TORRENT CLASSIFICATION – BASE OF RATIONAL MANAGEMENT OF EROSIVE REGIONS

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Abstract

A complex methodology for torrents and erosion and the associated calculations was developed during the second half of the twentieth century in Serbia. It was the "Erosion Potential Method". One of the modules of that complex method was focused on torrent classification. The module enables the identification of hydro graphic, climate and erosion characteristics. The method makes it possible for each torrent, regardless of its magnitude, to be simply and recognizably described by the "Formula of torrentially".
The above torrent classification is the base on which a set of optimisation calculations is developed for the required scope of erosion-control works and measures, the application of which enables the management of significantly larger erosion and torrential regions compared to the previous period. This paper will present the procedure and the method of torrent classification.

Keywords: *soil erosion; torrents; torrent classification.*

1 INTRODUCTION

In nature, there are a great number of torrents. The most widespread are the small torrents called gullies. Their lengths are several hundreds of metres and watershed areas are of proportional sizes. Their characteristic is that water and sediment flow in their channels only during and immediately after a heavy rain. On the other end of that huge spectre of torrents are the large torrential rivers, whose lengths and watershed areas amount to several hundreds and thousands of kilometres. The prefix torrent is derived from the characteristics of flood waves which occur very quickly, carry significant amounts of sediment, but instead of flooding, they destroy whatever is in their way.
During the twentieth century, Serbia was impacted by a great number of torrents of all magnitudes. They damaged and destroyed the settlements, the roads and interrupted the railway and road transport.
The State was faced with a great problem, because it did not have even an approximate knowledge of the number of torrents and could not plan the defence against torrential floods.
For this reason, in the first half of the twentieth century, the torrents in Serbia were inventoried. More than fifty thousand torrents of various magnitudes were listed. This is on the average one torrent per square kilometre of the hilly and mountainous part of Serbia.
Soon after the first inventory of torrents in Serbia, it was determined that the collected data were not sufficient. The main deficiency of the inventory was the fact that it was

designed according to the model of watercourse classification, which codes the main recipient and the tributaries of the first, the second and further orders. Such a classification is adequate for the inventory of large rivers and their tributaries. The unsolved issue was how to classify a gully, which is a torrential tributary of the first order of a large navigable river, as well as a series of other questions.

2 EROSION POTENTIAL METHOD

Systematic investigations of the intensity of erosion and torrents were begun in former Yugoslavia sixty years ago ("Jaroslav Černi" Institute for the Development of Water Resources, 1947.), and they enabled the development of The Method for the Quantitative Classification of Erosion (MQCE), 1954. During the investigation work it was notified that erosion intensity could be used for computing the amount of sediment that reaches the downstream part of a river so that the investigations were extended to include the observations of the transport of the sediments to the control profiles. During last fifty years of permanent developing process results as a complex methodology for investigation erosion process, mapping, sediment calculating and torrent classification. Name of this method is “Erosion Potential Method”. Since 1968. EPM is a standard method for erosion and torrent training engineering in water management. (Gavrilovic S. (1957); Gavrilovic S. (1966))
By the development of this original method, a complex method was created for the spheres of erosion and torrents, named "Erosion Potential Method". In short, this method has for a long time been the standard method and the tool for all engineering problems related to erosion and torrents in the field of water management and later on even for wider use. The method consists of:
Quantitative classification of erosion (1954)
Quantitative sediment regime (1955)
Torrent classification (1956)
Methods of optimizing calculations of the volume of erosion control works (1958)
The method was enhanced several times:
Erosion Potential Method I phase (1966)
Erosion Potential Method II phase (1968)
Erosion Potential Method III phase (1986)
Identification of erosive regions (1998)
Development of information and GIS procedures and applications for EPM (1985 - to date). (Gavrilovic S. (1972); Gavrilovic Z. (1988); Gavrilovic Z.Stefanovic M. (1998).)

EPM Quantitative classification of erosion

Some modules of the “Erosion Potential“Method are well known, such as the module for erosion mapping, often under the title “Gavrilović’s method or model“, after the surname of the creator of the method - Slobodan Gavrilović. Under his leadership, during the period 1952-1976, the basic modules were realised, two phases were completed and the third phase of the method improvement was started.
The EPM erosion mapping procedure requires investigations and computations to determine and present on a map the surfaces with the same quantitative erosion class. The basic EPM value of the quantitative erosion intensity is the Erosion Coefficient (Z). (Gavrilovic S. (1972); Gavrilovic Z. (1988))

The quantitative value of the erosion coefficient (Z) has been used to separate erosion intensity to classes or categories. The mean value of the EPM erosion coefficient (Z) for the catchment's area is the basics value for all EPM calculations.

