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EARTH DAM WITH COMPACT SPILLWAY AND OUTLET STRUCTURE

BY

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Abstract. This work concerns the development of an earth dam fitted with compact spillway and outlet structure which allows for the independent compaction of the filling the dam is made of.

The main body of the dam is made out of compacted earth (homonegeous, facing or watertight core) and the spillway is a reinforced concrete channel which traverses the dam. The walls of the channel are as tall as the dam itsself. In the upstream, the channel is fited with perimetral overflow, while one of its walls has the outlet meant to drain the dam. The draining process is controlled by a valve accessible by a walkway on the channel wall. The walls and foundation of the channel have diaphragms covered by earth that reduce infiltration.

Key words: compact spillway and outlet structure; earth dam; settlement sensitivity.

1. Introduction

The used method to allow draining of earth dams is through a shaft connected to either a concrete or metal pipeline that runs under the dam itself. The pipe is set directly on solid ground or indirectly using pillars. This solution has several disadvantages that come from the way the pipe and dam body work together namely

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a) overload of the concrete structure running under the dam;
b) differentiated settling of the dams core;
c) uncontrolled infiltration caused by uneven settling.

The output of the pipeline system is limited by the dimensions of the pipe itself, but also by the fact that the discharge capacity vaguely varies as the water level in the lake rises. At high levels, the pipe functions under great pressure and seepage occurs.

As is the case with concrete or steel structures traversing earth dams with a clayey consistency, it exists a heterogeneous rigid body phenomenon (Popovici, 2002). These structures are set on steady ground so that the operating strain and consequent deformation doesn't hinder their functionality (continuity). For this reason, the load on the upper part of these pipes is greater than the weight of the ground above them.

2. Material and Methods

In what follows Marston's results regarding the load of embankment filling on pipes (Moser & Folkman, 2008) are briefly presented.

The total vertical load is

$$P_v = C_e \gamma D_e^2 ,$$

where

$$C_e = \frac{\mathrm{e}^{2K\mu(H/D_e)} - 1}{2K\mu} \tag{1}$$

or

$$C_e = \frac{\mathrm{e}^{2K\mu(H_e/D_e)} - 1}{2K\mu} + \left(\frac{H}{D_e} - \frac{H_e}{D_e} \right) \mathrm{e}^{2K\mu(H_e/D_e)} . \tag{2}$$

with: $K = \mathrm{tg}^2(45^\circ - \varphi/2)$ – Rankine coefficient; μ = tgφ – friction coefficient of the ground; H_e – position of the plane of equal settlement (Fig. 1); D_e – exterior diameter of the pipe.

Marston determined the existence of a horizontal plane above the pipe where the shearing forces are zero. This plane is called the *plane of equal settlement*. Above this plane, the interior and exterior prisms of soil settle equally.

The eq. (1) stands for $H_e > H$ (the plane of equal settlement is imaginary) and the eq. (2) is valuable for the scenario in which $H_e < H$.

The additional load (over the weight of the ground) depends on the friction forces pointed downward which are contained in the vertical planes tangent to the pipeline.

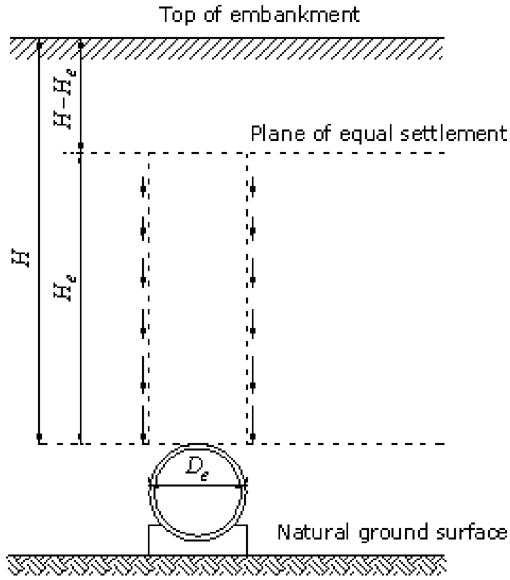

Fig. 1 – Earth vertical load on pipe.

For instance, for a clay earth dam with 5 m filling thickness over a pipe with a 1 m exterior diameter, the load is (per linear meter):

$$P_{v1} = \gamma H D_e = 19 \times 5 \times 1 = 95 \text{ kN/m},$$

where $\gamma = 19$ kN/m^3; $K\mu = 0.13$ (Furis *et al*., 2005); $H = 5$ m; $D_e = 1$ m.

According to Marston we have (considering the plane of equal settlement, $H = H_e$)

$$C_e = \frac{e^{2\times0.13\times5} - 1}{2\times0.13} = 10.26; \quad P_v = C_e \gamma D_e^2 = 10.26 \times 19 \times 1 = 195 \text{ kN/m}.$$

According the research performed by Furis *et al.* (2005) the eq. used to calculate vertical pressure is

$$P_v = C_r \gamma H D_e ,$$

where

$$C_r = \frac{e^{2K\mu H/D_e} - 1}{2K\mu H / D_e} = \frac{e^{2\times0.13\times5/1} - 1}{2\times0.13\times5/1} = 2.05,$$

therefore:

$$P_v = 2.05 \times 19 \times 5 = 194.75 \text{ kN/m}.$$

The obtained result represent an increased load on the vertical corresponding to the pipe, and a decreased one in the areas adjacent to it. When the pipe is set directly in the ground, the load transmitted to the ground is greater in the area corresponding to the pipe than in the area in it’s immediate vicinity. When pillars are used to set the pipe, the load on the ground shifts, being greater around the pipe rather then directly under it. This nonuniformity can lead to increased permeability. In many cases, dams bursting in as a result of problems that arise, at the bottom discharge conduit system.

Taking this observation into account, a solution that seeks to overcome at least some of these challenges has been developed. The key is a compact spillway and outlet structure that releases both flood water and serves as a drain when needed (Fig. 3). Upstream, the channel has a perimetral overflow that ensures a steady water level, while downstream it becomes a hydraulic energy dissipater (Fig.4). Its walls are designed to be as tall as the dam itself, thus avoiding subjecting the structure from loads coming from earth stacked on top of it. However, while this solution bears this advantage, it also means that the maximum height of the dam is limited. Once the 12 m mark is passed, this approach loses efficiency. Still, for dams under 12 m, this remains the best choice.

The only concern that remains is that of infiltration. To reduce this disavantage, two aspects are tackled: reducing infiltration levels and reducing underpressure.

For the dam itself, in order to determine water infiltration extensive calculations, can be done using Casagrande’s eqs. (Popovici, 2002).

As for the water infiltration levels on the outline of the contact surface between the concrete structure and the ground, the problem is a bit more complex. The infiltration path is made up of both horizontal and vertical segments. The vertical gradients increase the intergranular pressures causing compaction (Caquot & Kerisel, 1968) while the finer particles in the upper layers mix with the bigger ones in the lower layers and increase their overall density.

Horizontal permeability of the ground is greater horizontally, rather than vertically. This leads to greater speeds as far as the infiltrated water is concerned, which causes earth particles to shift thus causing internal erosion.

In order to size the outline of the contact surface of the structure traversing the dam, a rule is adopted that states that horizontal paths are reduced to a third of their length, while the vertical ones are taken into account fully. The hypothesis also assumes that the water drains in the immediate vicinity of the horizontal and vertical surfaces.

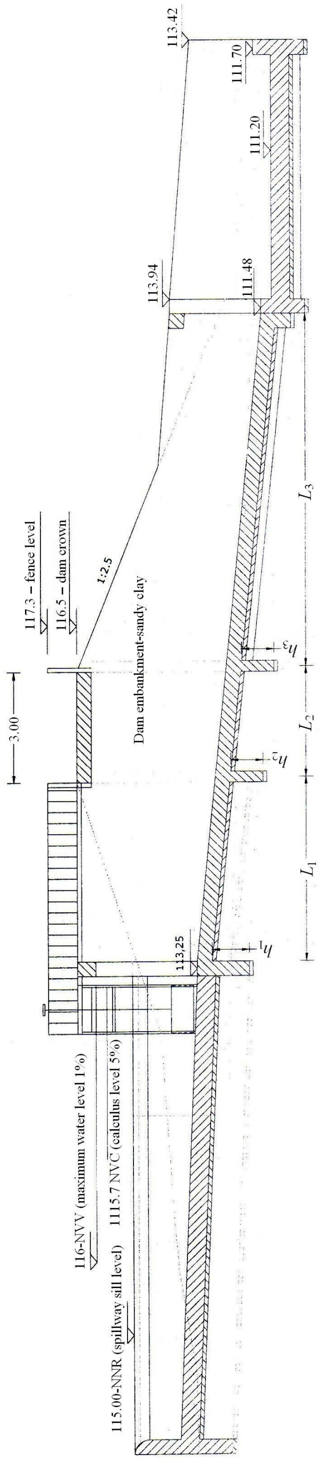

Fig. 2 – Barboşi Dam, Vaslui County; transverse section.

Critical flow gradient is (Fig 2)

$$i_{cr} = \frac{H}{\frac{1}{3}\sum L + \sum h}.$$

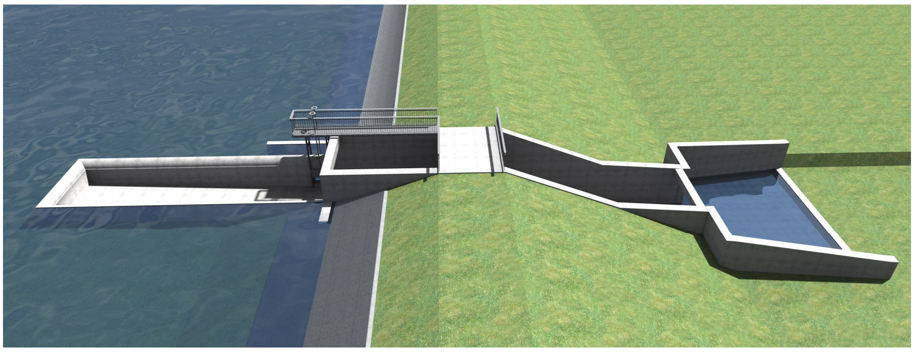

Fig. 3 – 3-D simulation of the Barboşi Lake spillway.

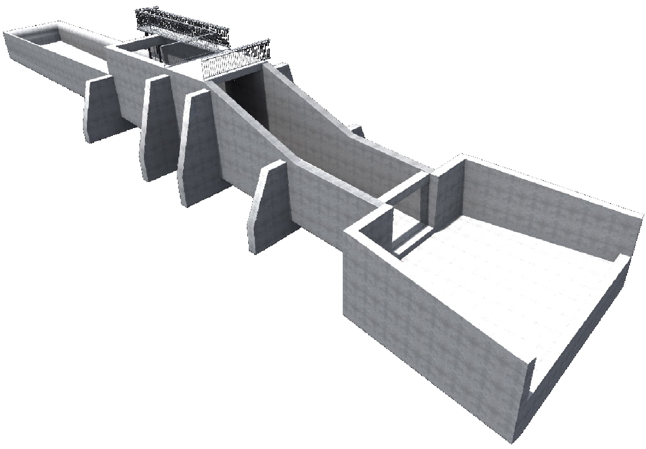

Fig. 4 – 3-D view – downstream.

3. Case Studies Presentation

In this section the Barboşi dam parameters are described. For the example in Fig. 2 and considering $C = 1/i_{cr}$ it results

$$C = \frac{1}{i_{cr}} = \frac{\frac{1}{3}(L_1 + L_2 + L_3) + 2(h_1 + h_2 + h_3)}{H} = \frac{11.8}{3.6} = 3.27.$$

The recommended values for *C* are those given by Lane (*apud* Caquot & Kerisel, 1968)

For clay the minimum value for *C* is 3. This means that in order to reduce seepage and to avoid particle shifting it is necessary to properly lower the infiltration speed, meaning the pressure gradients. The best way to realise this requrrement is to lengthen the contour of the contact surface. This can be obtained either by lengthening the horizontal elements (not recommended) or by adding vertical elements (the most efficient method).

In order to reduce water pressure along the seepage path, drainage of the contour must be performed. However, this also leads to an increase of pressure gradients and of the speed of the seepage. There is also a danger of piping. Because of that, drainage is only realised downstream. A layer of geotextile acting as a reverse filter (to keep the ballast and the foundation soil from mixing) is fitted. This layer is visible in Fig.2 after the last diaphragm.

4. Conclusion

For small earth dam the outlet and flood spilway must be a unique structure.

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BARAJ DE PĂMÂNT CU DESCĂRCĂTOR DE APE ŞI GOLIRE DE FUND ÎN STRUCTURĂ UNICĂ (COMPACTĂ)

(Rezumat)

Se studiază amenajarea unui baraj din pământ care este prevăzut cu descărcător de ape mari şi golire de fund realizate într-un singur element de construcție (compact) şi care permite tasarea independentă a umpluturii din care este realizat barajul față de construcția de descărcare a apei din lacul format prin construcția barajului.

Corpul barajului este din pământ (poate fi de tip omogen, cu mască sau nucleu) iar construcția pentru descărcarea apelor (ape mari şi golire de fund) este realizată ca un canal din beton armat care traversează corpul barajului. Pereții canalului au cota superioară la nivelul umpluturii din corpul barajului. În partea amonte a canalului este

amenajat un deversor perimetral, iar într-unul din pereții deversorului este practicată golirea de fund. Accesul apei prin golirea de fund este permis prin manevrarea unei vane plane de pe o pasarelă montată pe peretele canalului. Pereții şi radierul canalului au prevazute diafragme care intră în umplutură, pentru reducerea infiltrațiilor (mărirea drumului de infiltrare a apei).

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RESEARCH REGARDING THE LOSS OF THE FILTER SIT

BY

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Abstract. Correction of the water quality of the substances in suspension is achieved through the use of filter site. Filter sites are made of polyamide yarns with the density of 40, 50 and 80 mesh. Hydraulic load loss represents an important parameter at design and exploitation of the filter site. The experiments were a result of work pressure, pregnancy loss correlations depending on flow, degree of shuttered, cleanup and maintenance mode, etc. The obtained data can be used in the calculations for the design and operation of filters with elastic. This paper contributes to the research and making of filtering modules that can adjust to the specific water supply systems of low pressure and flow consumers.

Key words: filter site; head losses; transition regime; filtering modules.

1. Introduction

Water is a primordial element in irrigation systems. To ensure water quality for each method of watering is a primary requirement of the design. Water for micro irrigation must fulfill the special conditions concerning the content of solids.

Water quality in water supply systems is extremely important, first of all, for the users and then for insuring the reliability of the structure and

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the afferent installations. Depending on the source type (surface, underground) water quality is influenced by the existence of some pollutants which make that water be undesirable to the user.

The increase of water consumption from low and medium volume uses requires finding solutions of water quality improvement at an acceptable price, life span and operational parameters. Among such users we could mention: rural homesteads, micro-farms, green houses, micro-irrigation systems, remote dwellings, etc. Their water supply is affected from local sources which, more often than not, are not favoured by the users.

An important problem with the local water sources is the presence of the alluvial material of mechanical and biological nature. The improvement of water quality by a sieving – filtering process depends on the source nature and the user's requirements.

This paper contributes to the research and making of filtering modules that can adjust to the specific water supply systems of low pressure and flow consumers.

In today's social-economic development of individual homesteads, especially of the rural ones which tend towards micro-farm sizes, water quality is not achieved by a sieving – filtering process. This situation is due to the lack of filters that could adjust the present-day water in-take from local sources. The imported filters are inaccessible to the low flow users and they require an expensive maintenance.

Irrigation systems upgrading and watering methods diversifying require high quality water from the point of view of alluvial mattes. The uses of modern watering equipment involve water sieving and filtering. Micro-irrigation, a technique in continuous development in the local irrigation systems, requires water with a high filtering degree. Home industry does not offer low pressure and capacity filters for this domain of irrigation.

The existing sieving – filtering installations and devices used in our irrigation systems are extremely worn out, physically and morally, and need high maintenance costs. The increase of irrigation system output by an upgrading process involves solving the water sieving – filtering problem in various functional sections. Our industry produces a very narrow range of water sieving – filtering installations for water supply, irrigation and industrial fields. Most filters are fit for medium and high pressures, or for flows at atmospheric pressure.

At the same time, pressure filters are made for pipe diameters that do not fit local water supply systems.

2. Structural and Hydraulic Model of the Filter

Structural filter module was developed for flow rates and pressures. The filter will be used in the food systems of greenhouses. Module filtration is achieved with different lengths and diameters for the specific flow rates of greenhouses. From the constructive point of view, the filter module consists of the following elements (Fig. 1):

a) module body, made of plastics or aluminum;

b) filtering element which has the form of a filtering bullet made up of polyester fibre sieve;

c) auxiliary elements to be used in mounting, check-up, maintenance, etc.

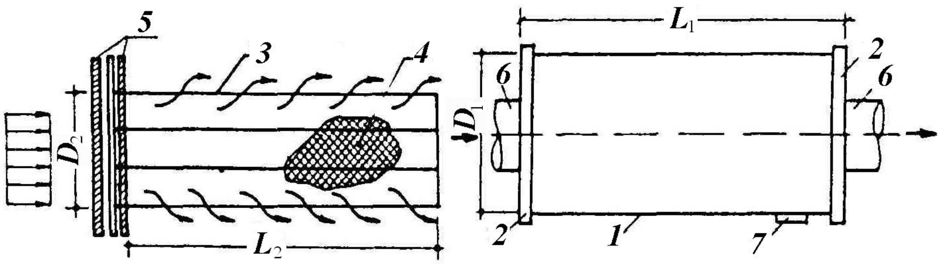

Fig. 1 – Constructive scheme of filtering module: *1* – module body; *2* – filtering element; *3* – filtering sieve; *4* – fitting.

The filtering module was conceived in two constructive variants, depending on the position of the filtering bullet with respect to the flow direction. In the former variant (*A*) the bullet is auxiliary mounted over the flow direction and is simpler from a constructive viewpoint.

In the latter variant the filtering bullet is mounted obliquely with respect to the flow direction, which complicates the constructive structure, but facilitates the maintenance operations.

The filtering module for variant *A* was experimented as a prototype for the local water supply and micro - irrigation systems (Fig. 1).

The module body is making up of an aluminum cylinder with a diameter 1.25...2.0 times bigger than the pipe's diameter on which it is mounted. The closing plates of the body are threaded and are provided with a connecting piece for their connection to the pipe. The filtering element is make up of a metallic or plastics support inside which the filtering fabric is tightly fitted. The filtering fabrics tailored after the shape of the filtering element and the placing is done with polyamide fibre. In experiments we have used filtering fabrics of polyester fibre with a density of 40...100 meshes (the side of the mesh being 0.445...0.150 mm). In designing the filtering element care has been taken to avoid the causes which determine the degradation of the filtering fabrics under the action of mechanical factors.

The sealing of the filter is achieved by means of some rubber rings placed between the closing plates, the filter's body and the upstream part of the filtering element. The fittings have been experimented for several types of materials with a view to test their sealing capacity, resistance to mechanical factors and endurance.

3. Theoretical and Experimental Research

The experimental research involved some tests concerning the behaviour of the filtering material, filter's structure and operation over the investigated range of water flow, pressure and quality.

The experiments concerned such factors as

a) structure integrity of the filter and of the filtering material in exploitation;

b) hydraulic characteristics of the filter and the filtering material: filtration coefficient, maximum pressures and breaking pressure, the curve flow head loss, variation of filtered flow with time, etc.;

c) endurance check - up of the filter;

d) filtering characteristics: filtering degree, absolute and relative filtering finesse, water turbidity after filtering, etc.

The analysis of filtering on a domain of flow rates, that determine a laminar flow regime, the transient and turbulent. In the study were considered filtering laws specific to each area:

a) laminar regime

$$v = kJ \; ; \tag{1}$$

b) transient regime laminar - turbulent;

c) turbulent regime,

where v is the speed of filtration, J – hydraulic slope, k – infiltration coefficient.

Darcy’s law has been established for sandboxes, but was later extended to other materials. Darcy's law has a lower bound of the clays and an upper limit on the gravels. Nonlinear seeping law has the form (proposed by Lindquist in 1933)

$$C_f \Re e = A + B \Re e \; ; \tag{2}$$

where C_f is hydraulic resistance coefficient; A and B adimensional specific seeping constants.

The theory proposes a formula type

$$v = k' J \; , \tag{3}$$

where k' represents an infiltration coefficient, which is variable with Reynolds number.

The tests were made on a special experimental stand built for that purpose. This stand simulates the real situation of a water supply system in rural areas. The pumping unit, the fittings, the pipes, the functional parameters, etc., are those specific to the frequently used ones in rural areas or in remote places.

Water turbidity in the experimental circuit was modeled according to the results of research carried out in the rural water supply systems. In the suction basin of the pump a water turbidity varying among 2.5 ... 4.0 kg/m^3 was obtained, depending on the variant under study.

The granulometric composition of silt varied and the values of its components were: sand 61%...73%, dirt 12%...24%, clay 16%...21%, gravel 4%...7%. Water temperature varied between 21^o...24^{o}C.

The experiments were carried out over a range of flows $Q = 0.15 \times \times 10^{-3}...0.64 \times 10^{-3}$ m^3/s at supplying pressures of 1.5...2.5 bars.

The maximum pressures introduced to check the breaking point of the filtering fabric varied among 3.0...3.5 bars.

Water velocities in the hydraulic circuit varied among 0.62...2.64 m/s and among 0.02...0.06 m/s on the filtering surface. The results, in detail, of our research, have been published in a research contract. From a hydraulic point of view, it was found that for the flow range of $(0.10...0.60) \times 10^{-3}$ m^3/s, the head losses vary between 0.08...0.42 m. As compared to other filters, the head losses are low. As compared to other filters (filtering element without sieve) tested with clean conventional water (without silt) the head losses are higher with 12%...15% in the regime flow areas. By mathematically processing the experimental pairs of values (Q_i , h_{ri}) the following correlation eqs. have been found:

a) for the 40 meshes filter

$$h_r = 0.733Q^{1.717}, \tag{4}$$

b) for the 50 meshes filter

$$h_\mathrm{r} = 0.772Q^{1.784}, \tag{5}$$

c) for the 80 meshes filter

$$h_\mathrm{r} = 0.540Q^{1.836}, \tag{6}$$

d) for the witness 80 meshes filter

$$h_\mathrm{r} = 0.720Q^{2.07}, \tag{7}$$

where the correlation coefficient had values of 0.988...0.997.

Eqs. (4),…,(6) are plotted in Fig. 2. The comparative analysis of the 80 meshes filter is shown in Fig. 3.

The experiments made with turbid water allowed us to determine the clogging degree and the operational time while the filter's sieve becomes clogged to a certain degree.

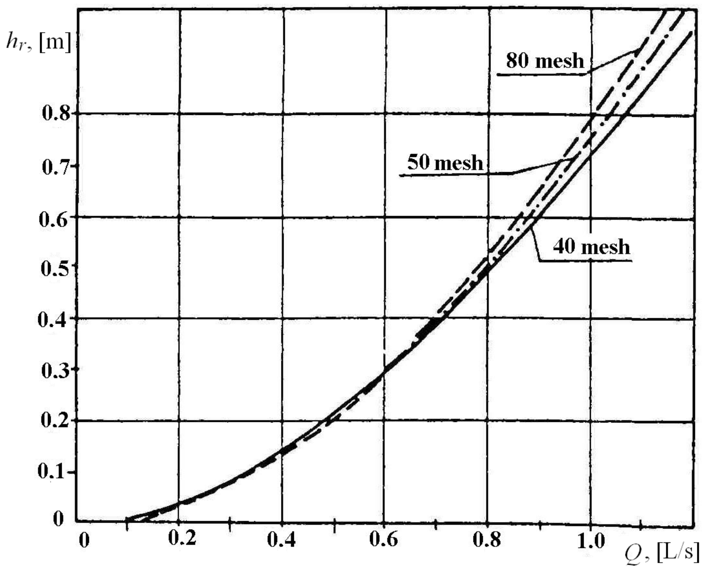

Fig. 2 – Correlation h_r *vs.* Q at studied filters.

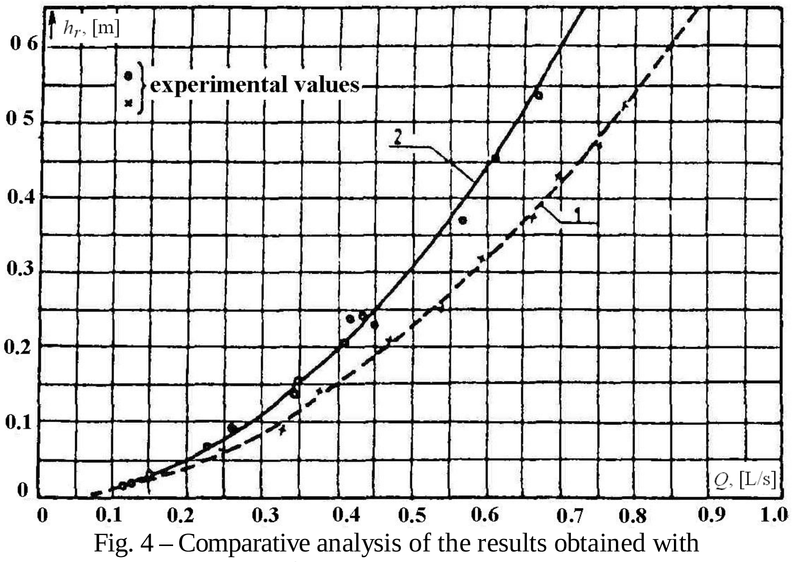

Fig. 4 – Comparative analysis of the results obtained with the filter having 80 meshes.

The experiments showed a good behaviour of the filtering fabric in the conditions of a water flow pressure, and turbidity variation along the pressure pipes circuit. The filtering sieve presented a lower clogging as compared to the metal sieves at the same density. This aspect is due to the much too higher elasticity of the polyester fibre tissue that, at pressure variation, determined the removal of solids from the sieve's mesh. This, in turn, determines a much simpler unclogging of the filtering element as compared to the metal sieve filters.

4. Conclusions

Theoretical and experimental studies allow the statement of the following conclusions:

1. Filtering water through experienced module is in a transient regime laminar turbulent and riotous. Continuous and random variation of parameters requires research for analysis of expansion of this field.

2. The mechanical, hydraulic and chemical properties of the polyester fibre tissues recommend them to be used in the filtering elements mounted on the low and medium pressure hydraulic systems.

3. The laboratory experiments have shown that the filters made up of polyester fabrics have different properties as the filters related with other materials.

4. The relative deformability of the fabric’s meshes enables a low clogging when solids pass. At the same time, this aspect contributes to a much simpler maintenance during exploitation.

5. The experimental filters with filtering fabrics of 40, 50 and 80 meshes have a very good pervious ness and the head losses have low values (0.20...0.60 m) for flows regime specific to the rural water supply systems. In designing one can use the graph from Fig. 3 and eqs. (1)…(3).

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CERCETĂRI PRIVIND PIERDERILE DE SARCINĂ LA SITELE FILTRANTE

(Rezumat)

Corectarea calităţii apei privind conţinutul de substanţe aflate în suspensie se realizează prin folosirea unor site filtrante. Sitele filtrante sunt realizate din fire poliamidice cu densitatea ochiurilor de 40, 50 şi 80 mesh. Pierderea de sarcină hidraulică reprezintă un parametru important în proiectare şi exploatare. Din experimentări au rezultat presiunile de lucru, corelaţiile pierderilor de sarcină în funcţie de debit, gradului de obturare, modul de curăţire şi întreţinere etc. Datele obţinute pot fi folosite la calculele de proiectare şi exploatare a filtrelor cu site elastice. Prezenta lucrare contribuie la cercetarea şi realizarea unor module filtrante adaptabile sistemelor de alimentare cu apă specifice consumatorilor cu debite şi presiune reduse.

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GRAPHICAL AND TEXTUAL DATA BASE OF A ROAD INFORMATIONAL SYSTEM

BY

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Abstract. The road informational system is defined as a sub-system for the roads evidence, systematic inventory performance, under technical, economic and legal respect, with the compliance with the basic regulations and with the data from the Cadastral Integrated System and from the Land Registry, concerning the real estate and its owner. The Data Bank is a main component of the Cadastral Informational System (SIC) that contains two types of information: a graphical one, indicating the spatial distribution of the items studied and a textual one, for storing their associated attributes.

A Data Bank’s application for the Cadastral Informational System of a road portion, is presented.

Key words: cadastres; survey; digital plane; data base; information; real estate; network; road.

1. Introduction

The Roads Informational Systems (RIS), accordingly to Law no.*7*/1996, re-published with its subsequent amendments and completions, are defined as

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sub-systems for the roads evidence, systematic inventory performance, under technical, economic and legal respect, with the compliance with the basic regulations and data from the Cadastral Integrated System (CIS) and from the Land Registry (LR), concerning the real estate and its owner.

The object of RIS consists in the lands that are the support for the roads infrastructure, the roads representing safety and protection areas, the lands for the roads logistic and social arrangements, as well as the other real estates (assets) belonging to the roads, respectively: buildings, courtyards, pathways, bridges, viaducts, tunnels and other artworks, town development networks, signalling (warning) networks, etc.

The purpose of roads cadastral works is that of performing the inventory, the determination and the recording into the LR documents, the representation on the Digital Cadastral Plans (DCP) of the assets (real estates) belonging to the road and their registration into the Real Estate Publicity (REP) documents. These have the role of providing technical, economic and legal updated information concerning the roads assets situation, concerning the dynamics of changes produced. After the completion of the reference material, represented by the RIS, all the data concerning the position, the shape, the surface, the utilisation and the owners/ administrators of the real estates belonging to these funds, are sent to the Cadastre and Real Estates Publicity County Offices (CREPCO).

The entering and maintaining works complex automation, is based on the topographical and cadastral data, collected under digital form, processed and edited within a data bank. The Data Bank (DB) is the main component of the RIS, as well as of the informational systems from other fields, containing two types of information: a graphical one, indicating the spatial distribution of the items studied and a textual one, for storing their associated attributes.

An application for achieving the DB for a national road portion, is shown below.

2. Presentation of the Data Base and of the Types of Information Utilised

The modality of organizing the information managed, that may be graphical or textual, is specific for a Cadastral Informational System (SIG/GIS).

The DB is a structured ensemble made of coherent data, which can be processed by several users, in a coherent manner. The data collection persists whereas, after the acceptance by the management system, they can be erased from the base, only through an explicit request, addressed to the Data Base Management System (DBMS).

In order to enter the cadastre, the Graphical Data Base (GDB) is performed in a digital format, vectorial system, displaying the graphical data building a real world model, the information storage being achieved through sets of coordinates (X,Y,Z), the objects being represented with one or several coordinates pairs. The digital graphic information is placed on thematic layers, in order to be easily handled. The Textual Data Base (TDB) is a semantic type information, by the mean of which the graphical items receive an explanation, having the following features: it is alpha-numerical, it has a descriptive value and the data are quantitative /qualitative.

The attributes that are attached to the graphical entities are recorded in a DB, which must provide the content of the LR. The data from DB can be both integrated (considered as a unification of several files), or shared (when they can be shared between several users).

The DBMS is the whole software ensemble which deals with all the access requests to the DB. They represent a programmes package, enabling the users to interact with a DB, allowing the data defining, consultation, interrogation and updating. The basic concept of the relational model is that of relationship/table, creating an interface between the users and the DB, that mainly allows its establishing, updating and consulting.

The DB of geographical information, aimed for creating layouts and maps, is an ensemble of layers, named in an ARCGis language, Geo-Files that will be created for the road sector and the adjacent surface, specified in the "shape" format, associated with ARCGis 93 format, for each entity type, in such a manner as to allow their import, directly into the project. The Geo-files will contain information about the land, enabling the setting up of it digital model, related to the road, to its neighbouring areas, to the buildings achieved in these areas and to the number of their dwellers. The descriptive information represented in the Geo-Files and aimed for the project readability, is imported from an AutoCAD file, unique at the road sector level, organized on layers, having the name made through the road string concatenation with the kilometric landmarks from the beginning and from the final edge of the road.

