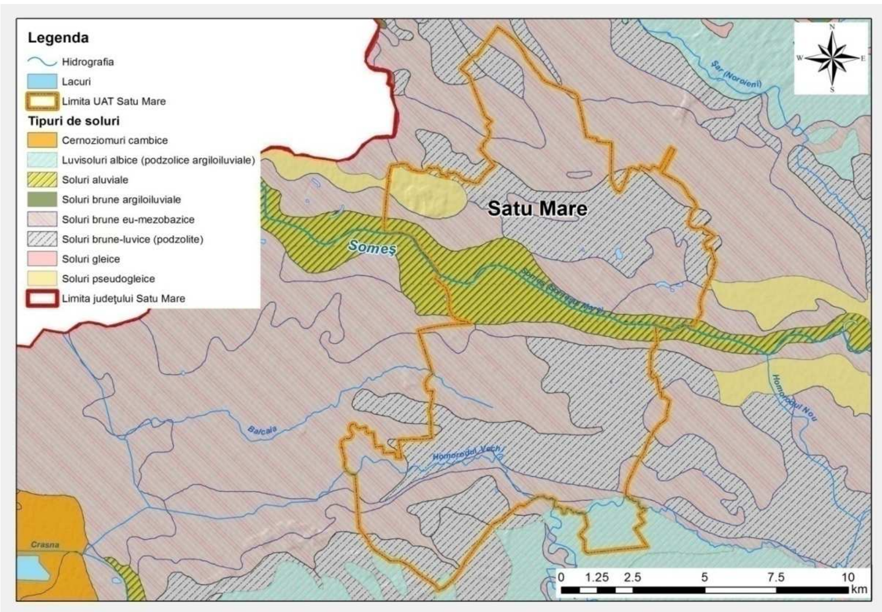


Fig.12. Spatial soil distribution in the Satu Mare urban area.
(Source: after Satu Mare City Hall Archive).

CHAPTER II. URBANIZATION DINAMIC

II.1. Spatial evolution of Satu Mare municipality

The emergence and evolution of the urban area was determined by the cooperation of the natural factors with the favorable historical and socio - economic ones. The first documentary attestation of the city of Satu Mare dates back to 972, being known in those days as Villa Zotmar. Documentary attestation as a well-defined locality appears like Castrum Zathmar (1213) or Castrum Zhotmar (1239). At the same time, on the opposite shore of Someș, another settlement, called Mintiu (Németi), was built. Satu Mare (Zhatmar / Zhotmar) was located south of a Someș River and Mintiu (Németi), north of Someș **(Figure 13)**.

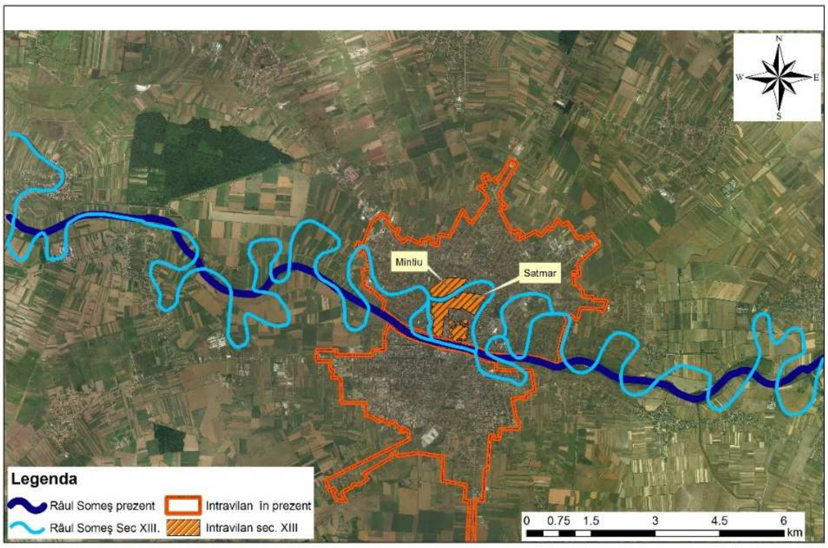


Fig. 13. The perimeter of the urban heart and Someș riverbed in XIII century.
(Source: reconstitution after Satu Mare County Museum and Satu Mare County Council Archive).

In 1760 it was decided to remove the arm separating the towns of Mintiu (Nemeti) and Satmar (Szatmar) through a closure dike. Prior to 1777, in the current urban perimeter (UAT), there were about 25 meanders downstream and 14 upstream (Radosav, 1984, Dancu, 2008). According to the reconstruction, the length of the bed totals in the 13th century, in the area of Satu Mare, about 64.8 km of meanders and arms, reaching the level of 2018, at a length of about 21.6 km. The course length in a straight line area is about 19.3 km, of which 14 km are integrated into the administrative territory of Satu Mare. In order to quantify the changes that occurred over time in the dynamics of Someș riverbed, in the area of Satu Mare municipality, the coefficient of meandering for the times represented graphically was calculated. Values less than 1.5 (Leopold, Wolman, 1957) include the river sector as the sinuous type of riverbed, and values greater than or equal to 1.5 are associated with the meandering riverbeds. Until 1850, Someș' bed was included in the type of meandered bed, following the rectification works to be included in the type of the sinuous river bed **(Figure 14).**

Thanks to the riverbed repairs, the old Someș' meander, which separated the towns of Satmar and Mintiu, was gradually restored, and its perimeter was gradually occupied by small orchards and small orchards, and is now largely built. The filling of the ditch's fortress and of the old meanders has been a long process, and the topography of the topographic surface is still observable.

