Environmental Engineering and Management Journal

August 2014, Vol.13, No. 8, 1971-1978

http://omicron.ch.tuiasi.ro/EEMJ/

"Gheorghe Asachi" Technical University of Iasi, Romania

TECHNICAL SOLUTION TO REDUCE SOIL EROSION PRODUCED BY TAZLAU RIVER IN TARATA PERIMETER, ROMANIA

Stelian Cartacuzencu, Iuliana Lazar, Valentin Nedeff, Gabriel Lazar*

"Vasile Alecsandri" University of Bacau, Calea Marasesti, 157, Bacau – 600115, Romania

Abstract

The paper analyses the hydrologic parameters of the Tarata perimeter with alluvial soils, in order to estimate the values of the Tazlau River behaviour, in case of flooding. Tazlau River flow rate has an annual average value of 4.9 m^3/s, with a torrential character when the level of precipitation is increasing. The analysis of this perimeter is of interest today as a result of the existing excessive erosion. We identified a possible solution to reduce soil erosion through the exploitation of mineral aggregates, releasing riverbed, which leads to river bed regularization. This can reduce the effects of any potential floods, which have a significant social and economic impact. The proposed solution is a technical one, resulted from the estimation of hydrologic parameters for the modified river bed. The calculated hydrologic parameters were presented in two situations: before, and after the exploitation process. The flowing sections, the resulted flow rates, the side of the long edge, the washed perimeter, the hydraulic radius and the flow speeds were calculated for 15 profiles, based on the roughness values of the Tazlau River. The results of the study show that during the past four years, the channel of Tazlau River has changed its flow on a distance of about 2 km. The effects of soil erosion can be noticed on approximately 4 ha. The increase of the washed perimeter and hydraulic radius leads to a decrease of water flow speed for the same flow rate, with beneficial effects on the erosion phenomenon.

Key words: flow speed, hydrodynamic parameter, river regularization, soil erosion

Received: February, 2014; Revised final: August, 2014; Accepted: August, 2014

1. Introduction

The mineral aggregates are important raw materials used in the construction industry. The extraction of sand and gravel from the minor riverbeds is much easier than from the quarry, and the quality of mineral aggregates obtained by streaming is excellent (Afzalimehr and Anctil, 1998; Galay, 1983; Afzalimehr and Anctil, 1998; Rinaldi and Simon, 1998).

In some locations, the exploitation in the flow is the only option to obtain mineral aggregate resources at local level. Many times, this practice represents an efficient instrument for the control of floods and the stabilization of the flowing channel (Collins and Dunne, 1989; Lach and Wyżga, 2002; Peterson and Mohanty, 1960). The rivers, the streams or creeks, respond rapidly to the active stimuli such as the extraction of mineral aggregates. In the same time, this activity can affect the hydraulic characteristics and the water quality. The effects include increased turbidity, the decrease in light penetration, and the damage of organic materials that may affect the aquatic habitat, including the spawning riverbed, the crustaceans and riparian habitats (Lee et al., 1993; Nayak et al., 2004; Steiger and Gurnell, 2003). The hydraulic impact can be: changes in the riverbed flow, creating deep rivers with significant effects on their thalweg and the degrading aesthetics (Alekseevskiy et al., 2008; Bunn and Arthington, 2002; Panigrahi et al., 2009).

The exploitations of mineral aggregates have influence both on the flow morphology and alluvial processes. The changes to the riverbed have an impact on the change of the conditions of active geomorphologic processes manifestation (Bradley,

* Author to whom all correspondence should be addressed: e-mail: glazar@ub.ro, Phone. +40234542411

1983). A particular aspect of these exploitation regimes is the condition under which the mine dump shall affect the flow both upstream and downstream. The evolution steps of the dumps that remain after the exploitations are the increase in the dump evacuation after the flow, the increase in the dump's depth, the increase in the dump lengths, influencing the flowing regime (Nanson and Hickin, 1986; Talmon et al., 1995).

One of the methods used for both mineral aggregates exploitation and river regulation is the exploitation by channelization. This method is recommended when an important control of the river course is intended, with the purpose of reducing the meandering degree, or the clearance of the minor riverbed course against the banks, on which major importance objectives are placed: dams, water catching wells, protection areas with a strict regime, industrial objectives etc. (Neumeier et al., 2006; Quaresma et al., 2007; Simon and Thomas, 2002). The exploitation must be made in the frame of the existing legislation and with the respect of the Integrated Water Resources Management (IWRM) concept (Pintilie et al., 2007; Teodosiu et al., 2009).