The achievement of the digital geographic support assumes various modalities of converting the existent maps and plans into an analogical format, as well as the possibility of their integration with the new data gathered by the mean of the terrestrial systems or of the aerial and spatial recording platforms and by finally getting certain digital cartographic products, that may be operated in various applications. In order to design a SIC/GIS, all the operations of collecting, storing, updating, handling, analysing and displaying various forms of data and information, that have the possibility of being be geo-referenced, are taken into account.

A. *The Design of the Data Base* for the Informational System, consist in a thorough setting up of the base structure, in the following four phases:

a) Identifying the spatial features, the attributes and the thematic layers needed.

b) Defining the storage parameters for each attribute.

c) Providing the registration of the coordinates.

d) Designing the working files.

B. *Loading the Geo-Spatial Data Base* of the Informatics System assumes

a) The acquisition of spatial data, resulted through digitizing process, through scanning–vectorization, through measurements on site, digital photogrammetry, GPS technology, their processing, topology checking, topological errors correction.

b) The acquisition of data needed for DB, consisting in establishing the attributes of the classes for the characteristic items and in identifying the errors at data inlet.

C. *Types of analyses* over a DB, allowed by an Informatics System, make reference to the analysis of the spatial, textual data and to the integrated analysis of the spatial and textual data.

D. *The Data Base Management* consists in transforming the data spatially referred into real coordinates, in updating the DB, in pasting the layers representing adjacent areas. To be noticed that, besides the data collection itself, a set of programs in order to provide the performance of the data structures specific operation, is necessary. This set of programs represents the Data Base Management System (SGBD).

3. Data Base – Application for a National Road Portion

Within the present application, a national road portion is studied (DN 29), on a length of 7 km, from kilometre 44+100 up to kilometre 51+100. The land limits are represented under the shape of a contour, through a closed poly-line, described through X, Y, Z coordinates. Associated to this shape, text information concerning eventual names and limits of the administrative localities, are represented within a distinct layer.

3.1. Topographical Survey

The support network is materialized though milestones FENO and wooden stakes or metallic bolts. The road traversing have been compensated on the support geodetic network points, identified through GPS technology utilization, supported on the spatial national geodetic network, in Stereo 70 coordinates system and Black Sea 1975 benchmarks system, within only one campaign, providing the measurements continuity.

In order to calculate the transformation parameters, the GPS, DORO (Dorohoi), SUCE (Suceava) and PASC (Paşcani) permanent stations have been utilized. The measurements have been performed by the mean of a Trimble R8 apparatus, in Real Time Kinematics (RTK), using ROMPOS system. Sets made of three points, at the beginning, at the middle and at the edge of the road portion studied, have been determined.

For each group, the stationing session was of 30 min. for each point, separately. The points have been determined in a Cartesian system, with ±1 cm errors, for the position in plan and ±2 cm errors, for vertical position.

a) *Creating the Topographic Plan*. Being directly related to the details geographical locating, the thematic application type SIC/GIS has as starting point the basic topographic plan, represented by physical plan, together with the descriptive data associated. Thus, in Fig. 1, the image of the basic topographical survey is represented, being framed within the territory, on the ortho-photomap, at scale 1: 5,000.

Fig. 1 – Creating the Topographic Plan.

b) *Attaching the descriptive data*. On the Topographic Plan graphical representation, the descriptive data of the interest items, are attached (Figs. 2 *a*, *b*, *c*).

A. *Road Axis*. It is the line defining, horizontally and vertically, the geometric features or the road route, being defined as the geometric place of the points equally spaced from the roadway side edges, made of straight and curved lines, without taking into account the over-enlargement within the curves (STAS 4032/1-90).

Each road axis will be represented under the shape of a three-dimensional (3-D) poly-line, described by the special coordinates *X*, *Y*, *Z*. The road axis will be split into sections, homogeneous under the respect of cross-profiles, of traffic, of traffic flow type, of road surface, of traffic speed and of road slope. Associated to the traffic, text information concerning the road name

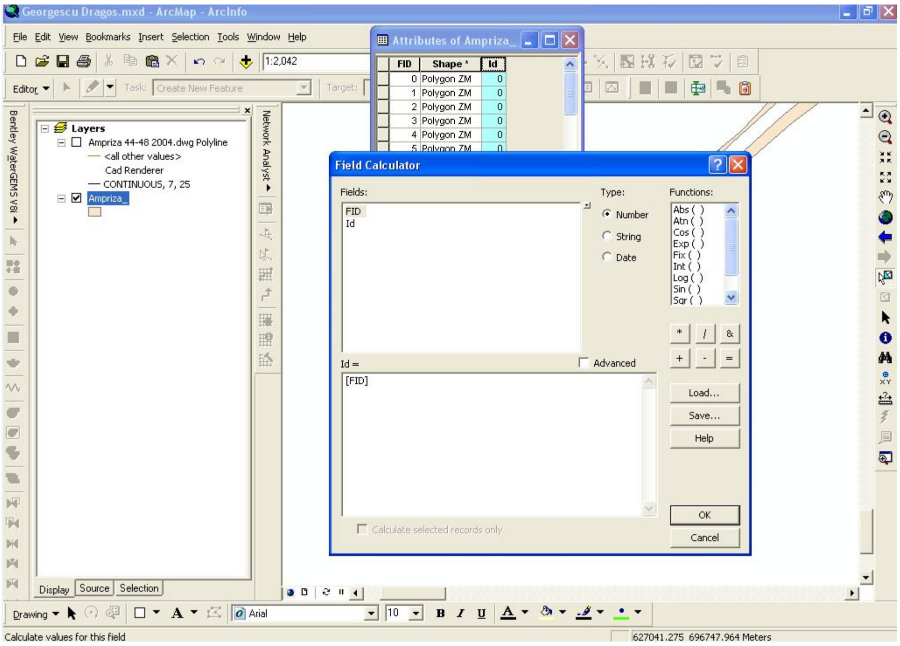

Fig. 2 *a* – Attaching the descriptive data – assigning the identification data to each polygon.

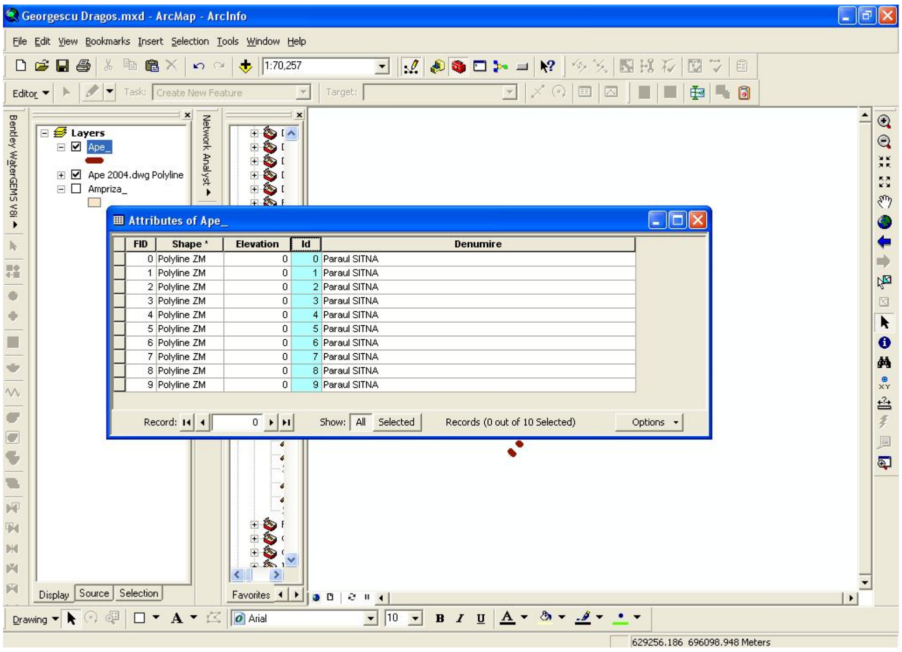

Fig. 2 *b* – Attaching the descriptive data – the registration of attribute name and of identification data.

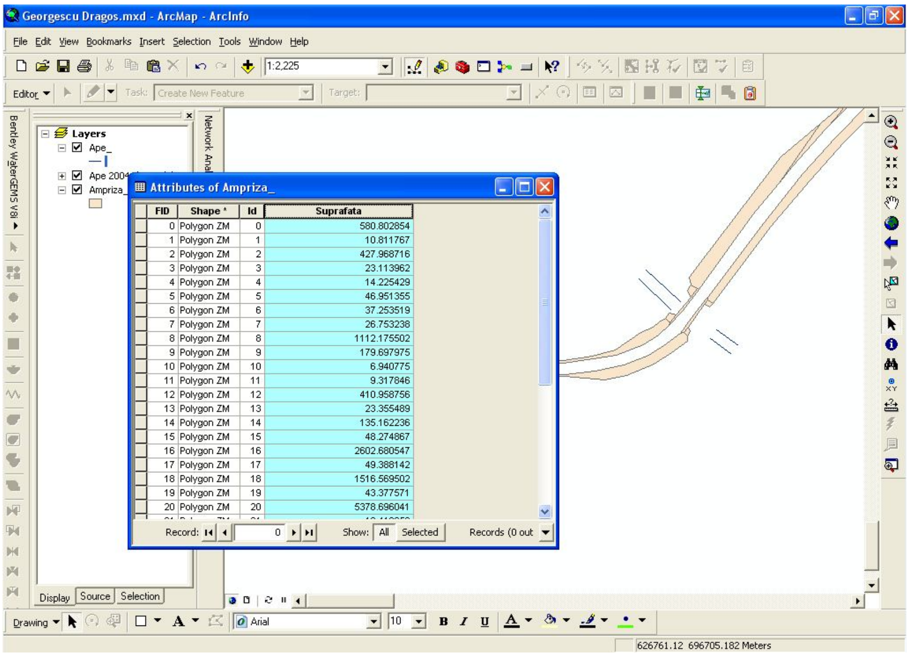

Fig. 2 *c* – Attaching the descriptive data; establishing the area; road territory.

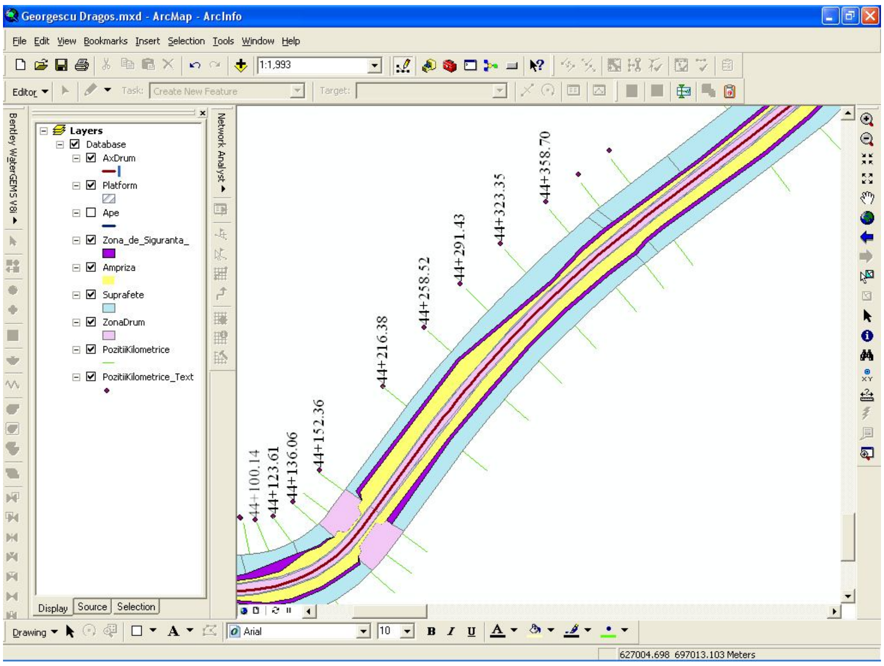

Fig. 3 – Kilometrical positions data.

and the position of kilometric landmarks along the sector, including the kilometric position of the sector beginning and at final end edges, will be represented in a text type distinct layer. Whereas the two alignments are connected through curves, they must be represented through characteristic items (curve radius, the inlet and outlet tangent lines, the bisector, etc.). In Fig. 3, the kilometrical positions are represented and in Fig. 4, the textual data of these positions.

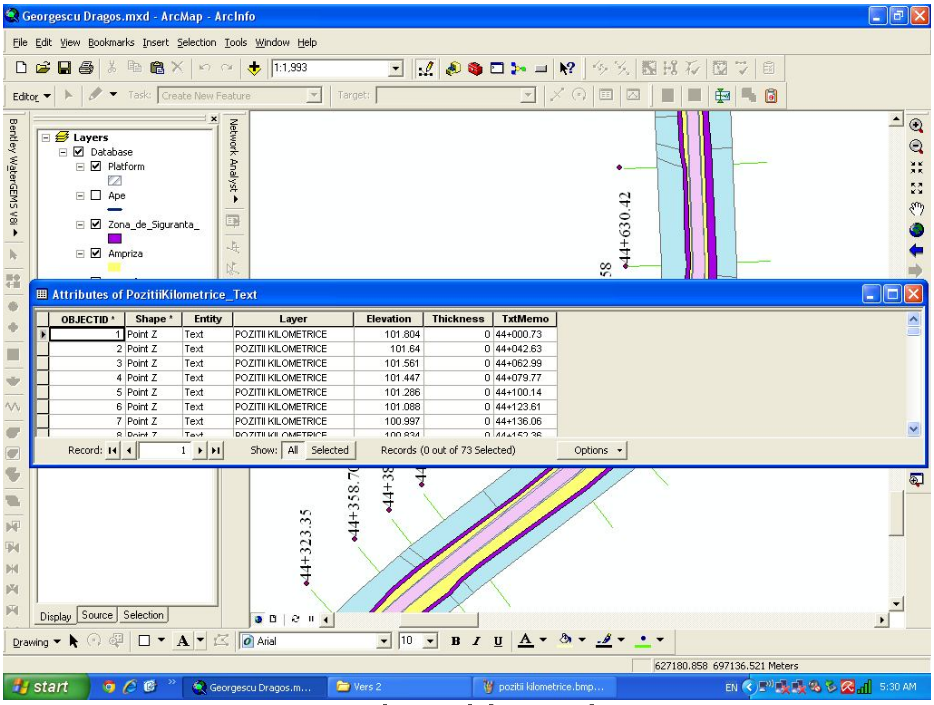

Fig. 4 – Textual DB in kilometrical positions.

Besides the sector beginning and at final end edges, the points where modifications of the road slope occur, are recorded: road gradient higher or lower than 2%, horizontally. The DB will comprise representations of the road territory, of the waters, of safety area, of road area, of side roads, of bridges, etc.

To be noticed that, between each graphical item and the textual /alpha numeric DB, there is a biunique correspondence. The identification of an item, through navigating within the tabular DB, will automatically lead the user to a corresponding item from the plan/map (Fig. 5).

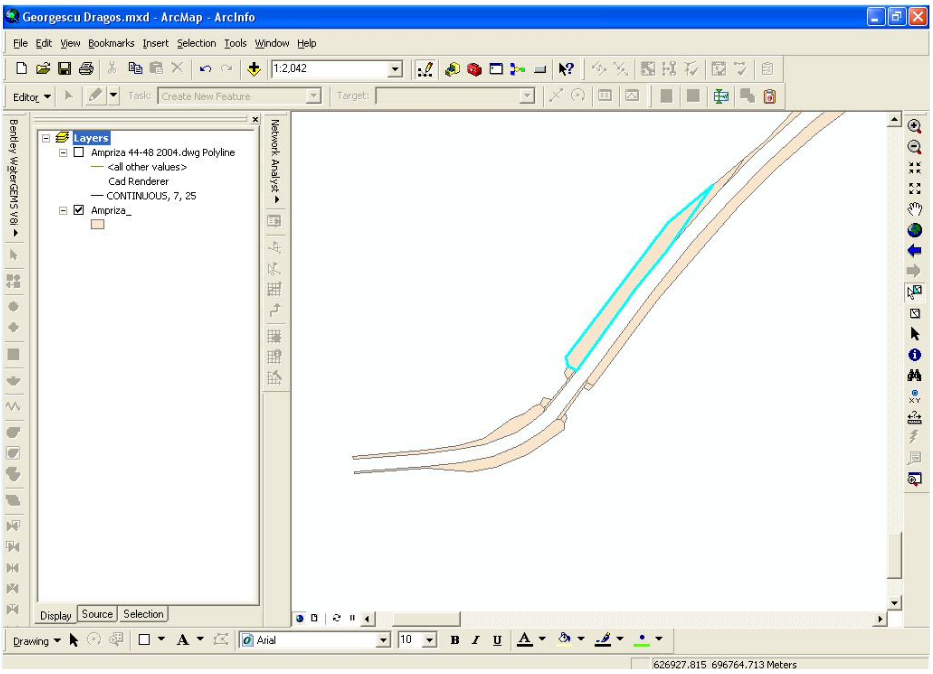

Fig. 5 – Navigating within a DB – viewing the road territory.

B. *Interrogating the DB.* All the SIC/GIS programme packages include operation for the DB interrogation, in view of obtaining a data subset. The spatial interrogations are the most important and they assume the selection of the entities, depending on the location and of the spatial relationship with the other entities. Other types of interrogation made useful, are the graphic ones, the attribute interrogations. These interrogations allow the performance of spatial data analysis and modeling that makes them distinctive from the other types of information systems.

The DB interrogation represents a convenient analysis tool, allowing the creation of tabular or graphic reports and in case of SIC/GIS system, the correspondence graphic item – attributes within the Data Base, that may be valorized through elaborating thematic maps (Figs. 6 and 7).

On a more comprehensive interrogation, at kilometrical positions level, the road territory width details, with the safety areas, with the road axis (alignment of curve), may be viewed, as shown in Figs. 3 and 4.

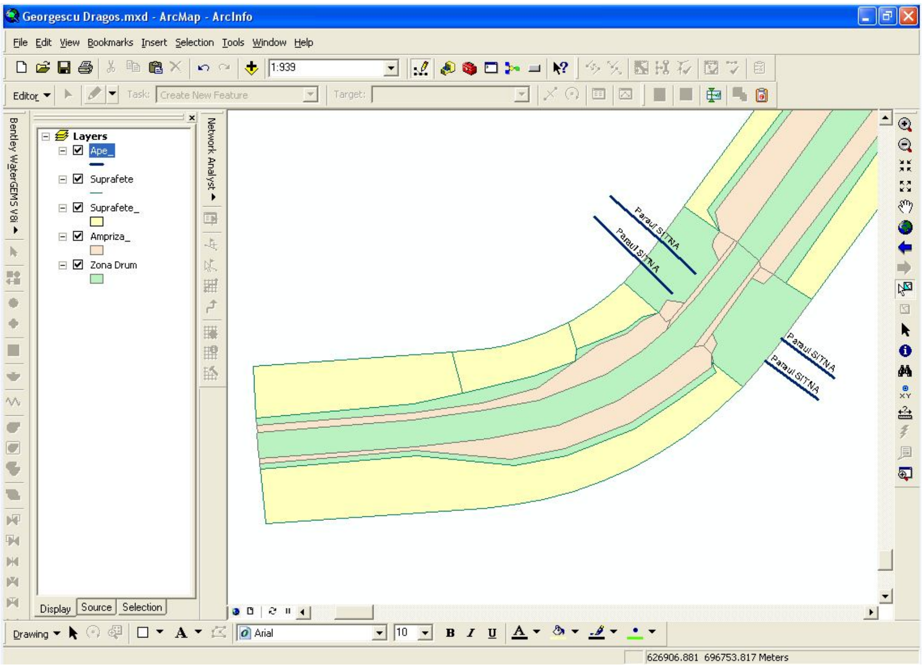

Fig. 6 – Data Base interrogation – water, surfaces, road territory, safety area.

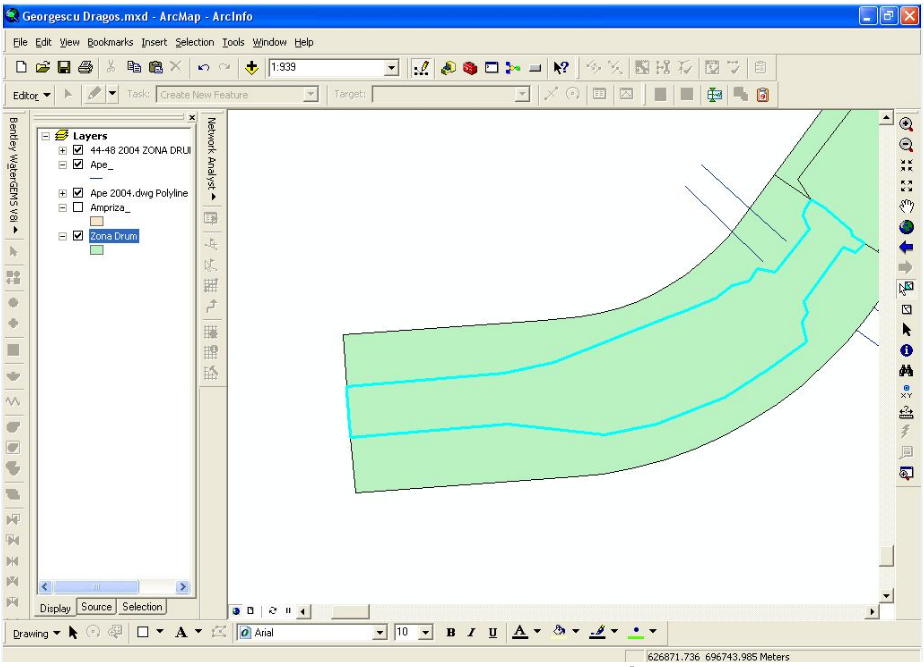

Fig. 7 – Data Base Interrogation – road zone.

On the road portion studied, a comprehensive interrogation of the kilometric positions of the two bridges, of the water flowing directions, of the bridges lengths, can be performed (Fig. 8). The side roads that may be found along the road portion studied, with details concerning the road type, the importance grade (class), the side roads pavement, etc., can be also established and viewed (Fig. 9).

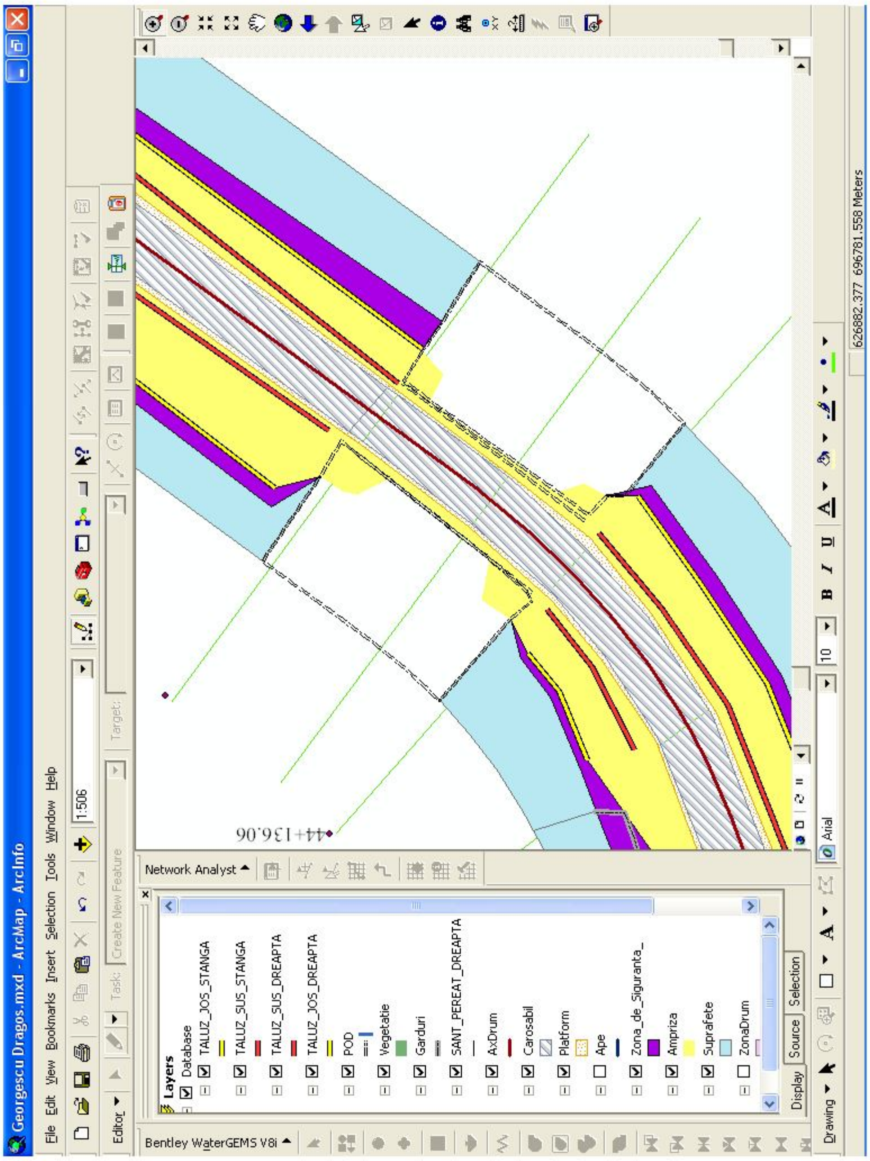

Fig. 8 – Bridge details with clearance of 29 m.

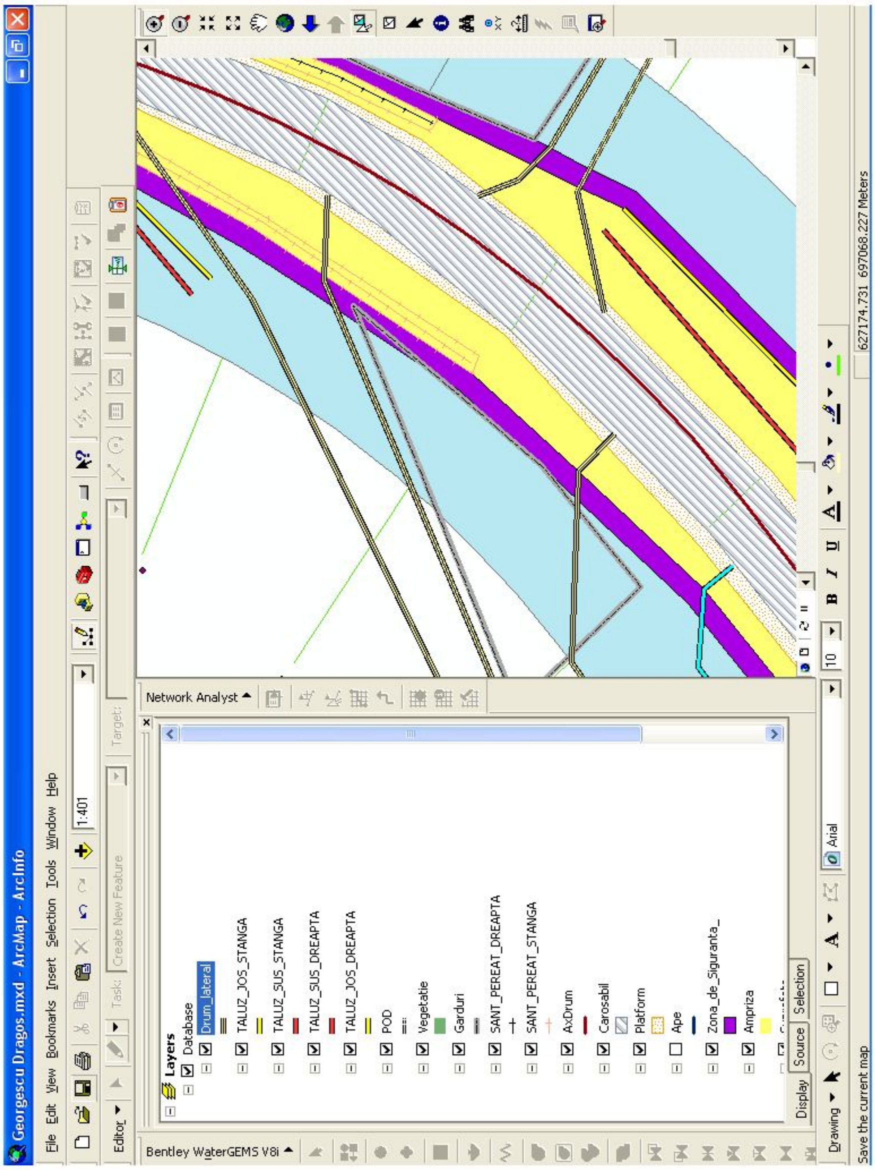

Fig. 9 – Side roads.

4. Conclusions

Informational System of Roads – SINCAD, is a fundamental component in getting quick technical, economic and legal data roads, in close connection with the current situation along the route.

Informational System of Roads makes it possible for data query in design and execution, as well as in rehabilitation and modernization.

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BAZA DE DATE GRAFICE ŞI TEXTUALE A SISTEMULUI INFORMAȚIONAL AL UNUI DRUM

(Rezumat)

Sistemul informațional al drumurilor este definit ca subsistem de evidență inventariere sistematică a drumurilor, din punct de vedere tehnic, economic şi juridic, cu respectarea normelor şi a datelor de bază din sistemul integrat de cadastru şi carte funciară, privind imobilul şi proprietarul. Banca de date reprezintă componenta principală a Sistemului Informațional Cadastral (SIC), care conține două tipuri de informații: una grafică, care indică repartiția spațială a elementelor studiate, şi alta textuală, pentru stocarea atributelor asociate acestor elemente.

Se prezintă o aplicație a băncii de date pentru Sistemul Informațional Cadastral al unui tronson de drum.

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ADVANTAGES OF USING OPEN SOURCE SOFTWARE IN THE CADASTRAL INFORMATIONAL SYSTEM

BY

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Abstract. With the rapid development of the information technologies and the up-to-date methods of measurement, it became necessary to upgrade the services delivered to the citizens and to automate the processing. The existing cadastre, consisting of paper map/plans and land registers, is now becoming insufficient. One of the best solutions at the local level is the creation and development of a digital plan and a database, as an implemented instrument used to sustain the institutional capacity, the local planning and progress, able to contribute when taking decisions for everyone’s benefit. A digital cadastral plan can be the basis for additional thematic layers, successively converting it into a complex system for management of administrative units. The aim of this paper is to research the advantages of digital cadastral plan and its uses in implementing a Cadastral Informational System for sustainable development.

Key words: cadastre; database; digital plan; open source.

1. Introduction

The cadastral system is the basis used for the protection of the property by means of title registration and cadastral plans. Each parcel and its owners are

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registered and all the spatial structures consisting of location, boundaries and contents are described in a cadastral plan. Therefore, the cadastral system is seen as a land information system affording information on real estate of a property. In rural areas, the claim to ownership increases the investment in agricultural lands and the property business. Then an appropriate cadastral system should be designed and established by and for a particular zone (Elayachi, 2001; Semlali, 2001).

In the light of the evolving digital technology, traditional cadastral plans on paper are not enough flexible and not suitable for the needs of the society. Moreover, the emerging new satellite technologies and high speed computing and processing capabilities have completely changed the face of the earth.

The data resulting from the classical model of land cadastre are now becoming insufficient. In the course of economic development the demand for more varied information items becomes increasingly pressing. Data stored in traditional cadastral systems fail to meet requirements connected with supervision, management, decision-making, forecasting and development planning.

The *first necessary step* can be made by unification all forces involved in creating and promoting informational systems in the local administration, in order to convince the decision factors of the advantages of using informatics, starting from the opportunity of using these applications and from the qualitative and quantitative advantages that can be obtained after exploiting such systems.

