Original scientific article

ESTIMATES OF ENDANGERMENT AND PROTECTION FROM TORRENTIAL FLOODS ON SMEDEREVO TERRITORY

Slobodan Đ. Miladinović*[1], Ljiljana M. Gavrilović**
* Academy of Criminalistic and Police Studies, Belgrade
** University of Belgrade, Faculty of Geography, Belgrade

Abstract: On Smederevo territory around 30 torrential floods are registered and their general condition is alarming**.** Along with the growth of urbanization some of them are induced into sewer systems and rain collectors, which are mostly inappropriate in size to receive a lot of water. Their common characteristics are disorderliness of watershed and worrying ecologic condition of river beds (vegetation, dumps). That is the reason of frequent torrential floods, which make great damages to settlements and economy. When assessing endangerments of floods, influence of range of natural and anthropogenic factors must be analyzed as well as consequent damages. The town of Smederevo implements integral defense from floods on the whole municipal territory, both for the areas which are endangered by torrentials without protective systems and for the areas endangered by systematic watercourse. In order to reduce the damages made from torrential floods it is necessary to anticipate and realize the works by operational plans every year, to specify the flood zone, forbid every sort of construction and determine spaces for building future retentions by the General urban development plan.

Key words: Smederevo, torrentials, causes of floods, endangerment assessment, protection from floods.

Date submitted: 15 May 2012; *Date accepted*: 25 June 2012

Introduction

Along with the development of urban, economic and infrastructure systems, there is a constant growth in value of material assets in coastal areas, which had effect on growth of flood damages and other adverse impacts of water flows. Flood damages, losses in yield due to reduce or total shutdown of production and traffic and costs of evacuation and engagement of man power and mechanization in the defense from floods often exceed the income of certain territorial unit during multi-year period.

Except natural causes of floods, man also has great influence on increase of water levels-by cutting woods he intensifies swelling from the water

[1] Correspondence to: gavriloviclj@yahoo.com

basin, by building dams, sluices and bridges he changes the regime of swelling, by building protective embankments he reduces earlier flooded areas (inundation), by inappropriate management, accumulations, retentions, residual canals, charters and other objects he can make unfavorable coincidence and super plunge of waves of big waters on downstream part of water flow, etc. Anticipated climate changes in this part of Europe lead to bigger and longer draughts, but also to more frequent and greater big waters (Arnell, N. W., 1999; Alexandrov, V. et al., 2004; Trenberth, K. E. et al., 2007; Petković, S., 2008; Ducić, V. i Luković, J., 2009). Concerning previous direction of anthropogenic impacts, the condition could be only worse.

Objects of system for protection from floods, along with net of systematic watercourse represent infrastructure systems of high priority, because they are the condition for normal functioning of almost every economic and all other activity in potentially flooded areas. However, the level of protection along the watercourse is uneven, regular maintenance of protective objects is not done according to norms and is only 30-40% of necessary, number of repairs have not been done, river sediment from water flows are exploited without a plan (Petković, 2003). That means that protection from strong effect of water should be a constant task, where the level of protection and reliability of current protective systems should be constantly checked with extension, reconstruction and appropriate maintenance.

On Smederevo territory there is a great number of torrentials, and that is why it is in great danger of floods. The aim of this work is to indicate to basic problems in previous flood protection and to possible directions on which the protection should be focused.

Legal framework of protection from torrential floods

Protection from harmful effects of waters is legally regulated by the Law on Waters (Sl.glasnik number 30/10) and by regulations of General plan for defense from floods (Sl.glasnik number 7/97). Obligation of making annual Operational plans for implementation of defense from floods on water flows with protective systems is defined by General plan, as well as Municipal plans for implementation of defense from torrentials floods on territory of municipals and cities in the Republic for the water flows which are not covered by Republic plans. Basic documents for making plans of development of systems for flood protection and regulation of water courses are the spatial plan of the Republic of Serbia (2011) and Basis for water management of the Republic of Serbia (2011).

Protection from erosion and torrential water flows is defined by the Law on waters in the chapter the water activity. Article 61 defines erosive areas, and article 62 defines operations and measures for prevention and removal of harmful effects of erosion and torrents. Article 63 is referred to providing

instruments for work and measures, and article 64 to obligation of execution of works and measures.

City plans define program of measures, works and activities which are connected to torrential floods on certain area. The plan regulates works, measures and activities by phases of defense and duties and obligations in each phase of defense are clearly presented to the participants. Plans of city areas which are protected from floods are complied with protection of water areas of the Republic and annual operational plans of the Ministry of agriculture, trade, forestry and water management of the Republic of Serbia and Directorate for waters.

The city of Smederevo makes and implements its plans for defense from floods both for the territory which is endangered by torrential water flows without protective systems and for the areas which are endangered by systematic water flows with protective water management structures. In that way integral defense on the whole territory is organized.