This study represents the data acquisition and analysis in a flowing section of the river in an area with low resistance degree against the hydric erosion. Data analysis refers both on the hydrological and geological parameters corresponding to the studied section. The study of this particular region has been performed because it was noticed an excessive hydric erosion form. Since August 2008, the analyzed minor riverbed totally changed its flow course.

In this paper, the solution chosen for the abatement of hydric erosion forms is less expensive one in terms of hydro-technical constructions, and more beneficial related to the economic needs. Therefore, the proposed method is to excavate mineral aggregates, along the entire length of the analyzed section, both on the left and the right bank of the river, aiming to control the riverbed. This control will result in a flow channel, having the ability to carry the water flow in a way capable of assuring the protection against floods and without massive loss of land because of hydric erosion.

2. Methodology

2.1. Study area

From the morphological point of view, the analyzed section, Tarata, belongs to Tazlau Sub Carpathians and is located within the administrative territorial unit of Parjol locality, Bacau County, Romania. The Tazlau River minor riverbed is characterized by the flow of water through its own accumulated silts that are in a constant transformation.

The flow regime within the analyzed section is strictly dependent on the rainfalls but is also influenced by the width of the minor riverbed, the geomorphologic characteristics and the afforestation degree. It shows a deep discontinuous characteristic, with a high degree of torrentiality.

Due to the fact that Tarata section is relatively deforested, with a lithology predominantly friable, with high flow slopes, the erosive and solid transport processes are particularly active. Because of erosions of the concave banks, the river develops continuously the flow course. The most important changes of the meanders occur during high waters, when some branches of these meanders disappear among sands while other branches may appear with a different route in other areas. The analyzed section can be seen in Fig. 1, with the river course topographically identified in May 2012 overlapped on the photoplan from August 2008. The significant changes of the watercourse that occurred in less than four years can be clearly observed.

The main feature of the relief is given by the wide development and repetition of the structural forms, generated by the monoclinal position of the layers and the alternation of horizons with low degree of resistance to erosion. The versants, especially the slopes with gradients of more than five degrees, are affected by landslides, torrential erosions and intense surface erosions. The actually analyzed corridor of the Tazlau River, within Tarata perimeter, has a variable width, being asymmetrical, with versants on the left side, always steep and high, accompanied by terrace fragments, and the ones on the right side steeper, with large terraces. In Fig. 2 it is presented the Tarata section, in vector projection, following the land surveys. Also the five exploitation perimeters proposed and discussed in the following sections are represented.

The ballast deposits in Tarata section are characterized by an intensely folded and varied structure in the form of parallel webs which are overlapping from West to East and are often fragmented as some scales. The granulometric composition of the entire deposit is presented as an accumulation of sands and gravels with blocks (Ion and Nicolae, 2009). The three fractions that make up the deposit within Tarata perimeter have the following distribution: sand 0.5-3 mm, in a proportion of 10%, gravel 3-20 mm (52%), blocks greater than 20 mm (36%) and 2% the levigable part.

The average altitude of the section analyzed is 303 m from the Black Sea level. The multi-annual average flow rate within Tarata perimeter is 4.90 m^3/s. The multi-annual average flow rate of suspension sediments is 9.50 kg/s (Ion and Nicolae, 2009).

2.2. Materials and instruments

The land survey of Tarata section, which stretches over a length of over 1.5 km, was performed using a total station Leica TPS 400. For the determination of coordinates and benchmarks in real-time, GPS ROVER S 82 V device was used. The coordinate system used to determine the (XY) coordinates was used in "STEREO-70" projection and the reference system for (Z) benchmarks was the zero level, assigned to the Black Sea. The site plan was elaborated at 1:1000 scale, using Autocad 2007 software, and the design of the transversal profiles and the longitudinal profile was performed using the ProfLT 10 application.

The estimated volume of the sand stock was calculated using the TopoLT 10 application, based on the Autocad 2007 software. The used calculation method, known as *the method of the parallel plans,* calculates the volumes on the 3D view of the terrain, taking into consideration both the differences of the level curves and the variation of benchmarks.

The surveying and bathymetric characteristics of the analyzed section were highlighted on the site map. The transversal profile of the river is an especially important element of analysis, because various river parameters can be calculated using it: the flow capacity, the slope, the distribution of speeds in the horizontal and vertical planes, etc. On the transversal profile can be marked: the levels of the river water, levels with different protection degrees, or with various probabilities of overflowing. In Fig. 3 it is illustrated a typical transversal profile, built using the topographic measurements. The analysis presented in this paper is based on 15 such transversal profiles, represented in Fig. 1.

