Hazards from Water Management Works in Tarnave River Basin, Romania

Mihai I. Voda, Dimitrie Cantemir University, Targu Mures, Romania

1. Introduction

The river basin size has an important role in the genesis and the evolution of hydrological phenomena. In a small drainage basin, the channel flow evolution follows the rainfall depth. In a significant river basin the channel flow evolution doesn't follow exactly the rainfall depth. The river basin surface regulates the runoff. A wider drainage area, as it is in the Blajului and Întresecaşe Tablelands increase the flood routing speed. The river basin average altitude influences the hydrological elements. The higher drainage area elevation receives more precipitation and has more important runoff than the lower one.

The annual runoff in the Târnave river basin is influenced by the rainfall depth, evaporation, morphometrical characteristics of the flood channel, cutoffs coefficient and hydro geological conditions of the drainage areas. When calculating the runoff we should include a series of parameters that will take into account the influence of accumulations and embankments built to prevent floods. Also, other parameters can be mentioned related to the cutoff coefficient, the morphometrical characteristics of the flood channel and the deposits.

There is emphasis on the practical importance of maximum runoff observation on watercourse management works. The analysis of the maximum runoff genesis as well as the distribution of the values according to genesis was based on a comparative analysis of the climatic and hydrologic variations.

The most serious floods in Tarnava river basin, occurred in May 1970, July 1975, March 1981, December 1995-January 1996 and June 1998. The flood analyses from 1970-2004 periods at Sarateni hydrometric post illustrate a great number of important floods in May 1970, July 1975, May 1978 and May 1984, followed by a period of 10 years with modest floods until 1995. The last decade presents floods in April 1999 and 2000, May and August 2005.Floods vary according to seasons, the most numerous occurring in spring (30%-45%), less in autumn (6%-10%). The maximum frequency is in April and March, followed by June.

The hydro technical works in Târnava basin started as a result of important damages caused by the floods in 1970 and 1975. They implied the construction of some storage reservoirs, both permanent and non-permanent, to protect different objectives within the territory. By means of redistributing the flow during the year, they created a balance in the hydrologic system, compensating for minimum discharges and decreasing the maximum ones.

2. Water management works in the Târnave river basin

The storage reservoirs

The Bezid storage reservoir is situated on Cuşmed, right tributary of Târnava Mică, having the largest surface of tributary basin (157 sq km) and the highest volumes of water in the basin. The storage reservoir is situated up stream from the confluence with Târnava Mică river, 1.5 km away from Sângeorgiu de Pădure. The aim is to decrease floods and protect against floods all the industrial and residential areas on the Târnava Mică riverside as well as to meet the need for fresh and industrial water supply in Târnăveni. Together with the development of the Târnăveni chemical platform it was necessary to increase the store discharge from 0.4 cubic meters/s, which wouldn't have been possible given the natural conditions on the Târnava Mică river, only by means of retraining the available discharges in a storage reservoir upstream to supplement the minimum discharges.

The daily average minimum discharge on the Târnava Mică river of a 95% probability is approximately 0.55 cubic m/s on the entire Odorhei-Mediaş sector, and the monthly average minimum discharge, of the same probability, increases on the same sector, downstream from 0.85 cubic m/s to 1.08 cubic m/s. These situations have led to the building of the Zetea storage reservoir that not only prevents floods but also ensures and regulates river discharges to meet water requirements. It also ensures the normal quantities of water needed in the next 10-20 years according to the development increase, the water supply scheme, the improvement of the present urban water supply system.

The detention reservoirs

The non-permanent storage reservoirs mainly aim to decrease floods damage. The most important in the Târnava Mică basin and even in the entire Mureş basin are the storage reservoirs at Vânători (25 mil.mc) and Bălăuşeri (24,5 mil.mc) there is also Nemşa, with a total volume of 7.94 millions cubic meters on the Moşna creek, left tributary of the Târnava Mică river.

The Vânători storage reservoir is situated on the Târnava Mică river in the urban area of Albeşti, Topa, Vânători and aims to decrease the floods on the upper stream protecting Sighişoara against floods by reducing the maximum discharge from 1364 cubic meters/s to 1100 cubic meters/s which results from the storage of 25 millions cubic meters of water, 0.1% insurance. The surface of the storage reservoir at 1% insurance is of 300.5 hectares and 583 hectares at 0.1 % insurance.