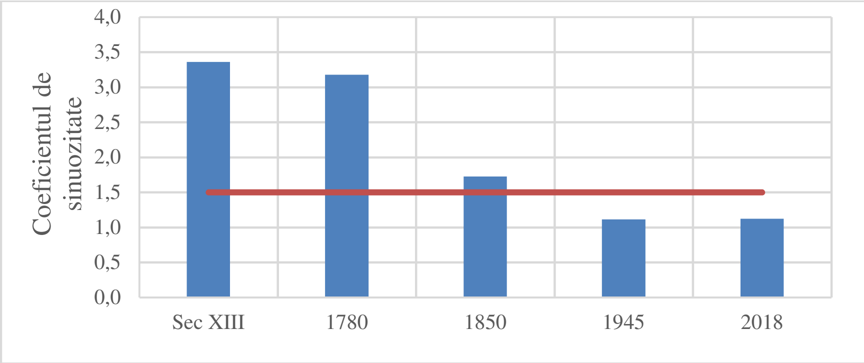


Fig. 14. Values of sinuosity coefficient of Someș River in different periods around Satu Mare municipality.

II.2. The structure of Satu Mare urban area

The structure of the functional areas of Satu Mare reveals the dominance of the inhabited areas (40%), followed by green and recreational spaces (15%), communication routes (14%), industrial units and warehouses (10%). With less weight, the other functional areas characteristic of metropolitan perimeters are noted **(Figure 15)**. On the whole, within the urban facies, the *central area* of the municipality includes the Old Town dominated by Freedom Square (Piața Libertății) at a distance of about 500 m north of the Someș River - the texture includes a central park arranged as a green space with promenade alleys and a built perimeter , consisting of old buildings built on its sides; with the exception of a few more recent constructions, the area largely preserves the old urban architecture - the area of the Old Center was extended to the Someș dam until the 1970s and 1980s, reducing itself as a surface by building the New Center; *the area of the middle quarters* makes the transition between the center of the city and the peripheral districts with a rectangular character, the streets being arranged parallel and perpendicular - this area is dominated by constructions made after 1960 with a peak of expansion in the years 1980-1990 dominating the blocks of flats P + 4, P +8 and P +10. The architecture is relatively homogeneous specific to the communist period; the *peripheral area* has a semi-rural character being relatively circular, the buildings being the type of dwelling houses with a more recent level with P +1 or P+M regime - the urban landscape is dominated by households with gardens and small orchards; the shopping area has expanded particularly over the past 20 years by building supermarkets and malls expanding either disseminated in residential areas or as a homogeneous body in the western part of the city; *the industrial area* is particularly dynamic over the last three decades, either due to the reduction to the suppression of some industrial units or to the conversion of other units or to the emergence of new industrial units.

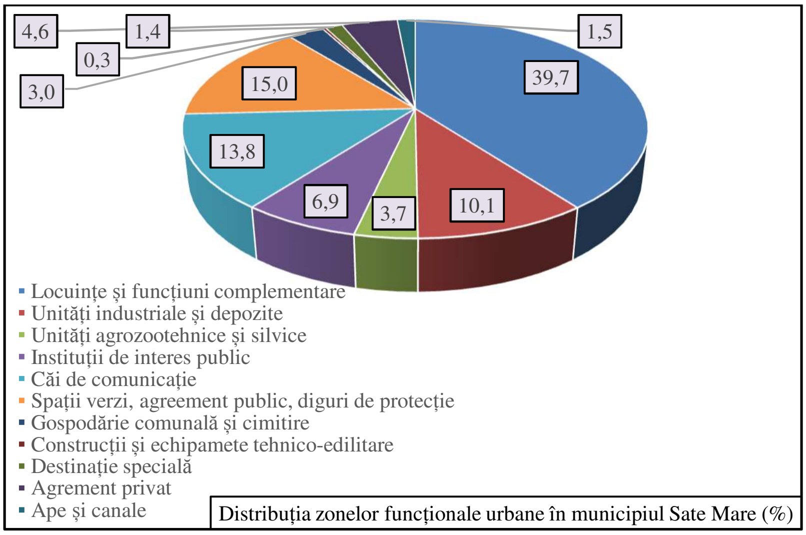


Fig. 15. The structure of functional areas in the Satu Mare urban area.

(Source: Satu Mare City Hall Archive)

CHAPTER III. WATER SUPPLY AND DISTRIBUTION SYSTEMS IN SATU MARE MUNICIPALITY

III.1. Water supply sources

III.1.1. Surface alohtone sources

The Someş River is the main hydrographic artery crossing the studied territory. The Someş River resource in the Satu Mare section totals an annual volume of 4.26 billion m³. This volume represents a potential of about 10.2% of the total potential of water resources provided by inland rivers that is 40 billion m³.

Apa Lake, formed due to the exploitation of natural aggregates from a pond situated near Apa, by intercepting the phreatic by the formed depression that played the role of drainage for the phreatic waters. The lake unit has a volume of about 3.12 million m³, the maximum depths ranging from 10.8 to 12.2 m. The difference between the shores of the banks and the water mirror is 5 - 6 m. The water level in the lake is kept relatively constant at the rate of 133.13 mdM.