2. Concept of Open Source

The concept of *free software* is not a new one. As soon as it appeared, computers have been adopted by universities as research tools. At that time software applications were distributed free, programmers were paid only for the programming time and not for the software made. Later computers have arrived in the business environment and programmers began to mentain them, restrict user rights on the software and charge for each copy of the program.

The concept of free software as development philosophy of the software was heavily popularized since 1984 by Richard Stallman, with the establishing of the Free Software Foundation (FSF) and project development General Public License (GNU). In the vision of the FSF, Free Software is a matter of freedom, not price. The concept refers to freedom, in the sense of freedom of expression, and not the free entry. Confusion between the two meanings is often encountered as in English, the word free, means both freedom and free. Free software is a matter of freedom for users of its use, copy, distribute, study, change and improve. More specifically, it's about four forms of freedom to its users namely

a) freedom to use, for any purpose (*freedom 0*);

b) freedom to study how the program works, and adapt it to your needs (*freedom 1*); access to source code is a precondition for this;

c) the freedom to redistribute copies so you can help others (*freedom 2*);

d) freedom to improve the program and release your improvements to the public, in the whole community benefits (*freedom 3*); access to source code is a precondition for this.

In 1998 it launched the concept of Open Source software as an alternative to free software formula. In this way it aims to eliminate ambiguity induced by the free form as well the disposal of the rigid issues promoted by FSF. Since then Open Source has know an exponential development. (Crăciunescu, 2007).

Open Source Software (OSS) is defined as a program in which the source code is available for modification and redistribution to the general public. There are many OSS's licenses and "Open Source Initiative" (http://www.opensource.org/) has assumed the role of arbiter of fairness general licenses.

The power of Open Source projects should be evaluated not only for technical merit or legal formulating of the license. OSS products should be evaluated based on cost, comparing the technical features and community vitality that maintains and improves project.

Open Source GIS includes products to fill every level of Open GIS spatial data infrastructure. Existing products are in a phase of rapid developmental points, using basic software structures that are already in place. OSS can provide a complete alternative to commercial software in most system designs.

3. Presentation of Quantum GIS Soft

Quantum GIS (QGIS) is an Open Source GIS software package. The project was born in May 2002 and was established as a project on Source Forge in June of the same year. It has a beautiful graphic interface easy to use.

QGIS has features and characteristics with those of other popular programs. The goal initially was to provide a GIS data viewer. QGIS is used freely, in accordance with the GNU General Public License (GPL). Major domains on the main screen of the program QGIS are the followings:

1. Contents (left).
2. Map overview of space.
3. Standard menu.
4. Zoom and other tools.
5. Main map in the center (where empty space now).
6. Status bar (at the bottom of the screen).

Basic features of QGIS are

a) OGR library support for raster and vector data.

b) Support for PostgreSQL spatially activated using PostGIS tables.

c) GRASS integration package for viewing, editing and spatial analysis.

d) GRASS digitizing and OGR / File shp (shapefile), producer of maps.

e) OGC support.

f) Overview of the working panel.

g) Spatial links (bookmarks).

h) Identification/selection features, editing/viewing/search attributes, feature writing inscriptions.

i) Choose map projection, save and restore projects, export map file for the Mapserver.

j) Changing symbols vector and raster data.

k) Extensible architecture, etc. (Nițu, 2008).

4. Advantages of Open Source Software

Open Source project success is not assured simply by publishing the source code. It occurs when the project takes shape around an active community of developers and users, united by common interests, which constantly maintain and improve the project. To attract a strong community, an Open Source project must meet a number of design rules, transparency and openness. The most important are the followings:

a) *Documentation*, a better documentation of the software application, both at user and developer level. This will minimize the time and effort invested by an new user/developer to get used with the software application and maximize its productivity.

b) *Design and implement application* should be made in a transparent manner. This involves primarily a code available *via* CVS, and the existence of public discussions lists, which are discussed development strategies, future plans, etc.

c) *Project development team* must also be transparent. Importance should be given to a developer of quality and quantity of contributions to the project and not the position held within an institution or company.

d) *Application design* should be one modular. This allows developers to add to the main application modules with specific functionality. Although the usefulness of a module may not interest the whole community around the project, it will add value to the application and will allow attracting new users.

The success of Open Source applications experienced a new phase, with the emergence of new business models that exploit commercially their functionality. As evidence, at present, a lot of Open Source applications is not just the result of some enthusiastic developers, but receive substantial support from large private companies (IBM, HP, SUN, etc.).

The concept of Open Source ensures customer full control over the technology they use and provide cost reductions by eliminating the presumed costs of buying the applications. In the same time, an Open Source project developer can control how the application is used to trade by awarding a license to use. There are currently many licenses adapted to different user needs and a institution which aims to centralize, document and arbitrate the correctness of the text for those licenses : Open Source Initiative (Crăciunescu, 2007).

In the teritory managing domain, the current trend is to use Open Source products because they are open and accessible free licenses offered due to the lack of significant costs in acquiring such products.

Open Source platforms can be used profitably because of the high degree of customization. Open Source approach offers several advantages over commercial approach, such as the increasing number of local expertise and the ability to share development solutions at no cost.

Open Source solutions are a viable alternative to the commercial platforms, both economically and from a technical standpoint. In addition, other social and economic benefits can be found using Open Source solutions.

It is well known that Open Source does not mean free! A complete development may be more expensive than a commercial solution, but several factors must be considered in order to perform a proper economic analysis. Open Source solutions can be developed by using and promoting local expertise, therefore, costs can also be justified from a social perspective. If you do a search on the Internet using keywords GIS, the number of answers commercial solutions is similar to Open Source solutions.

Open Source Community now offers a complete set of tools that are able to build a complete SIC (relational databases, graphical environment, geographic environment, geographic data, management systems, etc.).

4.1. Comparing the Advantages of Open Source Software with those of a Commercial Software

A comparison was therefore made of two approaches: commercial and free, in order to choose the best solution. The comparison was done by testing the following criteria:

A. *License costs*

If one accepts that standard marketing solutions always need customization for applications in the field of cadastre, license costs highlights the Open Source solutions. In this case, both desktop platforms (GRASS, QGIS) can be found for free.

B. *Maintenance costs*

Maintenance costs are also favourable Open Source solutions. Open Source All upgrades are actually delivered free, while commercial solutions if users are required to pay maintenance costs each year (approximately 20% to 30% of license costs).

C. *Development of Basic Functions*

Obviously, from this point of view, commercial solutions offer the best solutions due to the high level of basic performance and the functionality provided by the standard versions of the tools. Open Source solutions provide utilities developed for frequent users, who tested in detail these features and in most cases build new solutions that can be taken into consideration.

D. *Development of Advanced Functions*

A deadlock occurs in this element of evaluation. In all cases, a skilled user is necessary. Commercial Solutions offers a limited way to create advanced solutions, while Open Source solutions allow use of different ways. Open Source is considering developing solutions that meet international standards.

E. *Personalization*

Commercial platforms today allow a good level of customization using popular programming languages (*e.g.* Visual Basic for ESRI). However, the only difficult thing is that many of the tools available are not useful for applications in the cadastre field. Open Source solutions allow free customization and offers a large community, with free scripts source and customization and the posibility to contact the authors to solve problems.

F. *Flexibility*

This property is the ability to run software on different operating systems. From this point of view Open Source solutions seem to be less constraining.

G. *Updating*

This word means the natural evolution of the software and correct the malfunction of the software itself. In this case, Open Source provides a flexible and promising solution.

H. *Using Internet Services*

GIS solution is usually understood as a desktop solution. Many books and manuals talk about a GIS technology, which will then be published on the Internet. It is now possible to design a new type of GIS project, based on a client–server approach using an object-relational database, where all data (*e.g.*, geometric alphanumeric) can be collected together and directly managed by the client *via* the internet. Open Source Solutions now offers more flexible tools to manage this process in comparison with commercial solutions. An important element in the comparative analysis is the georeference function. Open Source Solutions pays special attention to the reference systems (datums). Mainly it's about library “Projections” used to define reference systems involved transformations from one system to another. Currently this possibility is also available in the commercial solutions (Rinaudo, 2007).

In terms of programming languages used in developing Open Source GIS applications are divided into two classes: "C" and "Java". A third category is represented by Web applications, such as those who provide Web services spatialized (Crăciunescu, 2007).

4.2. Trends Towards a Common Standard

OpenGIS is a project that started in 1993, with limited support from several federal agencies and commercial organizations in the United States.

OpenGIS is defined as transparent access to heterogeneous data resources geographic (spatial) and processing resources in a distributed environment (network). From this definition somewhat abstract, it appears that

OpenGIS covers two major aspects of GIS: data and applications.

Because each product GIS use data formats specific, users are usually tied to a particular manufacturer and their geographical applications. Those who use products and data from several producers have to bear an additional cost of data transfer and risk a loss of data integrity.

The aim of this project is to provide a comprehensive range of specifications for interfaces that will enable application developers to write interoperable components.

The interoperability means

a) ability to find information and tools to process them no matter where they are physically located;

b) ability to understand information and tools to process them, no matter what platform supports them and whether local or remote;

c) the ability to not be constrained by a single vendor offerings;

d) ability of a manufacturer to build the information and processing facilities of others, whether or not they evolve.

The main benefits of an OSS are the followings:

a) OpenGIS specification eliminates the need for standardization of data formats and costly data conversions.

b) Open interface determines the applications to allow real-time access to huge data sets and also processing resources.

Initially was discussed on the feasibility and the aim of future OpenGIS Specification (OGIS). Following the conclusions that were drawn, it was decided that it is useful and important to create a permanent organizational structure, to handle the development of such specifications. Thus, in August 1994, he founded OpenGIS Consortium (OGC), which aims to promote the development and use of appropriate technical standards and open systems, advanced spatial data processing and information technology related information technologies (Ibănescu, 2002).

2006 was a historic year for the community following the launch of OSGeo. OSGeo is a non-profit organization that aims to support and promote the development of open source geospatial technologies and free geospatial data.

OSGeo works as “vehicle” to promote Open Source technologies in the geospatial community, and provides the necessary infrastructure for sharing information, knowledge and data in collective projects. OSGeo also has the responsibility organizing an international conference and annual Sol Katz award for services to the geospatial community. The first conference organized by OSGeo up, FOSS4G2006 was held in Lausanne, Switzerland, and gathered together more than 500 participants (Crăciunescu, 2007).

5. Conclusions

1. The tendency of developing the Cadaster Informational Systems comes from *the necessity of using the terrain with maximum efficiency* from an

economical and urbanistic point of view. We must stress the fact that the data from the SIC (SIG) have an apparent temporal finality, because the continuous changing dynamics require that the data to be frequently /updated in the data basis, for a proper over time use.

2. When trying to solve the problems raised by the use of the Cadaster Information System and it's data base it came clear that to obtain such a system was very expensive, and this is why *the legislation must be improved in the future*, so that the responsable institutions to allocate enough resources for personel training which is another critical problem in the present.

3. Technology Geographic Information Systems (GIS) is an evolving technology, a computerized tool for recording and analysing all elements that exist in the world and the events that happen in the world. GIS technology integrates common database operations such as query and statistical analysis with the unique advantages of maps for visualizing and analysing geographic spatial data.

4. In Geographic Information Systems case, classical advantages of using Open Source applications are: cost reduction, control over technology used, etc. In addition there is a very important component: *compatibility with existing standards in this area*, most of GIS Open Source applications are 100% compatible with current standards.

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AVANTAJELE UTILIZĂRII SOFTURILOR OPEN SOURCE ÎN CADRUL SISTEMELOR INFORMAȚIONALE CADASTRALE

(Rezumat)

Odată cu dezvoltarea rapidă a tehnologiilor informaționale şi evoluția metodelor de măsurare, a devenit necesară îmbunătățirea serviciilor pentru cetățeni şi automatizarea procesului. Documentele cadastrale existente, constând din hărți pe hârtie/planurile şi registrele funciare, acum au devenit insuficiente. Una dintre cele mai bune soluții la nivel local o constituie crearea şi dezvoltarea unui plan digital şi o bază de date, ca un instrument de aplicare utilizat pentru a susține capacitatea instituțională, planificarea locală şi progresul, în măsură să contribuie la luarea deciziilor în beneficiul tuturor. Un plan cadastral digital poate fi baza pentru alte straturi suplimentare tematice, devenind astfel un sistem complex de management al unităților administrative. Se pun în evidență avantajele planului cadastral digital şi utilizările sale în implementarea unui sistem de Cadastru Informațional pentru o dezvoltare durabilă.

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CONTRIBUTIONS CONCERNING THE TRACING OF THE ROADS DESIGNED

BY

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Abstract. Tracing the roads assumes a specialty topographical survey assistance, during all the phases of the Project progress: for the *study* phase, as well as for the *design* and project *performance* phase. Each phase of a road achievement assumes specific topographical works, having an increased degree of the topographical survey measurements performance. The tracing items are graphically obtained from the layout, using the computer. It is obvious that, for the layouts drawn out at higher scales, the works for applying the route on site are significantly simplified and that it contributes to their quality increase.

Key words: stakeout; survey; digital plan; cadastre; road.

1. Introduction

Each road represents a comprehensive arrangement destined to the traffic means circulation and an ensemble of constructions. The constructions and arrangements are performed on a land strip named the *road area* and they are necessary for facing the landscape difficulties, as well as for providing to the upper roadway a running surface, as appropriate as possible. The provision of a running surface, in order to ensure a totally safe and comfortable traffic, is obtained through a special arrangement of the road upper side. The totality of

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these arrangement works represents the *road superstructure*. The ensemble of elements sustaining the road main part represents the *road infrastructure*. Removing the ground unevenness assumes certain earthworks performance (digging, land filing), protection–strengthening works, protection and draining works (supporting walls, pitching) and artworks (bridges, tunnels, culverts). The infrastructure and the superstructure are the two main parts of a road. The achievement of a modern traffic way assumes, during each phase, specific topographical works, having, in the traffic ways designing context, an extremely increased degree of the topographical survey measurements performance. Through the tracing works, the materializing on site of the specific points defining the traffic way route, both horizontally and vertically, is achieved, these being the specific alignment points and the connection elements points.

2. Topographical Survey Preparation for a Road Design, for its Applying/Tracing on Site and Tracing Operation

Following the road final version establishing, all the points going to materialize the final route must be traced on site, on the layout at a high scale. In Fig. 1, a layout therein a portion of a road final route is located, materialized through the points V_4, V_5, V_6 and V_7, so-called the *alignments intersection peaks*, is presented.

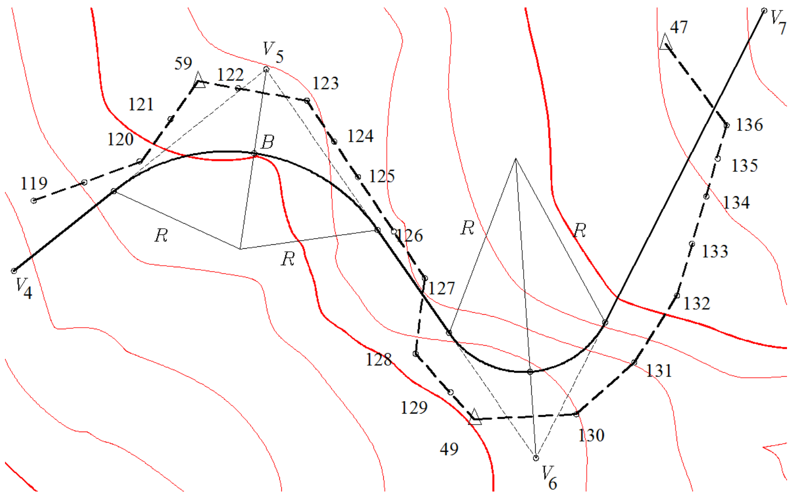


Fig. 1 – Layout.

2.1. Tracing the Alignment Peaks from the Support GPS Geodesic Network Points and its Applying on Site

The support network points for tracing is made of GPS geodetic points and planimetry traverse, existent from the land topographical survey, performed on the optimal version route.

The calculation of the topographical survey elements for tracing the points on site depends on the method utilized for the tracing process. Thus, in order to mark the peak, V_5, from acknowledged points, through polar method coordinates, the horizontal angles β_1 and β_2 and the horizontal distances d_1 and d_2 (Fig. 2), shall be calculated.

When the tracing process is performed through the angular intersection method, only the horizontal angles β_1 and β_2 will be calculated.

The tracing horizontal angles may be determined through the differences of directions orientation, calculated from the design coordinates.

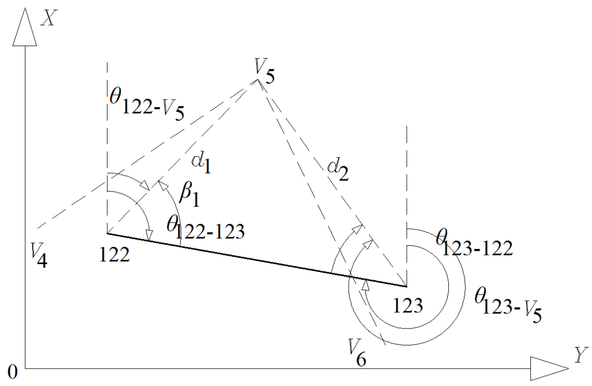


Fig. 2 – The alignment peak tracing elements on site.

The tracing horizontal elements are calculated simultaneously with the directions orientation. The relative coordinates are

$$\Delta x_{122-V_5} = X_{V_5} - V_{122}, \ \ \Delta y_{122-V_5} = Y_{V_5} - V_{122}. \qquad (1)$$

Whereas both relative coordinates are positive, that means the direction orientations are located in the first quadrant. In order to determine the calculation angle, responding to the first quadrant and whereas $|\Delta x|<|\Delta y|$, the cotangent relationship will be utilized

$$\beta_I = \text{arc ctg } (|\Delta x|/|\Delta y|) \qquad (2)$$

and the direction orientation will be

$$\theta_{122-V_5} = \beta_1. \qquad (3)$$

The horizontal distance between the two points, that is the tracing distance also, is calculated by the relationships

$$d_1 = \frac{\Delta x_{112-V_5}}{\cos\theta_{112-V_5}}\text{, and in order to control the calculation, } d_1 = \frac{\Delta y_{112-V_5}}{\sin\theta_{112-V_5}}. \quad (4)$$

The size of the horizontal tracing angles will be obtained through the difference between the directions orientations (Fig.2)

$$\beta_1 = \theta_{122-123} - \theta_{123-V_5}\,, \quad (5)$$

where the reversed orientation is calculated from the direct orientation, based on the relationship

$$\theta_{123-122} = \theta_{122-123} + 200^{g}. \quad (6)$$

a) *Tracing on site the angles or the alignments peak, through the polar coordinates method and through the forward angular intersection method*

After the office phase, consisting in the tracing process topographical preparation, therein the tracing elements have been calculated, we move to the site phase, where the topographic elements are applied, the alignment peaks being obtained. The modality for tracing on site the alignments peak, V_5, through the polar coordinates method, is performed as follows (Fig.3 *a*).

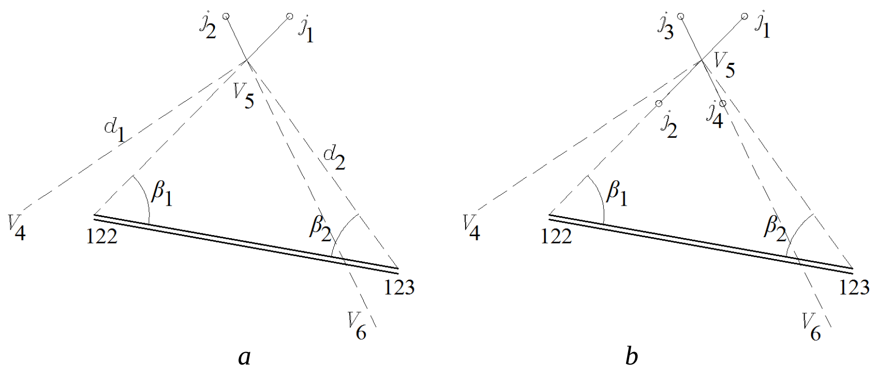


Fig. 3 – *a* – Polar coordinates method; *b* – forward angular intersection method.

The total station is installed in the point 122 acknowledged on site, it is centred, wedged up, the acknowledged signal 123 being viewed. The reading $c_2 = c_1 - \beta_1$ is recorded on the limb. On the direction thus obtained, the horizontal distance, d_1, is applied, the measurement starting from the point 122. At the edge of the distance, the peak V_5 is obtained, that is provisionally marked through a stake. The tracing process control is made by double tracing. The similar procedure is applied from the point 123, the horizontal angle β_2 and the distance d_2, being applied against the direction acknowledged, 123-122. After checking, the peak is materialized through a concrete landmark. The tracing on site of the peak V_5, through angular intersection method, is performed by the support of the tracing horizontal angles β_1 and β_2 (Fig.4 *b*). The total station is installed in point 122, the horizontal angle β_1 is drawn, signalling the direction with the prisms j_1 and j_2, subsequently, in point 123, through drawing the horizontal angle β_2, the direction is signalled, using the milestones j_3 and j_4. V_5 is provisionally materialized through a stake. After checking the tracing performed, by double-tracing, the final marking is made, through a landmark.

b) *Calculating the horizontal angle between the alignments*

The horizontal angle between the alignments, β_5, is obtained on site by the total station, after tracing the three peaks, V_4, V_5 and V_6, or by calculating, from the difference of directions orientations (Fig. 4). The orientations of the two directions are calculated from the coordinates of the three points projected. The horizontal angle between the alignments, with the peak in point V_5, will be

$$\beta_5 = \theta_{V_5-V_4} - \theta_{V_5-V_6} \,. \tag{7}$$

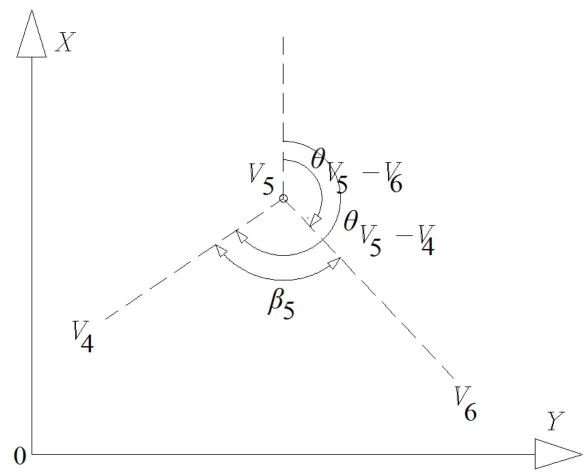


Fig. 4 – Calculating the horizontal angle between the alignments.

2.2. Calculating the Geometric Elements of the Connection Curve, T_i , B, T_e

The connection of road route alignments is performed through curves, in order to maintain the same motor vehicles speed, when passing through an alignment to another. The connection curve main points (T_i , T_e , and B) are defined by the connection curve geometric elements, namely: tangents length, T, bisectrix length, b, connection curve length, L, main deflection, f, main string length, $2c$, rectangular coordinates on tangent of the curve peak, X_B and Y_B (Fig. 5).

These are calculated depending on the angle between the alignments, β, and the radius, R, of the connection curve required through design, depending on the road specific technical conditions.

The calculation of the round connection curve is performed by the following relationships:

a) main tangent length

$$T = \overline{T_i V_5} = \overline{T_e V_5} = R\text{ctg}\frac{\beta}{2}; \tag{8}$$

b) bisetrix length

$$b = \overline{V_5 B} = R\left(\cos\frac{\beta}{2} - 1\right); \tag{9}$$

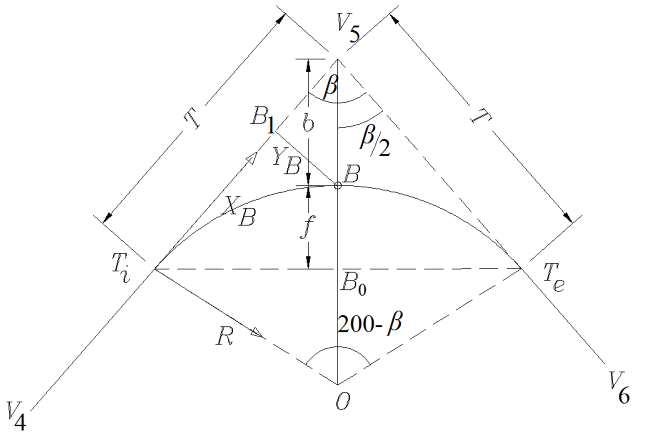


Fig. 5 – Main points and the round connection curve geometrical elements.

c) connection curve length

$$L = R\frac{\pi(200^{\text{g}} - \beta)}{200^{\text{g}}}; \tag{10}$$

d) main deflection length

$$f = \overline{BB_0} = R\left(1 - \sin\frac{\beta}{2}\right); \tag{11}$$

e) main string length

$$2c = \overline{T_i T_e} = 2R\cos\frac{\beta}{2}; \tag{12}$$

f) rectangular coordinates on tangent of the curve peak

$$X_B = \overline{T_i B_1} = R\cos\frac{\beta}{2}\,; \tag{13}$$

$$Y_B = \overline{B_1 B} = R\left(1-\sin\frac{\beta}{2}\right). \tag{14}$$

Tracing on site the round connection curve main points is performed using the geometric elements, in the following sequence:

a) Starting from peak V_5, the tangent length, T, is applied, through direct or indirect measurement, firstly on alignment $\overline{V_5 - V_4}$, getting thus the curve inlet point, T_i, and then, on alignment $\overline{V_5 - V_6}$, getting thus the curve outlet point T_e, that is materialized.

b) With the total station installed in V_5, the horizontal angle $\beta/2$ against the direction acknowledged of alignment $\overline{V_5 - V_6}$ and on the direction obtained, measuring the bisetrix length, b, the curve peak, B, is obtained, being materialized. The tracing process checking can be performed using the rectangular coordinates on tangent, X_B and Y_B.

2.3. Calculating the Connection Curve Intermediate Points through the Method of Rectangular Coordinates on Tangent

After tracing the main points T_i, B and T_e, follows the curve detailed tracing, through calculating and tracing the intermediate points along the arches T_iB and BT_e.

Depending on the accuracy required at the tracing process, the landscape conditions, on the instrumentation existent on site, the detailed tracing process may be performed through several methods.

a) *Rectangular coordinates on tangent*. Within this method, the intermediate points are defined through rectangular coordinates, in an axis system where the tangent is deemed as the abscissa and the curve radius, as the ordinate, having the origin in point T_i and, respectively, T_e. The method utilization can be performed in two ways: with equal abscissae and equal arches, both having a round value.

a$_1$) *When a round value is chosen for the abscissa*, for each intermediate point, the rectangular coordinates are expressed by the relationships (Fig. 6 *a*)

$$X_i = iX\,,\;\; Y_i = R - \sqrt{R^2 - X_i^2}\,, \tag{15}$$

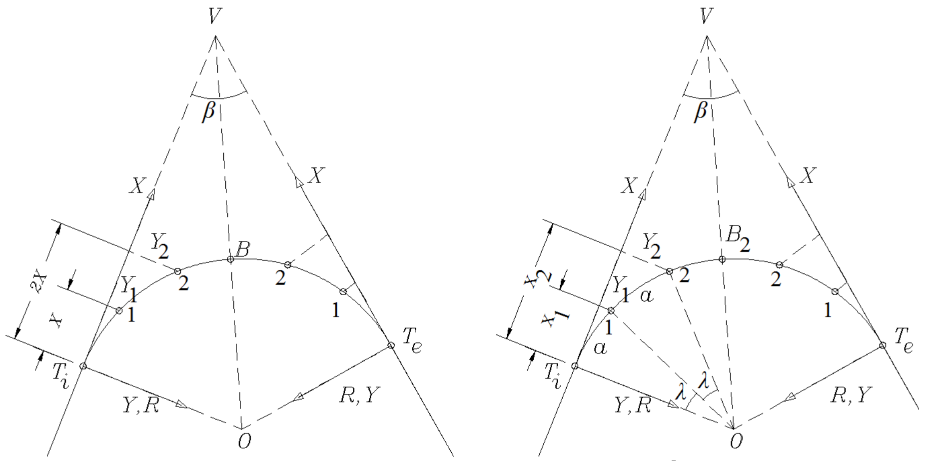
where i = 1,2,3,... The points' abscissae are obtained as abscissa multiples, as a round value and the ordinates are calculated depending on the abscissa and the connection curve radius.

a₂) *When for the circular arch, a round value is chosen*, in such a manner as the intermediate points will be located at equal distances between them, on the curve (Fig. 6 *b*). The central angle corresponding to the chosen arch is calculated with relation

$$\lambda^{g} = \rho^{g}\frac{a}{R}, \tag{16}$$

where $\rho^{g} = 63^{g},6620$ and depending on that, the intermediate points' rectangular coordinates are calculated too

$$X_i = R\sin(i\lambda),\ Y_i = R[1-\cos(i\lambda)],\ \ (i = 1,2,3,...). \tag{17}$$



a *b*

Fig. 6 – Tracing the intermediate points through the method of rectangular coordinates on tangent: *a* – round abscissae; *b* – round arches.

In both cases, the application on site of the intermediate points is performed as follows.

The abscissae values X_1, X_2, X_3,... are measured along the tangent, starting with point T_i. From these points, the perpendiculars are raised, using the total station, on the direction where the ordinates lengths Y_1, Y_2, Y_3,... are measured, up to the perpendiculars peaks, getting thus the intermediate points going to be materialized by stakes. Analogically, the points from the other half of the curve are applied, against the axis system having its origin in the curve outlet point, T_e.

2.4. Route Picketing and Points Numbering

The route picketing is the operation of detailed materialization on site of the road axis. The picketing is applied to the following points: the points from the beginning and from the end of route, the alignments peaks, the connection curve main and intermediate points, the kilometres and hectometres.

The pickets numbering is performed for the purpose of their identification. Simultaneously with their numbering, the route mileage is determined, the operation so-called *pickets*' *calculation*. The distances between the route picket are measured by the total station. The mileage calculation for the pickets representing the angle peaks, is performed by the relationship (Fig. 7)

$$V_5 = V_4 + \overline{V_4V_5}\,. \tag{18}$$

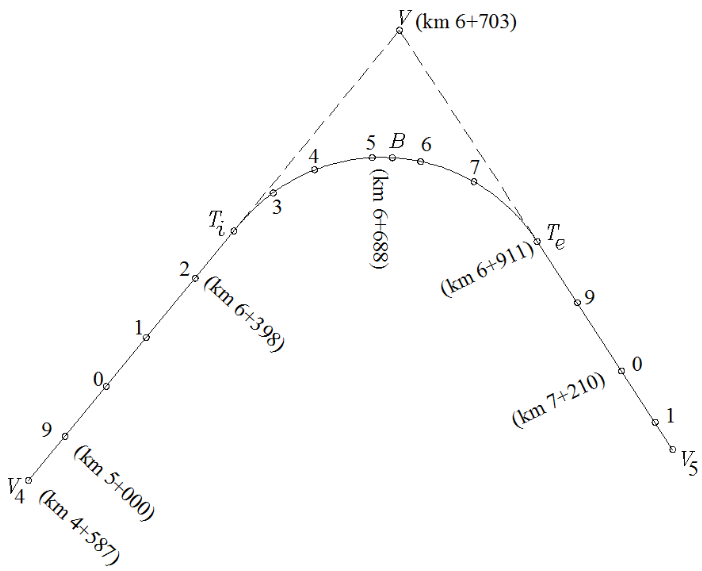


Fig. 7 – Pickets' calculation.

The main points' pickets' mileage is calculated using the lengths of the tangent and of the connection curve

$$T_i = \overline{V_4T_i} = V_4 - (\overline{V_4V_5} - T_5)\,, \tag{19}$$

$$B = T_i + \frac{L}{2}\,, \tag{20}$$

$$T_e = T_i + L\,. \tag{21}$$

The hectometres, materialized from 100 to 100 m, are numbered with figures from 1 to 9, in each kilometre. The procedure is performed by the total station.