EPM Erosion and torrent categorization			Table 1
Erosion and torrent category	Qualitative name of erosion category	Range of values of coefficient (Z)	Mean value of coefficient (Z)
I	Excessive erosion - deep erosion process (gullies, rills rockslides and similar)	Z > 1.0	Z=1.25
II	Heavy erosion - milder forms of excessive erosion	0.71< Z <1.0	Z=0.85
III	Medium erosion	0.41<Z<0.7	Z=0.55
IV	Slight erosion	0.20<Z<0.4	Z=0.30
V	Very slight erosion	Z< 0.19	Z=0.10

The erosion mapping module has been presented several times to the professional audience, because it is the module which represents the base of the method. Although erosion mapping by this method and module requires a trained specialist, the apparent simplicity of the method and the similarity to other methods led to several erroneously constructed erosion maps and unprofessional modifications.
Namely, all the mistakes made during the phase of erosion mapping bring in an exponential error to all subsequent calculations. This issue was devoted much attention to in several papers.
In Serbia and in the countries of the former Yugoslavia, which make up one fourth of the Danube catchments, there are several different types of erosion mapping, for which their authors claim to have applied EPM. However, they cannot explain why their maps present the weak erosion processes in the areas with the developed gully erosion in forests, or the severe erosion in the areas of mild slopes and intensive agricultural production. For this reason, it is recommended to be cautious in using the non-authorised erosion maps.

EPM Torrent Classification

The module which was more modestly presented to the professional public so far is the module of torrent classification. This module is intended for the specialists in torrent management and planning of complex erosion control works.
Already in the introduction, it was mentioned that this is the case of a variant of hydro graphic classification adapted to the characteristics of torrents. Namely, every stream, therefore also torrents, have the essential hydro graphic characteristics that can be reduced to flow, catchments, slopes, etc. (Gavrilovic S. (1972))
The characteristic by which torrents are distinguished from other streams is high erosion intensity, which is the source of sediment transported by the torrential flow.
Torrent characteristics also depend on climate characteristics of the region in which they occur. It is a rule of thumb that, in the optimal case, the only the data in torrential areas refer to precipitation and temperature. For this reason, this set of data is adopted for the definition of the effect of climate.

The basic idea of this module is to enable the assessment of torrential characteristics by one glance. This is made possible by the introduction of the entry called “Torrent Formula“. The formula consists of three parts, i.e.:

- Torrential class
- Torrential category
- Erosion intensity.

Torrential class is determined based on the value of hydro graphic coefficient of the torrential class (Hk) calculated by the formula:

$$Hk = F \times A \times K \times \frac{Lt+1}{L+1} \quad (1)$$

Where:
F- Catchments area
L – Whole length of torrent flow
Lt - total length of the tributaries of I - II order.
K – Climatic and topographic coefficient calculated by the formula:

$$K = T \times \sqrt{Ip} \quad (2)$$

Where:
Ip - mean pondered slope of torrent bed
T is temperature coefficient calculated by the formula:

$$T = \sqrt{\frac{t^\circ}{} + 0.1} \quad (3)$$

Where:
t° - Mean annual temperature
A - coefficient of catchments form calculated by the formula which defines the similarity of the form of torrential catchments with the fan-like semi-circular form which characterises the most intensive torrents.

$$A = \frac{P}{L \times (\pi + 2)} \quad (4)$$

P - Catchments perimeter
The calculated value of the coefficient of hydro graphic class Hk is the base of torrent classification. They are classified into six classes of torrents, as presented in the Table 2. (Gavrilovic S. (1972))

Torrent classification		Table 2
Torrent class	Description	Torrent hydrographic class coefficient (Hk)
A	Torrent Rivers	Hk>20
B	Small torrent Rivers	10<Hk<20
C	Torrent streams	1.0<Hk<10
D	Small temporary torrent streams	0.1<Hk<1.0
E	Landslide small torrents	0.05<Hk<0.1
F	Gullies	Hk<0.05

EPM torrent class (A-F) and erosion coefficient (Z) are basic values for antierosion and torrent training works optimization. Torrent Formula can be entered to the list in the form of alpha-numeric data of the following form:

Which means that it is a torrent

- Class **B** (Small Torrent River)
- **III** torrential category. See table 1.
- Mean value of erosion coefficient is Z=0.587, i.e. it is a more severe form of medium erosion.