The photoplan used for this study was achieved in 2009. By the comparison of the site plan with the photoplan, the soil losses, accumulated during the period of study could be identified because of their georeferencing. The photoplan used in the case of the studied section was taken over from Bacau Land Registry Office, Romania. The geologic data were taken over from the studies carried out by the National Agency for Mineral Resources, the Department of Territorial Inspection Bacau and the hydrologic and climatic data were collected from studies of A.N. "APELE ROMANE" S.A., Siret Branch, Bacau.

2.3. Calculated parameters

The movement of the water from the rivers is determined by the flowing slope, calculated as given by Eq. (1):

$$I = \frac{H_1 - H_2}{L} \cdot 100 \quad (\%) \tag{1}$$

where: H_1, H_2 represents the vertical coordinates of the water surface in the two points between which the gradient is calculated, and L represents the length of the flowing sections between the two points.

The altitude difference between a point situated upstream and another one situated downstream represents the water fall due to the gravitational force. The main parameters used in the analysis were the flow rate and the flowing speed, calculated from the topographic measurements using the Eqs. (2) (Savin, 2001):

$$Q = \frac{\Omega \cdot R^{2/3} \cdot I^{1/2}}{n}; \quad v = \frac{Q}{\Omega} \tag{2}$$

where: Q is the water flow rate (m³/s); Ω is the area of the active wetted section, calculated using the planimetry (m²); R is the hydraulic radius (m); I is the water surface slope; n is the roughness coefficient; v is the flowing speed (m/s).

The flowing rate can be determined precisely only by classical measurements, using a current meter or other homologated equipment for this type of operations.

The hydraulic radius (R) is calculated as the ratio between the area of the wetted section and the wetted perimeter, and the average flowing depth (h_m) is given by the ratio between the area of the wetted section and the water span (Eqs.3):

$$R = \frac{\Omega}{P}; \quad h_m = \frac{\Omega}{B} \tag{3}$$

where: P represents the wetted or moistened perimeter (m); B is the water span.

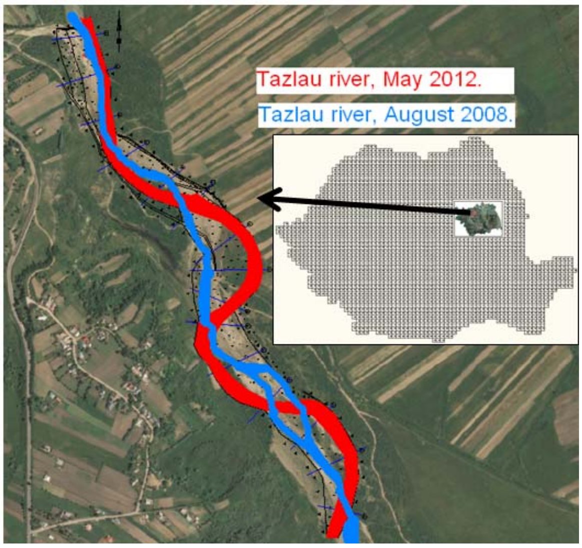

Fig. 1. View of Tarata analyzed section
(On the map there are represented the positions of Tazlau River on May 2012 and August 2008, the sections analyzed and the measurement points)

3. Results and discussion

3.1. Identification of soil areas lost by hydric erosions in the period August 2008 – May 2012

The evolution of soil erosion since August 2008 and up to the month of May 2012 is continuous and is carried out on large sectors with direct influences on the flow of the Tazlau River.

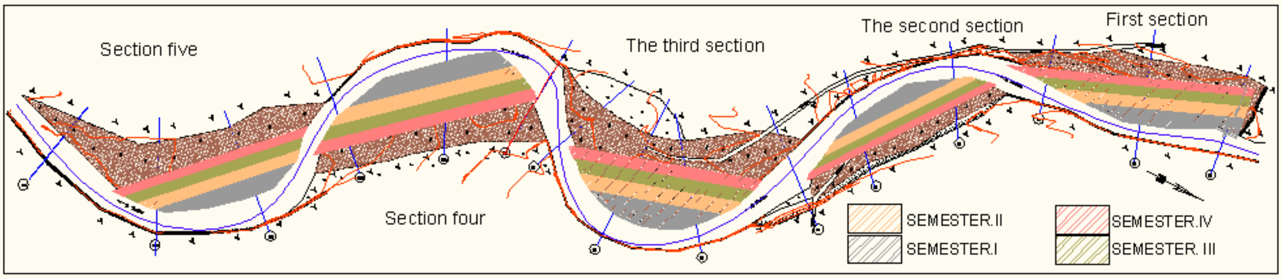

Fig. 2. The topographical plan of Tarata Section, in horizontal projection. The plan contains the river axis, the analyzed sections, the measurement points and proposed exploitation perimeters, divided by semesters