2.5. Tracing the Longitudinal Profile on Site

The longitudinal profile is drawn up based on the horizontal distances between the points, extracted from the picketing notebook and of the points' ground levels from the site route, determined through geometrical or trigonometric level measurement readings (Fig. 8).

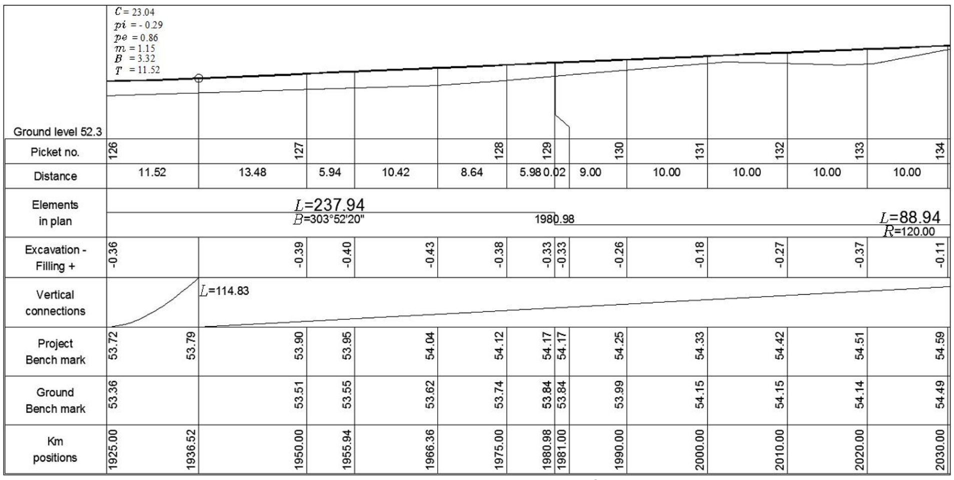


Fig. 8 – Longitudinal profile.

After the road design completion and approval, the tracing on site is performed. For the topographical survey civil works, the final longitudinal profile is necessary, with the site and design lines, transversal profiles, detailed designs for certain works.

Tracing on site the longitudinal profile is performed in three stages namely

a) *Tracing on site the declivity modification points*, from the level measurement benchmarks of the closest support network. These points' levels are applied to the geometrical or trigonometric level measurement readings, depending on the site landscape conditions.

Declivities connection is performed when crossing the peaks, the crests and the valleys. In case of peaks or crests, *convex* connection curves are introduced, and when passing through valleys, *concave* connection curves are introduced (Fig. 9). For the convex curves, the connection is performed by large radii (up to 10,000 m) and in case of concave curves, the connection is performed by small radii (up to 2,000 m). Tracing the designed ground level of the declivity changing point, 6, is performed from the closest support point of an acknowledged ground level, 124, through the *apparatus horizon method*. Whereas both the distance between the points and the level difference are relatively significant, the ground level application will be performed through two middle geometrical level measurement stations (Fig. 10).

b) *Tracing the intermediate points from the uniform slope lines, delimited by the declivity changing points*. These points can be drawn, either point by point, or by applying the performance level for each of them, or by applying the intermediate points of a continuous slope line, using the total station or the spirit level device, in relationship with the edge points of the alignment with the given slope.

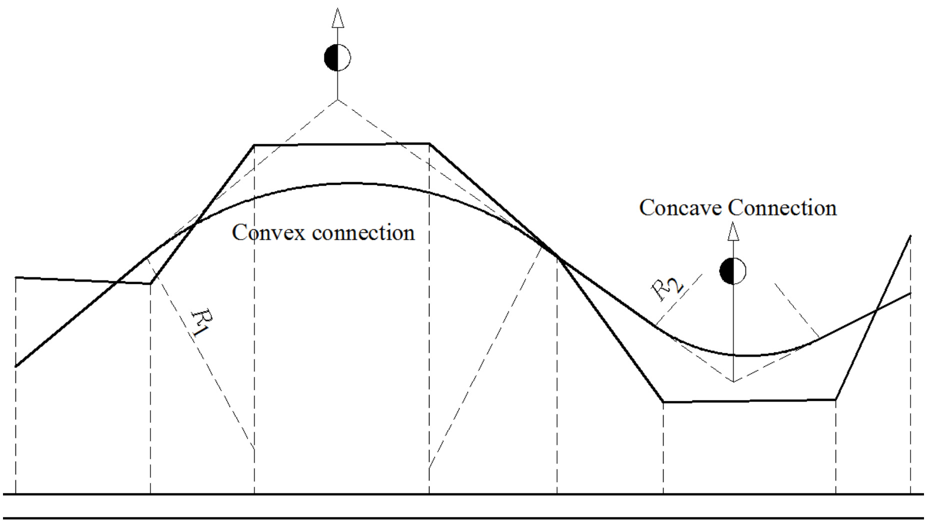


Fig. 9 – Declivities connection.

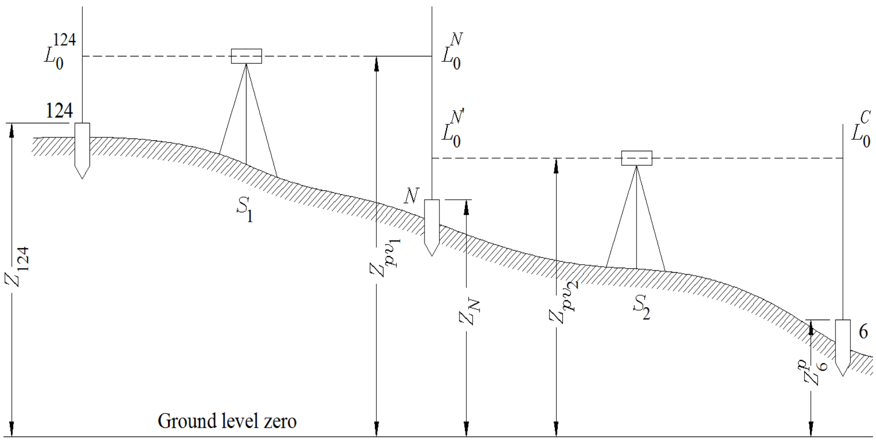


Fig. 10 – Applying the ground level designed through the apparatus horizon method.

Tracing the intermediate points of a continuous slope line, using the total station, is performed as follows. The total station is installed in the edge points of the line with a given slope, it is centred, wedged and the apparatus height *I*, is calculated. The lunette is brought on the alignment direction and through the lunette tilting, the tracing slope vertical angle is introduced (Fig.11)

$$\alpha_5 = \text{arctg}\frac{i_5\,\%}{100}\,. \tag{22}$$

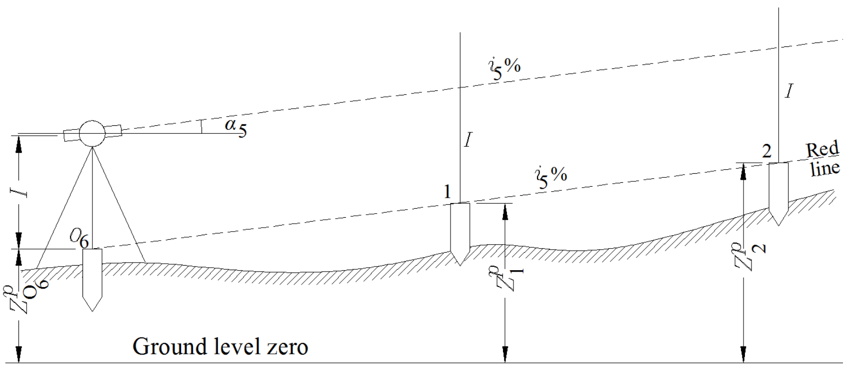


Fig. 11 – Applying the intermediate points, the line with the slope given, using the total station.

c) *Tracing the declivities connection*, is performed after applying al the declivities points, as previously shown. The choice of the execution profile tracing method is performed, in close connection, with the transversal profiles tracing method.

2.6. Tracing the Standard Transversal Profiles on Site

The procedure of tracing the standard transversal profiles on site is performed in relation to the stakes on the road axis, based on the measures required for tracing.

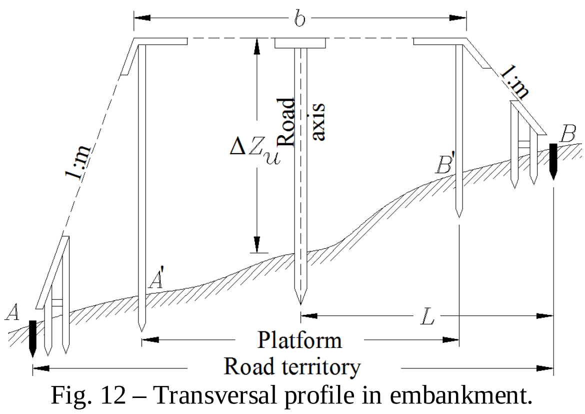


Fig. 12 – Transversal profile in embankment.

With help of the distances measured from the axis, *L*, the points *A* and *B* are determined and marked by stakes, defining the *road territory*. They represent the intersection points of the slopes of the embankments and excavations, with the surface of the natural ground. (Figs. 12 and 13). *The embankment slopes* are finished with the help of the patterns made of slats. *The road platform*, *A′B′*, the position of the ditches, drains, supporting walls, etc., is also to be finished using stakes. The road territory, *AB*, is measured in horizontal projection. Its tracing on the site is performed by measuring the horizontal distances, taken from the profile, from the road axis down to the base of the two slopes.

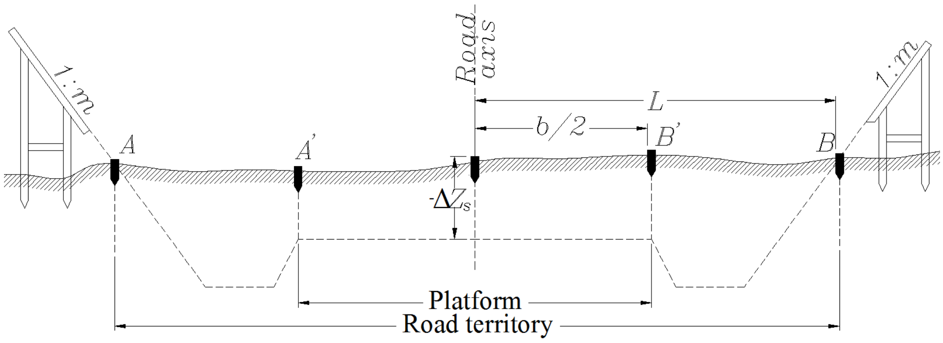


Fig. 13 – Transversal profile in excavation.

3. Tracing a Road Using Modern Methods – Automated Process.

Based on the topographical survey of the study zone we will realize the project of a road. From the project we will extract the characteristic elements of the road that be drawn on the field with the help of modern equipment, total station Leica TC 407.

Because each type of total station has its specificity in tems of design, construction and especially the software wich it is equiped, we will describe the specific menu used in this type of work.

3.1. Accessing the Stake-Out Program and Creating the Work Space

From the station’s main menu we select the programs list from which we want to use the stake-out application, which represents automatic initiation of stake-out.

At the same time it is created the job that will be called in accordance with the project that will be applied in the field (Fig. 14).

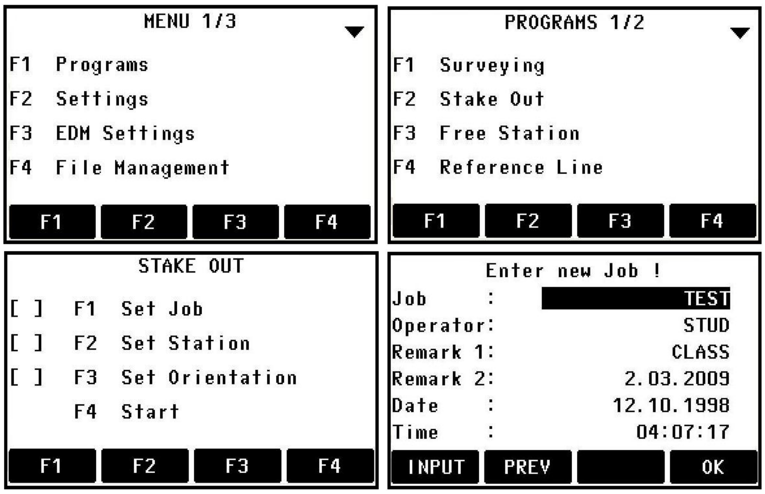


Fig. 14 – Accessing station's main menu.

3.2. Selecting/Defining Station

After defining the work field, the device requires browsing stage which consists in the establishing of the station point in which the device is to be installed, by centering. Setting the station and the introduction of absolute coordinates (*X*, *Y*, *Z*) can be achieved by

a) selecting the station point in the device memory (where point was defined and stored *prior* using the search function in the list of records);

b) manual input of the station point coordinates; using the alpha-numeric keypad and arrows, coordinates values will be inserted on predefined station axes (East, North, Height) (Fig. 15).

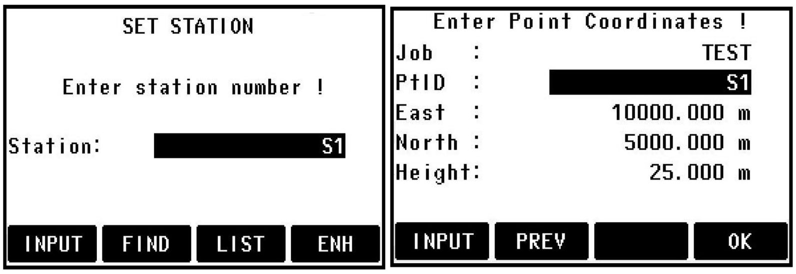


Fig. 15 – Selecting and defining station point.

At the same time, in the defining station process will be necessary introduction of instrument height after measuring it with the help of a tape measures or laser (Fig. 16).

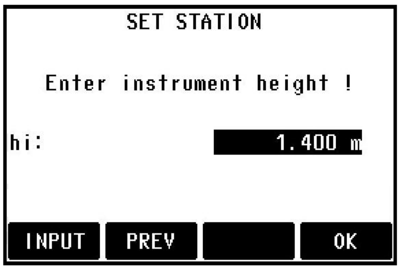


Fig. 16 – Introduction of instrument height.

3.3. Defining the Orientation of the Station

After placing and defining spatial position of the station by fixing the station point, introducing orientation is necessary, which will be achieved by

a) Manual entry of the value of orientation angle, after targeting known point without enter and its coordinates (Fig. 17).

Fig. 17 – Manual entry of orientation angle.

b) Determining the value of orientation angle in the automatic mode after targeting known point and enter coordinates manually or by selecting them from the station memory (Fig.18).

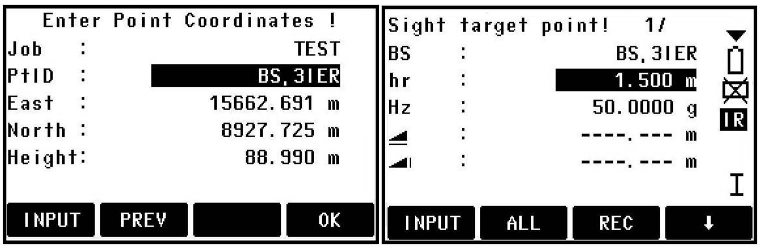


Fig. 18 – Automatic entry of orientation angle.

3.4. Stake-Out the Specific Points of the Project

In order to establish the position in the field of the new point that we have to stake-out, will be inserted into the station the absolute coordinates of the point. The station automatic program will calculate on the basis of the elements set out above (point station, station orientation), the orientation and distance between station point and the point to be stake-out.

On the orientation direction automatically calculated distance measurements are perfomed, until the position of the stake-out point is obtained. For a verification we will recalcuate the staked-out point and obtained data will be stored in the station memory (Fig. 19).

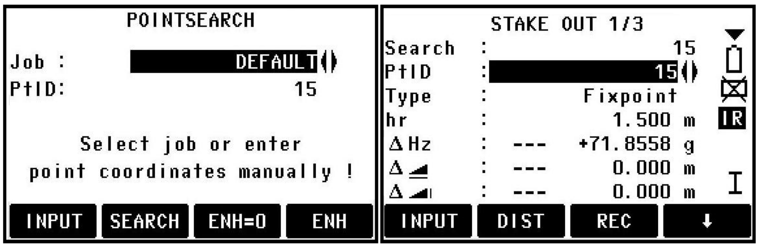


Fig. 19 – Stake-out the project point.

4. Conclusions

Creating a modern way of communication, under each of its stages, assumes performing specific topographical works, where, in the context of designing certain modern communication ways, the precision of the topographical measurements is extremely high. The topographic works accompanying the preliminary stage are the followings:

1. The design and the achievement of the support network for lifting–tracing conceived as surveying network and marking the chosen options on site.

2. The topographic works coming along the execution stage, namely

a) The horizontal tracing of the route of the communication way, which includes the processes of: picketing of the route and connecting of the alignments.

b) The vertical tracing of the communication way which includes the processes of: tracing the designed longitudinal profile, connecting the slopes and tracing the transversal profiles

Using the tracing works, the materialization on site of the characteristic points defining the route of the communication way, is performed, both horizontally and vertically, these being the characteristic points of the alignments, as well as of the connection elements.

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CONTRIBUŢII PRIVIND TRASAREA DRUMURILOR PROIECTATE

(Rezumat)

Trasarea drumurilor presupune o asistenţă topografică de specialitate în toate fazele realizării proiectului, atât în faza de *studii*, cât şi în cele de *proiectare* şi *execuţie*. Fiecare etapă de realizare a unui drum presupune lucrări topografice specifice, la care, în contextul trasării unui drum, precizia efectuării măsurătorilot topografice este ridicată. Elementele de trasare se obţin grafic de pe planul de situaţie, folosind calculatorul. Este evident că planurile la scări mari simplifică foarte mult lucrările de aplicare pe teren a traseului şi contribuie la creşterea calitaţii acestora.

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SOLUTION FOR ENVIRONMENTAL PLANNING OF WATERCOURSES

BY

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Abstract. This paper emphasizes the need of ecological planning of streams and presents some environmental design for river and its floodplain restoration and rehabilitation, evidences the natural functions of river and the necessity of ecological solutions for rivers adjustment to a new environment.

The proposed solutions provide a state of balance between river and floodplain by restoring laterally connectivity, recover environmental availability to provide services for flood protection, development of biodiversity, reduction of nutrients in water bodies and retention of greenhouse gas emissions. Time and space variation of watercourse flow (maximum and minimum discharges and levels) require different solutions to control quality and quantity of water.

Key words: biodiversity; floodplain; ecological balance; watercourses restauration/rehabilitation.

1. Introduction

River regularization works, in the design, used until now, have caused a series of negative phenomena to biological environment of the watercourse and

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adjacent floodplains, where the development of life was dependent by free oscillations of the river and the groundwater level.

The paper emphasizes negative aspects of sewerage watercourse and proposes solutions and concepts for the environmental planning river, which aim living with floods, conservation and development biodiversity, preventing the phenomenon of eutrophication in reservoirs (lakes, seas) by reducing the quantities of nutrients in water bodies, retaining greenhouse gases.

Watercourse quality, ecological potential may be influenced by accepted engineering solution, technology of building and materials selected for the realization of hydraulic works.

2. Aspect and Concepts of Watercourse Flow

Some measures applied on watercourses have produced a number of negative phenomena. We proposed some solutions and concepts which exploit the environmental availability to provide services.

2.1. Negative Effects of Sewerage Watercourse

Realization of hydraulic works on watercourse (regularization, recalibration, embankment, and dam) have changed the physical parameters of the riverbed (width, depth) and interrupted cross connectivity between river and floodplain or longitudinal connectivity for transversal damming works.

Phenomena to increase the flood levels (Fig. 1), regressive upstream erosion, bank erosion or breaks (Fig. 2), widening the riverbed with downstream alluvial deposition, break dams, exceeding of allowance of dams, have appeared on and along the river.

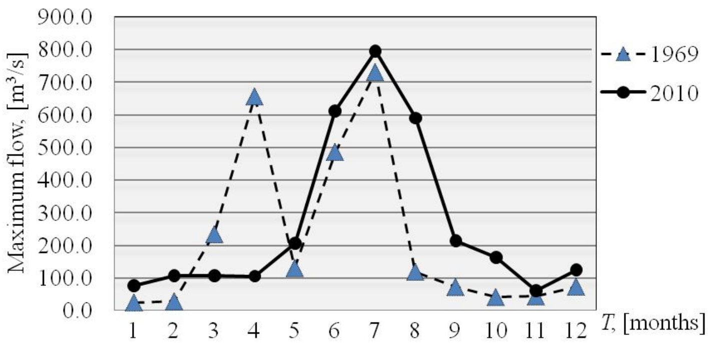


Fig. 1 – Hydrograph of maximum historical flow at Ungheni hydrometric station, Prut River: natural regime (till 1974) and controlled embanked regime (between 1978 and 2010).

In immediately upstream area by the channeled portion, local flow acceleration undertakes upstream erosion (regression erosion). Cuts of elbows reduce the length of the watercourse, increase the hydraulic gradient and velocities. High speeds produce erosion, training and depositing silt downstream. Reducing the length of the river and blocking the river lateral discharges by embankment yield an increase of water transit and intensity of downstream flooding and on the tributaries, producing the *remmu* phenomena.

Under natural flow conditions riverbeds offers breeding, feeding, rest and shelter of fish stock population, due to boulders or blocks of rock, roots, logs, aquatic plants, caverns under the banks. These areas of refuge depend on morphology conservation, dynamics and natural aquatic vegetation.

The canalization works dissolve the forms of housing and the maintenance works destroy the vegetable structure which form refuges in the river and floodplain, all of this having a negative impact on fish fauna density. Remove the laterally connectivity by embankments prevents the overflow of the river in the floodplain blurring development of fish fauna which used the flooded areas in natural flow of the river for breeding (Vlad, 2009). Increased speed and water level in the stream during floods obstruct the aquatic biocenosis to find a refuge.

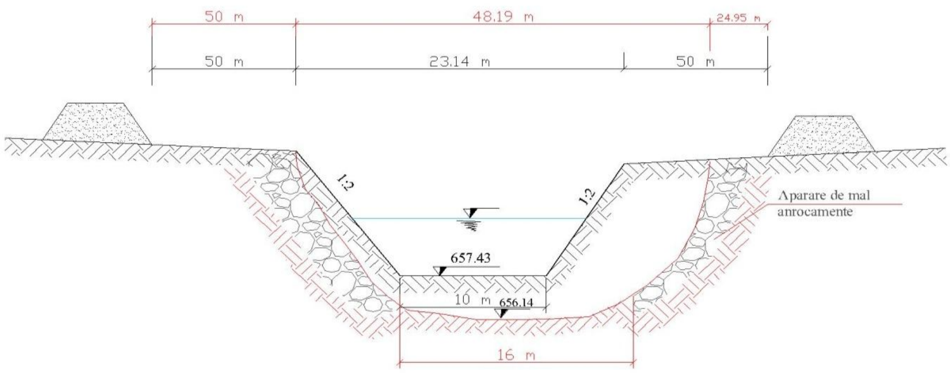


Fig. 2 – Negative effects of regularization on the bed of the River Olt in the Superior Ciuc-Citadel; compared transversal profile: adjustment 1985; profile in 2008 – emphasis banks and thalweg erosion (Ilaş, 2012).

"Hard engineering works" for banks protection with walls, concrete walls, rocks, sheet piling, gabions, etc., had blocked lateral dynamics of the river, especially the meandering rivers, and had replaced the ecotonal natural river. These works favour the erosion of the riverbed by thalweg lowering and simplify ecological importance of arranged banks, at least at locally area.

2.2. Concepts for the Restoration/Reconstruction of Watercourse

The proposed solutions in this paper exploit the environmental availability to provide services for flood protection, development of biodiversity, prevention of eutrophication phenomena in water bodies, by reducing the nutrient due to their retention and transformation in wetlands, and storage the greenhouse gas in wet habitats.

Depending on area morphology and hydraulic works, environmental planning solutions of restoration or reconstruction the watercourse can be adopted.

Ecological restoration (I.H.W.M., 2011) is a process that helps to restore an ecosystem that has been degraded, affected or destroyed and involves return/ recovery from a disturbed or totally altered condition to a previous situation, natural or anthropogenic ... or “the art of restoring (a river) to a former or original condition” (Downs & Gregory, 2004).

Referring strictly to restoration of the channeled watercourse, ecological restoration includes engineering activities, which generate biological and chemical processes that ensure water quality, biodiversity development, restoration of flow regime, natural sediment process and geometry stream, stabilization of banks and exploitation of adjacent riparian areas. Ecological restoration projects aimed the rendering the natural functions of the river, restoring floodplain connectivity and wetland restoration.

Some of the arrangements work like remeandering the river, disconnecting the drainage, draining network and the pumping stations from the agricultural lands, making ecological the riparian areas by turning the agricultural land to grazing and wetland, allow the water to flow naturally through the riparian corridor, in particular like groundwater or combination of surface water (in case of flood) and groundwater. Dams and portions of embankment can be relocated ensuring natural flooding of the riparian area and the floodplain, too. By topography adapting, function of the morphology of land, can be provided permanent flooding of wetlands.

It is aimed the original route restoration of the river, allowed stream mobility, the natural flow and flood in the floodplain, providing an area for freedom of the watercourse. Space mobility will allow the river to erode the banks and to find naturally the dynamic equilibrium.

The riparian wetland develops specific biodiversity, facilitates the settling of nutrients and transforms toxic products from water in less harmful compounds: the denitrification converts nitrites in atmospheric nitrogen, N, and phosphorus, P, is retained by sedimentary processes and becomes accessible to plants.

These solutions may be efficiently applied on agricultural land, intense fertilizate, placed in outside localities and are used successfully to prevent eutrophication in downstream reservoirs (lakes, seas) (Figs. 3,…,6).

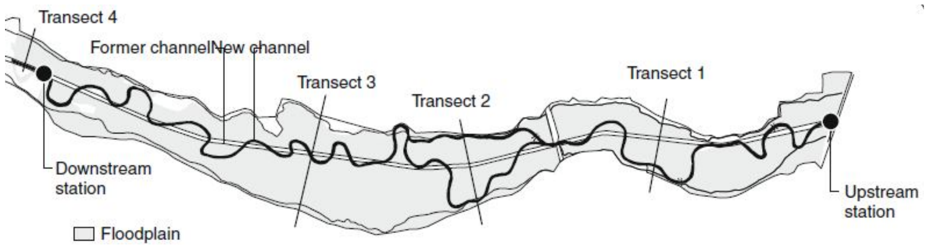


Fig. 3 – Restoration of Breda River in Denmark (remeandering, draining and pumping stations disconnecting, restoring riparian wetlands by natural flooding, location of monitoring sections (Transect 1 to 40) to estimate the quantities of nutrients retained in riparian wetland (Hoffmann & Kronwang, 2011).

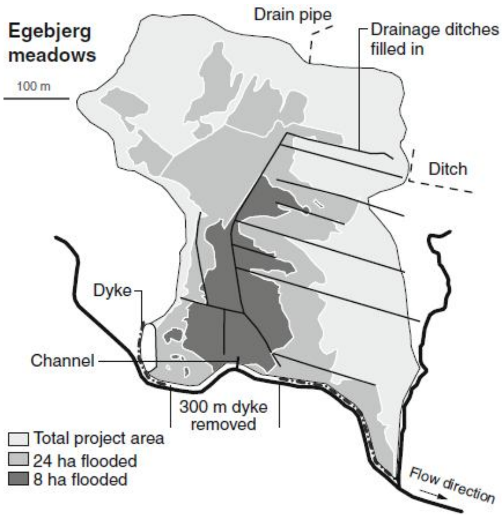


Fig. 4 – Meadow of Egebjeg River in Denmark (dams removed, draining network and pumping stations disconnecting); river will flood the wetland until 24 ha in case of high water and until 8 ha in case of permanent high water (Hoffmann & Kronvang, 2011).

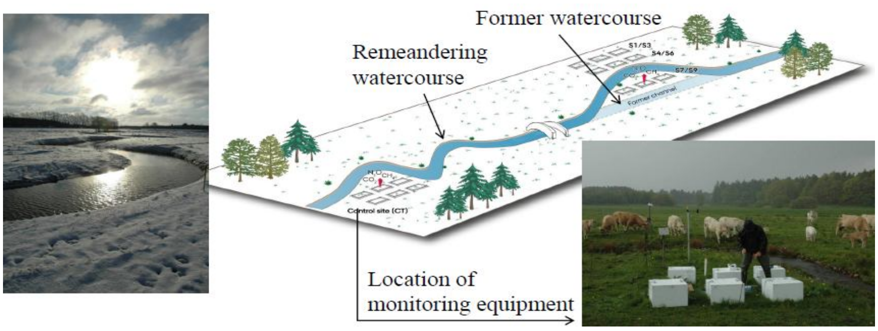
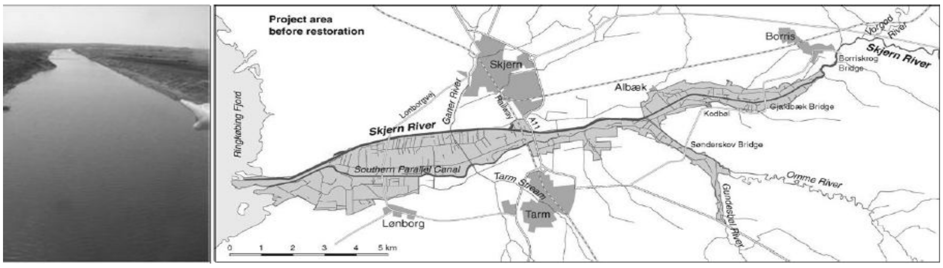


Fig. 5 – Rehabilitation of riparian wetlands of the Odderbae River in Denmark: remeandering form of watercourse and location of the monitoring network for determination of greenhouse gas absorbtion by restored wetlands (Audet, 2012).



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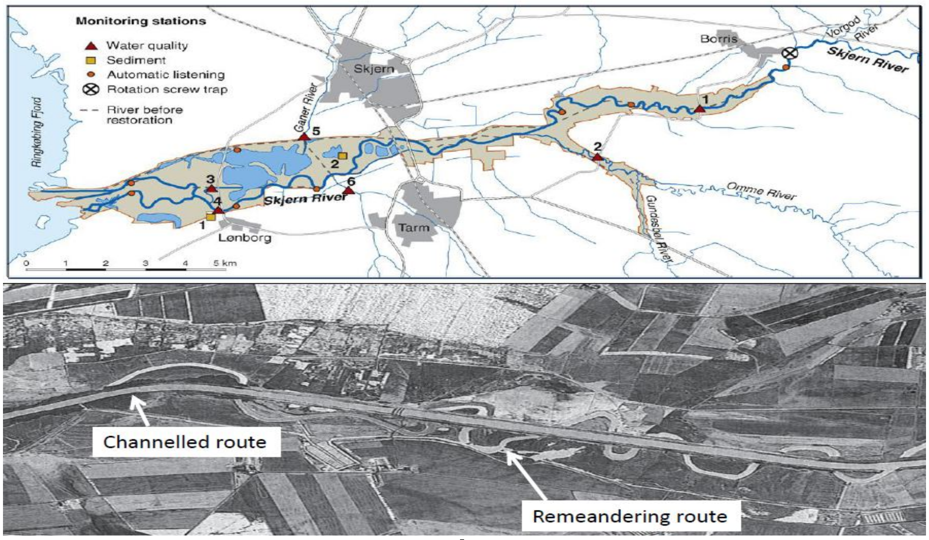

b

Fig. 6 – Skjern River – the largest restoration project in Denmark. Purpose: to reduce the level of nutrients in the North Sea, to restore environmental values of the floodplain by recreation of wetland habitats for migratory birds and promoting fishing in Ringkobing fjord, recreation of the tourist values: ***a*** – channelled regime; ***b*** – restoration regime: remeandering, interconnectivity between river and floodplain (Pederson, 2007).