Basic hydrological characteristics of the territory of the city of Smederevo

The territory of the town of Smederevo is characterized by wavy landforms, broad river valleys of gentle valley sides and vast alluvial plains. The exceptions are the upper parts of the basin of the river Ralja, and the Konjska River, and the immediate basin of the Danube to the mouth of the Morava. Most water flows in these regions is of torrential character. Their lower flows go into the wide alluvial plain of the Ralja, the Konjska River and Morava rivers where they flow. Hydrographic network on the north side is limited by the Danube at the length of 20 km and on the east side by the Velika Morava with flow length of 27 km. One of the most important tributary is the Jezava with the Ralja and the Konjska River. Other tributaries are short and with mainly torrential character. The area is characterized by the large number of channels that drain surface water. Depression and the abandoned bed of the Velika Morava, and Jezava and the Badrika are directed towards the river Danube by the system of canals and pumping stations of Smederevo and Kulic (Jovanovic,V. and Ocokoljic, M. 1992).

Significant changes of the hydrographic network and the regime change of surface water runoff are caused by the displacement of the Jezava bed and the introduction of its flow into the Velika Morava, where there has been cutting the natural flow of surface and ground water in the river basin of the Badrika. Regulation works on the Jezava are derived upstream from Smederevo, which protected the city from floods that have emerged after heavy rain and more frequent high water of the Danube, which slowed down the Jezava flow due to very small Jezava fall. New riverbed intersects Jezava Moravian mound near the village of Lipe. At the time of high water on the Morava River

embankment failure in closing and the Jezava retents water in the alluvial plain of the Velika Morava near the river embankments and floods the surrounding agricultural land.

Badrika, the side arm of the Jezava which according to R. Lazarevic (1957) is a branch of the Morava, was introduced into the new bed of the Jezava, which was a link between the Morava and the Jezava. Badrika basin developed on the left side of the Morava, on the inundation plane. On its east side water of the Velika Morava flows and on the west the Jezava and the Konjska River flood waters converge. So in this area there are numerous branches, still waters and marches. From external waters of Morava it is protected by an embankment. By changing the flow of the Jezava several branches are cut off (Badrika, Ševarika etc.) and thus prevented the water to flow from the protected area through these backwaters. A basin area of Badrika is unregulated, and flood protection is in the jurisdiction of the City Staff. Construction of drainage network and pumping station has not been realized, and excess water in the Jezava bed is evacuated through two tubular drains. Drains are constantly exposed to natural filling and coating from Zelezara. The evacuation of water from the Badrika into the Jezava is possible only when water levels are lower in the Jezava. At the time of melting snow and intense storms it can occur a greater influx of water from the basin of the Badrika. Then the outlet closes and its function terminates. Water is retained in the protected area and floods the large farmland. The extent of flooding depends directly on the flow of water, and can be flooded up to 500 ha of arable land. That means you need to build a network of canals and pumping station, which would be used in the dry season for irrigation (General Planning of hydropower project of Badrika basin, 2008).

Figure1 - *Hydrographic map of the city of Smederevo* **(see on page 158)**
(Source: Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006)

One of the most important physical-geographical factors for water runoff from a certain area is the density of river network. In the municipality of Smederevo it is well developed and includes over thirty streams. On the plateaus and terrace flow a large number of streams and rivers to Ralja, Velika Morava and Danube. In the field of Godomin there is a canal network that is mainly used for drainage.

Table 1 - *The density of river network of the city of Smederevo*

River basin	L (km)	F (km^2)	D (m/km^2)
Jezava	109,1	177	375
Ralja	195,8	302,6	647
Konjska river	104,7	180	550
Immediate Danube basin	29,7	49	606

L- Length of the main flow; F-basin area; D-density of river network.

The area of the city of Smederevo in hydrological terms makes Morava and Danube areas. Their specificity is distribution of torrential or periodic flows. In addition to the Danube and the Morava, in this area is only Jezava steady stream, while the rest are of torrential character. Only 18.4% are of the steady flows. In the basin of Ralja 66.6% are periodic flows in the basin of Konjska river and the Jezava all flows are periodic, and in the immediate basin of the Danube dry rivers are 68.4% (Miladinovic, 1997).