The accumulation of Călineşti Oaş was formed by the construction of a dam on the Tur River, near Călineşti Oaş. The normal retention level of the lake is 143.33 mdM, the total volume being 23.09 million m³. The accumulation could provide Satu Mare Municipality with a contribution of: 450 l/s in the conditions of maintaining all the current use of the accumulation; 700 l/s with full use of available storage water volume.

III.1.2. Sources from phreatic and medium depth waters

The underground and subterranean groundwater resources are linked to the existence of the alluvial cone of Someş, a hydro-structure that has a total surface of about 1000 km². It has a pavement of 4.6 m³/s on the surface of the entire cone resulting in an annual volume of 145.06 million m³. Of the total resource potential, 2.7 m³/s is exploited, with a resource reserve of 1.9 m³/s (Sofronie, 2000).

III.2. Steps in the development of water supplying systems

III.2.1. The step of incipient systems

Until 1889, the water supply information of the studied territory is precarious as there is no centralized system of drinking water abstraction and distribution. For a long time, the water supply of the city was made from point sources, rudimentary, fountain type or directly from the Someș River.

III.2.2. The step of extensive development

In 1912, the drilling works of the systematic drinking water wells began. The wells no. 1 and 2 at a later stage to drill the other wells in the Garden of Rome (Grădina Romei). The works have long been trained so that only in the year 1926 the primary distribution network, which had at that time a length of about 1 km, was inaugurated. The documentary sources of 1938 mention the existence of a distribution network with a total length of about 8 km. Since 1971, the water supply of the municipality from the Mărtinești -Noroieni-Micula catchment area has been merged with the old source from the Garden of Rome, following the commissioning of the first drillings and the Mărtinești Water Works. Feeding from the new capture front was gradually carried out, during 1971-1995, reaching a total of 60 drillings.

III.3. Water captation and treatment systems

III.3.1. Grădina Romei capitation front

It is the old source of capture of Satu Mare, being for 40 years the only water source that can be used for water supply. It is located in the Garden of Rome Park, in the immediate vicinity of the CFR railway station in the city and consists of 8 wells with an average depth of 60 to 125 m **(Table 2).**

Table 2. Steps to achieve the Grădina Romei captation front.
(Source: Apaserv Satu Mare Archive).

Number of drillings	Diameters	Depth	Execution step
2 (P1-2)	8	60	1914-1930
6 (P3-8)	12¾	100-125	1977-1979

III.3.2. Mărtinești – Micula capitation front

The main capture of the Satu Mare municipality was carried out between 1969 and 1995. It consists of a network of wells arranged in the form of an alignment between the localities of Mărtineşti and Micula. The alignment is in the northern part of the city. The capture front consists of 64 wells (P2 - P65), with depths between 100-125m, Ø = 12¾, located at a distance of 250-300m from each other. The stages of the Mărtineşti-Micula capture front are shown in **Table 3**.

Table 3. Execution steps for Mărtineşti – Micula captation (Source: Apaserv Satu Mare Archive).

Number of drillings	Execution step
7 (P2-P8)	1971
3 (P9-P11)	1973
10 (P12-P21)	1974-1977
16 (P22-P37)	1978-1982
16 (P38-P53)	1983-1988
3 (P54-P56)	1991
4 (P57-P60)	1994
5 (P61-P65)	1994-1995

III.3.3. Drinking water treatment

There are two water treatment plants in the municipality of Satu Mare: the Garden of Rome and the Mărtineşti water plants. The Garden of Rome water plant is the old treatment plant being located in the proximity of Garden of Rome catching front. It is currently being preserved due to closure of nearby utility shafts. Monitoring the quality of water captured, treated and distributed in the network is carried out by Apaserv S.A. Bacteriological analyzes are performed every four days. Coliform bacteria: *Escherichia coli and Streptococcus fecalis* were not detected either in the raw water or treated water. Common bananas fall within the limits allowed by the normative **(Table 4)**.

Table 4. Biological and bacteriological analyzes of raw water in July 2017 at the entrance to the Mărtinești treatment Plant. (Source: Apaserv Satu Mare Archive)

Place of sampling	Date	Number of colonies at 37°C/ml	Number of colonies at 22°C/ml	Coliphorm bacteria (no./100 ml)	Escherichia coli (no./100 ml)	Streptococi fecali (no./100 ml)
Mărtinești Water Plant (raw water)	03.07.17	2	1	0	0	0
	10.07.17	4	2	0	0	0
	17.07.17	2	0	0	0	0
	24.07.17	1	0	0	0	0
	31.07.17	2	9	0	0	0

Analyzes of chemical parameters and indicators are performed once every four days **(Table 5)**.

The hardness and capture hardness oscillates around 8 German grades, with a degree of hardness equivalent to 10 mg CaO/l or 7,142 mg MgO/l. The water reaction (pH) oscillates around 7-7.3 being slightly alkaline. Conductivity records an average value of 315 (µS/cm). Chlorides fall well below the maximum allowable range, oscillating around 5-6 mg/l. Nitrogen compounds (NO3, NO2) record low levels probably due to the high operating depth. Undesirable substances were not detected by laboratory analyzes. Due to the underground provenance there are no significant seasonal variations of physico-chemical and microbiological parameters.