Ecological reconstruction is a "process of rebuilding of a new type of ecosystem after other ecological destruction and/or regression" (I.H.W.M., 2011). The new ecosystem is semi-anthropic in case of ecological reconstruction, but it retains the many natural elements. This concept is similar with Down and Gregory's concept of rehabilitation: "To help (the river) to adapt to new environment" (Down & Gregory, 2004).

In case of damming and regulation works on long sections of river, with a previous of floods, bank erosion, thalweg deepening, etc., allocation of space for flood propagation is essential and can be achieved by: developing the polders, canals, wetlands that take, store and then evacuate flood flows. If planning solution is with polders, the division of them will allow to some departments to function as wetlands, in certain situations. In this way there are reactivated the ecological functions of wetlands by creating specific biotopes. Self-purification processes by silt depositing in the flooded area and groundwater refreshing are provided.

Water storage in river basins and along of watercourse, in long periods of time, is a highly efficient use of water resources in this climate change situation: the trend of temperature increase and the development of the “aridity” periodically phenomena in embankment enclosure. This solution supplies aquifers and allows the release of water resources in dry periods (the drain effect of the river).

The space between dams should be provided taking into account issues of safety, economic, social and environmental: in some cases reallocation of dams by increasing the distance between them would be an effective solution for the distribution of floods. Particular emphasis should be given to banks renaturation by leveling and development of vegetation to prevent erosion of the banks and training of sediments.

To activate the ecological functions of the dead arms or abandoned meanders can be used hydraulic flow control structures such sluices, spillways.

Restore ecological functions of riparian area is provided by riparian vegetation which gives favourable conditions for fauna (shelter, feeding and reproduction). It is known like “corridor” which provides a link between fragmented ecosystems. Banks vegetation contribute to maintaining low water temperatures, prevents eutrophication, help to maintain the oxygen in water by providing shade over the water. Riparian plants provide a constant supply of organic matter (vegetal and animal), necessary for the functioning of trophic network.

Tree roots, trunks of fallen trees and debris plant in the water provides place of shelter or food source for many species of fish and invertebrates. Riparian plants participate to eliminate/reduce diffuse pollution by decreasing the load water with nitrates, phosphates and pesticide concentration.

2.3. Materials and Structures Used

If the works are necessary to protect banks, the classical protection works with rigid structures, called “hard engineering works” (*e.g.* cement concrete work, walls – thresholds, liners bank protection, etc.) will be replaced with environmentally friendly techniques called “soft engineering works”, represented by elastic structures that can keep up with the bed forms (*e.g.* fascines, mattresses of different types, protection from broken stone, etc.), providing dynamic morphology of the river.

Rigid structures change their position in space by slope, roll, twist, creating spaces between elements or between them and the support, or they may break them self by action efforts, under the action of efforts developed especially during floods that are unable to take them.

For redevelopment/planning watercourses it is necessary to use natural materials (Fig. 8) that are favourable to maintaining ecosystems: earth materials (clay, sand, etc.), wood materials, (vegetables, ballast, stone, rocks, blocks, etc.). Some earth materials, ballast, wood materials, etc., favours the development of vegetation with native flora of natural ecosystems or compatible with it.

Fig. 8 – The use of river stone to stabilize the new stream thalweg of the remeandred Odderbae River in Denmark; development of fauna and flora (authors photo).

It will be avoided the using of artificial materials (concrete, metals, plastics, etc.) which do not fall in natural cycles of ecosystems; they produce pollution through physical and chemical transformations sometimes and are often avoided by fauna in habitats choosing. Such materials as concrete, metals, plastics, rock fill needs can develop only vegetation which is represented by certain moss, lichens and some species of algae. There are also adequate types of materials designed to develop a certain type of vegetation. It is the case of wire mesh or plastic with bitumen suspensions containing plant seeds of plant. These materials are integrated into all spatial hydraulic structures by using some methods such as: prefabricated concrete with special holes for vegetation, using special structures like plastic, textiles, metal, etc., which permit fixing and development of vegetation.

3. Conclusions

Identifying and implementing of green solutions for environment represent a priority. Reactivating the natural functions of watercourses we can capitalize environment availability to provide environmental services: supply services (raw materials, fish, reeds), regularization services (flood protection, recharge of groundwater, climate regulation, CO_2 sequestration and storage, filter for nutrients), cultural services (aesthetic value, tourism, recreation), support services that create conditions for providing all other services offered by ecosystems (photosynthesis, soil formation).

Preliminary study for ecological management of the river requires separate analysis, aiming a state of balance between social needs (protection against floods, development of economic infrastructure, etc.) and environmental factors in order to protect ecological functions and reactivation.

The paper proposed some restoration measures to restore the rivers flow and the original conditions of degraded ecosystems by anthropogenic changes and recommanded ecological reconstruction measures to activate the new ecosystems and sustainable features, minimizing the negative impact of anthropogenic changes.

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SOLUȚII DE AMENAJARE ECOLOGICĂ A CURSURILOR DE APĂ

(Rezumat)

Se evidențiază necesitatea amenajării ecologice a cursurilor de apă, se prezintă elemente de concepție ecologică pentru restaurarea şi reabilitarea râului şi luncii sale şi se evidențiază rolul funcțiilor naturale ale râului şi necesitatea aplicării de soluții ecologice pentru adaptarea cursului de apă la un nou mediu înconjurător.

Soluțiile propuse asigură o stare de echilibru între curs şi lunca majoră inundabilă prin refacerea conectivității laterale, valorifică disponibilitatea mediului de a

oferi servicii pentru protecție împotriva inundațiilor, de dezvoltare a biodiversității, de diminuare a nutrienților în corpurile de apă şi de reținere a gazelor cu efect de seră. Variația în timp şi spațiu a curgerii cursului de apă (debite şi niveluri maxime şi minime) necesită altfel de soluții pentru asigurarea calitativă şi cantitativă a corpurilor de apă.

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CONCEPTS OF SOIL WATER MOVEMENT

BY

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Abstract. The concepts of soil water movement (using Darcy's law) with an emphasis on saturated hydraulic conductivity (*Ks*) are reviewed.

The soil pores size is very important in terms of infiltration rate (movement of water into the soil) and the rate of percolation (movement of water through the soil). Pore size and pore number are closely related to soil structure and texture, and also influence the soil permeability. The permeability coefficient of unsaturated soils is a particularly important parameter in unsaturated soil mechanics, and its value is mainly determined by the pore size distribution and the water content.

Just as soil types vary in texture and structure, they also vary in their ability to conduct and retain water. The soil water moves by gravity flows through open pores between soil particles. The pore sizes vary function of soil texture and structure: water moves through the large pores (such as sandy soils) much faster than throught smaller pores (such as silty soils), or through the much smaller, flat-shaped pores found in clay soils. Others factors that affects soil pore size or pore shape, other than texture or structure, are organic matter and soil density. These factors will influence the capillary water retention and movement.

Key words: soil water movement; infiltration; permeability; Darcy's law.

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1. Introduction

Soil water movement is fairly simple and easy to understand in some ways but quite complex and difficult to understand in others. The water is always moving in the soil: *down* after rain or irrigation and *up* to evaporate from the soil surface. Two forces affect water movement through soils, *gravity* and *capillary action*. Gravity pulls water down. Capillary forces can move water in any direction. The force of gravity is most evident in saturated soils. Once the water enters in the soil, principles of water movement hold true whatever the source of water is. Just as soil types vary in texture and structure, they also vary in their ability to conduct and retain water. The soil water moves by gravity flows through open pores between soil particles. Any factor that affects soil pore size and shape will influence capillary water retention and movement. The pore sizes vary function of soil texture and structure: water moves through the large pores (such as sandy soils) much faster than throught smaller pores (such as silty soils) or through the much smaller, flat-shaped pores found in clay soils (Fig. 1). Others factors that affects soil pore size or pore shape, other than texture or structure, are organic matter and soil density. These factors will influence the capillary water retention and movement.

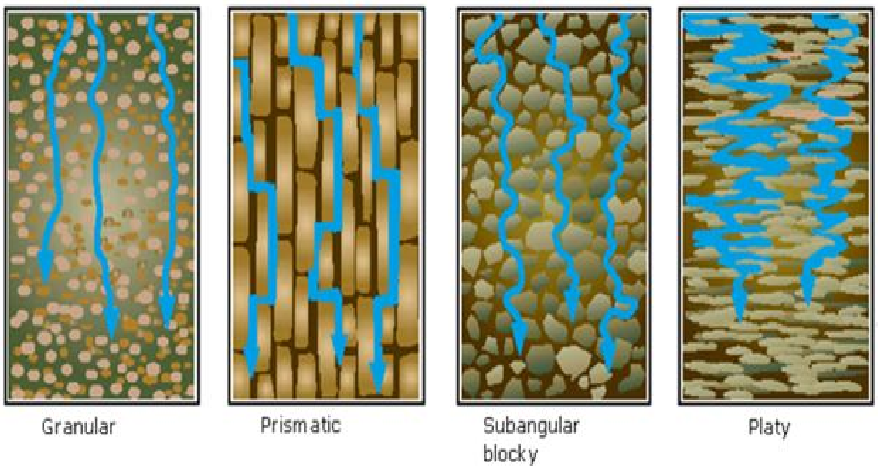

Fig. 1 – Water movement through different soil structure shapes (developed by USDA-NRCS).

Soil water movement is directly related to its pore size. In small pores of clay soils, water moves slowly in all directions by capillary action. Lack of space between large pores can lead to drainage problems and low levels of oxygen in the soil On sandy soils with large pores, water readily drains downwards by gravitational pull. Excessive irrigation and / or rainfall can leach soluble nutrients such as nitrogen from the root zone to the groundwater (Fig. 2).

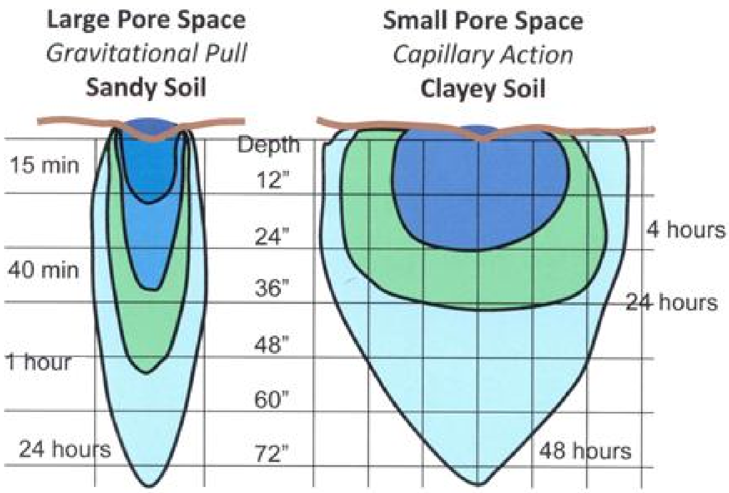

Fig. 2 – Comparative movement of water in sandy and clayey soils: in sandy soils, water readily moves downward due to the force of gravity; in clayey soils, water slowly moves out in all direction by capillary action (source: http://www.cmg.colostate.edu/gardennotes/213.html).

2. Infiltration and Permeability

2.1. Infiltration

Infiltration refers to the movement of water into the soil layer (the movement of water from the soil surface into the soil profile). Soil texture and soil structure have the largest impact on infiltration rate. Water moves by gravity into the open pore spaces in the soil, and the size of the soil particles and their spacing determines how much water can flow in. Wide pore spacing at the soil surface increases the rate of water infiltration, so coarse soils have a higher infiltration rate than fine soils. The rate of infiltration normally declines rapidly during the early part of a rainstorm event and reaches a constant value after several hours of rainfall. A number of factors are responsible for this phenomen: the filling of small pores on the soil surface with water reduces the ability of capillary forces to actively move water into the soil; as the soil moistens, the micelle structure of the clay particles absorbs water causing them to expand, this expansion reducing the size of soil pores; raindrop impact breaks large soil clumps into smaller particles. These particles then clog soil surface pores reducing the movement of water into the soil.

The infiltration rate (how quickly water enters the soil) is a function of many factors but is governed by the pore space in the soil – if the soil has an open structure at the surface water can flow into the soil easily; if the soil is capped or has small pores, the infiltration rate is reduced.

Low infiltration rate is caused by: a) small pore sizes (clay soils); b) compaction (wheeled traffic); c) capping (silts or sliding feet); d) some types of organic matter, including thatch; e) a combination of all of these.

2.2. Permeability

Permeability refers to the movement of air and water through the soil, which is important because it affects the supply of root-zone air, moisture, and nutrients available for plant uptake. Permeability is the measure of the soils ability to permit water to flow through its pores or voids. The coefficient of permeability is an important parameter and it is influenced by soil structure, soil particle distribution, soil porosity and soil water content. Soil permeability is affected by environmental conditions and is primarily an indicator of the capacity of soil to store water. Coefficient of permeability can be measured either directly (using Darcy’s law) or through empirical formulas. Permeability coefficient of saturated soil is determined by the number of pores (pore volume/volume solid part). Soil permeability in natural setting is extremly variable and difficult to measure, so measurements are performed in the laboratory.

Table 1

Permeability Classes

Class	Rate, [in/hr]
Very slow	< 0.06
Slow	0.06...0.02
Moderately slow	0.02...0.6
Moderate	0.6...2.0
Moderately rapid	2.0...6.0
Rapid	6.0...2.0
Very rapid	> 20

Under saturated conditions, the rate of water movement in a soil system is governed by the characteristics of the pore space; therefore, the actual geometry and flow pattern of a soil is extremely complex. An equation known as Darcy’s law, is used to express the flux density (volume of water flowing through a unit cross-sectional area per unit of time).

Henry Darcy (1803-1858) described the results of an experiment designed to study the flow of water through a porous medium.

He found that the rate of flow is proportional to $\Delta h/L$ or the hydraulic gradient, i, that is

$$Q = k\frac{h_{\mathrm{in}} - h_{\mathrm{out}}}{L}A = k\frac{\Delta h}{L}A = kiA\,. \tag{1}$$

The hydraulic gradient defined as loss of head per unit length of flow is

$$i = \frac{\Delta h}{L}, \tag{2}$$

where: Q is the value of the rate of flow, k – coefficient of permeability, h_{in}, h_{out} – pressure of water at top and, respectively, bottom of the sample, L – the length of the sample.

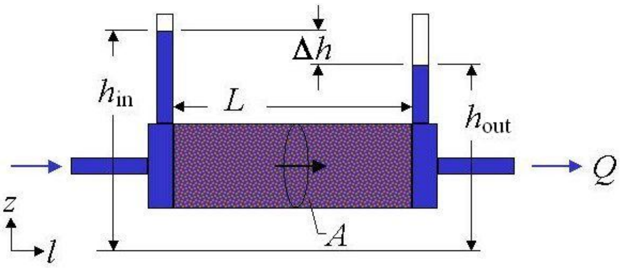

Fig. 3 – Simple column.

Infiltration in porous media theory is based on a generalization of Darcy's Law, "Velocity of Flow in Porous Media soil is proportional to the hydraulic gradient", where the flow is assumed to be laminar

$$v = ki, \tag{3}$$

where: k is coefficient of permeability, v – velocity of flow, i – the hydraulic gradient.

This law indicates that the flow of water through the soil is in the direction of, and at a rate proportional to the driving force acting on the system.

3. Factors that Influence the Soil Water Movement

Movement of water into the soil is controlled by gravity, capillary action, and soil porosity. The soil porosity is controlled by its texture, structure and organic content. Pores and fissures found in soils can be made larger through a number of factors that enhance internal soil structure. For example, the burrowing of worms and other organisms and penetration of plant roots can increase the size and number of macro- and micro-channels within the soil. The amount of decayed organic matter found at the soil surface can also enhance infiltration. Organic matter is generally more porous than mineral soil particles and can hold much larger quantities of water.

Many important processes are occurring in soil pores – the air or water-filled spaces between the particles. Texture and structure influence porosity by determining pore size, their number and interconnection of pores. Coarse-textured soils have many large (macro) pores because of the loose arrangement of larger particles with one another. Fine-textured soils are more tightly arranged and have more small (micro) pores. Macropores in fine-textured soils exist between aggregates. Because fine-textured soils have both macro- and micro-pores, they, generally, have a greater total porosity, or sum of all pores, than coarse-textured soils.

Unlike texture, porosity and structure are not constant and can be modified by management, water and chemical processes. Generally, increasing the soil organic matter, reducing the soil disturbance and minimizing the soil compaction and erosion will increase porosity and improve its structure.

4. Conclusions

Soil is a valuable resource that supports plant life, and water is an essential component of this system.

Knowledge about soil water movement is very important for many environmental studies, such as: management of salinity in irrigated agriculture (sustainability); irrigation and drainage strategies (efficient water use); uptake of water and nutrients by crops (agronomic interest); transport of nutrients and pesticides towards groundwater and surface-water systems (pollution); surface-water management of agricultural and natural areas (agronomic and ecological interest).

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CONSIDERAŢII ALE MIŞCĂRII APEI ÎN SOL

(Rezumat)

Sunt revizuite conceptele de circulaţie a apei din sol (folosind legea lui Darcy), cu un accent pe conductivitatea hidraulică saturată (*Ks*). Dimensiunea porilor solului este foarte importantă în ceea ce priveşte rata de infiltrare (circulaţia apei în sol), precum şi rata de percolare (circulaţia apei prin sol). Dimensiunea porilor şi numărul porilor sunt strâns legate de structura şi textura solului dar, de asemenea, influenţează şi permeabilitatea solului.Coeficientul de permeabilitate a solurilor nesaturate este un parametru deosebit de important în mecanica solurilor nesaturate, iar valoarea sa este determinată în principal de distribuţia dimensiunilor porilor şi conţinutul de apă. La fel

cum tipurile de sol variază în textură şi structură, acestea, la rândul lor, variază în capacitatea lor de a desfăşura şi reține apa. Apa din sol se mişcă în funcție de gravitație, prin porii mari dintre particulele de sol. Dimensiunile porilor variază în funcție de textura şi structura solului: apa se mişcă mult mai rapid prin porii mari (cum ar fi solurile nisipoase) decât prin porii mai mici (cum ar fi solurile lutoase), sau prin cei mult mai mici (în solurile argiloase). Alți factori care afectează dimensiunea porilor solului sau forma acestora sunt materia organică şi densitatea solului. Aceşti factori vor influența mişcarea şi retenția de apă capilară.

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INCIDENTS ANALYSIS PRODUCED BY FLOOD ROUTING THROUGH PRUT CATCHMENT AREA RESERVOIRS IN JUNE – JULY 2010

BY

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Abstract. Between the 17th of June and the 2nd of July 2010, important floods were registered in Prut catchment area. Using Ezer reservoir on Jijia river, Cătămărăşti and Dracşani reservoirs on Sitna river, from Botoşani county and Hălceni reservoir on Miletin river, from Iaşi county, the flash floods were routed with levels that exceeded „attention” critical threshold and with the turning in function of the overflow spillways. These flash floods that were routed through some reservoirs of *C* and *D* category of importance managed by other owners caused some damages in their hydrotechnical works. Dams ranked into categories of importance *A* and *B* belonging to the important owners, that have larger resources of strength to the external stresses and complex and functional monitoring systems, are less exposed to massive deteriorations, generally supporting without unsurmontable difficulties the routing of major floods. By contrast the *C* and *D* dams owned by local administration and businesses or small owners, having just current monitoring without other instrumentation beside some periodical geodetic measurements and without permanent and qualified monitoring staff, are more exposed to serious deteriorations and even to failures generated by large floods.

Key words: flash floods; reservoirs; critical thresholds; category of importance.

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1. General Aspects

Between the 17th of June and the 2nd of July 2010, important quantities of generally rain, fallen in several stages of 2…3 days, were registered in Prut catchment area. These rainfalls, combined with a high atmospheric pressure above the Russian Plains and the West-Central side of Europe, led to a dangerous evolution of the hydro-meteorological phenomena in the Prut hydrographic basin.

The floods were routed using the reservoirs administered by Water Basin Prut-Bârlad Administration without any special problems, but incidents and damages were registered at some reservoirs of *C* and *D* category managed by other owners.

Using Ezer reservoir on Jijia river, Cătămărăşti reservoir on Sitna river, Dracşani reservoir on Sitna river, from Botoşani County and Hâlceni reservoir on Miletin river, from Iaşi County, the flash floods that occurred in June…July 2010 were routed with levels that exceeded “attention” critical threshold and with the turning in function of the overflow spillways. These flash floods that were routed through some reservoirs of *C* and *D* category of importance managed by other owners caused some damages in their hydrotechnical works.

2. Reservoirs in Study

2.1. Ezer Reservoir

This reservoir, owned by Water Basin Prut-Bârlad Administration, is placed on Jijia river, upstream of Dorohoi city, Botoşani County. Ezer reservoir was designed to protect Dorohoi city against floods. Total storage volume is of 10.33 millions m^3 and the total surface area is of 262.1 ha. The reservoir is ranked into *B* category of importance according to NTLH-021/2002.

Brief description of the component works

a) The frontal earth dam is 750 m long, the cros section is thrapezoidal and the top width is 5.0 m. The upstream and downstream slopes are 1:4. The upstream slope protection was made with 15 cm thick concrete tiles.

b) The surface discharge is evacuated through a “Crocodile” type of spillway that has two discharge levels.

c) The bottom outlet is placed on the spillway wall.

2.2. Cătămărăşti Reservoir

Is owned by Water Basin Prut-Bârlad Administration and placed on Sitna river, 5 km upstream of Botoşani city. Cătămărăşti reservoir was designed to protect against floods the following villages: Răchiţi, Stăuceni, Băluşeni, Lunca, Suliţa, Todireni from Botoşani County. The reservoir is also used as a water supply for Botoşani city. Total storage volume is of 12.40 millions m^3 and the total surface area is 245.07 ha. The reservoir is ranked into *B* category of importance according to NTLH-021/2002.

Brief description of the component works

a) The frontal earth dam is 540 m long, the cross section is thrapezoidal and the top width is 6.0 m. The upstream and downstream slopes are 1:4/1:4.5. The upstream slope protection was made with 20 cm thick concrete tiles.

b) The surface spillway has a WES type weir with a 25 m long crest.

c) The bottom outlet has two openings of a 1,400 mm diameter.

2.3. Dracşani Reservoir

Is owned by Water Basin Prut-Bârlad Administration and placed on Sitna river, near Suliţa and Dracşani villages, Botoşani County. Dracşani reservoir was designed to protect against floods the near by villages. Total storage volume is 26.73 millions m^3 and the total surface area is 574 ha. The reservoir is ranked into *B* category of importance according to NTLH-021/2002.

Brief description of the component works

a) The frontal earth dam is 610 m long, the cross section is thrapezoidal and the top width is 6.0 m. The upstream and downstream slopes are 1:4/1:3.5. The upstream slope protection was made with concrete tiles.

b) The surface discharge is evacuated through a "Crocodile" type of spillway that has two discharge levels.

c) The bottom outlet is placed on the spillway wall.

2.4. Hălceni Reservoir

Is owned by Water Basin Prut-Bârlad Administration and placed on Miletin river, 2 km upstream of Vlădeni village, Iaşi County. Hălceni reservoir was designed to protect against floods the following villages: Vlădeni, Cârniceni, Şipote, Ţigănaşi. Total storage volume is 39.39 millions m^3 and the total surface area is 1,089 ha. The reservoir is ranked into *B* category of importance according to NTLH-021/2002.

Brief description of the component works

a) The frontal earth dam is 1,013 m long, the cross section is thrapezoidal and the top width is 5.0 m. The upstream and downstream slopes are 1:4/1:3.5. The upstream slope protection was made with concrete tiles.

b) The surface spillway has a Keuttner type weir with a 45 m long crest.

c) The bottom outlet has three openings of 1.5×1.8 m each.

2.5. Popeni Reservoir

Is owned by a company, situated on Ibăneasa river, a left side tributary of Jijia river, on the administrative territory of George Enescu village, Botoşani County, has the use of fish breeding and flood mitigation. The total storage volume of the reservoir is 0.475 millions m^3, and the total area is 25.4 ha. The reservoir is ranked in *C* category of importance.

Brief description of the component works

a) Dam: trapezoidal section, upstream slope protected with placed stone and grass cultivated slope downstream; front sealing length = 140 m, height = = 4.6 m, top width = 4 m.

b) Bottom outlet: overflow tower with circular culvert made of reinforced concrete 800 mm diameter and overflow windows 4.6 × 1 × 1 m sized.

c) Overflow spillway: frontal with a rectangular profile. The front access is 16 m long.

2.6. Polonic Reservoir

Is owned by City Hall, situated on a right side uncoded tributary of Jijia river, on the administrative territory of Dorohoi City, Botoşani County, has the use of fish breeding and flood mitigation. Its total storage is 0.027 millions m^3, and the total area is 1.33 ha. The reservoir is ranked in *C* category of importance.

Brief description of the components works

a) Dam: a trapezoidal section, grass cultivated slopes upstream and downstream; front sealing length = 200 m, height = 8 m, canopy width = 35 m.

b) Bottom outlet: overflow tower with circular pipe made of reinforced concrete 800 mm diameter and overflow windows 8.1 × 1.4 × 1 m sized.

c) Overflow spillway: frontal with a rectangular profile; the front access is 16 m long.

2.7. George Enescu (Arborea) Reservoir

Is owned by a company, situated on Tricova river, left side tributary of Ibăneasa river, on the administrative territory of Arborea locality, George Enescu village, Botoşani County, has the use of fish breeding and flood mitigation. The total storage of the reservoir is of 0.114 millions m^3, and the total area is of 9 ha. The reservoir is ranked in *C* category of importance.

Brief description of the components works

a) Dam: homogeneous type, made of local materials, with a trapezoidal section, upstream slope protected with placed stone and grass cultivated slope downstream; front sealing length = 105 m, height = 4 m, canopy width = 4 m.

b) Bottom outlet: overflow tower with circular pipe made of reinforced concrete 800 mm diameter and overflow windows 4.1 × 1 × 1 m sized;

c) Overflow spillway: frontal, with a rectangular profile. The front access is 16 m long.

2.8. Gorban Lateral Accumulation

Is owned by a company. The reservoir is formed sideway Prut river, and is placed outside Prut river impounded area, on the administrative territory of

Gorban village, Iaşi County. It has the sole use of fish reproduction and growth. The area arranged for fish breeding is of 50.0 ha, is partitioned into four chambers (nursery, growing ponds). The total storage is 0.560 millions m^3. The pond is ranked in *C* category of importance.

Brief description of the components works

a) Contour dike: front sealing length = 11.5 m, height = 2…2.7 m;

b) Water intake: near the contour dike toward the interior of the impounded area.

c) Access channel to the pumping station that aspirates the water from Prut river (three pipes)

d) Main supply channel, 150 m long, is situated on the east side of the reservoir and samples and adjusts water level. The water is routed through three spillway towers equipped with wood gates.

e) The discharge is made gravitationally through an evacuation channel directly into Prut river.

3. Incidents Produced by the Flood Routing

3.1. Ezer Reservoir – Jijia River, Botoşani County

In June 2010 heavy rainfall values were recorded at the rain gauge from the reservoir, that totalize 184.1 L/m^2 in the period 23.06.2010 – 05.07.2010.

The following exceedings of critical rainfall thresholds were highlighted at the rain gauge from the Ezer reservoir:

a) “code orange” in 28.06.2010 (32.0 L/m^2 between the hours 12^{15}-13^{15} and 36.0 L/m^2 between the hours $17^{00}…17^{50}$);

b) “code yellow” in 29.06.2010 (21.0 L/m^2 between the hours $18^{40}…19^{20}$).

At Pădureni rain gauge, placed on Buhai river, that confluences with Pârâul Întors upstream from the junction with Jijia river and downstream Ezer reservoir, the following overtakings of critical rainfall thresholds were highlighted:

a) “code orange” in 28.06.2010 (42.2 L/m^2 between the hours $12^{30}…13^{00}$);

b) “code yellow” in 03.07.2010 (22.3 L/m^2 between the hours $21^{05}…22^{05}$) and in 06.07.2010 (15.2 L/m^2 between the hours $08^{00}…09^{10}$).

In 28.06.2010 due to a rainfall registered at Pădureni rain gauge (42.2 L/m^2), a flash flood formed on Buhai river, in addition with the flood formed on Pârâul Întors. The flood inundated downtown Dorohoi city and caused the accumulation of large volumes of water downstream Ezer reservoir’s embankment. The downstream dam berm, the piezometer wells, the driftmeters, the drainage manholes and the downstream gutter were flooded.

Due to the backwater formed on Jijia river, because of the high level of Buhai river, the waters entered the reservoir from downstream to upstream, heavy increases of water levels in Ezer reservoir were highlighted starting

28.06.2010, 18^{00} hour, from 151.22 m above Black Sea, until 23^{00} hour, when the recorded level was 152.42 m above Black Sea, exceeding the first phase of defense (152.30 maBS). The upward trend of the water level in the reservoir, from downstream to upstream was kept during the next hours, exceeding successively the second phase of defense – 152.50 maBS in 28.06.2010 at 04^{00} hour when 152.84 maBS level was recorded and, respectively, the third phase of defense – 153.00 maBS in 29.06.2010-01^{00} hour, when 153.65 maBS was recorded.

Starting with 29.06.2010, 01^{00} hour, in the artificially created reservoir downstream to the embankment the water level exceeded the first weir crest of the overflow spillway (153.00 maBS) and a downstream to upstream discharge over weir crest occurred, until 01.07.2010 at 12^{00} hour. The maximum height of the overfall over the first weir crest (153.00 maBS) was 93 cm and the maximum height of the overfall over the second weir crest (153.50 maBS) was 43 cm.

The maximum water level in the reservoir of 153.93 maBS was maintained for a gap of 2 h, from 29.06.2010, 05^{00} hour. The water level of Buhai river and the water volume accumulated downstream embankment began to decrease gradually, and so on the date of 12.07.2010, 18^{00} hour the water level in Ezer reservoir fell below the first phase of defense (152.30 maBS).

The Table 1 presents the extreme values of the water level in the reservoir recorded in the period 28.06.2010…12.07.2010:

Table 1

Maximum level			Minimum level			Medium level	Previous maximum historical level	
Level maBS	Date	Hour	Level maBS	Date	Hour	Level maBS	Level maBS	Date
153.93	29.06.2010	05^{00}	151.15	28.06.2010	06^{00}	153.93	153.09	21.08.2005

The maximum flow discharged over the spillway from the downstream to the upstream of embankment was of 52.86 m^3/s, for a gap of 2 h.

From visual observations made post-event by the operational staff at the riverbed downstream reservoir, the silting of Jija river was highlighted on the rectified section downstream Ezer reservoir on a length of 1 km, with a 1 m thick alluvial deposit.

The reservoir drainage system worked drowned, due to flood and silting of the outlet channel of drain water. The drainage manholes and the downstream gutter were flooded. A number of nine piezometer wells placed on the downstream berm and the driftmeters were flooded and partially clogged.

Due to high levels of the water in the reservoir recorded from the commissioning and destructive wave action, the degradation of concrete slabs pitching near the left wall of the overflow spillway has increased.

3.2. Cătămărăşti Reservoir – Sitna River, Botoşani County

In June 2010 heavy rainfall were recorded at the rain gauge from the reservoir, summing 133.3 L/m^2 in the period 23.06.2010…05.07.2010. The following exceeding of critical rainfall threshold was highlighted at the rain gauge from the Cătămărăşti reservoir:

a) "Code yellow" in 29.06.2010 (21.3 L/m^2 between the hours 18^{10}…18^{30}).

The rainfall occurred in the catchment area controlled by the reservoir led to important increases of the water level in the reservoir, starting with the date of 25.06.2010, 06^{00} h, when the first phase of defense (119.00 maBS) was exceeded, when the recorded water level was 119.03 maBS.