Table 2 - *Torrential water flows in the city of Smederevo*

Water flow	**River tributary**	**F km²**	**Os km**	**L km**	**Ls km**	**i_F %**	**J %**	**H_U m**	**H_{max} m**	**H_{sr} m**
Sastavak	Danube	18.34	22.34	8.59	8.07	13.55	2.14	68	269	190.5
Selište	Danube	6.05	12.39	4.63	4.76	12.55	3.07	70	221	171.4
Potok	Danube	4.97	9.39	3.52	3.69	16.64	3.72	70	201	165.3
Hajdučka voda	Danube	4.70	9.18	3.33	3.20	12.71	3.51	70	219	173.5
Petrijevo stream	Jezava	14.69	23.45	8.9	8.12	9.23	1.38	78	220	175.8
V. Davido	Ralja	8.50	13.57	6.1	4.79	7.02	2.02	99	222	160.4
Vučak stream	Jezava	9.38	16.04	7.42	6.65	7.41	1.98	75	222	174.9
Vodanj	Ralja	1.59	5.65	2.63	2.36	7.70	2.93	119	196	164.6
D. Jasenje	Ralja	8.21	13.95	4.89	5.30	8.29	2.33	107	223	173.3
Carevac	Ralja	10.26	15.92	7.66	6.50	13.38	1.97	109	291	194.3
Vodica	Ralja	18.17	22.18	10.64	9.73	10.38	1.50	100	280	191.2
Bitinac	Ralja	10.78	16.63	8.70	7.01	6.79	1.47	97	227	175.1
Barski p.	Ralja	13.11	15.6	5.43	4.99	5.96	1.38	97	185	161.6
Drmanovac	Ralja	0.71	4.01	1.75	1.7	9.39	4.46	105	183	155.5
Konjska river	Jezava	161.26	83.05	43.22	26.15	7.01	0.67	79	382	166.1
Dojnak	Konjska river	62.96	33.27	12.09	11.16	4.74	0.95	105	220	157.2
Ribnik	Konjska river	17.99	24.13	11.33	9.00	1.91	2.00	155	382	232.1
Đergadin	Konjska river	11.02	15.88	7.29	6.27	13.39	2.24	155	332	231.0
Kaluđerica	Barski potok	1.76	5.36	2.31	2.21	7.61	3.25	110	185	171.7
Mustavka	Barski potok	1.63	5.43	2.13	2.17	5.22	2.91	117	179	167.0
Ćirilovac	Petrijevo stream	4.70	11.02	5.34	4.89	7.16	2.43	92	222	183.6
Beluće	Ralja	7.28	12.68	5.27	4.38	17.11	3.09	119	291	199.4

F-basin area; Os-scope of the basin; L-length of the watercourse; Ls-basin length; i_F-average decline in basin; J-average decline of the river; H_U-elevation of the mouth; H_{max}-maximum elevation of the basin; H_{sr}-average altitude of the basin.

(Source: Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006)

The greatest impact on forming torrential water flows in great waters is the decline of the river basin. These declines on the territory of the city of Smederevo are very different. Beluce has the greatest value, tributary of the Ralja- 17.11%, and the least is Ribnik, tributary of the Konjska river-only 1,91%. It is also noted that immediate tributaries of the Danube have significantly higher average basin decline (13.86%) from the tributaries of the Ralja and the Konjska River.

In most watercourses cross sections of the river bed and its bandwidth is not in compliance with the high waters discharges, which is the main cause of flooding. All torrential water flows have such disadvantages. Dimensions of

the bed are usually minimal. Width of bed in the level of the coast ranges from 2 to 4 m, with a maximum depth of the thalweg line of 1-2 m.

The systematization of torrential water flows

General characteristics of torrential water flows in the analyzed area are non-systematization and concerning ecological condition of their beds. (Local Environmental Action Plan of Smederevo, 2007). They are overgrown with vegetation solid waste is disposed in them and they have been creating illegal dumps, which is a great natural obstacle for a runoff of water as it significantly reduces the throughput capacity of the river bed. The vegetation is not destroyed, the accumulated sediment is not removed after the passing of flood waves, and the issue of construction of sanitary landfills is not resolved in the municipality and is not taken enough efforts on education and raising environmental awareness among the population. This means that they do not take measures that would contribute to improving the water regime of torrential flows and reduce flood risk.

A major problem associated with torrential water is illegal construction along the coast, and even in the river bed. It swept the town of Smederevo, and is particularly pronounced at the periphery of the city and the suburbs. Residential and commercial buildings in the immediate vicinity of rivers are built, so as bridges of insufficient bandwidth, made gaps for water of insufficient capacity at the intersection of streams and roads, installed water pipes and other utility installations in the profile of the bed, etc.. These phenomena have multiple negative consequences. Occupying the coastal zone prevents the regulation of river flow that would be inevitable in the future. One of regulatory measures is safe and expansion of the river bed without the demolition of built structures which is not possible. Constructions significantly increase the damage from possible flooding.

Smederevo is one of the cities with the largest number of refugees and displaced people in Serbia. More than 11 000 displaced and close to 5000 refugees live here. This has a significant effect on illegal construction, especially in suburban areas immediately adjacent to the torrential streams. This should include a wild weekend settlements, illegal commercial property and illegal change in land use (General Plan "Smederevo 2020", 2004). There are no official data on endangered areas, but the consequences are visible at every step. The construction on the hilly terrain outside the influence of flood waves is noted in villages. There has probably been experience in floods for centuries and the wisdom that it is safer to build buildings on the edge of the river valleys.

Endangerment of coastal areas by torrential water flows

The degree of endangerment and the criterion for the estimate of endangerment

The threat of torrential streams results from their specific genesis and manifestation. Fast and high concentration of water in their beds prevents the application of traditional methods of flood control. The introduction of the degree of regular and special flood control which is applied in large rivers in these cases is not used, because there is no hydrological justification. Due to the sudden coming and the short duration of high water there is often no time to declare flood control, which may be only an emergency with such watercourses. Previous experience in torrential floods is not positive because immediate measures of protection are often not taken, but most of the activities are related to the rehabilitation of the consequences of flooding.