Table 5. Physico-chemical analysis of raw water in January (cold season) and July (warm season) 2017, at the Mărtinești Treatment Plant. (Source: Apaserv Satu Mare Archive)

Phisico-chemical parameters	January 2017		July 2017		CMA value
	Raw water	Treated water	Raw water	Treated water	
pH (pH units)	7.02	7,23	7,09	7,18	6.5-9.5
Turbidity (NTU)	0.59	0,16	0,70	0,17	≤5
Conductivity (µS/cm)	316.1	311,8	318,6	314	2500
Oxidisability (mgO_2/l)	0.516	<0.5	< 0,5	< 0,5	5
Total iron (mg/l)	1.832	<0.01	1,893	< 0,01	0.2
Manganese (mg/l)	0.335	<0.03	0,349	< 0,03	0.05
Chlorides (mg/l)	5.15	5.61	5,49	5,99	250
Amonium (mg/l)	0.122	<0.025	0,121	< 0,025	0,5
Total hardness (° germ.)	8.38	8.08	8,59	8,24	min 5
Free residual chlorine (mg/l)	-	0.51	-	0,44	0.5
Nitrates (mg/l)	< 0,08	0.317	< 0,08	0,2868	50
Nitrites (mg/l)	< 0,0025	<0.0025	< 0,0025	< 0,0025	0,5
Dossolved oxygen (mg/l)	0.13	8.1	7.45	0.125	-

III.4. Water distribution system

III.4.1. Factors that influence the water distribution network scheme

The local geomorphologic conditions required the adoption of technical solutions specific to the plain areas for the distribution of drinking water in the municipality. In the original project of 1897, it was planned to place a water castle in the central square, where water would be distributed by free fall to consumers. The absence of a significant level difference between the different sectors of the municipality does not allow the gravity distribution system.

Conformity of the street network imposed the tracking of their route, the distribution network being buried under the sidewalks, the middle of the streets being dedicated to the sewerage network. In general, the distribution system path coincides with the architecture of the street network for technical reasons (emergency interventions).

The dynamics of urbanization required the correlation of the evolution of distribution networks with the rhythm of urban development from different periods. There have been times when the development of the power supply network has not been correlated with the pace of urban development resulting in a number of malfunctions of the distribution system (low pressure areas, water supply syncope, etc.).

III.4.2. Characteristics of water distribution network

The distribution network of Satu Mare municipality is of an annular type **(Figure 16)** tracing main arteries in the form of a central pipe ring that branches both inwards and outwards by lower-order pipes. This type has the advantage of increased safety in operation due to the provision of at least two circuits and better fire behavior due to flow through the entire network (Mănescu, Sandu, Ianculescu, 1994 cited by Contiu, 2006).

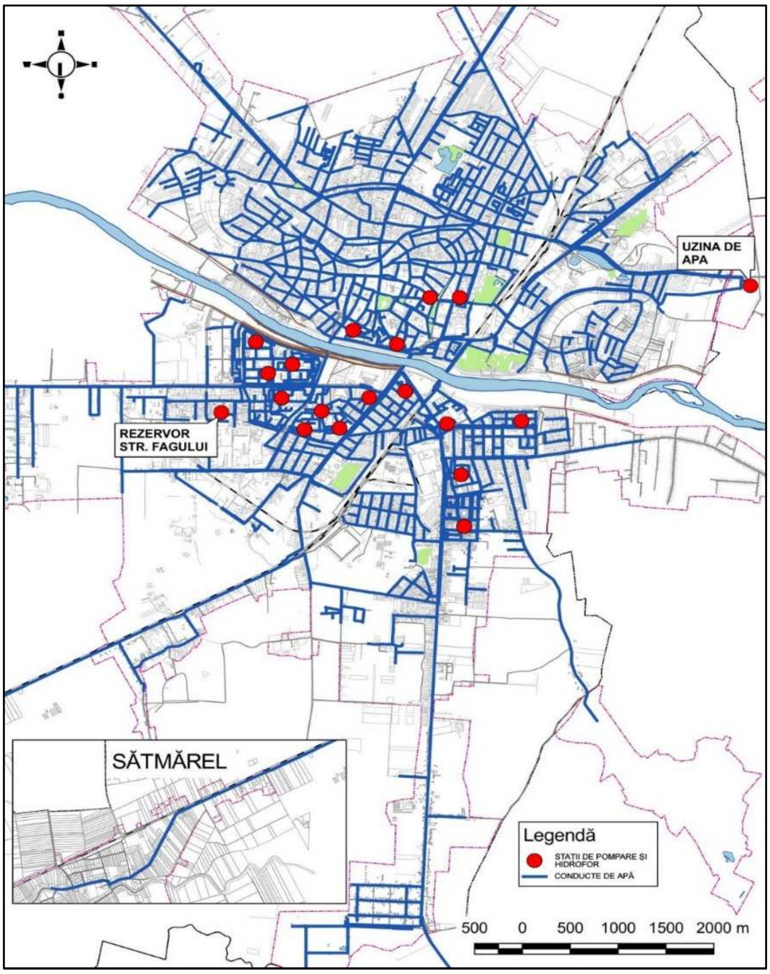


Fig. 16. Map of the drinking water distribution network in Satu Mare.
(Source: after Apaserv Satu Mare Archive).

III.3.5. Disfunctionalities of water captation, treatment and distribution systems in Satu Mare

The malfunctions are aimed at drilling of drilling, corrosion of the supply-distribution network, high operating costs, distribution network failures, etc.