The upward trend of the water level in the reservoir was kept during the next days, by succesively exceeding the second phase of defense (119.25 maBS) in 29.06.2010, 15^{00} h, and then the third phase of defense (119.50 maBS) in 30.06.2010, 9^{00} h, when the recorded water level in the reservoir was 119.53 maBS. In 30.06.2010, 24^{00} h, the water level exceeded the weir crest elevation (120.00 maBS – critical threshold level of attention). The maximum flood level of 120.15 maBS was recorded in 01.07.2010, 21^{00} h, for a gap of two hours.

In 05.07.2010, 06^{00} h, the water level in the reservoir fell below the second phase of defense when the recorded level was 119.23 maBS, and in 05.07.2010, 24^{00} h, the water level of 118.96 maBS was inferior to the first phase of defense.

The Table 2 presents the extreme values of the water level in the reservoir recorded in the period 23.06.2010…05.07.2010:

Table 2

Normal retention level maBS	Maximum level			Minimum level			Medium level	Previous maximum historical level	
	Level maBS	Date	Hour	Level maBS	Date	Hour	Level maBS	Level maBS	Date
118.90	120.15	01.07.2010	21^{00}	118.09	23.06.2010	06^{00}	119.68	119.35	08.07.1991

The maximum inflow was of 25.4 m^3/s in the date of 30.06.2010. The maximum flow discharged over the spillway was 2.91 m^3/s, for a gap of 2 h.

The Table 3 presents the extreme values of Sitna river levels recorded in the period 23.06.2010…05.07.2010 to the downstream stage gauge.

Table 3

„0" stage maBS	Maximum level			Minimum level			Minimum level	Previous maximum historical level	
	Level maBS	Month	Day	Level maBS	Month	Day	Level maBS	Level maBS	Date
104.16	105.83	07.2010	1…5	104.57	06.2010	23…24	105.41	105.66	19.08.2005

From visual observations made post-event by the operational staff at the riverbed downstream reservoir, no erosion or obstruction of Sitna river were highlighted.

Due to high levels of the water in the reservoir recorded from the commissioning and destructive wave action, the degradation of concrete slabs pitching increased.

3.3. Dracşani Reservoir – Sitna River, Botoşani County

In June 2010 heavy rainfall were recorded at the rain gauge from the reservoir, that totals 93.7 L/m^2 in the period 23.06.2010…11.07.2010. The following exceeding of critical rainfall threshold was highlighted at the rain gauge from the Dracşani reservoir:

a) "Code yellow" in 28.06.2010 (22.5 L/m^2 between the hours 11^{35}…13^{20}).

The rainfall occurred in the catchment area controlled by the reservoir led to heavy increases of the water level in the reservoir, starting with the date of 01.07.2010, 09^{00} h, when the first phase of defense (78.50 maBS) was exceeded, when the recorded water level was of 78.51 maBS.

The upward trend of the water level in the reservoir was kept during the next days, by succesively exceeding the second phase of defense (78.80 maBS) in 02.07.2010, 10^{00} h, and then reaching the maximum flow level of 78.93 maBS in 03.07.2010, 15^{00} h, and maintaining it for 27 h.

The weir crest elevation is 78.50 maBS, so the spillway worked till 12.07.2010, 06^{00} h. The maximum height of the overflow was of 43 cm.

The Table 4 presents the extreme values of the water level registered in the period 23.06.2010…11.07.2010.

Table 4

Normal retention level maBS	Maximum level			Minimum level			Medium level	Previous hystorical maximum level	
	Level maBS	Date	Hour	Level maBS	Date	Hour	Level maBS	Level maBS	Date
78.00	78.93	02.07.2010	10^{00}	78.03	28.06.2010	06^{00}	78.73	78.98	21.03.2003

The maximum inflow was of 44.1 m^3/s in 02.07.2010, 06^{00} h.

The maximum discharged over the crest of the spillway was of 9.97 m^3/s, for a period of 27 h.

The Table 5 presents the extreme values of the Sitna river levels recorded in the period 26.06.2010…12.07.2010 to the downstream stage gauge.

Due to high levels of the water in the reservoir recorded from the commissioning and destructive wave action, the joints between the tiles in the operation tower area were affected. Due to the washing of the ballast drainage layer, a few tiles were settled between the operation tower and the stage gauge stairs.

Table 5

„0" stage maBS	Maximum level			Minimum level			Minimum level	Previous maximum historical level	
	Level maBS	Month	Day	Level maBS	Month	Day	Level maBS	Level maBS	Date
104.16	107.25	07.2010	3	105.80	06.2010	26	106.64	105.66	19.08.2005

3.4. Hălceni Reservoir – Miletin River, Iaşi County

In June 2010 heavy rainfall values were recorded at the rain gauge from the reservoir, that totals 117.7 L/m^2 in the period 23.06.2010…05.07.2010. No exceeding of critical rainfall threshold were highlighted at the rain gauge from the Hălceni reservoir.

The rainfall occurred in the catchment area controlled by the reservoir led to significant increases of the water level in the reservoir, starting with the date of 28.06.2010, 16^{00} h, when the first phase of defense (54.70 maBS) was recorded.

The upward trend of the water level in the reservoir was kept during the next days, by succesively exceeding the second phase of defense (54.85 maBS), in 29.06.2010, 12^{00} h, when the recorded water level was of 54.91 maBS, respectively the exceeding the third phase of defense (55.00 maBS), in 29.06.2010, 18^{00} h, when the recorded water level was of 55.10 maBS.

In 30.06.2010, 06^{00} h the water level exceeded critical threshold level of attention (weir crest stage – 55.23 maBS). The maximum flow level of 55.42 maBS was reached in 01.07.2010, 14^{00} h, was kept for four hours. The maximum height of the overflow was of 19 cm.

In 04.07.2010, 03^{00} h, the water level decreased below the third phase of defense when the level of 54.98 maBS was recorded. Twelve hours later the water level fell below the second phase of defense when 54.68 maBS level was recorded, and then, after another 12 h, the water level fell below the first phase of defense when 54.68 maBS level was registered.

The Table 6 presents the extreme values of the water level registered in the period 23.06.2010…05.07.2010.

Table 6

Normal retention level maBS	Maximum level			Minimum level			Medium level	Previous historical maximum level	
	Level maBS	Date	Hour	Level maBS	Date	Hour	Level maBS	Level maBS	Date
54.50	55.42	01.07.2010	14^{00}	54.02	23.06.2010	06^{00}	55.11	55.78	27.03.2002

The maximum inflow was of 45.0 m^3/s in 29.06.2010.

The maximum discharged over the crest of the spillway was of 6.28 m^3/s, for a period of 4 h.

The Table 7 presents the extreme values of Miletin river levels recorded in the period 23.06.2010…05.07.2010 to the downstream stage gauge.

Table 7

„0" stage maBS	Maximum level			Minimum level			Minimum level	Previous maximum historical level	
	Level maBS	Month	Day	Level maBS	Month	Day	Level maBS	Level maBS	Date
50.32	49.47	01.07.2010	15^{00}	48.57	28.06.2010	06^{00}	49.26	49.85	19.06.1985

Due to high levels of the water in the reservoir recorded from the commissioning and destructive wave action, the shore erosion near the left bank consolidation was affected.

3.5. Popeni Reservoir

After the heavy rainfall that occurred in 28.06.2010, from Dragalina reservoir, situated upstream Popeni reservoir was discharged over the spillway a 2.0 m high flow.

In the following days, 28…29 June, 2010, a 20 m wide breach was formed in Popeni embankment, and flow evacuated was approximately 30 m^3/s. The sides of the breach were protected in order to avoid complete destruction of the dam.

Fig. 1 – Breach in the embankment.

The flash flood was partially routed through the spillway and through the central formed breach, and the lake was completely emptied.

Fig. 2 – Downstream view of the embankment and the partially stoppered breach.

3.6. Polonic Reservoir

Fig. 3 – Downstream slope of the embankment.

After the heavy rainfall that occurred in 28…29.06.2010, the water level in the reservoir exceeded the normal retention level.

In 29.06.2010 the maximum flood level was approximately 1.2 m below canopy elevation.

Measures were taken by executing an earth channel toward the right side of the embankment to avoid spillage over the top (Fig. 4).


Fig. 4 – Earth channel executed in the embankment.

3.7. George Enescu (Arborea) Reservoir


Fig. 5 – Downstream slope of the embankment.

After the heavy rainfall that occurred in 28…29.06.2010, the water level in the reservoir exceeded successively the normal retention level and the canopy elevation, then eroded the downstream slope of the embankment on a length of 4 m.


Fig. 6 – Downstream slope of the embankment–eroded area.

In the fast channel of the spillway a ravine was formed when the concrete invert was destroyed. The reservoir was emptied till the complete repair of the embankment and the spillway and till the obtaining of the regulatory documents.


Fig. 7 – Spillway fast channel – ravine.

3.8. Gorban Lateral Accumulation

Fig. 8 – Breaches in the contour dyke.

After the heavy rainfall that occurred in June…July 2010, that led to high levels of Prut river and the exceeding of the third phase of defense of Prut river embankment – Țuțora-Gorban impounded area, Prut river flooding occurred in the flood plain.

Fig. 9 – Eroded slope.

Perimeter dikes and the partition dikes from the chambers were eroded on the entire length. The contour dike breached in two places, on a length of approximately 50 m, respectively 70 m.

The equipments from the pump station were severely affected due to stagnation of the water when Prut river flooded the area.

The Operative Report released by the Local Committee for Emergency Situations revealed damages on three household annexes and on a 412.97 ha area of farmland.

4. Conclusions

1. Dams ranked into categories of importance *A* and *B* belonging to the important owners, that have larger resources of strength to the external stresses and complex and functional monitoring systems, are less exposed to massive deteriorations, generally supporting without unsurmontable difficulties the routing of major floods.

2. By contrast, the *C* and *D* dams owned by local administration and businesses or small owners, having just current monitoring without other instrumentation beside some periodical geodetic measurements and without permanent and qualified monitoring staff, are more exposed to serious deteriorations and even to failures generated by large floods.

3. The activity of assessment of *C* and *D* dams safety condition proved in time its effectiveness by imposing to the owners, structural and nonstructural measures for securing or improving safety in operation. So most of the facilities that suffered failures, either were not assessed from the safety standpoint or required repairs there were not carried out for lack of funds.

4. The main reasons for dam failures are overtopping with a large nape (from tens of cm to 2 m or even higher, resulting in scouring) and internal or external erosion. Internal erosion acts sometimes insidiously at the unappropriately treated contact between spillway walls and earth filling.

5. In most situations involving failures of small dams, the existing discharge facilities were blocked by debris or by the damaged mechanical equipment. Most of the small storage reservoirs have a high degree of sedimentation, severely reducing their mitigation capacity.

6. Most of the small dams were built between 1950…1970 by the local authorities or companies for providing limited functions and using poor design techniques and standards. Most of the affected dams didn’t have approved operation rules.

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* * * Water Basin Prut-Bârlad Administration – database.

ANALIZA INCIDENTELOR PRODUSE DE TRANZITAREA VIITURILOR PRIN ACUMULĂRILE DIN BAZINUL HIDROGRAFIC PRUT ÎN PERIOADA IUNIE – IULIE 2010

(Rezumat)

În perioada 17.06.2010...05.07.2010 s-au produs importante viituri în bazinul hidrografic Prut. Prin acumulările Ezer – r. Jijia, Cătămarăşti şi Dracşani – r. Sitna, din jud. Botoşani, Hălceni – r. Miletin, jud. Iaşi, viiturile din perioada iunie – iulie 2010 au fost tranzitate cu depăşirea nivelurilor corespunzătoare pragurilor critice de „atenție" pentru nivel cu intrarea în funcțiune a descărcătorilor de ape mari. La o serie de acumulări din bazinul hidrografic Prut administrate de persoane fizice, agenți economici sau primării, tranzitarea viiturilor produse de căderile însemnate de precipitații din lunile iunie – iulie 2010, a condus la producerea de avarii în corpul barajelor şi la descărcătoarele de ape mari. Barajele încadrate în categoriile de importanță *A* şi *B*, care au resurse de rezistență mai mari la solicitările exterioare şi sisteme de urmărire complexe, sunt mai puțin expuse degradărilor masive, suportând în general fără probleme deosebite tranzitarea viiturilor majore. Prin contrast barajele încadrate în categoriile de importanță *C* şi *D*, deținute de agentii economici, administrația locală sau mici proprietari, având doar urmărire curentă, fără alte instrumente de măsură şi control în afară de măsuratorile topogeodezice periodice şi fără personal permanent şi calificat de urmărire, sunt mai expuse degradărilor şi chiar cedărilor produse de viiturile mari.

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THE CONTRIBUTION OF GEODETIC ENGINEERING TO SPECIAL CONSTRUCTIONS MONITORING

BY

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Abstract. Strategic constructions are of great interest because of the materials and the technology used but they also require special attention in terms of monitoring their behaviour in time and in case of reengineering works. The present paper aims to determine the vertical displacements of the electrical pumps foundations from two thermo-electrical centrals situated in Timişoara municipality, Romania, namely CET Centre and South. The first part consists of an ample work, more exactly a technical examination for reengineering the electrical pumps from the specified objectives which also includes vibration measurement, mild experiments on pump foundation in order to determine the concrete class and for geotechnical studies. The technical examination aims at evaluating the foundations of electrical pumps within the studied perimeter in order to decide upon required structural interventions and consolidation measures, taking into consideration scheduled changes within the project. Up to now, terrain samples have been taken and the specific geotechnical parameters were determined as well as the concrete class. Also, vibration measurements were effected. The first topo-geodetical works have been carried out during February, at low temperatures. During the next stage, another period of measurements will be realized at the end of October, following the high temperatures from this summer, in order to establish the behaviour and characteristic elements for the new foundations.

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Key words: pump foundation; displacement; geodetic works; thermo-electrical central.

1. Introduction

In time, deformations have a great impact on engineering structures (such as dams, bridges, high buildings, etc.) due to environmental factors such as changes of ground water level, tidal phenomena, tectonic phenomena, etc., or antrophic factors. This is why monitoring the dynamic behaviour of large structures has always been a re-emergent topic to which geodetic engineering brings considerable input.

The application of the modern topo-geodetic methods to the study of the behaviour of different types of constructions represents an essential condition in highlighting the evolution in time for a part of the construction or for the whole structure seen altogether (Brebu & Bălă, 2011).

An eloquent example of special constructions is represented by the thermo-electrical centrals (Fig. 1) located in Timişoara municipality.

Fig. 1– Thermo-electrical centrals CET South (left) and CET Centre (right), Timişoara.

CET Centre Timişoara had its start up at November 12, 1984, and was then called "The electrical plant Timişoara", consisting in the first electrical plant in Europe which ensured public illumination on the streets.

Each central is located in strategic points of the city, in populous areas (Fig. 2).

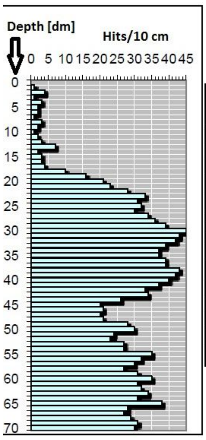
The technical examination aims at evaluating the foundations of electrical pumps within the studied perimeter in order to decide upon required structural interventions and consolidation measures, taking into consideration scheduled changes within the project: CET Centre – at electrical pumps EPT 1, EPT 2, EPT 3 engines are to be replaced, and at electrical pump EPT 4 the entire electrical pump assembly will be replaced, and CET South – at electrical pumps Step 1: EPT 1/I, EPT 2/I, and Step 2: EPT 2/II, the engines are to be replaced.

Fig. 2 – Satellite image for CET South.

2. Material and Methods

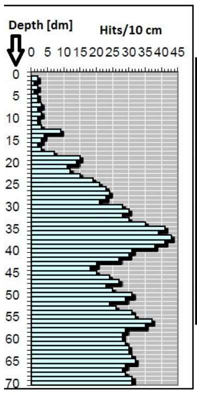
In what follows are presented the methods and materials specific for monitoring the behaviour in time of hydrotechnical constructions through a multidisciplinary approach which involves knowledge in the fields of soil mechanics, civil engineering, hydromechanics and geodesy.

In order to determine the geotechnical parameters, dynamic cone penetrations were realized (Figs. 3 and 4).



H m	N10 lov/10cm	R_d daN/cm²	R_p daN/cm²	n %	e	I_C	I_D	M2-3 daN/cm²	E daN/cm²
0.0-0.5	2.3	6.22	4.85	52.49	1.10	0.52	0.15	51.00	56.10
0.5-1.0	2.0	5.53	4.31	52.90	1.12	0.51	0.14	51.00	56.10
1.0-1.5	3.0	8.30	6.47	51,45	1.06	0.54	0.18	54.27	59.69
1.5-2.0	7.2	19.91	15.53	47.99	0.92	0.63	0.29	70.23	77.26
2.0-2.5	27.2	75.21	58.66	41.69	0.71		0.60	94.47	160.60
2.5-3.0	34.2	94.56	73.76	40.45	0.68		0.68	98.65	167.70
3.0-3.5	41.2	113.92	88.86	39.40	0.65		0.75	102.04	173.47
3.5-4.0	40.0	110.60	86.27	39.57	0.65		0.74	101.50	172.56
4.0-4.5	34.0	94.01	73.33	40.48	0,68		0.67	98.54	167.52
4.5-5.0	22.0	60.83	47.45	42.80	0.75		0.53	90.60	154.02
5.0-5.5	26.2	72.44	56.51	41.89	0.72		0.58	93.79	159.44
5.5-6.0	31.0	85.72	66.86	40.99	0.69		0.64	96.86	164.65
6.0-6.5	32.6	90.14	70.31	40.71	0.69		0.66	97.77	166.21
6.5-7.0	30.5	84.33	65.78	41.08	0.70		0.63	96.56	164.15

Fig. 3 – First dynamic cone penetration PDU 1.



H m	N10 lov/10cm	R_d daN/cm²	R_p daN/cm²	n %	e	I_C	I_D	M2-3 daN/cm²	E daN/cm²
0.0-0.5	1.5	4.15	3.24	53.88	1.17	0.50	0.12	51.00	56.10
0.5-1.0	2.4	6.64	5.18	52.26	1.09	0.52	0.16	51.00	56.10
1.0-1.5	4.0	11.06	8.63	50.36	1.01	0.56	0,21	59.51	65.46
1.5-2.0	6.0	16.59	12.94	48.75	0.95	0.60	0,26	66.91	73.60
2.0-2.5	14.2	39.26	30.63	44.95	0.82		0.42	82.62	107.40
2.5-3.0	22.4	61.94	48.31	42.70	0,75		0.53	90.93	154.58
3.0-3.5	30.2	83.50	65.13	41.13	0.70		0.63	96.38	163.84
3.5-4.0	40.4	111.71	87.13	39.51	0.65		0.74	101.68	172.86
4.0-4.5	25.2	69.68	54.35	42.09	0.73		0.57	93.08	158.23
4.5-5.0	23.8	65.81	51.33	42.39	0.74		0.55	92.04	156.46
5.0-5.5	28.2	77.97	60.82	41.50	0.71		0.61	95.13	161.72
5.5-6.0	32.2	89.03	69.45	40.78	0.69		0.65	97.55	165.83
6.0-6.5	29.6	81.84	63.84	41.24	0.70		0.62	96.01	163.22
6.5-7.0	30.0	82.95	64.70	41.17	0.70		0.63	96.26	163.64

Fig. 4 – The second dynamic cone penetration PDU 2.

Aiming to determine the quality of the concrete used for the electrical pumps' foundations, concrete tests hammer were realized as part of the combined non-destructive method of testing. Compared to other non-destructive methods, the combined method has the following advantages:

a) The accuracy of strength measurement is generally superior to simple non-destructive methods.

b) Knowledge about concrete maturity is not required.

c) Is less influenced by uncontrolled variations in mixture and concrete type or in aggregate granularity than the ultrasonic method.

For monitoring the behaviour in time of the foundations of electrical pumps from CET Centre Timişoara, different stages of topo-geodetic works have been passed through:

a) acknowledgement of the terrain, of the position and state of bench-marks installed on constructions, choosing the levelling routes, other preliminary works with a view to executing measurements;

b) execution of levelling measurements for determining benchmark settling within CET Centre Timişoara;

c) processing of on-site data, evaluation of displacement and benchmark settlings.

On site, high precision geometric levelling was effected, both ways and in closed loop, between the fundamental benchmarks RF1 and RN, in order to determine their stability. During the field works, the hot water boilers were functioning. The weather temperature during the geodetic measurements was of +12ºC in the morning and of +17ºC at noon. In the machine room, the temperature was of +20ºC.

For monitoring the behaviour in time of the foundations of electrical pumps from CET South Timişoara, different stages of topo-geodetic works have been passed through

a) acknowledgement of the terrain, of the position and state of bench-marks installed on constructions, choosing the levelling routes, other preliminary works with a view to executing measurements;

b) execution of levelling measurements for determining benchmark settling within CET South Timişoara;

c) topographic survey;

d) processing of on-site data, evaluation of displacement and benchmark settlings.

On site, high precision geometric levelling was effected, both ways and in closed loop, on the fundamental benchmark R13, in order to determine its stability.

On both locations, the materialization of the levelling points (foot plates for geometric levelling) was effected on stable ground, without running the risk to degrade over time, protected against mechanical actions.

The geometrical levelling was effected with the LEICA DNA 03 (Fig. 5) automatic electronic level and with an invar kit, instruments technically checked and functioning properly. Moreover, a local topographic survey was also carried out with a view to putting together the layout plan for the electrical pump foundations in accordance with technical norms in force.

Fig. 5 – The levelling instrument Leica DNA 03.

The measurements were effected using the LEICA TCRA 1205+ total station, having an angular precision of 5^{cc} and the distance of 2 ppm, in good temperature and environment conditions.

3. Case Study

The situation at CET Centre is the following: the electrical pumps EPT 1, EPT 2, EPT 3 are located into a single room (Fig. 6) and the electrical pump EPT 4 is installed separately, into an adjacent room.

As regards the electrical pumps EPT 1, EPT 2, EPT 3 (Fig. 7), structurally speaking, each pump is fitted separately, on a massive foundation block of reinforced concrete, supported by a raft foundation which is common for all of the three foundations .The foundation blocks are identical and have the following dimensions: 3.20 × 3.00 × 1.90 m. The sole of the pump's foundations is situated at 1.60 m under the slab level.

Fig. 6 – Location of electrical pumps EPT 1, EPT 2, and EPT 3.

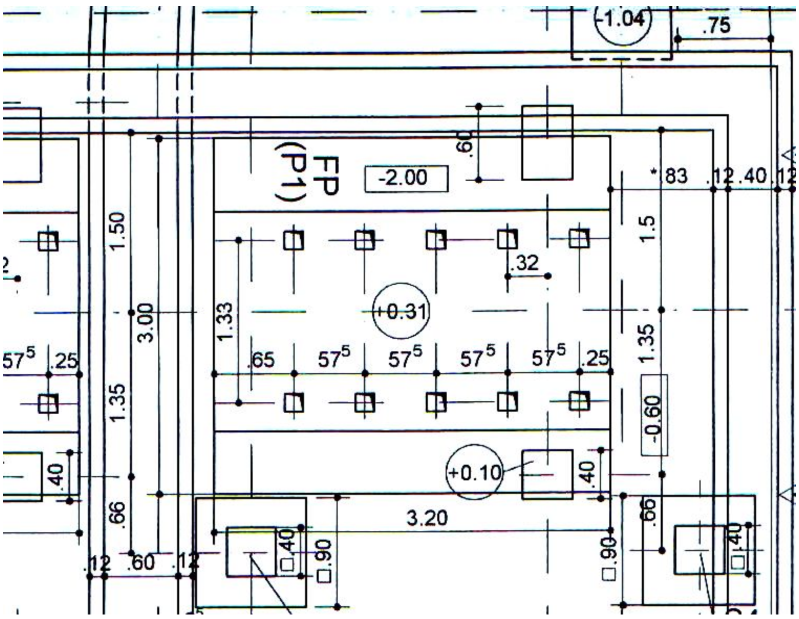


Fig. 7 – Electrical pump EPT 1 – plan view.

The electrical pump EPT 4 has a massive reinforced concrete foundation which in time has been enlarged (Fig. 8). In order to enlarge the connection surface and to reduce the vibration level a reinforced concrete encasing was provided around the foundation block, the reinforced concrete encasing is supported on the slab. On the slab it was added a 20 cm thickness layer of concrete, and this operation has been performed in the same time with the encasing of the electrical pump's foundation block.

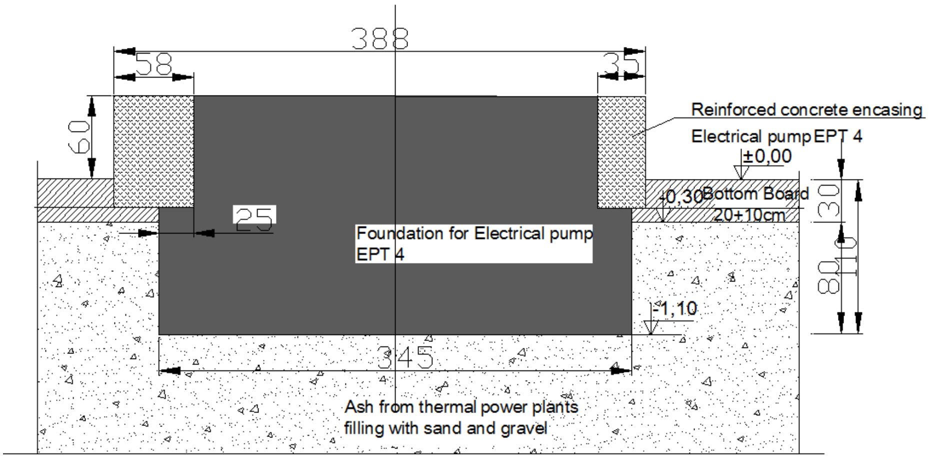


Fig. 8 – Foundation block EPT 4 – longitudinal section.

Moreover, each three groups of electrical pumps are subjected to periodically tests in order to measure the vibration at the level of the motor bearings and of the pumps according to the service specifications which are synthesized in Table 1.

Table 1
The Amplitude of the Vibration Displacement

Direction	*A*	*H*	*V*
Displacement, [mm]	0.151	0.130	0.133

The topo-geodetic measurements were effected with the view to determine the vertical movements of foundations from electrical pumps EPT 1, EPT 2, EPT 3, EPT 4 within CET Centre Timişoara, and, respectively, of foundations from electrical pumps Step I: EPT 1/I, EPT 2/I and of foundation for electrical pump Step II: EPT 2/II within CET South Timişoara.

The foundation blocks for the electrical pumps EPT 1/I, EPT 2/I (Fig. 9) are identical, massive from reinforced concrete. Each foundation block (Fig. 10) has the following dimension in the horizontal view: 210 × 280 cm and the height of 290 cm. The foundation is situated at 2.30 m (D_f) under the systematic ground level (Fig. 6). The foundation elevation rises with 60 cm over the ground level. Around the foundation it has been added a concrete border of about 20 cm thickness. The foundation block is supported by the natural ground (dusty sand).

Fig. 9 The electrical pump EPT 2/II within CET South Timişoara.

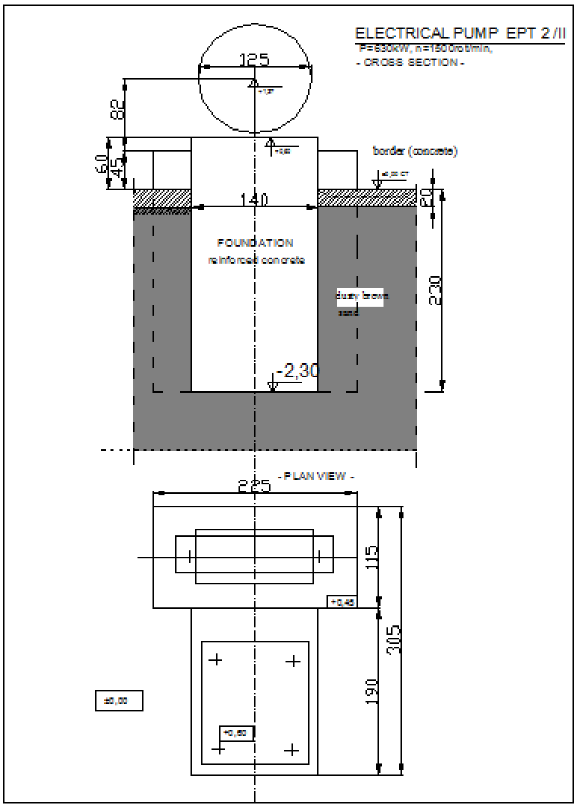


Fig. 10 – Electrical pump EPT2/I.

The concrete class determined by non destructive testing is C16/20.

The estimated amplitudes for foundation displacements are shown in Table 2.

Table 2
The Amplitude of the Vibration Displacement

Direction	*A*	*H*	*V*
Maximum speed, [mm/s]	1.46	5.06	1.72
Displacement, [mm]	0.0187	0.0324	0.0091

4. Conclusions

The electrical pumps EPT1, EPT2 and EPT3 are considered, from a technical point of view, to be meet the current norms, have properly foundations, have a proper anti-vibration insulation between the foundation block and the foundation raft and also joints on the lateral faces. While operating, they have shown an adequate behaviour. There have been no settlements, deformations or magnitudes of the vibrations which endanger the normal operating of the pump. The concrete class of the foundation is corresponding to the current operating regulations and the foundation conditions (the foundation is situated inside the building, it is protected from the rain and the freezing – thawing phenomenon, the foundation soil is not aggressive, etc.). So it can be concluded that the actual conditions in which the electrical pumps EPT 1, EPT 2 and EPT 3 operate correspond from a technical point of view and the technological upgrade will improve their functioning period.

The foundation of the electrical pump EPT4 not corresponds and must be taken down and redone, changing the size of the aggregate to a small one will not solve the problem.

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CONTRIBUŢIA GEODEZIEI LA MONITORIZAREA CONSTRUCŢIILOR SPECIALE

(Rezumat)

Construcţiile strategice prezintă un interes deosebit atât din punctul de vedere al materialelor şi tehnologiilor folosite, cât şi din prisma monitorizării comportamentului lor în timp sau în cazul lucrărilor de retehnologizare. În lucrare se determină deplasările verticale ale fundaţiilor electropompelor de la cele 2 centrale electrotermice, CET Centru şi CET Sud, situate în municipiul Timişoara, România. În prima parte sunt descrise lucrările ample întreprinse ce au făcut parte din expertiza tehnică de evaluare a stării tehnice a fundaţiilor electropompelor din incintele obiectivelor şi au inclus măsurători de vibraţii, încercări nedistructive pe fundaţiile electropompelor pentru determinarea clasei betoanelor şi studii geotehnice. Expertiza tehnică urmăreşte evaluarea fundaţiilor electropompelor existente în perimetrul studiat, pentru a decide necesitatea intervenţiilor structurale şi măsurile de consolidare care se impun având în vedere modificările prevăzute de proiect. În momentul actual, probe de pământ şi de beton au fost recoltate în vederea determinării parametrilor geotehnici şi a clasei betoanelor. De asemenea, au fost efectuate măsurători de vibraţii. Primul ciclu de măsurători topografice a fost realizat în luna februarie, la temperaturi scăzute, urmând ca, în luna octombrie, să fie realizate alte măsurători pentru a putea stabili comportarea şi elementele caracteristice ale noilor fundaţii.

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ATTENUATION OF WATER HAMMER EFFECTS AT THE TECUCEL VALLEY UNDERCROSSING IN TECUCI IRRIGATION SYSTEM

BY

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Abstract. This paper presents a solution to reduce the effects of water hammer that occurs on a pipe due to the sudden closure of the downstream butterfly valve. The designed shock absorber increases the period in which the valve closes, under the action of a floating level regulator, reducing the extreme pressures.

Key words: shock absorber; undercrossing; water hammer.