Figure 2 - *Places threatened by torrential floods in the city of Smederevo* **(see on page 162)**
(Source: Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006)

On the territory of the city the scope of torrential streams flooding widely varies depending on the geomorphological characteristics of the basin and morphological parameters of the water flows. Very important impacts are also human factors, the degree of development of residential and commercial properties in the vicinity of river beds. If the density of the population near the rivers increased, the more local people are interested in the flood protection.

The general plan of Smederevo by 2020 (2004), in the analysis of potential danger areas of torrential floods, points out that almost all water flows in the categories of medium and high flood risk belong to a group of unregulated streams and are located outside the Republic of water management plan for the protection of water. Regulated streams are also not absolutely protected from flooding, as the upper limit of the large flow of water to which the defense system can always be projected to be higher, which will affect the outflow from the regulated bed (Flood protection and water flow regulation in the Republic of Serbia, 2001).

The criteria for assessing endangerment of coastal areas from torrential water flows should be based on a parallel analysis of the impact of natural and anthropogenic factors. The most important factors are the natural hydrological (catchment area, cross-section of the river and decrease in river beds), geomorphic (length and width of the river valley, the degree of erosion) and biological (presence of vegetation in the beds and on the banks). Anthropogenic factors are numerous and are related to human activities that contribute to increasing the level of flood risk, such as reducing flow profile by building bridges and culverts, placing installations (pipes) in the river channel to reduce the profile,

illegal construction of residential and commercial buildings on the banks and illegal dumps in the river bed.

In assessing the degree of endangerment special attention should be directed to the damages caused by torrential floods. They depend on the value of coastal areas and the width of the flooded river valleys, presence of arable farmland and construction of residential and commercial properties in coastal areas. Great damage can be caused by interruption of traffic and endangering traffic. It is therefore important in assessing the endangerment to separate local, regional and main roads and railway lines. Damages caused by traffic disruption vary greatly depending on road category.

The characteristics of torrential floods

In the territory of the city a lot of damage can be caused by overflowing water from the river Danube, Morava, and Jezava, which happened in 1981 and 2006. The risk of flood in greater waters of these rivers depends on the degree of development of protective structures to protect the city and Godomin field, such as embankment and revetments. Damage with these floods may be disastrous.

Great damage can be caused by the flooding and torrential water flows that are tributaries of large rivers. Their risk of flooding depends on the intensity and duration of torrential rainfall in the basins and flow capacity of the river beds. Height of flood damage is directly dependent on the distance of property from river beds. The risk is high for streams that flow through the city and next to the fortress (Petrijevo stream), through the village (Ralja and Jezava) or in the area of industrial plants (Ralja and Jezava in the zone of Zelezara).

Picture 3 - *Smederevo fortress flooded in 2006* **(see on page 164)**
(Source: Photo documentation of Staff of flood protection in the town of Smederevo)

In the delta areas of tributaries to the home river flood risk depends on the amount of water level of the home river and the state of the river bed in the delta. It is not adequately regulated the mouth of Badrika into the new bed of the Jezava, and neither the mouth of the stream Bitinac, Lower Jasenje, Vodica, Big Davido and Carevac into the Ralja are regulated. Overgrown vegetation and untidy mouths of these streams can cause flooding upstream and in the smaller streams of water. Flooding can be caused by the overflowing of canals that were built as part of land reclamation systems, or not covered by these systems. The risk of flooding depends on the intensity of torrential rains in the basin, draining channels, channel flow capacity and operation of pumping stations. Amount of damage in these floods is much smaller than the natural flows of torrential flooding because of the possibility of evacuation.

There are the most valuable goods in the Danube coast line on flooded areas, such as the town of Smederevo, the medieval fortress - a cultural monument of the first rank, industrial zones, regulated irrigation area and urban water supply source. Along the coast of the Danube and from the mouth of the Morava to former mouth of the Jezava (Marina) there is Godomin field with low elevations of the terrain, making it by far the inundation zone to the south, a zone defense line is 10.3 km upstream from the Marina to the Old Zelezara. In the area of the city there are tightly restricted coastal hills, because of which flooding line narrows towards the Danube (Report on the Condition of coastal protection from backflow HE "Djerdap", 2001). Despite its small area, the value of goods affected is enormous and potentially irreparable, because human lives are endangered.

The left embankment of the Velika Morava, from the mouth to the border of the town, is characterized by flat ground. Morphologically it is the river terrace with arable land and settlements. Flood damages depend on the tributaries of the Morava river bed and regulating the bed and the mouth.