The torrents classified in this way can also be presented in the cartographic form, because in this way the real torrential risk of the torrent can be much better evaluated. Torrent classification has improved the monitoring of the results of erosion control works and the elaboration of the optimizing calculations for the planning of the required volume of erosion control works in the function of erosion intensity and torrential class.
The inaccuracies made during the planning of this type of works, in addition to the irrationally high or low investments, can also result in a torrential disaster.

EPM Antierosion and torrent training works optimization calculation

Long duration of intensive complex antierosion and torrent training works help us to find optimal volume of the works. Long term investigation was successful. The Figures present the dependences of the optimal volume of works in the function of torrent class and erosion intensity. The dependences related to technical works and biological works are presented separately. The presented dependences are the result of fifty years of systematic work on torrent management and erosion control and the continual monitoring of the realised effects. The presented dependences relate to the region of Serbia and a greater part of the European countries. Figure 1 show relation who help us to define optimal volume of biological and biotechnical works depending on erosion intensity (Z) and torrent class. Figure 2 show similar relation for technical works. (Gavrilovic Z. Stefanovic M. Milojevic M. Cotric J. (2006))

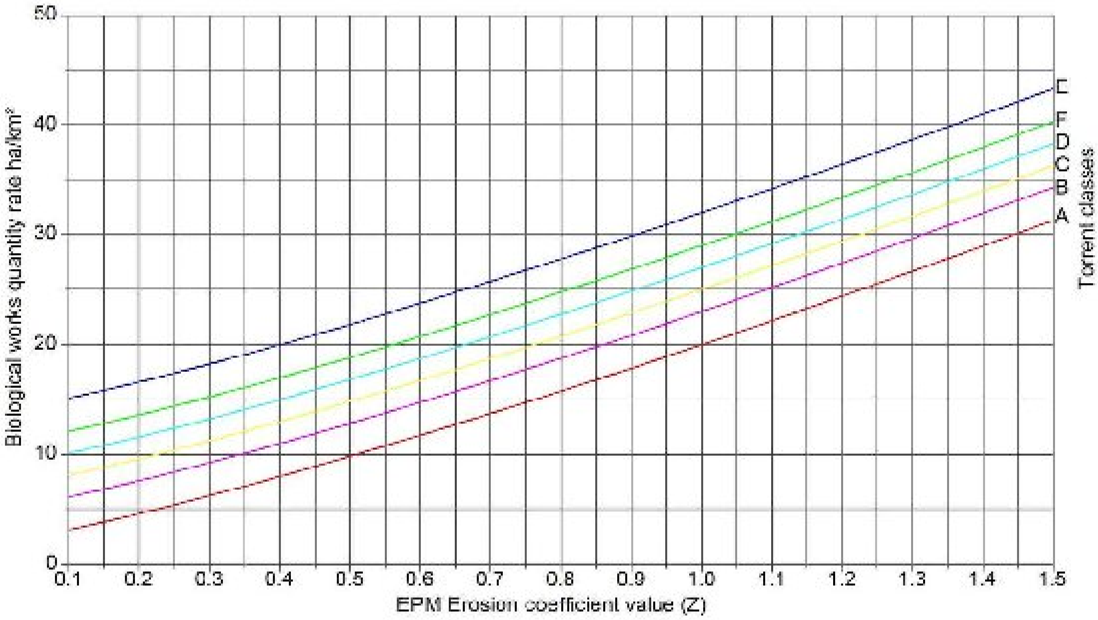

Figure 1. Relations between erosion coefficient and biological works quantity rate