CHAPTER IV. DRAINAGE OF SURFACE WATERS AND THE TREATMENT AND SEWAGE SYSTEMS OF WASTE WATER IN SATU MARE MUNICIPALITY

IV.1. Drainage of surface waters

IV.1.1. Sources and characteristics of surface water flows in Satu Mare municipality

Liquid precipitation in the urban area is the main source of urban flow. For Satu Mare municipality, urban flood generators are torrential rains. The duration of the torrential rains in the area of Satu Mare can reach 190 minutes (Geography of Romania, I, 1983). Akan and Houghtalen (2003) appreciate that the natural drainage network in anthropogenically untransformed regions is replaced by a much shorter drainage network consisting of gullies and collectors characteristic of urban perimeters resulting in a concentration of rainwater flows.

Torrential rains are characterized by high amounts of precipitation falling within a short period of time. As a case study for the calculation of torrentiality, we used two high-intensity rainfall slopes in Satu Mare, both of which are quantified by the Satu Mare automatic hydrometric station on the Someș River, which is located in the central district of the urban perimeter. These torrential rains have generated the formation and propagation of urban floods on the surface of the city. The first was recorded on May

13, 2017, the maximum recorded intensities being in the range of 0.15 - 0.53 mm / minute reaching the maximum value of 0.53 mm / minute at 14:15 **(Figure 17).**

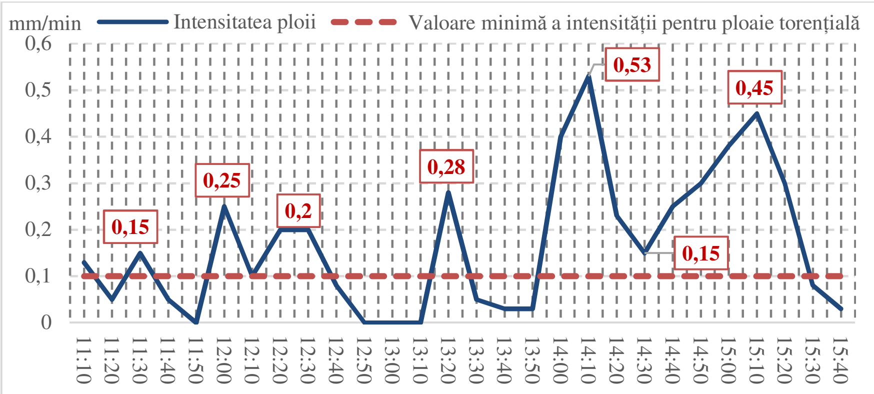


Fig. 17. The rainfall's intensity registered in 13.05.2017 at Satu Mare hydrometric station. (Source: after SGA Satu Mare Archive).

The snow layer records an average annual number of days with a snow cover of 40-50 days in Someş Plain, but lately the number of days with a snow layer has been considerably reduced. The average thickness of the snow layer ranges from 5 to 20 cm in January (Mikos, 2005). In the area of Satu Mare, the average number of days with snow is between 15 - 20 days a year.

River floods can be a source of surface draiange as high levels of Someş can cause infiltrations through the body of the dikes or through subtractions at their level.

IV.1.2. Factors that influence urban water flow

The relief through its morphometric features influences the urban flow over the perimeter studied. The relief plane in the Someş Plain is nearly quasi-general. This prevents the gravitational drainage of the waters, resulting in over-humidification, stagnation and puddling on the territory of the municipality.

The natural drainage network is anthropically modified so that the local base level is anthropically imposed by hydrotechnical works. A network of drainage channels and pumping stations has been set up to replace the original drainage network.

The edaphic characteristics and the nature of the vegetal cover. Anthropic plots of varying degrees of permeability and saturation can influence the infiltration and the degree of rainfall of rainwater on urban areas.

The degree of waterproofing of the surface due to urban expansion leads to the establishment of leakage coefficients raised in relation to the natural flow from the natural perimeters.

IV.1.3. The components od drainage system

The organized water drainage systems in the Satu Mare municipality include the totality of the trenches and gutters; open channels; drainage/evacuation channel network of pluvial waters; the network of main collectors and transport pipelines.

Non-organized drainage systems incorporate all the areas that are leaked through areas of natural drainage: unsettled streets (characteristic of new districts in the east and south of the city), courtyards and annexes, gardens, certain industrial areas, etc.

IV.2.The sewage system of Satu Mare municipality

IV.2.1. Steps in the development of the sewage system

The chronological analysis of the sewage systems in the studied urban area reveals two evolutionary stages: *the beginning stage - 1966 and the 1967 - 2017 stage*. In 1966 the sewerage network totals about 26 km serving only 20% of the urban territory, and water discharge domestic and rainwater was done without prior treatment in Someș. The network was under-dimensioned and the slopes were insufficient. The sewerage network was expanded in line with the intense urban expansion that characterized the period 1967-1990. In 2005, the sewerage network totals a length of 177 km of which: 144,5 km with Ø 20-50 cm, 18,4 km with Ø 60 - 100 cm and 14,1 km with Ø> 100 cm.