It can be concluded that the flood may occur due to water penetration on critical points in the regulated riverbeds of Danube, Velika Morava, Jezava and Ralja, and the influx of high water into the beds of Jezava and Ralja from unregulated bed of their tributaries. Flooding is usually the result of low bandwidth and unregulated river mouth. Flooding of some parts of Smederevo in the conditions of torrential rains and high waters of the Danube is highly possible. Flooding can be caused by insufficient bandwidth sewage of mixed type. In Smederevo, storm water and sewage are connected, and through the pump station "Jezava" they take into collector in Petrijevo, and then drain into the Danube. Petrijevo collector collects water of that stream and sewage of the city. Also, the waters of Vučak stream together with water connections of the sewage are pumped via pump stations in the Danube. Heavy rains and slow down of the Danube can cause flooding which can manifest insufficient capacity of collector and sewer discharge and flooding through sewer manholes in the city, what happened in 2006. (The issue of removal of atmospheric and used waters of city of Smederevo, 2006).

Access to the defense against torrential floods and urban development plan for flood

In order to make efficient and rational flood defense, the approach to defense should be adjusted to the characteristics of torrential processes. One should always have in mind the genesis and development of torrential streams, as well as the short time for organizing and implementing the protective measures. This means that all possible measures must be prepared in detail and in advance so the arrival of the flood wave can be realized immedi-

ately. This requires a good structure of Flood protection staff, in which all activities are coordinated and harmonized, and all entities involved in the defense of the right time.

There are streams that are only partially regulated, but the flood protection of them is performed as if they were unregulated. This approach is necessary because the integrated flood protection is implemented throughout the watershed. Continuous and precise coordination of protective measures are implemented along any waterway. Participants of flood protection on the streams, which are in the Republic water management plans, are precisely defined in that plan, and for flows not included in the Republican water management plan, plans for the defense were made by the city staffs. They accomplish the defense in cooperation with national authorities responsible for flood water management as a shared activity of water management and urban subjects.

The area covered by the General urban plan of Smederevo in terms of flood protection is the responsibility of water utilities. Their responsibilities are regulated by contract with the Public Water Management Company "Srbijavode" about the maintenance of protective structures and implementation of flood protection on streams with built facilities and about the maintenance of drainage systems in their structure. The role of manpower, machinery and equipment of water management companies in the flood protection is defined by the annual operational plan of the Ministry of Agriculture, Trade, Forestry and Water Management, Directorate for Water, as well as water management technical documentation for flood protection (Flood protection and water flow regulation in the Republic of Serbia 2001).

In addition to flood protection, adverse effects of water include also erosion processes. They are subject of specific plans related to protection against erosion, which are special obligations of municipalities (Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006). Erosion processes can create layers in the zone of bridges and culverts for water and they can be a potential cause of flooding.

City plans for defense against torrential floods are unified for all of Serbia, and methodology were made by the Ministry of agriculture, trade, forestry and water management. They include general and an operating part (a General plan for flood protection, 1997). The general part is about the long term, according to the period of validity of the General Water Management Plan. In consists of: the general characteristics of areas important for flood protection, the basic concept of the organization of flood torrential streams, management and coordination application among the mechanisms of defense, determining the criteria for the introduction of different phases of defense depending on the risk and defense organization. Operational Plan clearly defines and shares authority in the implementation of activities necessary for effective defense at all stages (preparation of the defense prior to the floods, and emer-

gency actions during floods). The Plan systematize problems identified in the field, determines the plan of measures and activities which must be carried out in flood control, prescribes a priority in solving the problem based on the degree of threat to people and property, systematize data on manpower, equipment and machinery that are used for defense and brings plan of commitment for manpower and equipment required, depending on the assessed risk.

Data sources for the general and operational parts of the Plan are conducted questionnaires, the current documentation, Hydro meteorological Service of Serbia data and Data Commissioner on critical sites and unregulated streams in the area.

Previous measures of protection against torrential floods on the territory of the city of Smederevo

Water flows in the area of the city, except for the river Danube, Morava and partly Jezava, tend to have torrential hydrological regimes. Random channel and basin are causing great damage to settlements, agricultural land, transport and other infrastructure. About thirty torrential flows are recorded. Some of these flows are introduced into sewers and rainwater collectors by urbanization of the city, or some of them are only partially regulated at the top or bottom of the flow.

In order to protect the settlements, industries, roads and agricultural land different types of objects are used. Objects of *passive safety*, defensive embankments have been constructed according to the content of protected space and they are "urban" type through settlements and the "wild" type if they are used to protect agricultural land. Profiles of watercourses with dams through settlements are dimensioned so that they may fail a hundred years of high water, with no leakage. If agricultural land is located in the coastal, embankments are dimensioned to accept a smaller return water period. Embankments are only on river Ralja. They were constructed along the left bank of the mouth in Jezava to the village Vranovo in length of 0.9 km, and from the railway Belgrade - Mala Krsna in the village Ralja to Živkovac stream in length of 15.4 km.

Facilities for *active protection* from floods are less frequent and they are in the upper parts of the flow of small streams. This is primarily related to the retention and water accumulation, but the situation is not satisfactory, because the defense lines are closed, and the floods come from the hinterland. Significantly reduced level of protection on regulated waterways due to improper maintenance is noticed. Retentions are in basins of Petrijevo, Ćirilovac, Vučak and stream of river Jezava.