Bălăuşeri storage reservoir is situated on the Târnava Mică riverside having a length of 4500 meters, a width of 900 m and a surface of approximately 325 hectares. Is meant to function only when the discharges exceed the 5% insurance on the Târnava Mică river otherwise the surface remains dry and is cultivated. The maximum value of the storage reservoir of 0.1% insurance is of 24.5 millions cubic meters.

Water users within the Târnave basin

The water users in the basin are grouped according to the conditions on the water quality. The stored discharges should be used as fresh water supply for residential areas and then for irrigations. The irrigation canals can carry discharges that will ensure the necessary water for other water users along the way. The water users represent fresh water supplies (34% out of the total volume), industrial water (63.4% out of the stored volume) and irrigation systems (2% out of the stored volume) which are only additional as irrigation is needed only in the draughty years.

The complete hydro technical works of the hydrologic basins are absolutely necessary at the moment in order to improve the water supply system. It implies an integrating structure based on integration relationships.

3. Evaluation methods and techniques of the regulated runoff in the Târnave river basin

In order to correctly evaluate the water supply in an area it is necessary to know the natural flow conditions. As a result of human activity the degree water usings has also risen. Under the circumstances, in order to find out the potential of natural water resources, it is necessary to make calculations that will eliminate the influence of human factors modifying the flow. The results obtained will indicate a situation where there wouldn't be any flow modifying factors and will allow for a quantitative analysis of water resource trends. Currently, the immense water course training caused the measured discharge, namely the measured runoff, not to reflect the natural runoff as measured at most hydrometric stations.

The natural runoff should be known so as to follow the evolution in time of the natural water resources and evaluate the influence of the human factors on the flow. Reconstruction refers only to the modifications of the natural flow as they appear in riverbeds and not to the modifications influencing the flow forming factors.

The reconstruction of the natural water flow into riverbeds is defined as the calculations through which, starting from the modified flow hydrometrically registered, the modifying factors are eliminated or corrected so as the final results reflect the flow irrespective of water trainings.

4. The effects of water course management and water users on the surface runoff within the Târnave river basin

The main modifying factors on the hydrologic regime in the river basins are the complex water trainings. The storage reservoirs distribute and regulate the flow during the year by minimizing the maximum discharge, when the reconstruction corrections have positive values (DQ >0), namely the compensation of minimum discharge the values of the reconstruction corrections being negative (DQ <0).

The influence of water users on the hydrologic basin is reduced to diminishing the average monthly discharge with relatively significant values (5-10%) as cumulation of the water users with the storages of the main storage reservoirs. The approximately constant influence of the water users is generally insignificant when there is a lack of important accumulation in the storage reservoirs yet it can compensate for important lack of accumulation such as those in January that follow high water periods. The reconstruction of the natural flow on Târnava river started in the 80's, corrections of reconstruction being made every year even though the average flow was not influenced by any modifying factors for more than 5 years out of the 22 years under analysis.

4.1. Changes in the annual mean runoff

The overall evolution of the flow in a water trained area of the Târnava hydrographic basin highlights a fight connection among K values, DQ correction discharges and the water volumes consumed by water users. During the years when the K values were most reduced the percentage of the correction discharges exceeded 5% and the volumes of consumed water were some of the highest; there are years when there was no compensation of minimum discharges because of discharges lower than natural discharges and average multi annual natural discharges.

In Târnava hydrographic basin the the effects of water training and water users were particularly obvious between 1986 and 1990. Significant changes in the annual average flow were registered in 1986 in Târnava Mica basin, at Bălăuşeri, Târnăveni and Blaj. The average annual discharges registered at Mihalt hydrometric station show high values in 1984 and 1985, of 32,2 m^3/s and 43,2 m^3/s at the beginning of the period analyzed, followed by the 10 years of discharges bellow the average of 23,6 mc/s. Since 1996 there has been an increase in discharges under observation, reaching the highest values of 50,9 in 1998. The reduced values of the average annual discharges measured in the years 1986, 1987, 1989-1995 and 2001-2004, lower than the reconstructed average annual natural discharges of the same years and inferior to the average multi annual values of natural discharges emphasize the lack of compensation on reduced discharges. The average monthly discharges registered and reconstructed were below the average multi annual values, but water user in the basin consumed 31,6 mil. mc. of water in 1986, almost three times as much as during the previous year, 1985, which registered a high flow capable of compensating the quantities stored and consumed by the water users.