IV.2.2. Analiza sistemului de canalizare al municipiului Satu Mare

The existing sewerage network serves 97.1% of the city's drinking water users. With the exception of the Micro 17 and Carpathian II districts, estimated at about 10% of the urban reception area, the system is totally designed. The length of the sewerage network in the municipality of Satu Mare is 228,886 km and is made of 78,01% concrete pipes, 12,03% PVC and 9,96% polyethylene. The sewer system includes five main collectors in which the secondary collectors are discharged **(Figure 18).**

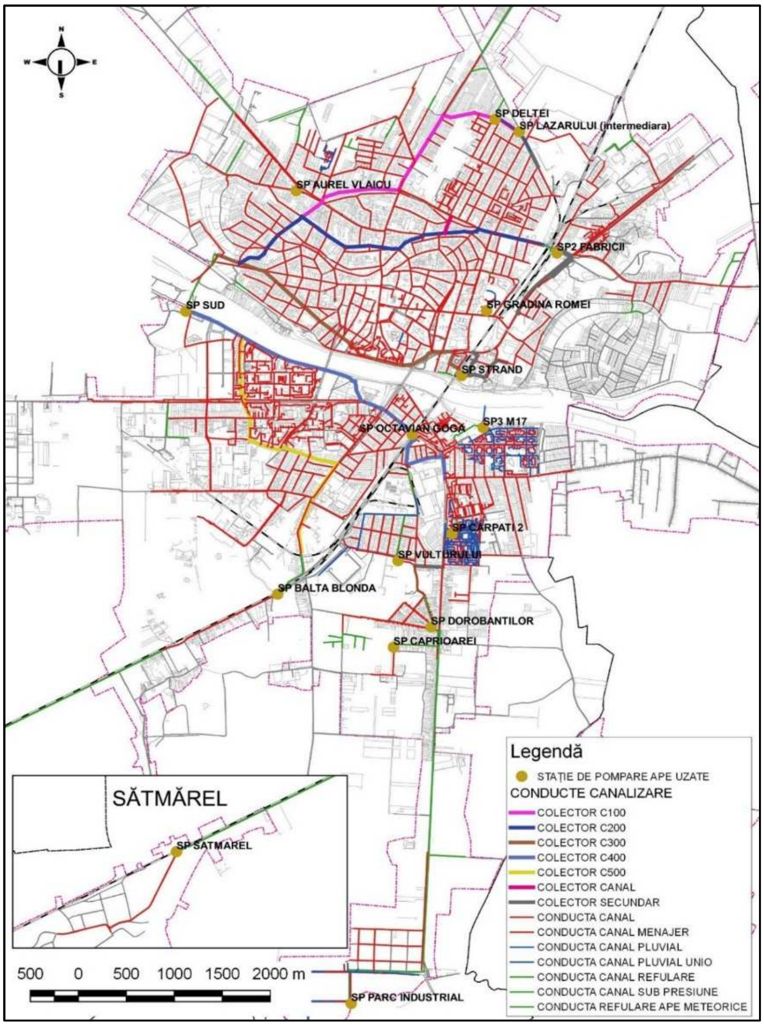


Fig. 18. Structure of sewage network for waste and pluvial waters, and the spatial distribution of the sewage pumping stations in Satu Mare. (Source: Apaserv Satu Mare Archive).

IV.3.1. Analysis of the Satu Mare wastewater treatment plant

The sewage treatment plant of Satu Mare is located on the right bank of Someș at about 500 m from the perimeter built at the end of Diana Street. The sewage treatment plant is of the mechano - biological type with a current capacity of 900 l/s, a flow equivalent to an urban population of 180,000 inhabitants. The capacity of the wastewater treatment plant increased from 175 l/s at the start of operation to 900 l/s, as follows: 1972 - Q installed = 175 l/s; 1976 - Q installed = 400 l/s; 1986 - Q installed = 800 l/s; 1989 - Q installed = 900 l/s.

IV.3.2. The quality of evacuated waters

On the whole, the efficiency of the treatment plant is over 90%, the yield on the individual values of the chemical indicators including: 83% total nitrogen, 87% total phosphorus, 91% CCOCr, 96% CBO5 and 97% suspensions **(Figure 19)**.

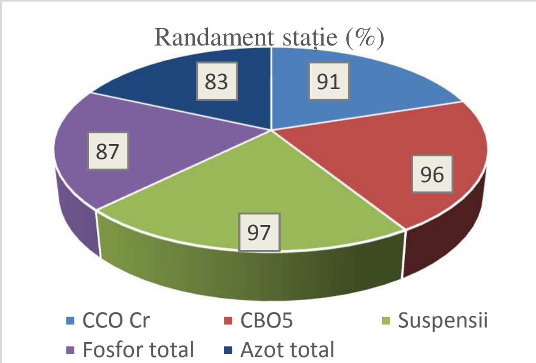


Fig. 19. The efficiency of the Satu Mare wastewater treatment plant.
(Source: Apaserv Satu Mare Archive).

CHAPTER V. THE WATER BALANCE IN SATU MARE MUNICIPALITY

V.1. General considerations

In general, the water supply systems of the localities in the country record a waste of the water resource, considering that the average losses in Romania are about 50 - 55% (Şofronie, 2000): 10% losses in individual households, 15% technological losses and 25-30% losses on transport and distribution networks.

V.2. Components of water balance in Satu Mare municipality

V.2.1. Water from supllying systems

The water taken by Apaserv SA totalized in 2017 a volume of 10,943,106 m^3 of which 9,950,550 m^3 from the capture front Mărtineşti - Micula and 95,386 m^3 were exploited in Moftinu Mare. In total, lost water accounts for about 43.72% summing up a volume of 4,350,267 m^3 **(Table 6)**.