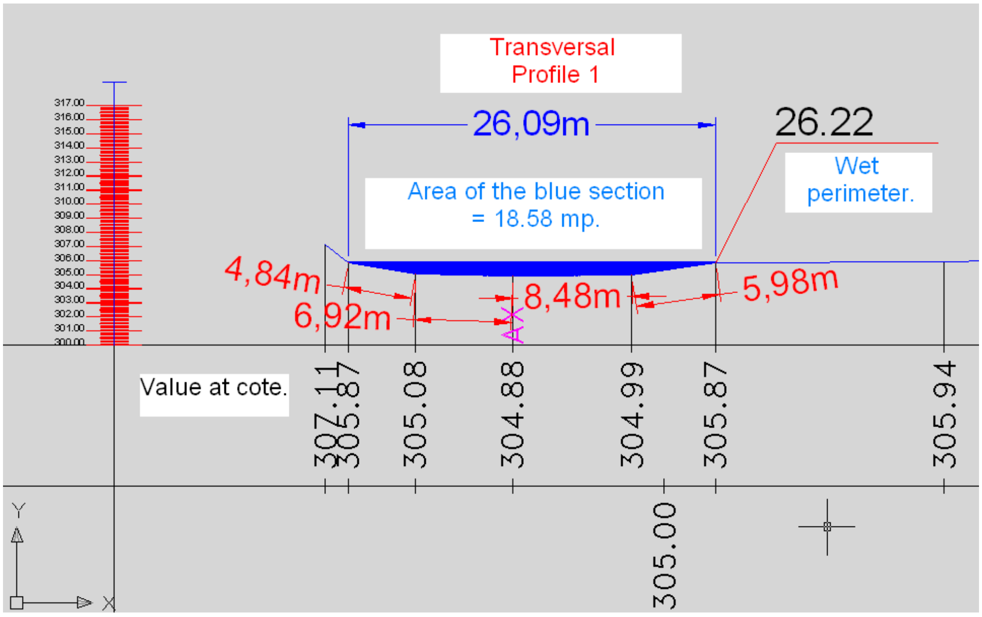

Fig. 3. View of the first flowing section of the transversal profile 1
(The profile was built using topographic measurements and can be used to calculate several dynamic and static parameters of the river. The *x* axis indicates the profile direction, and they axis indicates the vertical direction, relative to the water surface)

The erosion and silting forms of the riverbed occur on short periods of time because the watercourse of the Tazlau River changed its route during this period, but also because of the torrential feature of Tazlau River. This change in the watercourse which took place since 2008 and up to the month of May 2012 resulted in damages inflicted upon the fertile lands of form the vicinity of Tarata perimeter, where the surface affected by hydric erosion exceed the value of 40000 m^2, on a distance of the watercourse exceeding not as much as 2 km. These lands had the “tillable” usage type, and the cereals that were cultivated here were the corn and the wheat, and in some sectors they were predominated by grasslands and hayfields.

Overlapping the measured site plan with the photoplan, the fertile, productive soil areas from the terraces, from the vicinity of the alluvial soils, formed by the hydric erosion were identified. The differences between the two maps highlight the effect of erosion on the flowing course of the river and suggest the position of the proposed exploitations. The five proposed perimeters will reduce the meandering degree and are positioned as follows: the first perimeter – between the transversal profiles 1 and 3, the second perimeter – between the transversal profiles 4 and 5, the third perimeter – between the transversal profiles 7 and 8, the fourth perimeter – between the transversal profiles 11 and 12, and the fifth perimeter – between the transversal profiles 13 and 14. As a secondary effect, the reduction of the meandering leads to increasing velocities of the water. To avoid other erosion episodes, supplementary works, in order to consolidate the river shed, are needed.