The modifying factors of the natural flow imposed the use of reconstruction modifications in 9 out the 22 under analyze years. The modifying factors of the natural flow imposed the use of reconstruction modifications in 9 out the 22 under analyze years. The modifying factors exceeded 5% in 1986-1989, 1991-1993, 1995, 2003 and in 1990. The years when the value K coefficients are most reduced coincide with the years when it was necessary to apply the reconstruction correction such as 1986, 1987, 1989, 1990 and 1995. In 1990, the value of the coefficient is of 87, 46%, which represents the share of the measured discharge out of the reconstructed natural discharge. In the same year 1990 they registered the highest degree of average flow modification from the entire period analyzed.

Although in 1990 registrations did not show the highest annual water storage consumed in the period analyzed, the K values are the lowest because of extremely reduced average annual discharges. In 1995, when they registered the highest net water storage of 34,7 mil cubic m, the K value is of 91, 79% but the values of the measured and natural average annual discharges almost doubled in comparison with those of the year 1990.

On the Tarnava Mica river, at Blaj hydrometric station , the K value is the most reduced in 1986, year with the most insignificant modifications on the average flow due to the large volumes of water consumed by the water users and also to the low average discharges measured and reconstructed. At Tarnaveni, Tarnava Mica hydrometric station, they registered significant influences of different water users on the average flow conditions in 1986, the highest value being DQ= 6,28%. In all these years reconstruction measurements (calculations) were needed. Since 1995, they have registered an increase of the discharges observed in the whole of the Tarnava basin, reaching a peak in 1998 with 16,6 m^3/s. The reduced average annual discharges measured in 1986, 1987, 1989-1994, 2000, 2001, 2003 and 2004, lower than the natural average annual discharges reconstructed in the same years and also lower than the multi annual average values of the natural discharges emphasize the lack of compensation effects of the minimum discharges.

4.2. The effects of water course management on the monthly mean discharges in the Târnave river basin

A high degree of flow modification is noticed in 1986 in the Târnava Mica basin, at Bălăuşeri and Târnăveni hydro stations where the show of the correction discharges exceeded 5% in 10 months, except for March and April. The natural discharge reconstructed at Balauseri in September were of 2,14 m^3/s as compared to 4,64 m^3/s (the multi annual average value of September) and in December Qnat =1,99 m^3/s as compared to 5,94 m^3/s (the multi annual average value of December). At the hydrometric station of Tarnaveni the natural discharge reconstructed in November were of 2,56 m^3/s compared to 5,84 m^3/s (the multi annual average value of November) and in December Qnat =2,38 m^3/s compared to 7,06 m^3/s (the multi annual average value of December). In March and April the K values reflect a reduced value of flow change, but they remain low in the other months of the year, reaching a peek in September and December at the hydrometric station of Balauseri, namely in November and December at Tarnaveni.

In 1990 the water management works had a great influence on the discharges in the Tarnava river basin. At Mihalț the volumes stored in this year were of 34,7 cubic m mil value similar to the one in 1988 in which the discharge was higher, matching its peak. The highest rate of flow stored also were recorded in August and September, months which presented the lowest monthly rate of flow in 1990 and also the highest correction discharges (Fig. 1). The reconstruction correction works were necessary beginning with April (6,88 %) till the end of December (15,47 %). The highest correction discharges are in August (26,81 %) and September (24,16 %).