Petrijevo stream rises above the village Petrijevo at 179 m above the sea level. East of the Karadordje hill in Smederevo receives right tributary

Ćirilovac stream, and then, their waters drain with channels into the Danube. Basin area of Petrijevo stream is 14.69 km^2. Its valley was fully populated, with buildings of individual housing construction. Water levels of streams are very oscillating, from dry bed to torrents and floods in the spring. Settlement construction changed the hydrologic conditions. Reducing arable land and increasing the surface of the streets, yards and buildings, increase runoff and flooding are more common. The coefficient of runoff from arable land is 0.08 to 0.1, from lawn 0.2, from housing 0.4, and from asphalt 0.9 (Study on Spatial of Petrijevo stream in Smederevo, 1978). The solution for floodable problems was found in flow regulation of Petrijevo stream and building the "Smederevo" and "Petrijevo" retentions.

Water solutions of Petrijevo stream relies on the creation of real opportunities to defend the city against floods and arranging the bed of the stream flow area through the city. Basin of Petrijevo stream is not hydrologically studied, no water level is observed, and no flow is measured. Hydrologic analyzes showed that the large century-old water cannot hold one retention, which dam, due to the geomorphologic conditions, may not be large. Therefore it was decided to build two retention dams.

The "Petrijevo" retention was built in 1983, and "Smederevo" retention was built in 1985. Both of them are synchronized and in control of the river basin area of 9.56 km^2. Prior to their construction, with stronger rainfall, Petrijevo stream was flooding coastal terrain, especially the part about the city hospital.

The volume of retention space "Petrijevo" is 202 000 m^3. The dam has outlet pipes with a diameter of 300 mm, which is constantly in use, maintaining the retention space empty, and allows acceptance of arrival flood wave. The existing retention area can receive, without overflowing, flood wave from the basin of Petrijevo stream in 1000 years return period. To empty the retentions "Petrijevo" after the passage of the wave, return period of 100 years, it takes about 7 days (Study on Spatial of Petrijevo stream in Smederevo, 1978).

The volume of retention space "Smederevo" is 122 000 m^3, and it corresponds to volume of flood wave that can happened once in one hundred years. Based on the morphology of the valley of Petrijevo stream and rainfall in its catchment area, one can conclude that the maximum height of a flood wave in the dam area is the highest, and can reach 2-3 m. Due to the effect of wave scattering, depth of water downstream from the dam would be quickly reduced, and at a distance of 500 m was about 1 m, and in the urban part of town would not exceed 0.5 m (Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006).

From the point of safety area, upstream from the dam "Petrijevo" and "Smederevo" is necessary to provide the functionality of the collector and its flow. Particularly important is the entrance to the sewer, because the flood waves can partially or completely shut it down by the object they carry.

The role of Petrijevo stream is also the collector implementation of atmospheric and sewage waters from the narrow part of the city through the pumping station "Jezava" into the Danube. The total amount of water discharged this way in the Danube is 6.5 m^3/s (Gavrilović and Miladinović, 2009).

Ćirilovac stream, right tributary of Petrijevo stream, once enjoyed on the outskirts of Smederevo as an open course, but today the mouth is piped, and both streams flow through the city collector of sewer lines. As the valley of Petrijevo stream, the whole valley of Ćirilovac stream is fully constructed residential buildings and small businesses. Accelerated urbanization, which has lasted for more than twenty years, imposed the need for protection of urban areas from the flood of torrential streams. Retention "Ćirilovac" was built in 1985. and controls 3.52 km2 of catchment area. In it there is a bottom outlet steel pipe with diameter of 300 mm, which maintains retention area empty. The volume of retention space is 85 000 m^3 and it corresponds to volume of flood wave that can happened once in one hundred years (Plan for the proclamation of erosion areas in the municipality of Smederevo, 2006). If less probability waves reach it, it could cause some material damage and a host of other s problems in the city. For the duration of emergency flood protection, organization responsible for water management is required to provide enhanced control of the facility 24 hours continuously.

Vučak stream appears southwest of the village Vučak from the source of 0.03 l/ s intensity. Flow length is 5.5 km, it has a small flow rate and runoff. Water current drains all atmospheric and offspring waters in the surrounding area. It empties into the old riverbed Jezava. Since the new flow Jezava is in the Velika Morava, no permanent solutions for drainage of the Vučak stream are given. According to the decision of "Hydro project," the Vučak stream waters remain in the old riverbed of Jezava and form a reservoir "Jezava" from which, a portion is released to the Danube via the existing drainage network and pumping stations for drainage of Godomin field. Because of torrent water regime, Vučak stream has been threatened the bridge on the regional road Smederevo - Požarevac and railway Smederevo - Mala Krsna.