Table 6. Values of the water balance in Satu Mare municipality, in the year 2017. (Source: after Apaserv Satu Mare Archive, SGA Satu Mare Archive).

<table>
<tr><th>Water from own sources (m^3)</th><th>Water entering the system (m^3)</th><th>Water supplied (m^3)</th><th>Water sold (m^3)</th><th>Volume prelevate by other usages (m^3)</th><th>Total treated volume (m^3)</th></tr>
<tr><td>10.397.720</td><td rowspan="3">10.493.106</td><td rowspan="3">9.950.550</td><td>5.600.283</td><td rowspan="3">144.540</td><td rowspan="3">7.643.452</td></tr>
<tr><td>Water from other systems (m^3)</td><td>Wasted water (m^3)</td></tr>
<tr><td>95.386</td><td>4.350.267</td></tr>
</table>

The water lost through the adductions and the network totals a volume of 1,942,583 m^3 representing 15% of the total. Losses due to leakage or non-leakage of the connections show 796.044 m^3 representing 8%, and tank losses total 99.506 m^3 representing 1% of total captation.

V.2.2. Water from rainfalls

The average annual precipitation in the year 2017 was 724.8 m with a maximum of 55.4 mm/24 hours. Of the landfall, a segment is intercepted by vegetation or infiltrated into the soil in permeable areas and the rest is taken over by the drainage and evacuation network (through the purification station or directly into the Someș River). Reporting the amount of rainfall that fell in 2017 on the territorial-administrative surface of the municipality, we obtain an annual volume of 108.8 million m³. Referring to the urban area where the degree of waterproofing is high, we have an annual rainfall volume of 30.1 million m³.

V.2.3. The analysis of water balance in Satu Mare municipality

The total volume of water collected in the urban area in 2017 is 10637646 m³, of which almost 50% represents losses. The volume of purified water in the year 2017 was 7.643.452 m³. The volume of purified water includes: wastewater volumes from the population, institutions and businesses including the volumes of drinking water from its own sources and the rainwater fraction that passes through the treatment plant. For the period 2005 - 2017 the volumes of water captured recorded values between 12.777.000 m³ in 2005 and 8.772.170 m³ in 2015. The range of the treated volumes from the same period oscillated between 11,373,000 m³ and 7,819,849 m³.

CHAPTER VI. HYDRIC RISKS - SATU MARE MUNICIPALITY

VI.1. Floodings of pluvial nature

VI.1.1. The evaluation of maximum water flow potential

In order to calculate the maximum flow within a precipitation area, it is necessary to estimate the maximum drainage potential. One of the simplest and best known methods is the rational method, a method originally designed in the early 1889 by the original Kuichling for small urban river basins and torrential rainfalls:

$$Q_{\max p\%} = 0{,}167 \cdot i_{p\%} \cdot \alpha \cdot F \quad (1)$$

where, Qmaxp% - maximum flow rate, in m^3/s with probability of exceedance / insurance p%

ip% - average rainfall intensity in mm/min, probability p%, equal to the drainage concentration time in the analyzed river basin, which generates the maximum flow rate.

α - average drainage coefficient of the river basin

F - hydrographic area, expressed in km^2.

Based on the analysis of the maximum flow calculation equation, it is noted that the rational method is admitted that the maximum average rain intensity and probability p% generate a maximum flow of the same probability (Bilasco Șt., 2008). Max flow rates can be estimated using tabular values in the literature. The average draiange coefficient **(Figure 20)** is a non-physical ratio, showing the amount of water generated by the hydrographic basin in the case of precipitation. It is the fraction of precipitation that turns into leakage.

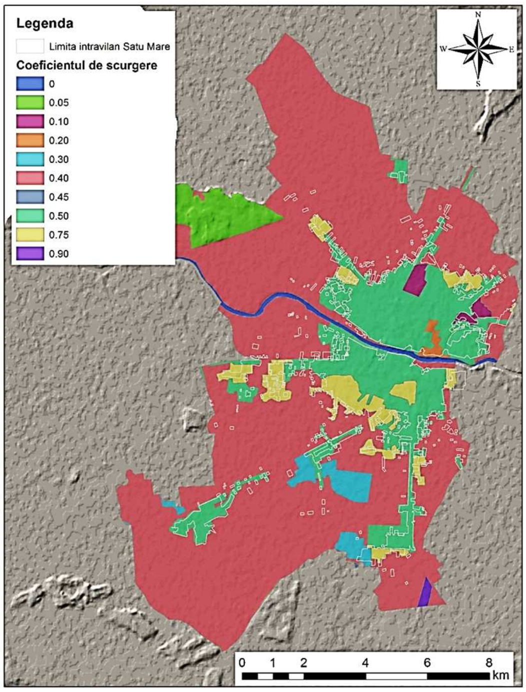


Fig. 20. The water flow coefficient used for calculating Qmax by rational calculation method.