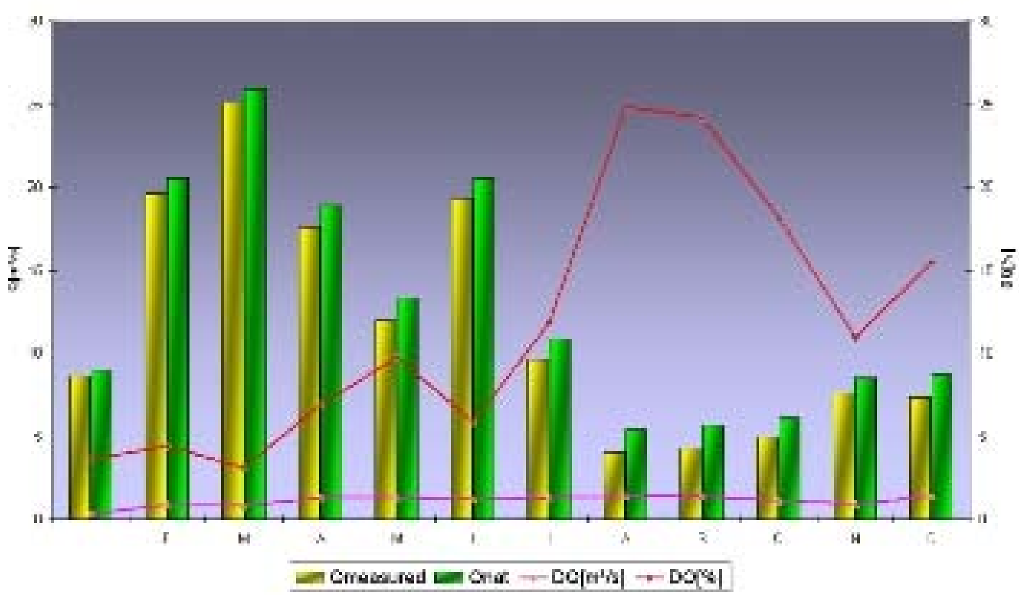

Fig.1 The average natural and reconstructed monthly discharges variation at Mihalț hydrometric station in 1990

In the river basin of Tarnava Mica, at the hydrometric station Tarnaveni, in 1990 the highest rate of runoff was recorded in August (Fig. 2), months with the highest correction discharges and with the highest water consumption of 1,3 mil.mc.

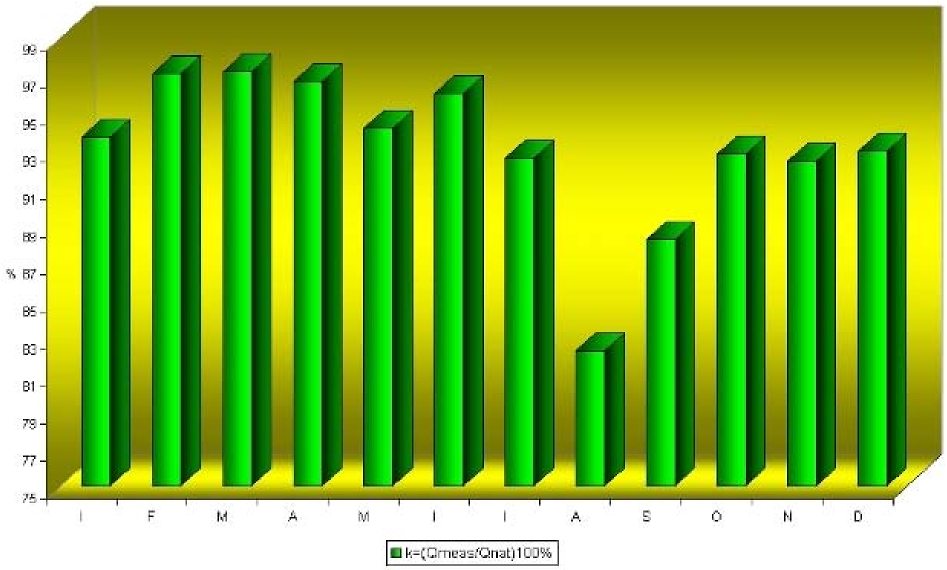

Fig.2 The monthly average discharges degree of modification in 1990 at Târnăveni

In 1998 the highest runoff from the whole analyzed period was recorded. The annual average discharges were of 51,6 m^3/s at the hydrometric station Mihalt. The discharges of water stored in the basin were of 22,1 m^3/s . Analyzing the variation of the average rate of flow measured and reconstructed as well as the share of correction discharges in 1998 at Mihalt, we observe the positive role of the storage reservoirs in Tarnave basin, put in use after 1990. The mitigation of maximum discharges is illustrated by Q natural > Q measured > Qan.av.meas. values of the following months: January, April, June and July. The accumulations regulated the flow by storing extra volumes, redistributed gradually in time. In some of the moths of 1998 were important flows registered. A positive influence of water training works is noticed in the basin through the perennial storage reservoir Zetea and Bezid.

4.3. The effects of water course management and water users on the minimum runoff

In the Tarnava river basin two long intervals of drought were registered, the first one between 1945-1951, and the second one between 1983-1994. As compared to the previous period, 1983-1994 droughts presents a few particularities, being longer in time, but in the same way less homogenous than the previous one. The discontinuities of recorded values were noticed in 1985-1988. A major negative influence of water users on the flow in Tarnava basin was noticed in 1986, 1987 and 1990 when the discharges decreased below the multi annual average values, restrictions were not imposed for the storing water and the perennial storage reservoirs to compensate the discharges, didn't exist. The draught phenomena must be monitored with great attention, by better control of water users to decrease the risk of pollution, reactivate own sources of water supply so as to reduce discharges consumed from centralized sources. By extension duration, intensity and effects, the drought in 2000 can be considerate one of the most powerful in our country in the XX th century. On the whole territory of the country in rainfall decreased by 33.4 % of the usual quantities. In 2000, on small surface creeks in the Tarnava basin, the annual flow was lower than the multi annual, some even become dry on the whole river course: e.g. The storage reservoirs in the basin played an important part in supplementing the discharges in drought periods thus meeting the water users needs. In the Tarnava hydrologic basin, in 2003, the discharges decreased below the monthly average yet without reaching the warning threshold. On the main river courses in the basin there weren't significant discharge drops to the densely forested areas in the upper basin where the tributaries have an even flow and also to the permanent storage reservoirs such as Zetea on the Tarnava Mare river and Bezid on the Tarnava Mica river, which compensate for the lightly deficit on these watercourses.