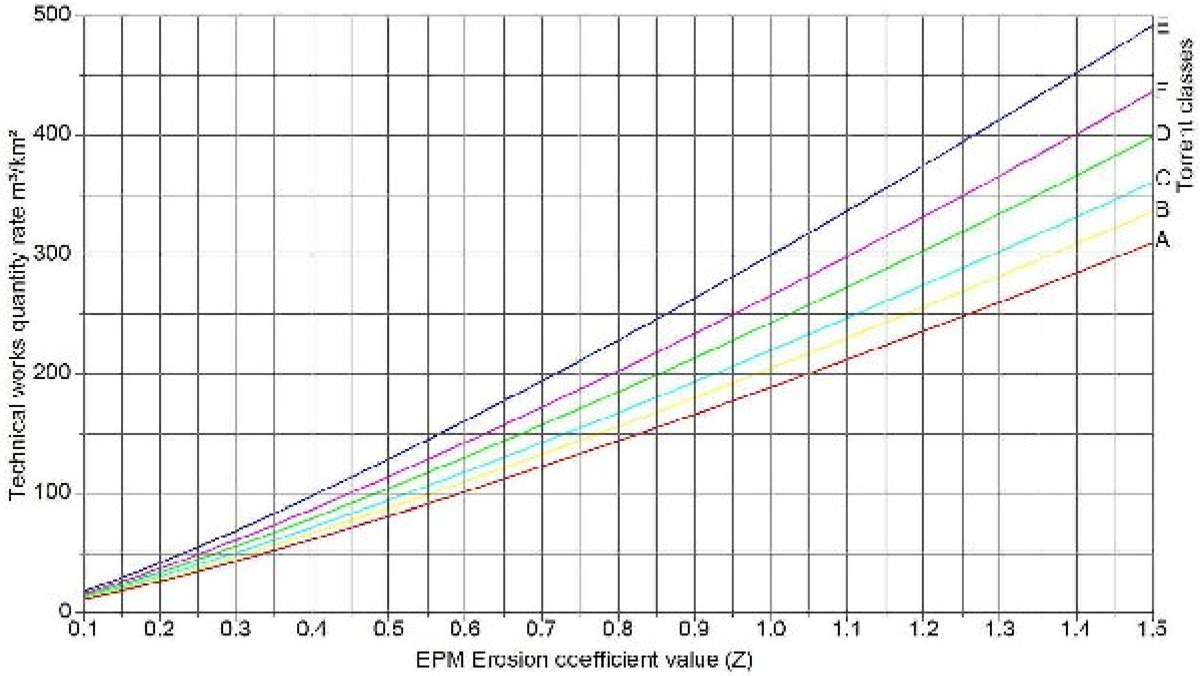

Figure 2. Relations between erosion coefficient and technical works quantity rate

Technical works are expressed in m^2/km^2, and biological works in ha/km^2.
By applying the presented dependences, the required volume of technical works and biological works can be simply calculated for each classified torrent.
The calculated quantities of the necessary works are adequate solutions for the realisation of reduced erosion intensity and the mitigation of torrential characteristics. Namely, it is technically impossible to realise the irresponsible promise given by many engineers, that erosion will be reduced to “zero“ and that there will be no more torrential floods. By erosion control works and measures, it is only possible to mitigate the slopes and to improve the biological protective cover. However, the natural soil erodibility cannot be changed. (Gavrilovic Z.Stefanovic M. (1998))
The positive effects of technical works are recorded immediately after the construction, while the period for the effects of biological works is longer than ten years. Evidently, the estimated volume of works should be realised within the period of ten to twenty years, depending on the realisation of the desired effects and potential changes.
Thanks to the lack of respect of the above facts, numerous errors were made in the past both in Serbia and in other regions. Torrents were regulated exclusively by the systems of technical structures (dams and regulations), without any biological protection for the mitigation of erosion processes. Also, there were the opposite cases of the exclusive use of biological protection, which was successful by itself, but the total effect was negative, because the deep erosion processes were intensified, as it can be seen in the Figure 3.
The exclusive use of technical structures for torrent regulation was favoured in the cases of road and settlement protection, because the results were seen immediately. In such cases, there are no serious problems in the events of the usual regular torrential floods. The problem develops in the events of torrential floods of the lower probability of occurrence. In such cases, the sediment silts up or destroys the built torrent regulation structures.

Figure 3. Gully erosion downstream of the successful afforestation.

Figure 4 presents a detail of the torrent regulation at the crossing with the road. Before the torrential flood, the water was 3m below the bridge.