Hydrological conditions are substantially worsened by construction of residential blocks in the suburban area called Papazovac, as well as the rapid settlement of the area between Smederevo and Vučak, because the surface runoff is significantly increased. Therefore it was necessary to build retention "Vučak" , in order to accept the large wave of water from this stream. In addition, partial control of the bed of Vučak stream has been done downstream, by combining the arrangement of surface flow and piped. The dam is an earth retention, and volume of retention area is 224 800 m^3 and it corresponds to volume of flood wave that can happened once in a thousand years (Study on geotechnical conditions for the main project of construction the dam, concrete bar-

riers, the existing dam and control the Vučak stream, 1990). Retention "Vučak" and accumulation "Jezava" are intended to be synchronized.

From the aspect of the territory protection downstream from the dam "Vučak" and accumulation "Jezava", the importance of the basic operation of the dam and outlet pipe culverts under the road Smederevo - Požarevac must be emphasized. Permanent control should ensure flow, especially during the evacuation of the big waters for floating objects that can close gaps.

The river **Jezava** is a branch of Velika Morava, which appears 2 km downstream from the mouth of Jasenica near the village Trnovče and used to flow into the Danube at Smederevo's Fortress. Riverbed of Jezava is formed at the contact of alluvial plains and higher terraces of Morava. It is separated from river Velika Morava by embankment that was built after the disastrous floods in 1897. Until the construction of embankments bed of Jezava was used as a spare bed that, during the flood, received and drained part of the Morava water into the Danube, it was a kind of natural water run-off regulator. The bed of Jezava is fed by the water from many sources and peripheral streams, Konjska river, Ralja river, Segda river and Vučak stream. During the floods of the Danube, the slow down, several kilometers long , was created on Jezava, and major floods in the lower part of the course occurred. Such were the floods in 1965 and 1977, when the Little quay of Smederevo port, and Small Town of Smederevo's Fortress was flooded. Therefore there was no settlement around Jezava, but the city went out into the surrounding hills.

After the construction of Hydroelectric Power Station "Djerdap I" and the creation of the Danube backwater, in order to defense Godomin field from torrential floods of Jezava tributary and high Danube waters, the right embankment was built along the river Jezava, from the mouth of the Danube to the high terrain, 7 km upstream Radinac. Godomin field is protected by right embankment of the Danube, left embankment of the Velika Morava, right embankment of Jezava relocated bed, and part of left embankment of Ralja. On the west side, the protection is completed by the right embankment of Jezava old bed. Godomin field is not only important for the municipality of Smederevo, but for the whole region. It stretches over 5741 hectares of arable land of the first class quality. It has six settlements and Steel plant. Intersected by the road the first rank, the M-24, railroad Belgrade - Nis and the Danube waterway. In Godomin field is the source of drinking water, which yields by more than 1000 l/s significantly exceeds the current needs of Smederevo (Miladinović, 1997).

In order to protect the coastal zone, the riverbeds of Jezava and Ralja are regulated. New riverbed of river Jezava was built in the 70's of the last century in order to protect Godomin field from backwaters of Danube. Jezava was introduced in regulated riverbed of Velika Morava, or branch of the Morava. So far, numerous problems in the functioning of this system are recorded. Velocities in the branch are not enough to accept water from Jezava, so there is a

backwater and flood. Wastewater of Steel plant through two collectors pours into Ralja, just before its intersection with Jezava. Technological waste water is loaded with the suspended solids which deposit as a red mud.

According to rough estimates, it was found that the USS Serbia released into the open flow about 15 000 t of hematite (Fe_2O_3) per year, which directly undermines the ecosystem of the watercourse (Gavrilovic and Miladinovic, 2009). Distance from the waste water collector to the mouth of Jezava is 9 km. In this part of the flow, due to a small drop of water bed, and the low-speed of the water, pulling power of the flow reduces, and the process of deposition of suspended solids at the bottom of the channel in the form of sludge, speeds up. Calm sludge adversely affects the size of the flow profile, creating a slow-down and causes floods of the both rivers Jezava and Ralja.

Regulation works carried out upstream of Smederevo, a city and its wider environment are protected from frequent flooding, but the problem of Jezava old bed remained unresolved, about 8 km in length, which has a steady stream of water from Vučak stream and Segda.

Filling the old bed, the surface water would be the pouring uncontrollably in Godomin field and flooded it, because the existing canal network is not enough to drain excess water. In order to preserve the functioning of drainage systems, water drainage controlled in the protected area and the city of Smederevo was protected from flooding, old bed Jezava in 1981 was converted into a reservoir. Until the construction of retention "Vučak", reservoirs of Jezava received the entire water catchment of Vučak stream.

The construction of dams on Vučak stream in 1991, caused the reduction of water flow at the time of maximum rainfall, but due to increased urbanization, the runoff coefficient is increased, so, the accumulation of "Jezava" significantly improved hydrological picture of this area. It has taken an important role in protecting Godomin field, as well as in the work of pumping stations "Smederevo" that drained Godomin field. The total volume of the reservoir area is 900 000 m^3. Accumulation "Jezava" is primarily used for sediment retention and flood protection, downstream from agricultural area Godomin filed and urban areas of Smederevo. The accumulation consists of the volume of sediment and the volume of the flood wave reception.