Between the 1st and the 3rd profile from the site plan, we designated the area of the first sector that suffered a continuous erosion process. The soil affected by erosion in this perimeter has a surface of 3839.61 m². Between the 4th and the 5th profiles, the surface of soil affected by erosion is 6399.49 m². In the third perimeter, the soil surface affected by erosion is of 13292.3 m^2. Between the 10th and the 12th profile, the area affected by the erosion is of 8886.22 m². In the last perimeter, between the 13th and the14th profile, the soil loses extend on an area of 8754.39 m². The total value of the surface affected by erosion in the analyzed sector, summing all areas (not only from the proposed sectors) is of 43344 m². One example of calculation is presented in Fig. 4, for the situation of erosion surfaces between the 10th and the 12th profile.

3.2. Calculated parameters of mineral aggregates exploitation

Following the study of Tarata section, a solution was proposed regarding the exploitation of mineral aggregates for the regulation of Tazlau riverbed, which shall be achieved from 5 exploitation perimeters.

The area of the first perimeter in the site plan is of 10022.91 m². The regular exploitation proposed is intended to be achieved in four semesters, for each semester the surface proposed for exploitation being of 2507.38 m². The digging depths of the mineral aggregate exploitations, according to the sections projected on the transversal profiles were appreciated for each transversal profile. The average digging depth of this perimeter is of 0.74 m. The quantities of mineral aggregates proposed for exploitation are calculated by the transversal profiles, by their projection and the volumetric calculations, while the values of the forecast volumes were calculated by the application of TOPO LT 10 – Model viewer 3D software. After the creation of the 3D model by the radiated points resulted after the land surveying, both the area of the exploitation perimeter and the volume that is to be exploited shall be subject to modifications. Thus, the quantity of the mineral aggregates forecast to be exploited from the first perimeter is of 9938.4 m³, on an area of 7177 m².

The second perimeter goes through the 4th and 5th transversal profiles, according to the site plan. The exploitation shall be performed in four semesters on an estimated area of 1680 m² each. The forecast quantity is of 4450 m³, on a total area of 4908 m². In the second perimeter, the average digging depth related to the exploitation process is of 0.89 m.

The 7th and 8th profiles go through the third exploitation perimeter, according to the site plan. It shall stretch on an area of 10992 m², where the available volume to be exploited has the value of 8000 m³. The forecast volume of mineral aggregates is of 6038 m³, on an area of 8223 m². The exploitation process shall be achieved at an average digging depth of 0.54 m. The surface for each of the four exploitation semesters has the value of 2748.26 m².

According to the site plan, the fourth perimeter goes through the 11th and 12th profiles. The perimeter has an area of 12712.35 m² and an available volume to be exploited of 12000 m³. On an area of 9352 m², value determined by the application TOPO LT 10 – Model viewer 3D, the forecast volume of mineral aggregates is of 10456 m³. The average digging depth shall be of 0.51 m. The exploitation will be performed on four semesters, on equal surfaces.

The last perimeter that is to be exploited goes through the 14th and 13th profiles. There can be noticed on the site plan that the perimeter area has the value of 8804 m² and a volume of 5000 m³. The forecast area is of 6240 m², having a volume of 4493 m³. The exploitation shall be performed in four semesters, at an average digging depth with the value of 0.68 m.

The total area proposed to be exploited in Tarata perimeter is of 49277.81 m², and the total forecast area is of 35900 m². The total forecast volume proposed for the regulation of Tazlau minor riverbed by channeling, after the clearance of the riverbed, is of 35375.4 m³.

3.3. Calculated parameters of river flow

The estimation of the effects of the proposed regularization by mineral aggregates exploitation was made comparing the parameters of river flow before and after the process.

The evolution of Tazlau riverbed has been achieved on the longitudinal profile. This estimation has been projected on four flowing sections, for both studied cases, before the exploitation and after the achievement of this anthropic activity. This simulation related to the variation of the flowing forms has been performed under the conditions in which the water level arrives at the watermarks of the transversal profiles, where the reference point was considered to be the maximum watermark from the studied profiles of the shortest banks. For example, off the 1st profile, shown in Fig. 3, following the land surveying, the maximum watermark of the left bank is of 307.11 m, and the maximum watermark of the right bank is of 307.01 m.

The analysis of the evolution forms for Tazlau riverbed off the 1st profile has been performed under the conditions in which the flowing section off the thalweg watermark is of 304.88 m (Fig. 3), for the 1st profile, up to the watermark value of 307.01 m. This evaluation has been performed for four flowing sections, corresponding to four water levels. The calculations were made for all four sections, but the article presents only the results for the situation of the higher water level.