4.4. The effects of water course management on floods in the Târnave river basin

In the Tarnava river basin most of the floods are generated by rain. Thus at Odorhei hydrometric station the highest floods recorded before 1970 were the floods caused by rainfalls in August 1955, July 1957, 1959 whose peak, discharges were of 80-90 m³/s. After 1970 the highest discharges, of 205 m³/s were recorded on 13.03.1981. At Blaj hydrometric station the most important floods are caused by rainfalls, for example those in 1953, April-May 1956, July-August 1960. The peak discharges of 851 m³/s were recorded on 04.07.1975. Because of the significant increase of the basin's storage surface the mixed floods whose frequency is comparatively inferior to the frequency characteristic to floods caused by rainfalls, could present peak discharges and huge volumes of water.

In 1970, between 12 and 16 of May were recorded peak discharges of 700 m³/s (15.05.1970) were recorded at the hydrometrical station from Topa on the Tarnava Mare river and 323 m³/s at the hydrometrical station from Sarateni on the Tarnava Mica river. The flood was formed because of heavy rainfalls and melting snow in the upper basin. In 1975, they registered the most increased discharges at Simonesti, Medias, Blaj, Tarnaveni and Mihalt stations. Heavy rainfalls on a highly saturated soil caused severe floods on the Tarnava Mica and Tarnava Mare rivers. Peak discharges of 135 m³/s were registered at Simonesti on Feernic in 02.07.1975, 900 m³/s at Medias on Tarnava Mare in 03.07.1975,851 m³/s at Blaj on Tarnava Mare, one day later and 830 m³/s in 03.07.1975 at Tarnaveni on the Tarnava Mica river. At Mihalt hydrometric stations 1350 cubic m/s were registered**.** In 1998 were recorded two periods of substantial precipitations were recorded in the same months: June. The first between 11-15 1998, and the second between 16-20 1998. Peak discharges recorded on Tarnava Mica were of 335 m³/s at Balauseri and of 196 m³/s at Tarnaveni.

The flood analyses from the period of 1972-2004 at the hydrometric post from Tarnaveni shows a major flood in July 1975, when at 5 pm on 3 July 630 m³/s were registered a value 60 times higher than the average discharges characteristic of July at this post. Analyzing the flood routing between Sărăţeni and Târnăveni, we can observe the speed increasing of the flood wave, from 1,5 to 4 km/h, because of the hydro technical works done after 1977.

The rainfalls in December 1995 caused peak flows on the Târnava Mică river in the Târnava Mică river basin with high water overrun and serious damages. Serious damages were recorded in the following villages: Suplac: 528 hectares of arable terrain and right river bank erosion in the outskirts; Adămuş: 82 flooded households, 22 houses and 380 hectares of arable terrain. Consequently, it is absolutely necessary to start flood protection works in the area of Suplac, Adămuş, Corneşti and Crăieşti.