1. Introduction

The studied pipes are located in the Northern part of Terasa Tecuci – Nicoreşti Irrigation System between the accumulation basin at BPS 2 and BPS 3 discharge basin where water hammer occurs as a result of the type of system automation (Fig.1).

The pipes on which water hammer takes place join the two basins and have a butterfly valve at the downstream end. The valve, acted by a float, has the role to maintain a constant water level in BPS 3 discharge basin. Due to the

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variation of the water level in the BPS 3 waves appear that make the float oscillate and thus, the butterfly valve at the end of the pipe to close/open suddenly. The pipe's solicitation, both to overpressure (especially in the critical section that is the part undercrossing Tecucel rivulet), but also to underpressure (especially in the valve area) leads to water column separation.

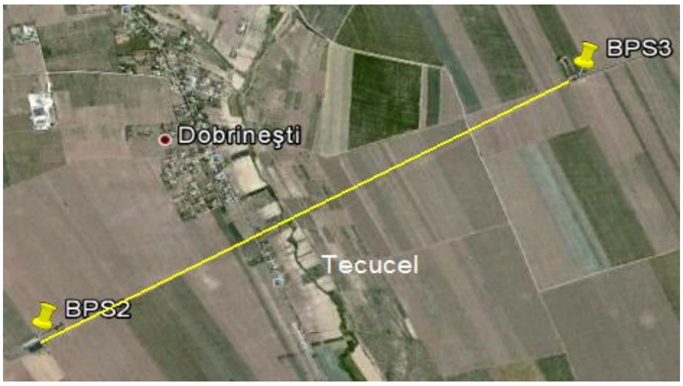


Fig. 1 – The Tecucel valley undercrossing.

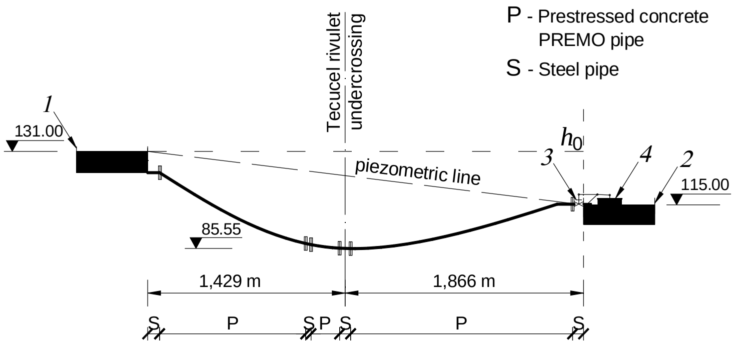


Fig. 2 – Schematic representation of the pipelines.
1 – accumulation basin at BPS 2; *2* – BPS 3 discharge basin; *3* – butterfly valve; *4* – float.

The levels considered in the calculations are the BPS 2 accumulation basin level, of 131.00 m and that of BPS 3 discharge basin at the butterfly valve, of 115.00 m (the valve being half opened). The calculus was performed on one of the two pipelines that connect gravitationally the two reservoirs in Nicoreşti – Tecuci irrigation system (Fig.2). This pipe is mainly made of prestressed concrete PREMO pipes, but also of steel pipes in some sections. The data used in computation for the pipeline are the following: overall length of steel pipes – L_{OL} = 174.0 m; overall length of prestressed concrete PREMO pipes – L_{PREMO} = = 3,121.0 m; total main length – L_{TOT} = 3,295.0 m; volumic flow rate – Q = = 1.9 m^3/s; velocity – v = 2.3 m/s; diameter – D = 1.0 m.

2. Water Hammer without Means of Protecting the Pipe

Water hammer was computed using the Schnyder-Bergeron method (Bartha, 1998; Cioc, 1975; Pistilli, 1951). For higher precision and accurate results, the graphic intersection of the water hammer characteristics, pipe and valve characteristics, were made using the AutoCAD software.

The eqs. of the characteristic pressure waves, *F* and *f*, have the form

$$H - H_I = \pm m\left(Q - Q_I\right), \tag{1}$$

where

$$m = \frac{c_{\text{med}}}{gA} \tag{2}$$

is the angular coefficient of pressure waves; c_{med} – average velocity of pressure waves; g – acceleration due to gravity; $A = \pi D^2 / 4$ – cross section.

The maximum overpressure is calculated with Jukowski's formula for sudden closure of the valve

$$\Delta P = \rho m c_{\text{med}} v_0 , \tag{3}$$

or expressed in water column

$$\Delta H = \frac{\Delta P}{\gamma} , \tag{4}$$

resulting: ΔP = 1,545,410.32 N/m^2; ΔH = 157.50 m.

The overpressure in the area undercrossing Tecucel rivulet is

$$\Delta H = \frac{1.5 H L_{\text{av}}}{L_{\text{av}} + L_{\text{am}}} \tag{5}$$

and for L_{am} = 1,429 m and L_{av} = 1,866 m, it results

$$\Delta H_s = 133.80 \text{ m}.$$

The graphical solution is presented in Fig. 3 (*a* – intersecting characteristics; *b* – pressure diagram; *c* – extreme pressure envelope along the pipe).

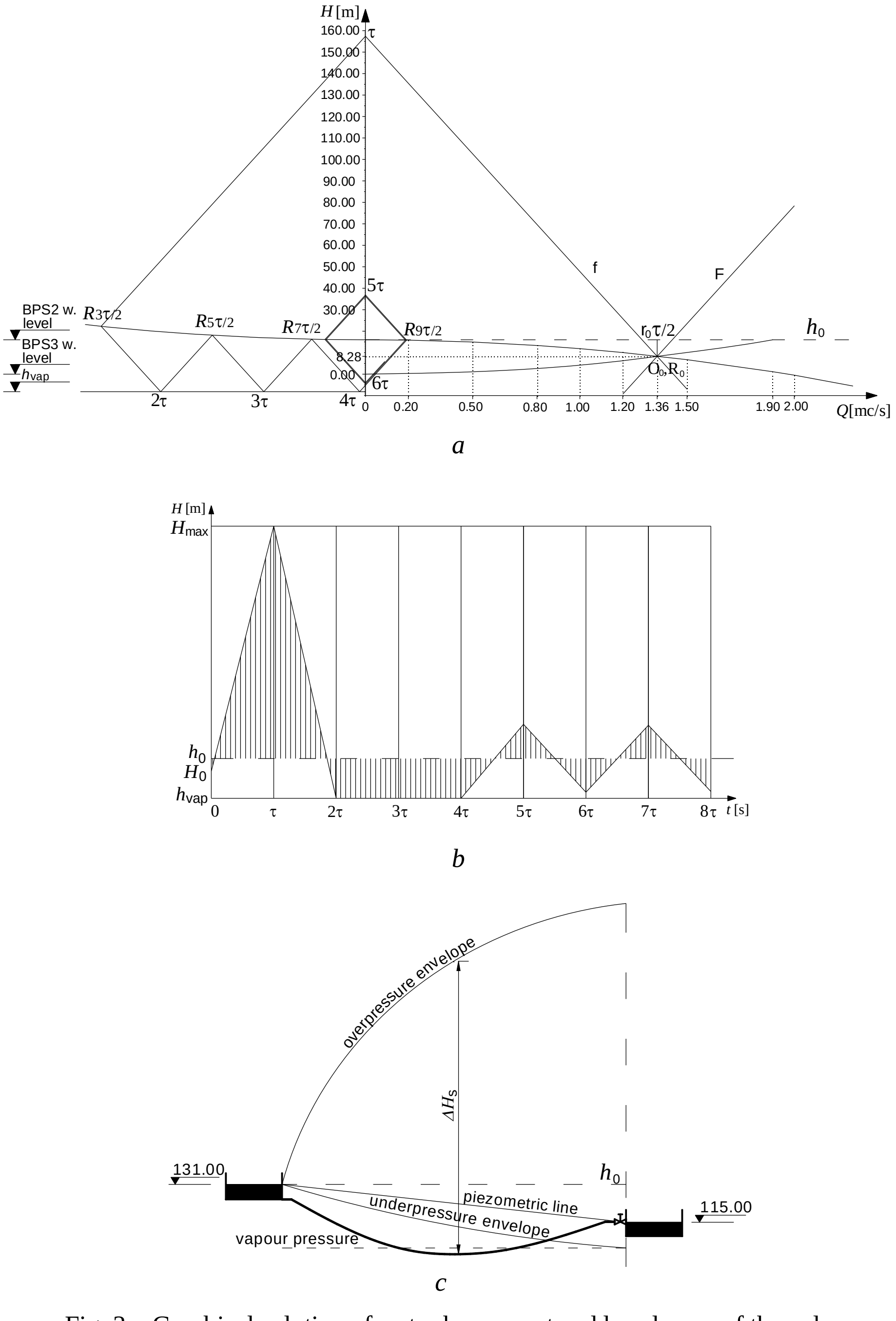


Fig. 3 – Graphical solution of water hammer at sudden closure of the valve.

In this situation, during water hammer, for a period, liquid column separation occurs (Bergant, 2004; Brunone, 1990), leading to the maximum extreme pressures (vacuum pressure for operating temperature).

During the mains' operation, some solutions were applied in order to reduce the effects of water hammer.

At first, in order to reduce overpressure, two 2″ pipes were installed (one on each pipeline) just upstream the butterfly valve, as surge chambers. Since these pipes did not reduce the overpressure created by the water hammer sufficiently, they were removed (Fig. 4).

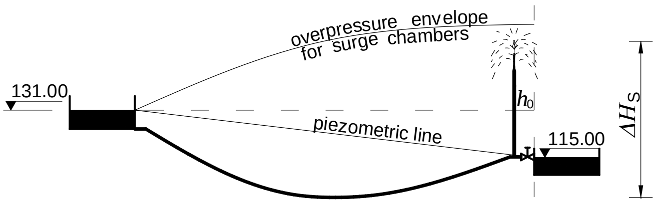


Fig. 4 – Overpressure envelope at sudden closure of the valve for the 2″ pipes used as surge chambers.

Afterwards, the butterfly valves on each pipeline were removed. This is the present-day situation in the study area, although it is not the best solution because the amount of water loss recorded is high.

3. Technical Solution to Reduce Water Hammer

In order to reduce the effects of water hammer phenomenon in the studied pipe, the controlled increase of the valve's closing time is suggested. The installation of a hydraulic shock absorber will increase the butterfly valve's closing time to 120 s. Therefore, the occurrence of excessive pressure and vapour pressure that leads to liquid column separation is prevented.

Such a hydraulic shock absorber is a technical tool that consists in a modified hydraulic cylinder (Bartha, 2002) (a cylinder inside which a piston moves under the action of external force that leads to hydraulic or pneumatic pressure). The cylinder and the piston are fixed to the float lever (that acts the butterfly valve) and on a fix point at the main.

3.1. The Shock Absorber Calculus

The shock absorber presented schematically in Fig. 5, having the cylinder diameter d = 100 mm, and an external tube with a regulating valve through which the synthetic oil flows, are considered. The piston rod moves upwards as a result of the lifting of the lever that acts on the butterfly valve when the float rises, and downwards when the float moves under the influence of the waves. The force acting on the piston due to the float movement, as a consequence of the lowering and rising of the water level in the basin, is equal to $F/2$ (F being the Archimedes force developed by the float lifting/lowering due to the level rising/dropping in BPS 3 basin as shown in Fig. 6). The shock absorber is considered positioned as in Fig. 6. In order that the lever acting on the piston and on the butterfly valve to move with $\Delta h_{max}= \pm 10$ cm in 120 s, it is necessary to calculate the tube's diameter, δ.

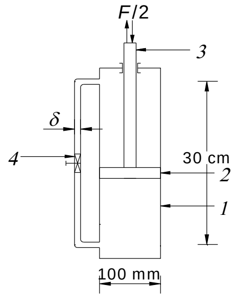


Fig. 5 – Schematic representation of a shock absorber:
1 – cylinder, *2* – piston, *3* – piston rod, *4* – valve.

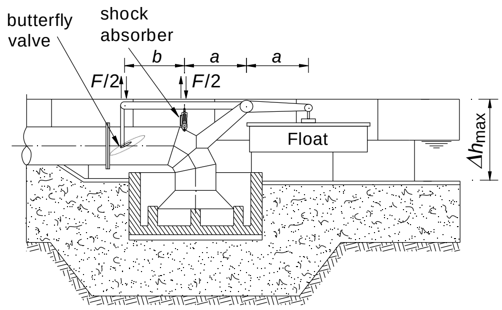


Fig. 6 – The positioning of the shock absorber.

The force developed by the float under the influence of the waves from BPS 3 basin, is calculated as follows:

$$F = \Delta h_{\max} \gamma_{\text{water}} \frac{\pi D^2}{4}, \tag{6}$$

where $D = 1$ m is the float's diameter.

The pressure developed inside the dumper is

$$p = \frac{F/2}{S} = \frac{2F}{\pi d^2}, \tag{7}$$

where $d = 0.1$ m is the diameter of the shock absorber.

The necessary oil flow rate through the short pipe by-passing the piston for achieving an imposed closing time of the butterfly valve is

$$Q_{\text{oil}} = \varphi \varepsilon A \sqrt{2gH} \ , \tag{8}$$

$$Q_{\text{oil}} = \frac{V}{t} \, , \tag{9}$$

where V is the volume of oil that must flow through the tube in $t_{\text{closing}} = 120$ s.

For the same movement of the piston like that of the arms of the lever, the volume of the oil flow results

$$V = \pi \frac{d^2}{4} \Delta h_{\text{max}} \, . \tag{10}$$

From eq. (7) it results

$$H = \frac{p}{\gamma_{\text{oil}}} = \frac{2\Delta h_{\text{max}} \gamma \pi D^2 / 4}{\gamma_{\text{oil}} \pi d^2} \, . \tag{11}$$

For a synthetic oil with $\rho_{20°} \approx 995$ kg/m^3 and $\gamma_{\text{oil}20°} = 1{,}164$ mm^2/s = 1,164 × × 10^{-6} m^2/s, the contraction coefficient is $\varepsilon = 0.55$, and the velocity coefficient

$$\varphi = \frac{1}{\sqrt{\lambda l/\delta + \zeta_i + \zeta_e + \zeta_r}} \, , \tag{12}$$

where

$$\lambda = \frac{64}{\Re e_{\text{oil}}} \tag{13}$$

with

$$\Re e_{\text{oil}} = \frac{vd}{\nu_{\text{oil}}} \tag{14}$$

and

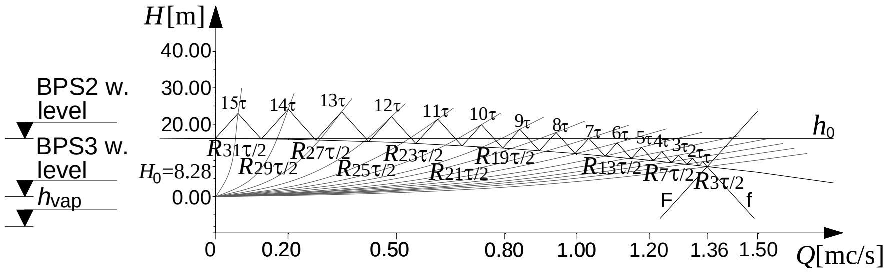
$$v = \frac{Q_{\text{oil}}}{A} \, , \tag{15}$$

δ being the diameter of the shock absorber's by-pass.

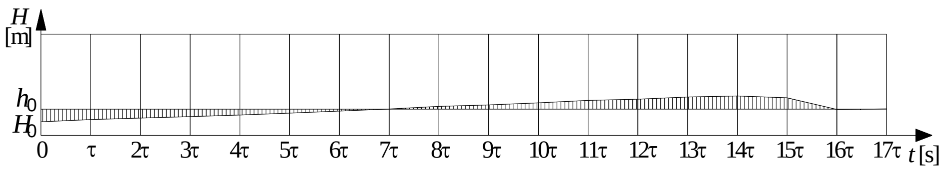
Performing the calculus it results φ = 0.790 and δ = 0.001 m. The diameter of the shock absorber's by-pass results from iterative calculus and has the final value δ = 8.9 mm. Therefore, a 10 mm diameter tube is adopted, fitted with a 1/4″ valve for precise adjustment of the valve closure time to 120 s.

3.2. Water Hammer Calculus Using a Shock Absorber

The water hammer computation for valve closing/opening in t = 120 s (Fig. 7) shows the overpressure envelope dropping to values supported by the pipes in the critical section (Fig. 8).



a



b

Fig. 7 – Graphical solution of water hammer at slow closure of the valve
a – intersecting characteristics; *b* – pressure diagram.

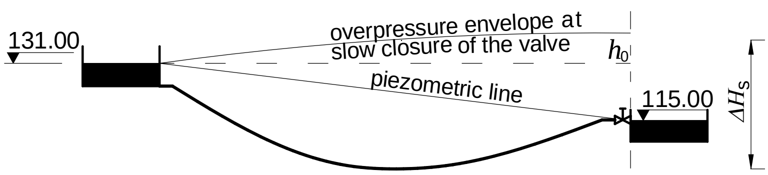


Fig. 8 – The overpressure envelope at slow closure of the valve.

A comparison between extreme pressures in the pipe for the three considered situations is presented in Fig. 9.

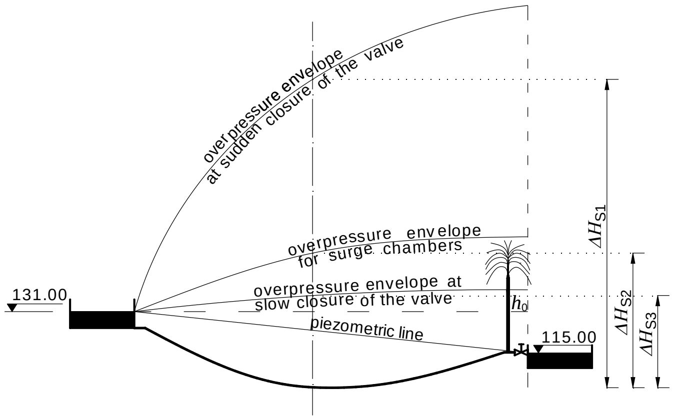


Fig. 9 – The extreme pressures' envelopes in the three considered situations.

The extreme pressures in the pipe in the valve section and in the critical section (the Tecucel rivulet undercrossing), are given in Table 1.

Table 1
The Extreme Pressures in the Valve Section and Tecucel Rivulet Undercrossing in the Three Considered Situations

Section	Whole pipe				Tecucel rivulet undercrossing			
Pressure / Situation	Δp_{max} N/m^2	Δp_{min} N/m^2	H_{max} mH_2O	H_{min} mH_2O	Δp_{max} N/m^2	Δp_{min} N/m^2	H_{max} mH_2O	H_{min} mH_2O
Sudden closure of the valve (no protection)	1.5×10^6	-8.0×10^4	157.50	–8.17	1.3×10^6	-6.8×10^4	133.80	–6.94
With surge chambers	5.2×10^5	-8.0×10^4	52.65	–8.17	4.4×10^5	-6.8×10^4	44.72	–6.94
With shock absorber	2.4×10^5	8.1×10^4	24.45	8.28	2.0×10^5	6.9×10^4	20.77	7.03

As shown in Table 1, the maximum pressure drops about three times in the case of surge chambers as compared to the first case (no protection), but the minimum pressure remains at the vapour pressure level, leading still to water column separation. In the third case, when the shock absorber is used, the maximum pressure drops about 6.5 times as compared to the first case and twice as compared to the surge chambers case; the minimum pressure in the third case does not reach the vapour pressure level, water column separation being thus prevented.

4. Conclusions

By using AutoCAD to intersect the characteristics of the pipe, valve and water hammer, accurate solutions of the phenomenon are obtained.

Small diameter pipes used as surge chambers do not reduce sufficiently the extreme pressures.

The shock absorber designed assures the closing/opening time of the butterfly valve, reducing thus the extreme pressures due to water hammer at values that are harmless for the pipe.

The shock absorber can be made either with a perforated piston or with a by-pass tube equipped with a regulating valve.

The closing time can be set at different values, by controlling the opening degree of the regulating valve on the by-pass tube.

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SUBTRAVERSAREA PÂRÂULUI TECUCEL DIN SISTEMUL DE IRIGAȚII TECUCI

(Rezumat)

Se prezintă o soluţie în scopul reducerii efectelor loviturii de berbec ce are loc într-o conductă, datorită închiderii bruște a vanei fluture din aval sub acțiunea unui flotor regulator de nivel. Amortizorul hidraulic considerat, creşte perioada de timp în care se închide vana, reducând presiunile extreme.

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ANALYSIS OF SPATIAL AND TEMPORAL PATTERN OF CLIMATIC PARAMETERS IN BAHLUEŢ RIVER SUB-BASIN WITH RESPECT TO THE STUDY OF EUTROPHICATION OF THE PODU ILOAIEI RESERVOIR

BY

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Abstract. Analysis of spatial and temporal pattern of some climatic parameters developed in the first part of this study is provided using an observed and recorded multi-annual datasets obtained on the weather stations from the watershed area of Bahlueţ river. Variation of the climatic parameters are important for both the environment has seen in its entirely by many implications that it causes (the resources of water supply, the complex hydrological processes, land surface modelling of rainfall-runoff processes in normal and exceptional circumstances, the impact on soil and water by the erosion processes (Băloiu, 1980), the dynamic of nitrogen and phosphorus constituents with pollution potential that migrates from the surface layers of soil to the hydrographical network, etc.) as well as urban agglomerations, climate factors having a

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decisively influence on the quantity and quality of available water resources for different uses, but also because of the destructive potential of the rainfall in particular, which can lead to the forming of the torrential floods on streams, with major economic and social effects.

Same climatic parameters as precipitation, temperature, evaporation are overwhelmingly influence to complex transport processes, biochemical metabolic reactions and bio accumulation of phytoplankton and zooplankton in the water bodies, the balance between quality and improper conditions being extremely fragile one. Thus, imbalances in biotope named RO19 water body typology Bahlueț CAPM (The Water Quality Synthesis of the Prut-Bârlad River Basin, 2012) can lead to impact phenomena of the basins such as eutrophication processes.

Key words: Bahluieț; eutrophication; phytoplankton; spatial analysis; the climate parameters.

1. Introduction

For knowing the spatial distribution of climatic parameters, some of them are the transport vectors for some of pollutants to water resources is important to perform a modern climate data processing. This involves using of geo-statistical interpolation methods, where this paper was used the IDW (Inverse Distance Weighted) method. IDW is a fast and accurate deterministic interpolation method based on Tobler's Law (the things from close are more similar to one another than from far). To predict a value for unmeasured location, IDW uses values surrounding locations so that values close locations will improve more the predicted value than the distant place values (Stanciu, 2010).

Altitudinal distribution maps of temperature and precipitation were created by generating the regression line, spatial interpolation of data available from systematic records and a digital elevation model of the terrain. (Fries *et al.*, 2012).

In the last 50 years, eutrophication has become one of the main reasons why surface water has risk not to achieve "good status" (Word Resource Institute, 2012). Worldwide, many research studies have been undertaken, concerning eutrophication of lakes and determining the causes of these phenomena, as for example in U.S. studies conducted on eutrophication of Michigan, Carolina Beach, Washington lakes (Leng, 2009; Pauer *et al.*, 2008), Winnipeg (McCullough *et al.*, 2012), etc. Thus, the non-point sources of pollution are major causes of water pollution in the U.S., where 72%...82% of eutrophic lakes requires control of non-point source of phosphorus pollution to meet water quality standards (Diaz, 2011), although point sources pollution could be drastically reduced (Carpenter *et al.*, 2009).

In the U.S. and Europe, only 30% of the phosphorus chemical fertilizers was assimilated by plants, which had the effect of producing a surplus of 22 kg P/ha.year. Concerning nitrogen, only 18% of the nitrogen fertilizer was used by the plants and a surplus created increased to 174 kg N/ha.year. This pressure manifested by management policies agro-technical works contributed to accelerated eutrophication of lakes (Carpenter *et al.*, 2009).

In the Netherlands have been made in recent years more research on the eutrophication potential of the Naarmedeer, Reuwijk, Oude Venice, Dutch lakes (Hosper, 1997), while globally the first study lakes were undertaken between 1968…1976 by Vollenweider and in the Netherlands between 1976…1977 (Volenwider, 1969). According to them, often under hypertrophic conditions of today, algal biomass may be limited by reducing nitrogen and phosphorus forms, light and other factors, so that the phosphorus load is widely regarded as the most important variable to quantify the eutrophication phenomenon.

In our country, recent research on eutrophication were made for Izvorul Muntelui reservoir (Darabi & Miron, 2006), Oltina, Bugeac, Dunăreni lakes (Torok, 2006).

The physical-chemical, biological, microbiological of Podu Iloaiei reservoir are dependent on the environmental and quality characteristics, in the Bahlueț river basin susceptible to non-point pollution of nitrogen and phosphorus from agricultural practices, point source pollution resulting from effluents urban agglomerations, but are dependent also on local climatic conditions.

To assess the risk of eutrophication of the Podu Iloaiei reservoir (Volpert, 2009), some models have been used to study water quality of lakes to quantify empirical eutrophication processes (Walker, 1985), in the steady state of water, considering the mass balance of nutrients resulting from advection transport processes, diffusive transport and nutrient sedimentation from a hydrographic network and loads the basin based on land use, topography and soil types.

2. Material and Methods

1. Preparing the database of meteorological variables: precipitation recorded in the national network of meteorological observations for the period 1961…2011 and temperatures for the period 2007…2011, data were obtained from the Regional Meteorological Centre, Moldova, Iaşi.

2. Preparing the digital elevation model of terrain – DEM, geo-referenced to topographic conditions of Romania, Stereo 70 projection system, Black Sea 1975 reference system. Primary raster file was obtained from the website http://www.nasa.cgiar.gov.

3. Climatic data series analysis using geo-statistical methods:

a) Calculation data set of average annual temperature, extraction *Z*-weather stations altitude of points of the numerical model of terrain and setting of elevation lower limit (Z_{det}) of the studied area.

b) Extraction altitudinal gradient (Γ) of the regression will be used in the reference level calculation formula determined for each weather station

$$T_{\text{det}} = T_{\text{temp}} + \Gamma\left(Z_{\text{det}} - Z_{\text{station}}\right), \quad (1)$$

where: T_{det} is the reference level of weather station, [m]; T_{temp} – annual average temperatures corresponding to point Z, [$^{\text{o}}$C]; Γ – altitudinal gradient; Z_{det} – elevation lower limit of the study area, [m]; Z_{station} – altitude point Z, [m].

c) The interpolation of points using IDW interpolation method through ArcGis software, using ArcToolbox function →Spatial Analyst Tools→ Interpolation→ IDW.

d) Restoring of vertical distribution of weather stations- points using a DEM support using the relation

$$T\left(x,y\right) = T_{\text{det}} + \Gamma\left(Z^{\text{MDT}}(x,y) - Z_{\text{det}}\right), \quad (2)$$

where: $T(x,y)$ is the vertical distribution of points, [m]; T_{det} – the reference level of weather station, [m]; Γ – altitudinal gradient; $Z^{\text{MDT}}(x,y)$ – Z (elevation) of weather station-point, [m]; Z_{det} – lower limit elevation of the study area. [m].

e) Generating maps containing altitudinal distribution of average annual temperatures using ArcGis software→ ArcToolbox function→ Spatial Analyst Tools→ Map Algebra→ Raster calculator, where we enter the relation:

$$T_{\text{det}} + \Gamma\left(\text{MDT} - Z_{\text{det}}\right), \quad (3)$$

where: T_{det} is the reference level of weather station, [m]; Γ – altitudinal gradient; Z_{det} – elevation lower limit of the study area, [m]; DEM – digital elevation model.

4. Preparing the database of meteorological parameters (average annual precipitation, evaporation), hydrological parameters (average annual flow for the Bahlueț watercourse, the outflows from Podu Iloaiei reservoir, the discharged flow from the waste water Treatment Plant of Târgu Frumos City agglomeration) on land use (type of land use data were obtained from the watershed model SWAT (Păduraru, 2012)), the morphometric data of Podu Iloaiei reservoir, the water quality data (some water quality parameters of Bahlueț watercourse, discharge of waste water – Târgu Frumos City and Podu Iloaiei reservoir water quality parameters between the constituents of nitrogen and phosphorus, chlorophyll "a", Secchi disk.

Data were obtained from the Moldova Regional Meteorological Centre, Iaşi and the Prut-Bârlad River Basin Water Administration.

5. Application of eutrophication models for lakes WILMS and BATHUB, to quantify the empirical eutrophication processes in steady state

conditions, taking into account the mass balance of nutrients resulting from advection transport processes, diffusive transport and nutrient sedimentation from the river network of Bahlueț sub-basin, loads of Bahlueț sub-basin based on land use, topography, soil types and loads from point sources (Waste Water Treatment Plant of Târgu Frumos City).

Variables are simulated using empirical relationships developed and tested for the reservoirs (Walker, 1985) as follows:

A. Modeling of phosphorus dynamics is based on a combination of kinetic models of first and second order:

a) The kinetic model of first order ($A_1 = 1$)

$$\mathrm{P} = \frac{\mathrm{P}i}{1 + KA_1T}, \tag{4}$$

where phosphorus sedimentation rate is equal to

$$\mathrm{CP} = A_1\mathrm{P}^{A_2}, \quad \text{[mg/cm.year]}. \tag{5}$$

b) The kinetic model of second order ($A_2 = 2$)

$$\mathrm{P} = \frac{-1 + \left(1 + 4KA_1\mathrm{P}iT\right)^{0.5}}{2KA_1T}. \tag{6}$$

B. Modelling nitrogen dynamics is also based on kinetic models of first and second order

a) The kinetic model of first order ($A_1 = 1$)

$$\mathrm{N} = \frac{\mathrm{N}i}{1 + KB_1T}, \tag{7}$$

where nitrogen sedimentation rate is equal to: $B_1\,\mathrm{N}^{B_2}$, [mg/cm.year].

b) The kinetic model of second order ($B_2 = 2$)

$$\mathrm{N} = \frac{-1 + \left(1 + 4KB_1\mathrm{N}iT\right)^{0.5}}{2KB_1T}. \tag{8}$$

c) Models for longitudinal dispersion coefficient

The models are based on eqs. developed by various researchers (Fisher *et al.*, 1979) based on dimensional dispersion eq. of pollutant dispersion eq. (Walker, 1985) (Table 1).

Table 1

Models for Predicting the Dispersion Coefficient

Dispersion models	Mathematical equation
Fischer *et al*. (1979); Walker's dispersion eq.(1985)	Width, $W = As/L$ Cross section area, $Ac = WZ$ Velocity, $U = Q/Ac$ Dispersion coeff., $D = KD100W^2\, Z^{-0.84}$ Maximum, $(U,1)$ Num. dispersion, $D_n = UL/2$ Change, $E = \max(D - D_n, 0)Ac/L$

3. Results and Discussion

Weather stations and analysis of average annual temperatures database in the period 2007…2011 is presented in the Table 2.

Table 2

Average Annual Temperatures at Different Weather Stations

Weather stations	Multi-annual average temperature °C
Cotnari – Weather Station	10.7
Iași – Weather Station	11.0
Bârnova – Weather Station	9.5

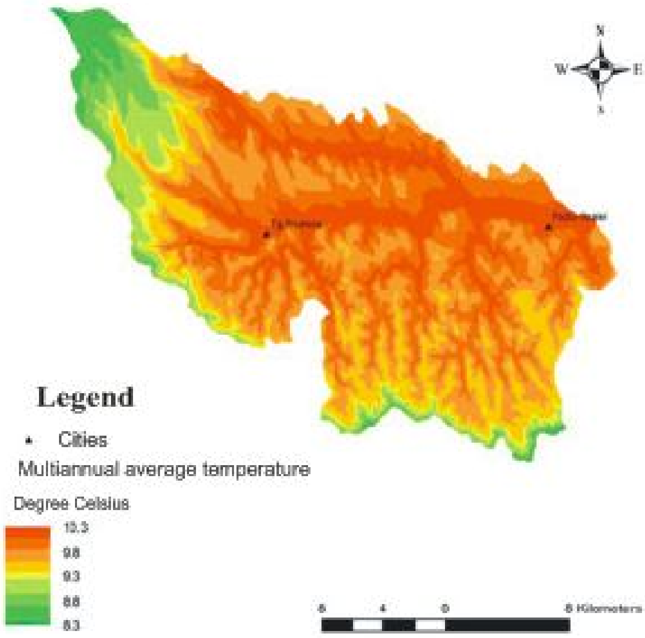


Fig. 1 – Map of average annual temperatures of river basins Bahlueț by altitudinal gradient; period 2007…2011, data set expressed in °C.