In order to determine the values of the main parameters, the flow rate and the flowing speed, for each profile, the particular coefficients of river flow have been determined and analyzed. Thus, for each profile, after the land surveying and the projection of the transversal profiles, both the thalweg watermarks and the watermarks of the wetted perimeter were determined. By means of these values and the intermediary watermarks between the above mentioned ones, the flowing sections were calculated. The flowing slope was also calculated using the topographic data, and the roughness coefficient was assumed to be constant, having a value of 0.042. The value of roughness coefficients was determined following the geological studies and is specific to the flowing category and form of the studied river.

The longitudinal profile of Tarata section stretches on a length of 1698 m. The analyzed section has a linear length of 1373.78 m, according to the site plan. The sinuosity coefficient after the ratio of the two values presented above is of 1.24. The calculated flowing slope is almost constant on all studied river length, of 0.26%.

The proposed exploitation has as impact the increase of the flowing width only in four sections, P5, P7, P11 and P13, as can be seen in Fig. 5. The highest flowing width, according to the site plan, of the Tazlau River, before de exploitation, belongs to the 8th profile, having a value of 160.64 m, unchanged after the exploitation.

The lowest value belongs to the 5nd profile, with a width of 31.69 m, before the exploitation. After the exploitation, the narrowest portion of the river is of 37.91 m, in the section number 12.

The evaluation of the transport capacity of the river for all studied sections highlights two zones which encompass problems in the case of increased volume of water. For the section P5 the estimated debit which can be picked up by the riverbed in normal conditions has the value of 4.55 m^3/s, and for section P7, 5.76 m^3/s, both values close to the average flow rate of 4.9 m^3/s. These sections of the river are exposed to flood and increased erosion risk even in the case of relatively normal precipitations.

The proposed solution of exploitation of mineral aggregates increases the estimated flow rate which can be picked up by the riverbed to 13.0 m^3/s in section P5 and 14.37 m^3/s in section P7. All calculated values of the transport capacity of the river, before and after the exploitation, are presented in Fig. 6.

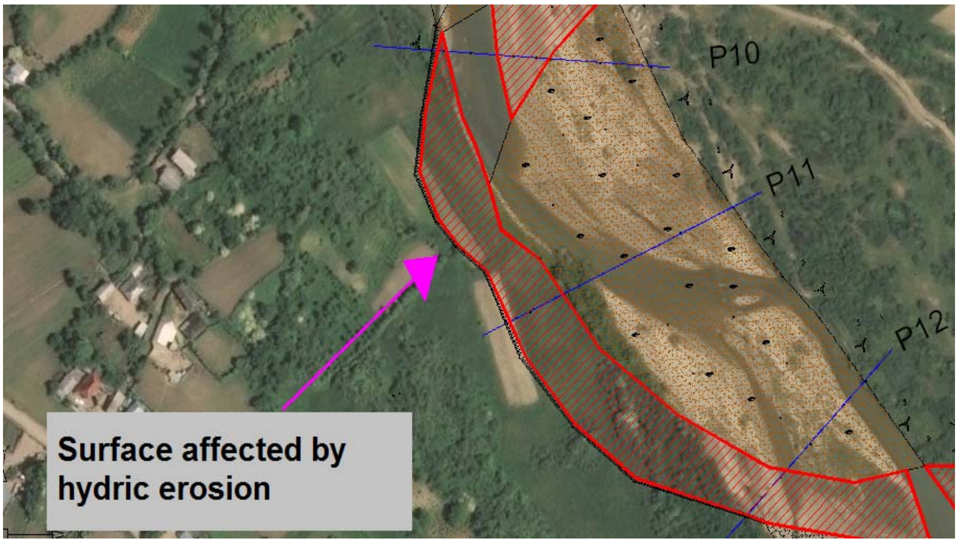

Fig. 4. The surface affected by hydric erosion of the 10th, 11th and 12th profiles