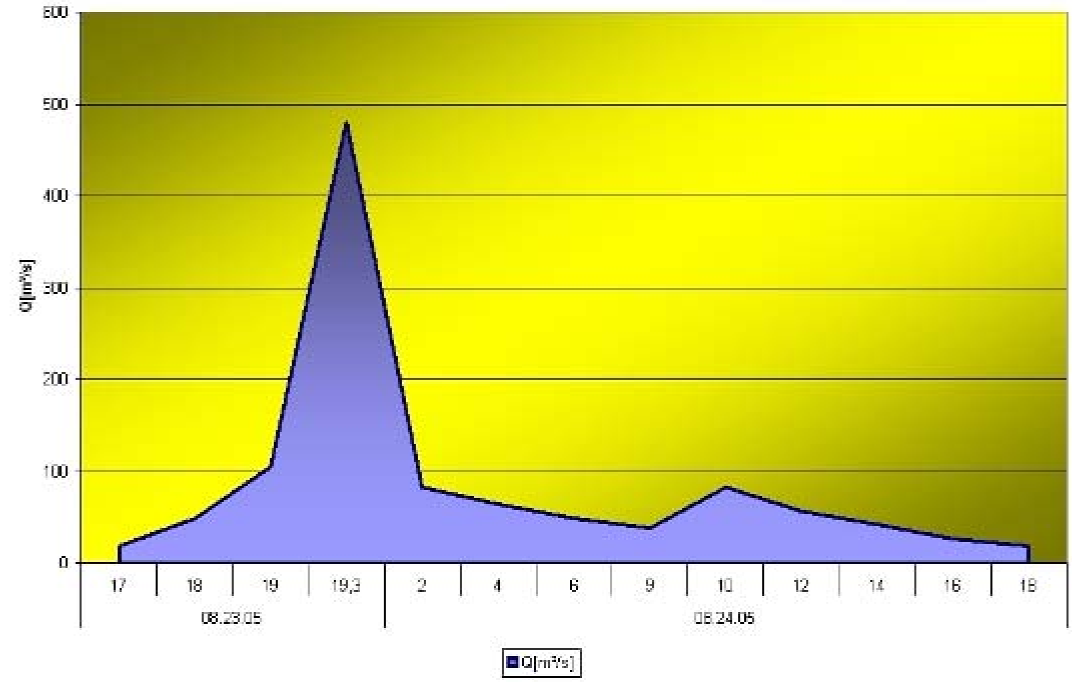

Fig.3 Feernic flood wave hydrograph in 2005 at Simoneşti

In August 2005 the flood wave recorded at the Simoneşti hydrometric station was very strong (Fig. 3), the water level grew fulminatory, starting at 06.00AM (H-10, Q-2.16 m³/s) the 23rd of August 2005 with 70 cm until 5.00PM (H-80, Q-18.1 m³/s). This way at 18.00h (H-140, Q-48 m³/s), in one single hour the water level has grown 60 cm, while at 19.00h (H-200, Q-104 m³/s), another 60 cm.. The highest level of the flood is reached a half an hour later, at 19.30h (H-367, Q-480 m³/s). In an only 30 minute spell the water level raises with 1.67m , and the water discharge of the Feernic grows with 460%. Practically in 2 and ½ hours, between 17.00 and 19.30, the Feernic's water level rises with almost 3m! The danger-quote has been excelled with 217 cm in the evening of 23.08.2005, the water level remained high until 02.00 in the night (H-180, Q-82 m³/s), after that it started to lower until the morning of 24.08.2005, at 09.00AM (H-120, Q-38 m³/s). It rises again until 10 o'clock (H-180, Q-82 m³/s), receding then back at 14.00h under the danger-quote (H-130, Q-42 m³/s). In two hours eight places (locality) – Odorheiu Secuiesc, Lupeni, Porumbeni, Simoneşti, Mugeni, Corund, Feliceni and Dealu - have been covered by the floods started on the surrounding hills and the swollen creeks, which have outran 100 l/sqm in less than an hour. The pick flows have killed 13 people in Lupeni, Feliceni and Simoneşti, another 3 persons have been missing in these places, probably swallowed by the pick flows, which have destroyed in only a few minutes 55 houses.

5. Conclusions

The floods from August 2005 have lined out the need of the elaboration of a national defense strategy against flooding, inundations. Adjustments to flooding are either structural or non-structural. Structural adjustments are designed to modify flooding hazards so that humans are protected and can continue to live in areas that are periodically subject to flooding. Non-structural adjustments are arrangements imposed to restrict the use of floodplains. Spite these, the specialists say that it is impossible to insure a 100% defense. There is a risk if it is thought that the damages produced by the floods are smaller, than the made investments. The reasons for an increase in flood damages caused by reliance on structural works can be associated with design standards, and over-confidence in such adaptations. At present, in Romania there are 10.000 km of dams and over 1.200 barrages and storage reservoir lakes. These numbers make Romania one of the best gifted countries from this point of view, the only problem remains their administration because non-structural works have to be integrated with structural works to reduce the impact of flooding in the Târnave river basin.

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Author contact information:

Mihai Voda, PhD Lecturer
Dimitrie Cantemir University
Targu Mures
3-5, Bodoni Sandor st,
540545 Romania

Office: +40 365801822
Fax: +40 365401125
Mobile:+40 740138777
mmvoda@yahoo.com