Capacity for sediment is 80 000 m^3, occupying the space between the lowest elevation of the reservoir bottom 69.52 m above sea level, and is in the area of normal backwater elevation 70.40 m above sea level. Volume for the receipt of a flood wave is 420 000 m^3 and is located in an area of normal backwater elevation 70.40 m above sea level. Overflowing peak is 72.86 m above sea level. According to calculations, this volume is sufficient to accept the wave of high water of Vučak stream that overflow from retention "Vučak" to the accumulation of "Jezava" (234 000 m^3) and the estimated volume of water waves of large streams of Vučak stream, probability of occurrence once in

1000 years downstream of retention "Vučak" (Plan to designate the erosion areas in the municipality of Smederevo, 2006). If we consider that the accumulation of "Jezava" is practically in the city area, it provides an opportunity for local tourism development and the development of sports and recreational activities related to water. Enrichment of fish stocks may encourage the development of fisheries. It is therefore important to maintain water quality in the reservoir and the environment in the entire basin.

Regulation of small streams as a measure of flood protection

Increasing of effectiveness of the flood protection of the Danube and Velika Morava is provided by the expensive hydro engineering works (dams and embankments). For smaller streams, besides hydro works, noninvestment works and measures can be applied. It is extremely important to be guided by the integrated principle of flood protection, cover the entire basin and not only the waterway.

Hydro engineering works include repair of existing facilities, rehabilitation of damaged parts, flattening of peak embankment and others. Started regulations should be finished, as the proper territory of the town of Smederevo and the entire municipality. The construction of small water reservoirs in the upper parts of watersheds torrential streams, if there are conditions, should be linked with protection functions and other forms of water use - irrigation, sport, recreation and fishing.

Conclusion

In our country torrential floods are very common natural disaster. A small number of cities and municipalities have adopted Plan of flood control, although the law required them to do so long time ago. The responsibility of municipalities and cities is even higher if we add the tolerance of illegal construction in flood zones and lack of maintenance of river beds. Forecasts of climatologists and hydrologists are not optimistic. They find that the extreme water disasters in the future will be more and more.

Flood protection is a complex activity that involves a number of works and measures in river basins. In Serbia the previous development of this branch of waterpower engineering was based on the construction of major capital construction, such as dams, dikes and reservoirs, regulation of the watercourses and construction of canals, all in order to secure the protection of people and material assets in flood zones.

The world is increasingly used a new concept of protection from flooding, known as "Living with floods" (Varga and Babić Mladenović, 2001). Its essence consists of integrating human aspects of care, which includes the preservation of human life and property, with environmental, con-

servation and restoration of natural functions of the flooded area. Serbia in the future must adapt to the new way of flood protection taking into account the current situation and the economic strength of its community. Proper alignment of investment and non-investment measures and works should provide quality solution for protection and regulation of flood areas in Serbia. Given the economic condition of society and the nature of the basins of small and medium-sized streams, non-investment measures (preventive action and the good organization of the implementation of defense) should be given more importance than investment.

Protecting the town of Smederevo from torrential floods is very complex and includes economic, technical and social aspects. Access to flood control must be adequate, and solving this problem should involve all relevant actors of defense. Holders of flood protection are the city authorities, water management institutions, which role defines Republican operative plan for flood protection, urban systems (utilities, police, fire protection, medical services), representatives of the economic system and the media. An effective defense against torrential flooding is not possible without well organized staffs and understanding of the roles of all participants in the defense. Staffs have to apply the modern concept of flood control, which is integral defense in the entire basin.

The general condition of torrential streams in Smederevo is alarming as the man and the nature are joined together. Expressive disorder of river beds, river beds vegetation, landfill, inadequate bridges and culverts for water are complex issues to be resolved is the considerable time and money. Uncontrolled urbanization and construction in flood zones increases runoff and effects on increase of maximum flow of torrential flows. Connecting atmospheric and sewage system is not aligned with the expanding of the City. Collectors who receive torrential flows don't have required capacity, because when calculating their leaky capacity, planned retention for reducing flood waves have been taken into account, and that have not been made yet. In the city there are not enough sinks, and many of them are not maintained, so the swelling of the collectors is disabled. It is not precisely defined who is responsible for the maintenance of torrential streams which flow into the sewage system. Also, cleaning of collector's receiving parts is insufficient and irregular.

To minimize the damages caused by torrential floods and overcome the difficulties that currently burden Smederevo, it is necessary to make operational plans each year, which will predict and execute works that will gradually reduce the damage caused by torrential floods. Provision of timely and regular torrential downpours forecast by the Hydrometeorological Service of Serbia is of great importance. Master City Plan should specify the flooding zones and prohibit any type of construction, and also specify the purpose of this land. It is

important to predict the future construction of facilities for retention and start planning their construction. Of crucial importance is to provide the funds in the City and State budget, for the implementation of these tasks and for organizations that need to implement them.

References (see on page 173)