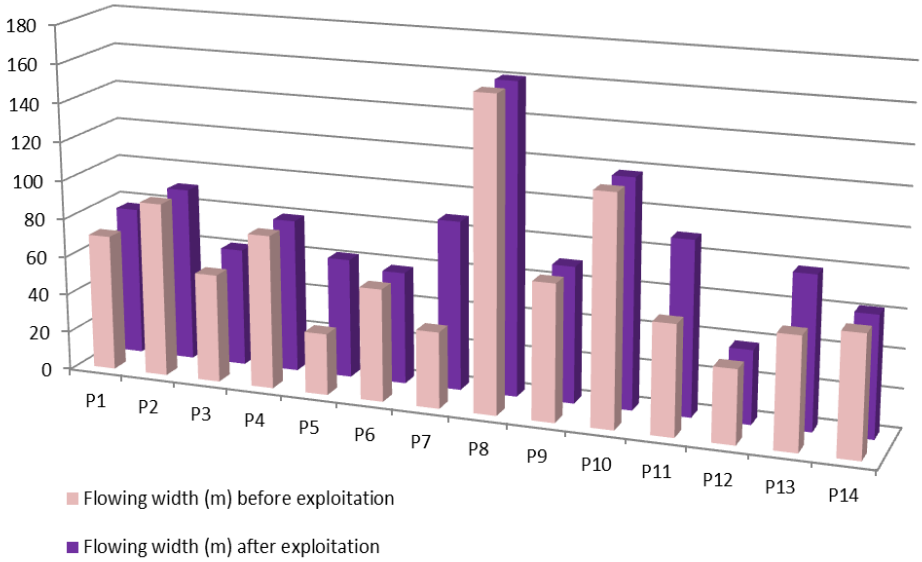

Fig. 5. Values of the river width for each examined section, before and after exploitation

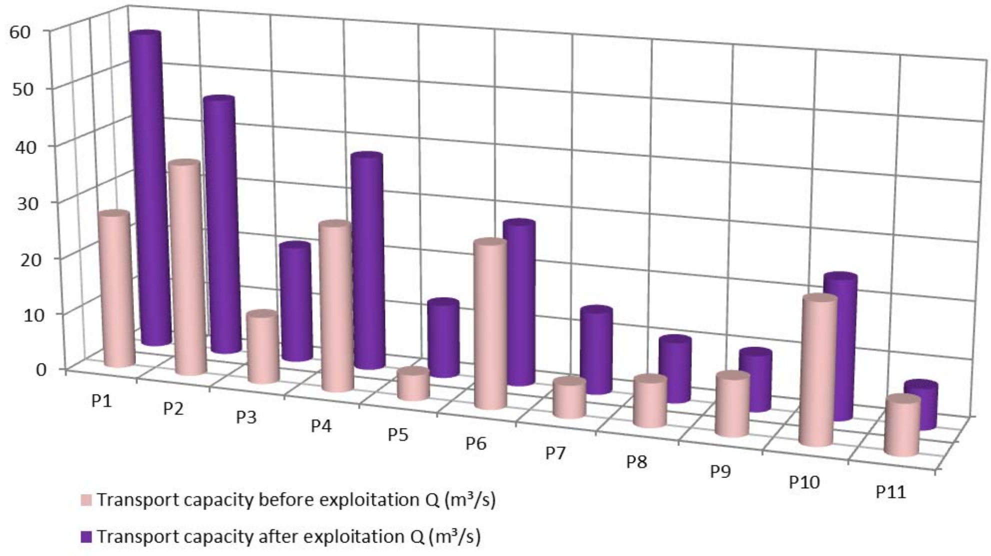

Fig. 6. Values of the transport capacity of the river for each examined section, before and after exploitation

4. Conclusions

The purpose of this work was to apply a method to analyze the abatement of hydric erosion of the Tazlau River, in Tarata perimeter.

The solution proposed is to achieve the control of Tazlau minor riverbed, in Tarata perimeter, so as the final result to be a channel, with the capacity to transport high values of Tazlau River flow rates, but also to have a direct influence on the soil erosion which usually generated soil lost of more than 4 hectares only in Tarata section, during 4 years.

This analysis of Tarata perimeter does not take into account other environmental factors such as the vegetation and the fauna corresponding to the studied section, but an efficient and regular exploitation technology would have a low impact on the site biodiversity.

Due to the technological progress related to the performance of land surveying, at the highest precisions levels, and the easy interpolation of points regarding the elaboration of the site plan and the transversal profiles and the longitudinal one, the interpretation of land surveying data is much more precise than other planimetric methods, even if, it is apparently a costly procedure. The accuracy of results is very close to the current ones due to the configuration of the points obtained after field land measurements.

Acknowledgements

The authors acknowledge to O.C.P.I. Bacau, Romania – for the photoplan in section Tarata, to A.N.R.M. Bacau, Romania – for the geographical and geological data in Tarata perimeter, to A.N. „Romanian Waters" S.A., A.B.A. Siret Bacau – for the hydrological and climatic data in Tarata perimeter. The equipment used in this article was provided by S.C. PRO-GLOBO A.D. S.R.L. Bacau, Romania.