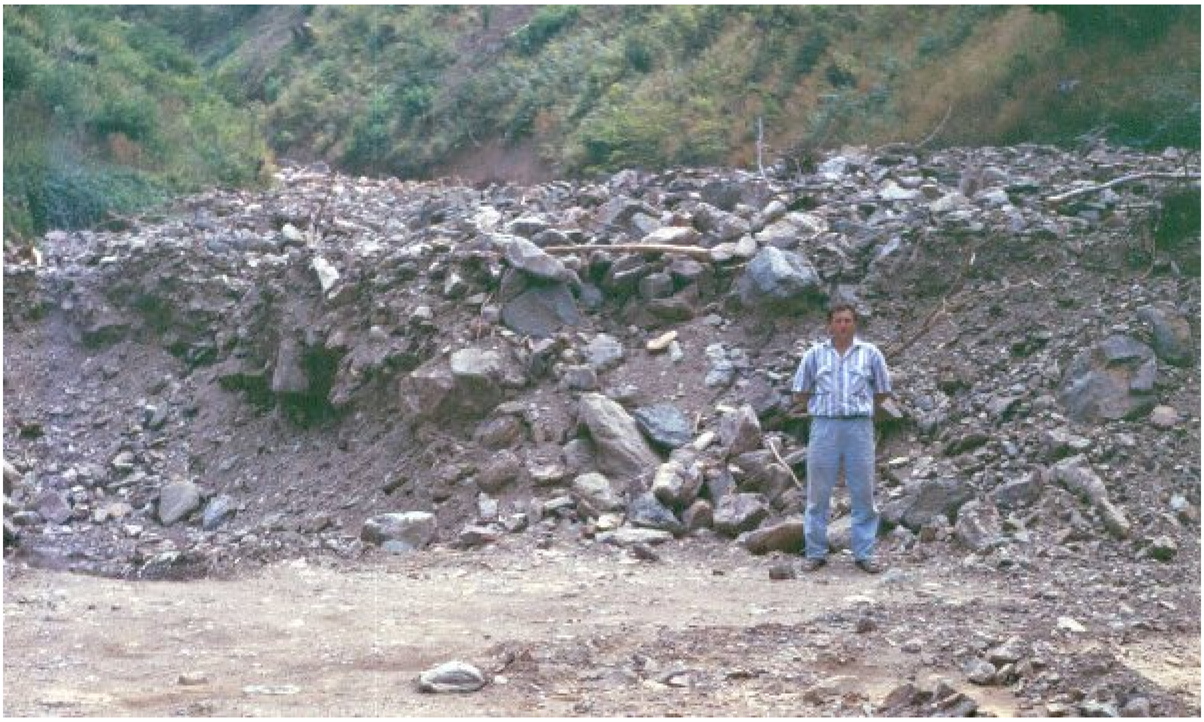

Figure 4. The bridge destroyed during torrent flood and the channel was silted up.

In the presented case, the local technical works and biological works were performed at the higher positions of the catchments. The technical works for the protection of steep gullies in the zone of biological works were not performed.
A special problem occurs in the regulation of small torrents, for which the total volume of required works is proportionally low. In such cases, the investors try to perform all the necessary works in the shortest possible term.

Figure 5.The downstream check dam of several ones which were constructed at the same time.

In Serbia, the usually applied torrent classification used to be carried out based on the torrent cadastres, which helped the engineers and the Ministries in bringing the decisions and the road planners in selecting the optimal traces. Also, the above classification was applied for the improvement of the eroded catchments of the storage reservoirs. However, because of the economic problems in Serbia, torrent cadastres had to be discontinued. The consequence is the use of the old data from the time when the catchments were eroded, and the volume of the performed erosion control works was several times lower.
Those optimizations relations make fundamental changes during antoerosion and torrent training works. Optimized quantity of applied works directly mean greater territory covered and protected.

3 CONCLUSION

Torrent classification based on EPM ensures a set of short and clear information for the assessment of the torrent state. Taking into account that the classification of torrentiality depends directly on the quality and scale of erosion mapping, the

mapping scale of 1 : 25,000 provides the required data set also for the gullies, whereas the smaller scales are applicable for the large torrential rivers and rivulets.
Torrent management works and erosion control works belong to the group of long-term activities that have to be planned and synchronised in the realisation.

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