VI.1.2. Pluvial floodings characteristics and effects

The high degree of waterproofing, the flatness of the relief and the existence of some anthropic relief forms, which do not allow the discharge of rainwater into the emissary in natural regime, result in rainfall formation of rainwater flooding on the urban surface **(Figure 21)**

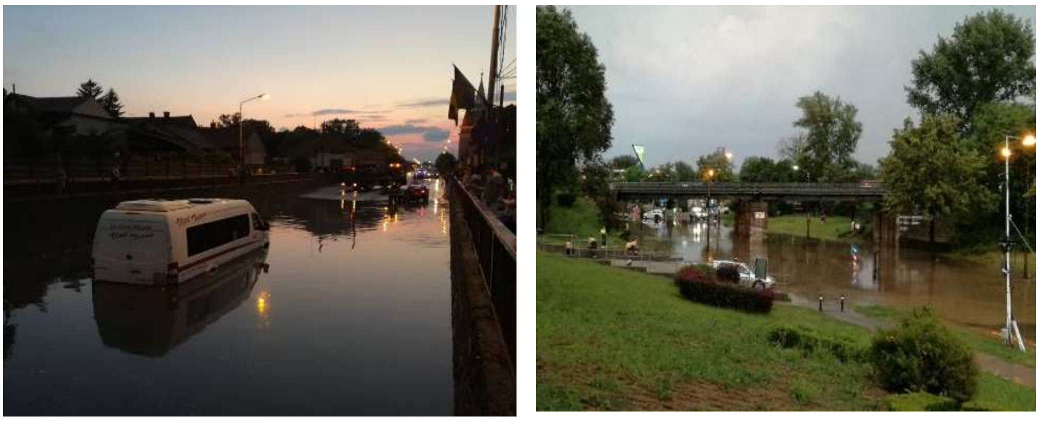


Fig. 21. Pluvial floodings in Soarelui and Botizului passages.
(Source: Personal photo archive - Mareş Corneliu Ovidiu; https:// portalsm.ro).

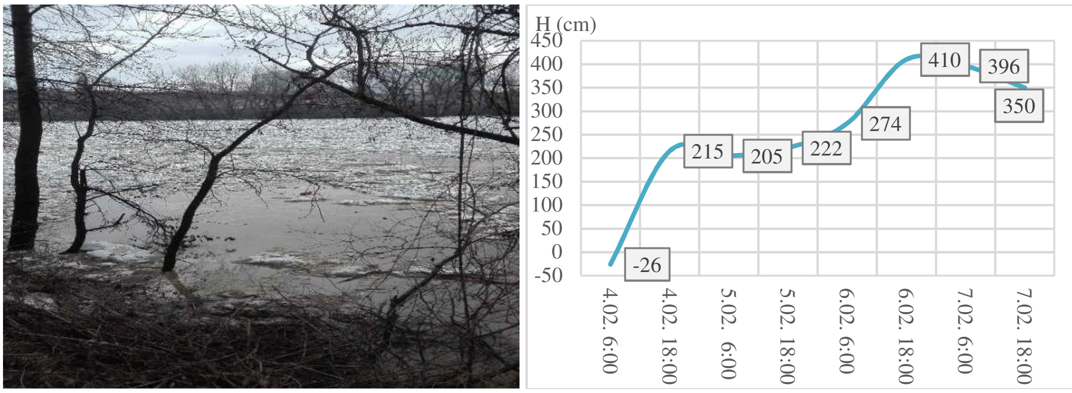
VI.2. Floodings of fluvial nature

The documentary sources mention the vast floods of Someş in Satu Mare, repeating with a cycle of 40-50 years. The terrains located on the right bank have been subject to frequent floods over the years. Catastrophic floods are quoted in the years 1778-1782, 1784, 1834, 1855, 1870, 1888, 1893, of which 1888 had a share of + 630 cm. Numerous flood defense measures have been undertaken over the years, such as closures, upgrades and recalibrations. Since ancient times, Someş has recorded floods that have caused different degrees of damage to the studied urban territory, detaching itself from this series of events through amplitude, manifestation and consequences, the spring flood of the 1970s. Its genesis had mixed origin being the result of melting snow fell in conjunction with the fall of a heavy rainfall.

VI.3. Hydric risks associated with winter phenomena

Of the phenomena we chose the snow because it is the phenomenon, we consider, the most dangerous for the section of studied territory. I have chosen, for example, the ice dams on February 6, 2017, on Someş River, in the Satu Mare section **(Figure 22a).**

a



a b

Fig. 25. Ice dam formed on the Someş River in the Satu Mare section between February 5th and 6th, 2017 (a, b) and the hydrograph of the levels during the ice dam in the same section (c). (Source:after SGA Satu Mare Archive).

The warming of the weather and the increase of the river's level due to the failure of the snow and ice layers caused the separation of the ice bridge and the formation of the ice. Under these conditions the level suddenly increases from -26 cm to 410 (426 cm) in 36 hours **(Figure 25b**).

VI.4. Prevention and control works of flooding effects

After 1970, the dams were restored and raised according to the project no. 322-1973, the right bank of 47 km from Seini to the Hungarian border, and the 37.3 km long left bank ditch running from the village of Cărăşeu to the border with Hungary. The dams were insured according to the May 1970 flood parameters and the probability of new floods occurring on the Someş River in the analyzed sector **(Table 7**).

Table 7. The degree of dyke insurance and corresponding flows on the Someş River in the area of Satu Mare. (Source: SGA Satu Mare Archive).

ASSURENCE DEGREE (%)	CORRESPONDENT DISCHARGE(m^3
0,1	**5400**
0,5	**3 900**
1,0	**3 500**
5,0	**2 400**
10	**1 950**

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