References

Afzalimehr H., Anctil F., (1998), Estimation of gravel-bed river flow resistance, *Journal of Hydraulic Engineering,* **124**, 1054-1058.

Alekseevskiy N.I., Berkovich K.M., Chalov R.S., (2008), Erosion, sediment transportation and accumulation in rivers, *International Journal of Sediment Research,* **23**, 93-105.

Bradley J.B., (1983), *Transition of a Meandering River to a Braided System due to High Sediment Concentration Flows,* In: *River Meandering. Proceedings of the Conference Rivers '83,* Elliott C.M. (Ed.), New York, ASCE, 89-100.

Bunn S.E., Arthington A.H., (2002), Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity, *Environmental Management,* **30**, 492-507.

Collins B., Dunne T., (1989), Gravel transport, gravel harvesting, and channel-bed degradation in rivers draining the southern olympic mountains, Washington, U.S.A, *Environmental Geology and Water Sciences,* **13**, 213-224.

Galay V.J., (1983), Causes of river bed degradation, *Water Resources Research,* **19**, 1057-1090.

Ion M., Nicolae F., (2009), *Guide to Field Description of the Soil Profile and Specific Environmental Conditions (in Romanian)*, SITECH, Craiova, Romania.

Lach J., Wyżga B., (2002), Channel incision and flow increase of the upper Wisłoka River, southern Poland, subsequent to the reafforestation of its catchment, *Earth Surface Processes and Landforms,* **27**, 445-462.

Lee H.Y., Fu D.T., Song M.H., (1993), Migration of rectangular mining pit composed of uniform sediments, *Journal of Hydraulic Engineering, ASCE,* **119**, 64-80.

Nanson G.C., Hickin E.J., (1986), A statistical analysis of bank erosion and channel migration in western Canada, *Geological Society of American Bulletin,* **97**, 497-504.

Nayak P.C., Sudheer K.P., Rangan D.M., Ramasastri K.S., (2004), A neuro-fuzzy computing technique for modeling hydrological time series, *Journal of Hydrology,* **291**, 52-66.

Neumeier U., Lucas C.H., Collins M., (2006), Erodibility and erosion patterns of mudflat sediments investigated using an annular flume, *Aquatic Ecology,* **40**, 543-554.

Panigrahi J.K., Ananth P.N., Umesh P.A., (2009), Coastal morphological modeling to assess the dynamics of Arklow Bank, Ireland, *International Journal of Sediment Research,* **24**, 299-314.

Peterson D.F., Mohanty P.K., (1960), Flume studies of flow in steep, rough channels, *Journal of the Hydraulics Division ASCE,* **86**, 55-76.

Pintilie S., Brinza L., Betianu C., Pavel L.V., Ungureanu F., Gavrilescu M., (2007), Modelling and simulation of heavy metals transport in water and sediments, *Environmental Engineering and Management Journal,* **6**, 153-161.

Quaresma V.d.S., Bastos A.C., Amos C.L., (2007), Sedimentary processes over an intertidal flat: A field investigation at Hythe flats, Southampton Water (UK), *Marine Geology,* **241**, 117-136.

Rinaldi M., Simon A., (1998), Bed-level adjustments of the Arno River, central Italy, *Geomorphology,* **22**, 57-71.

Savin C., (2001), *Rivers Hydrology - Theory and Applications (in Romanian)*, Reprograph, Caiova, Romania.

Simon A., Thomas R.E., (2002), Processes and forms of an unstable alluvial system with resistant, cohesive streambeds, *Earth Surface Processes and Landforms,* **27**, 699-718.

Steiger J., Gurnell A.M., (2003), Spatial hydrogeomorphological influences on sediment and nutrient deposition in riparian zones: observations from the Garonne River, France, *Geomorphology,* **49**, 1-23.

Talmon A.M., Struiksma N., Van Mierlo M.C.L.M., (1995), Laboratory measurements of the direction of sediment transport on transverse alluvial-bed slopes, *Journal of Hydraulic Research,* **33**, 495-517.

Teodosiu C., Cojocariu C., Musteret C.P., Dascalescu I.G., Caraene I., (2009), Assessment of human and natural impacts over water quality in the Prut River basin, Romania, *Environmental Engineering and Management Journal,* **8**, 1439-1450.