The analysis of the map (Fig. 1) shows that the areas with the lower temperature corresponds to regions with specific microclimate altitudes over 400 m – the case of woodland from the North-West and South of the Bahlueț sub-basin. In contrast, areas with the highest temperatures corresponds to minor bed of the river basin.

Using the same methodology as in the above model was created an altitudinal distribution of average annual precipitation from the range of 1961…2011 years, [L/m^2], in the Bahlueț sub-basin. Rainfall stations and analysis of average annual precipitation database over a period of about 50 years (1961…2011) are presented in the Table 3.

Table 3
Values of Annual Average Rainfall at Various Weather Stations, [L/m^2]

Rainfall Stations	Average annual precipitation, [L/m^2]
Ciurbeşti	503
Cotnari – Weather Station	536
Ezăreni	538
Hârlău	530
Iaşi – Weather Station	573
Bârnova	775
Pârcovaci	544
Podu Iloaiei	534
Tg. Frumos	495
Ciurea	646

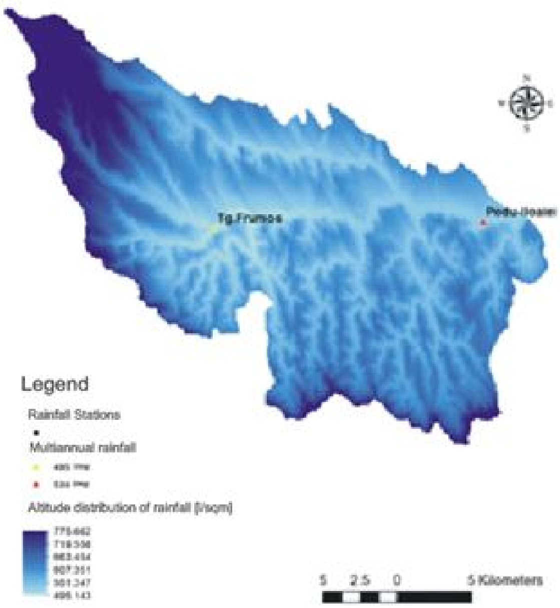


Fig. 2 – Altitudinal distribution of average annual precipitation in Bahlueț basin in the period 1961…2011, [L/m^2].

After the analysis of the map (Fig. 2) it can be observed that significant rainfall areas correspond to regions with specific microclimate altitudes over 400 m is the case of woodland in the extremely North-West and South of the Bahlueț sub-basin. In contrast, quantitatively lower rainfall areas correspond to river network in northern central part of the basin.

3.1. Discussion Regarding the Results Obtained from Spatial Analysis of Climatic Parameters

a) From the analysis of time distribution of precipitation in the study area (Fig. 3) and comparing the results with those obtained in other regions (average annual rainfall in Subcarpathian Region about 700…1,000 mm/year from 1,000 to 1,200 mm/year in the Carpathian Mountains and 500…700 mm/year in the Western Plain Region) show that Bahlueț basin is in a deficit area in terms of the contribution of precipitation.

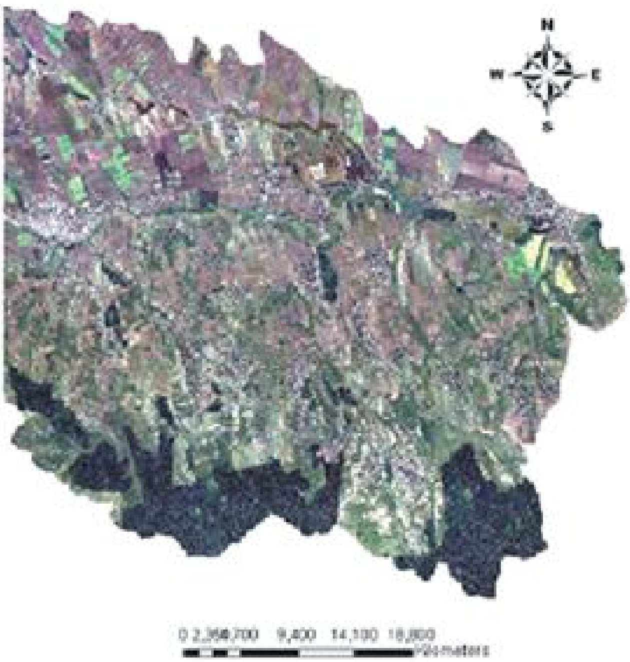


Fig. 3 – The map of the Bahlueț-basin study area.

b) In the study area, the balance between actual evapotranspiration (664.60 mm) and potential evapotranspiration (650…700 mm) shows a clear deficit (ANM, 2008), so the region is suitable for civil engineering facilities of hydrotechnical domain for water retention, but also discontinuous nature of the flow is observed on small rivers, with the impact on water supply and recharging of reservoirs (Vartolomei, 2008).

c) In conditions transiting on riverbed of the hydrographical network tributary to the Bahlueț watercourse of some lower flow (multi-annual average flow of the Bahlueț watercourse is 0.95 cm/s) the biochemical phenomena of the organic matter decaying and kinetics of nitrification process can lead to affecting of water quality of Podu Iloaiei reservoir.

d) To highlight the eutrophication processes of reservoirs, especially Podu Iloaiei reservoir was considered most representative of Bahlueț sub-basin.

In terms of physical and geographical conditions, the Podu Iloaiei reservoir is located in the Southwestern part of the Podu Iloaiei town; geographical coordinates are bounded upstream of 47°12 \'N, 27°12\' E longitude and downstream the geographical coordinates are 47°12 \'N, 27°15\' E longitude, is part of the Moldavian Plateau, on the contact between Suceava Plateau from West, to South is Central Moldavian Plateau and in the North-East is the Moldavian Plain, on the Iaşi Plain sub-division to the East (Moldovanu *et al.*, Frunzuc, 2009).

Podu Iloaiei reservoir is from hydrological regime viewpoint dependent upon the Bahlueț watercourse, having an annual average flow of 0.95 m/s, consisting of a reception area of 551 km^2 (of which reservoirs is 232 ha), length of 41 km, altitude 355 m upstream and the downstream of 51 m, average riverbed slope of 7‰, sinuosity coefficient of 1.23 (Ujvari, 1972).

In the WILMS eutrophication model were introduced hydrological data and water quality and land use data (Table 4).

Table 4

Values of Hydrological Parameters for the Area under Study

Hydrological parameters	Values
Bahlueț Catchment area, [ha]	475.61
Total runoff , [mm]	189.95
Podu Iloaiei lake surface, [ha]	251
Podu Iloaiei lake volume, [million m^3]	5.02
The average depth of the reservoir, [m]	2
Precipitation-evaporation, [mm]	448.2
Hydraulic load, [cm/year]	8,859.325
Specific charge, [m/year]	13.4
Reservoir recharge	745.90

Also, the reservoir eutrophication modeling involved study of land use database, according to CORINE LAND USE classification and extraction from it of interest data (Fig. 4).

In Table 5 and 8 is presented a synthetic statement of non-point loading pollution sources (Fig. 5), depending on the type of land use.

Table 5

Land Use, the Areas Determined and Load of Pollutants from Non-Point Sources

Land use	Symbology	Area, [ha]	Loads, [kg/ha.year]		
			Low	Most common	High
Gardens planted with vegetables	PEAS	715.68	0.30	0.70	1.35
Comercial activities	UCOM	2,396.82	0.30	0.50	0.80
Industrial	UIDU	110,87	1.0	1.50	2.0
Agricultural land	AGRL	25.096.26	–	–	–
Vineyards	GRAP	459.86	0.20	0.40	1.0
Fruits	APPL	543.12	0.25	0.45	1.10
Annual crops	AGRR	75.49	0.50	1.50	5.0
Land row crops	AGRC	1,187.19	0.30	0.80	4.50
Pastures	PAST	10,444.01	0.10	0.30	0.50
Mix Forest	FRST	5,482.99	0.05	0.09	0.18
Range pastures	RNGE	622.50	0.10	0.25	0.50
Dunes and sand	LENT	56.081	0.05	0.10	0.10
Wetland	WETL	369.70	0.10	0.30	1.0

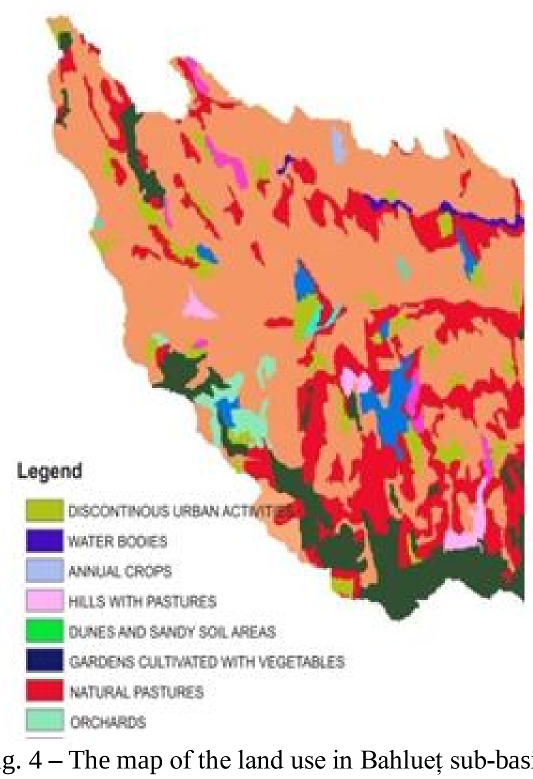


Fig. 4 – The map of the land use in Bahlueț sub-basin.

In Tables 6 and 7 are represented the loads in total P from point sources of pollution (Waste Water Treatment Plant of the Târgu Frumos City and Septic Tanks).

Table 6
Total P *Constituent Loads from Sources of Pollution* (*Waste Water Treatment Plant of the Târgu Frumos City*)

Point sources	Flow m^3/year	Loads, [kg/year]			Load %
		Low	Most common	High	
Waste water treatment plant Târgu Frumos	2,522.880	53,910.5	60,000.0	398,937.7	63.3

Table 7
Total P *Constituent Loads from Sources of Pollution (Septic Tanks)*

Point sources	No. pop/year	Loads, [kg/year]			Load %
		Low	Most common	High	
Discharge septic tanks	2,750.0	0.30	0.50	0.80	–
Amount of phosphorus retained in the soil		98.0	90.0	80.0	–
Charge of septic tanks, kg/year		16.50	137.50	440.0	0.1

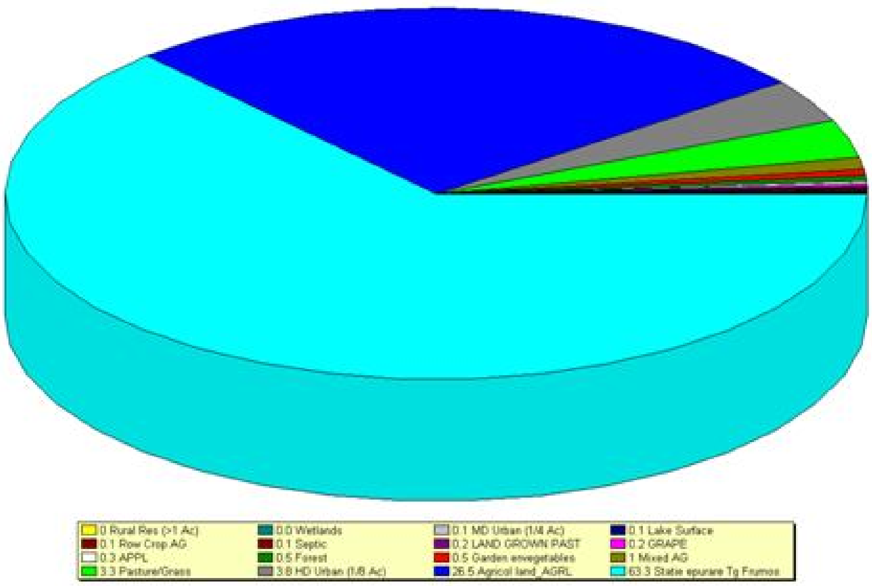


Fig. 5 – Diagram of P_{total} loads of pollutants resulting from non-point pollution sources and point sources in the Bahlueț catchment area.

Table 8

Total P *Loads Constituents Deriving from Sources of Pollution* (*Waste Water Treatment Plant of the Târgu Frumos City*) *and Non-Point Sources of Pollution*

Type of loads	Low	Most common	High	Loads, [%]
Point source loads, [kg]	53,910.5	60,000.0	398,937.7	63.3
Non-point sources loads, [kg]	17,235.7	34,565.3	194,877.3	36.5
Specific loads, [mg/m^2.year]	28,363.26	37,762.29	236,868.14	–
Total	71,187.8	94,778.1	594,506.0	100

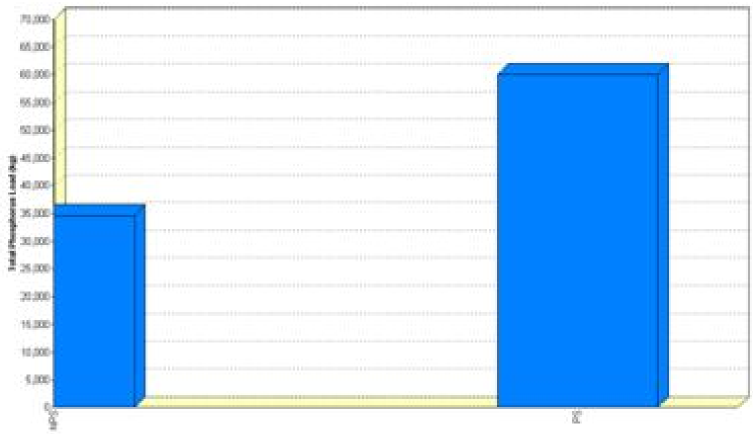
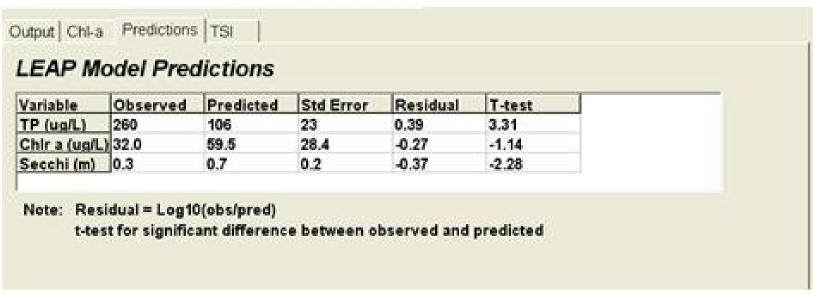


Fig. 6 – Diagram of comparative size loads from non-point sources of pollution *vs*. point sources.

a) *The potential eutrophication analysis of Podu Iloaiei reservoir*

With the values obtained on the size of constituent quantities of total phosphorus from both point and non-point sources of pollution (Fig. 6) was estimated the degree of eutrophication of the Podu Iloaiei reservoir with WILMS model tab Lake Eutrophycation Analysis Procedure and obtained the data presented in Figs. 7 and 8.



Variable	Observed	Predicted	Std Error	Residual	T-test
TP (ug/L)	260	106	23	0.39	3.31
Chlr a (ug/L)	32.0	59.5	28.4	-0.27	-1.14
Secchi (m)	0.3	0.7	0.2	-0.37	-2.28

Fig. 7 – Obtained results concerning indices of eutrophycation at Podu Iloaiei reservoir simulated values *vs*. observed values.

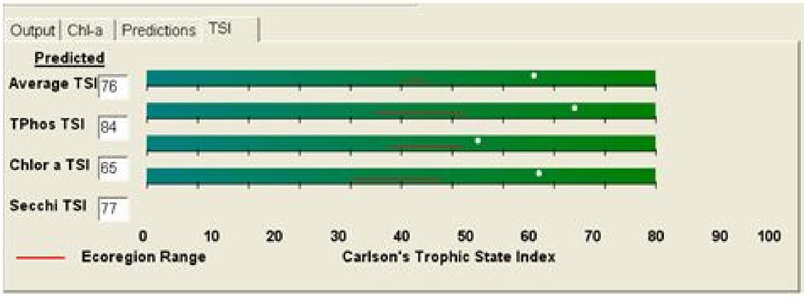


Fig. 8 – Obtained results concerning the TSI eutrophication index (scale Carlson TSI).

3.2. Discussion Concerning the Obtained Results after Running WILMS Model

a) From the results analysis of potential eutrophication modelling of the Podu Iloaiei reservoir and the Carlson TSI results index has a high value for all relevant indicators: total phosphorus – TSI, chlorophyll "a"–TSI-TSI Sechhi. According to Carlson evaluation a TSI value greater than 70 units shows that Podu Iloaiei reservoir has a hypertrophycal characteristics.

b) Therefore, by runnig WILMS eutrophication model was quantified risk of eutrophication of Podu Iloaiei reservoir, placing this reservoir in category of hypertrophycal lakes, for the parameters P_{total}, TSI (TSI simulated value = 84) and Secchi transparency (simulated value TSI = 77), while for the chlorophyll-a parameter, the Podu Iloaiei reservoir was assessed to eutrophyc reservoir (TSI simulated value = 65).

Using the BATHUB model for the study of eutrophication of the Podu Iloaiei reservoir involved using hydrological data, morphological and water quality are obtained the following results

a) Water quality data for Podu Iloaiei and for the Bahlueț watercourse are given in Tables 9 and 10.

Table 9
Water Quality Initial Data for Podu Iloaiei Reservoir

	P_{total} ppb	N_{total} ppb	Chl-a ppb	Secchi m	$N_{organic}$ ppb	*Ortho*P ppb
Podu Iloaiei reservoir	260	111	129.20	0.30	30	160

Table 10
Water Quality Initial Data for Bahlueț Watercourse

	Abasin km^2	Average multi-annual flow $h.m^3/year$	P_{total} ppb	N_{total} ppb	*Ortho*P ppb	$N_{anorganic}$ ppb
Bahlueț watercourse	551	29.96	680	5,340	589	5,100

b) Hydrological data concerning the precipitation regime in the area, evaporation, multi-annual average flow of Bahlueț watercourse, morphometric data of Podu Iloaiei reservoir (same as in the case of WILMS model); data are obtained from Prut-Bârlad River Basin Water Administration and Regional Meteorological Centre, Moldova, Iaşi.

3.3. Results Obtained from Running BATHUB Model

Were obtained data for mass balance for the parameters total P_{total} and N_{total} (Tables 11 and 12).

Table 11

Total P *Mass Balance Results for the Podu Iloaiei Reservoir*

Trib	Type	Location	Flow h.m^3/year	Flow % total	Load kg/year	Load % total	Conc. mg/m^3
1	1	Trib 1	30.0	95.4	20,372.3	99.6	680
Precipitation	–	–	1.4	4.6	75.3	0.4	53
Inflow to river network	–	–	30.0	95.4	20,372.3	99.6	680
Total inflow	–	–	31.4	100.0	20,447.6	100.0	651
Advective outflow	–	–	31.1	99.0	6,574.5	32.2	212
Total advective flow	–	–	31.1	99.0	6,574.5	32.2	212
Evaporation	–	–	0.2	0.6	0.0	0.0	–
Retention rate	–	–	0.1	0.4	26.6	0.1	212
Retention	–	–	0.0	0.0	13,846.5	67.7	–

Table 12

N_{total} *MassBalance Results for the Podu Iloaiei Reservoir*

Trib	Type	Location	Flow h.m^3/year	Flow % total	Load kg/year	Load % total	Conc. mg/m^3
1	1	Trib 1	30.0	95.4	159,982.1	98.5	5,340
Precipitation	–	–	1.4	4.6	2,510.0	1.5	1,751
Inflow to river network	–	–	30.0	95.4	159,982.1	98.5	5,340
Total inflow	–	–	31.4	100.0	162,492.1	100.0	5,176
Advective outflow	–	–	31.1	99.0	83,903.9	51.6	2,701
Total advective flow	–	–	31.1	99.0	83,903.9	51.6	2,701
Evaporation	–	–	0.2	0.6	0.0	0.0	–
Retention rate	–	–	0.1	0.4	339.0	0.2	2,701
Retenție	–	–	0.0	0.0	78,249.2	48.2	–

Hydraulic residence time = 0.1207 years
Outflow rate = 12.4 m^3/year
Average water depth = 1.5 m

3.4. Discussion Concerning the Results on the BATHUB Model

1. There are large differences for the observed *vs*. simulated values of total N (2.70 mg/L to 0.11 mg total N simulated/L total N observed). Typically the total N values in the reservoir should tend to zero relatively quickly because it is consumed by phytoplankton as it is shown in Fig. 10.

2. The fact that there are values of total N in reservoir signifies the existence of a rich benthic organic nutrient reserves due to intake nitrogen constituents transported by the Bahlueț watercourse in recent years.

3. The analysis parameters antilog PC-1 (4,228 simulated values, maximum is 2,460.4) Carlson TSI SEC (values simulated 74) as it is represented in Fig. 14, show that the Podu Iloaiei reservoir has a high potential for eutrophication. Carlson scale TSI indicator shows that for TSI > 70 values, the reservoir has a great trophyc characteristics of large (hypertrophyc reservoir).

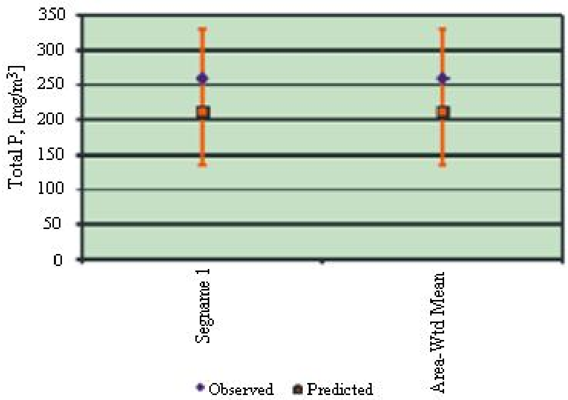


Fig. 9 – Total P simulated values *vs*. observed values.

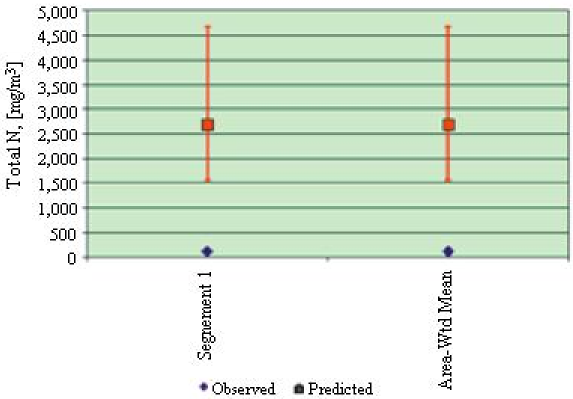


Fig. 10 – Total N simulated values *vs*. observed values.

4. Concerning the total P concentration, it is situated within acceptable limits on the Podu Iloaiei reservoir (total P 0.211 mg/L to a maximum of 0.274 mg/L), as it is shown in Fig. 9.

5. Relatively high nitrogen constituents of Podu Iloaiei lake is due to non-point pollution in the Bahlueț catchment area.

6. The fact that existing biomass of the reservoir fails to assimilate fully entire pollutants load shows systematic nature of this non-point pollution.

4. Conclusions

1. The relatively high nitrogen constituents content of the Podu Iloaiei reservoir is due to non-point pollution in the Bahlueț watershed, contributing to the proliferation of phytoplankton biomass. Thus, the results of monitoring carried out by ABA Prut-Bârlad shows that they vary between a minimum value of 26.50 mg/L and a maximum of 129.2 mg/L, while the chlorophyll-a values for Izvorul Muntelui lake reached 2.60 mg/L (Aoncioaie *et al*., 2011).

2. Practically, the modeling performed with WILMS and BATHUB models have revealed that evaluation, according to the Water Framework Directive 2000/60/EC of the ecological status of the Podu Iloaiei reservoir category for hypertrophic and eutrophyc nutrient regime to that of the biological potential, is correct and explained by the present case study, the mechanisms of producing nutrients and their dynamics through the soil profile to surface receivers.

3. Comparative analysis of simulated and measured results of the two models, WILMS and BATHUB (Figs. 11,…,14), show that results are comparable between the two models for Secchi transparency (Secchi TSI values WILMS = 77 *vs*. TSI values Sechhi BATHUB = 74) and total P (TSI values – WILMS P_{tot} = 84 *vs*. TSI values BATHUB P_{tot} = 82) and less for chlorophyll-a (WILMS TSI values of CHLA = 65 *vs*. BATHUB TSI value CHLA = 71). Differences between Chlorophyll-a simulation can be attributed to different input values (we used for a simulation with BATHUB maximum chlorophyll-a data obtained from monitoring).

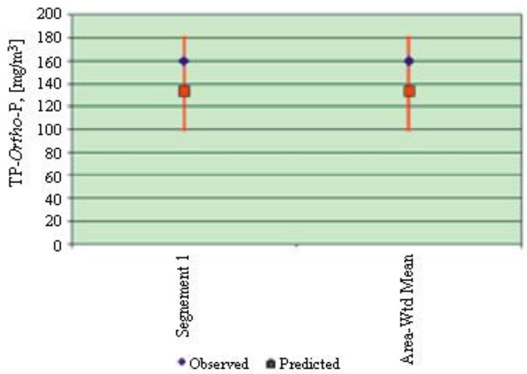


Fig. 11 – Total P-*Ortho*P simulated values *vs*. observed values.

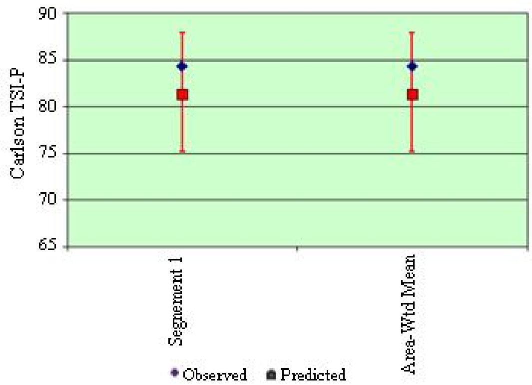


Fig. 12 – Carlson TSI- P simulated values *vs*. observed values.

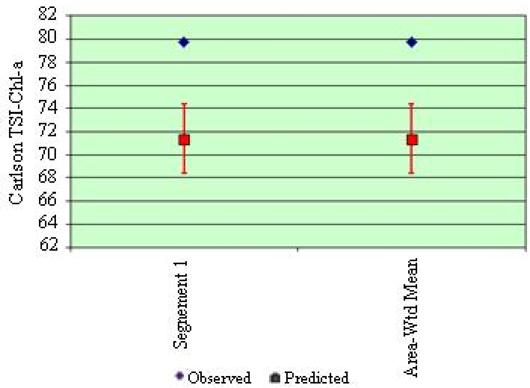


Fig. 13 – Carlson TSI- Chl-a simulated values *vs*. observed values.

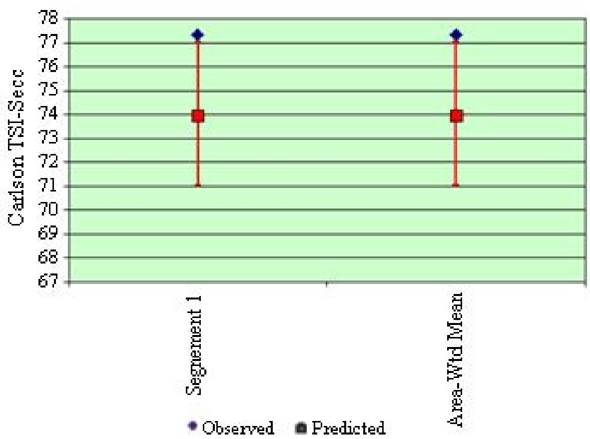


Fig. 14 – Carlson TSI- Secc simulated values *vs*. observed values.

4. Based on comparative analysis of the models, the utilized ones can be validated, which means that can be applied to other water bodies in similar conditions.

5. Applicability of eutrophication models WILMS and BATHUB must be seen as regards the concrete possibilities to perform the study and synthesis of water quality, the basin forecast, contributing to better quantify the mechanisms of monitoring water quality eutrophication in perspective through watershed management plans to river basin scale.

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ANALIZA MODELULUI SPAȚIAL ŞI TEMPORAL A UNOR PARAMETRI CLIMATICI DIN SUB BAZINUL HIDROGRAFIC BAHLUEȚ LUÂND ÎN ONSIDERARE STUDIUL DE EUTROFIZARE A ACUMULĂRII PODU ILOAIEI

(Rezumat)

Analiza modelului spațial şi temporal a unor parametri climatici, dezvoltată în prima parte a acestui studiu, a utilizat date măsurate şi înregistrate în stațiile meteorologice existente în bazinul hidrografic Bahlueț.

Parametrii climatici, precum precipitațiile, temperatura, evaporația influențează procesele complexe de transport, reacții metabolice biochimice şi de bioacumulare a fitoplanctonului şi zooplanctonului în corpurile de apă, balanța între condițiile de calitate şi cele improprii fiind extrem de fragilă în acest caz. Un astfel de dezechilibru în acest biotop poate conduce la fenomene de impact în bazinul Bahluețului, cum ar fi procesele de eutrofizare.

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MODELLING HYDROLOGICAL SYSTEMS AS LINEAR TIME-INVARIANT SYSTEMS ON DISCRETE TIME

BY

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Abstract. In this paper we introduce a mathematical model for a hydrological system, seen as a dynamic linear time-invariant system in discrete time. In the first section we study the case of a system without controlled inputs and we write the dynamics of such a system as $x(k + 1) = Ax(k) + Gv(k)$, where A is a Jordan block corresponding to the eigenvalue 0 and the matrix G is based on the unit hydrograph of the system. In the second section we introduce the cotrolled inputs term, $Bu(k)$, and we investigate the closed-loop system using dynamic or static feedbacks, and we conclude with some remarks about the possibility of interconnecting multiple subsystems having this type of dynamics.

Key words: hydrological systems; linear time-invariant systems; unit hydrograph.

1. Introduction

In this paper we will introduce a mathematical model for a hydrological system, seen as a dynamic finite-dimensional linear time-invariant system that

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operates in discrete time

$$\begin{cases} x(k+1) = Ax(k) + Bu(k) + Gv(k), \\ y(k) = Cx(k), \\ z(k) = Hx(k), \end{cases} \tag{1}$$

where: k denotes the time variable, and will always be a natural number $k \in \mathbb{N}$; $x(k) \in \mathbb{R}^n$ – the state of the system at time k; $u(k) \in \mathbb{R}^n$ – the control input of the system; $v(k) \in \mathbb{R}^q$ – the disturbance input of the system; $y(k) \in \mathbb{R}^p$ – the measurement output of the system; $z(k) \in \mathbb{R}^r$ – the to-be-controlled output of the system; A, B, G, C and H – real matrices of dimensions $n \times n$, $n \times m$, $n \times q$, $p \times n$ and $r \times p$, respectively.

So the system has two types of inputs: the control, $u(k)$, and the disturbance, $v(k)$. The control, $u(k)$, can be used to regulate the system, whereas the disturbance, $v(k)$, is uncontrollable, and enters the system from exterior. The disturbance is unknown, but need not be of stochastic nature.

The system has also two types of outputs: the measurement, $y(k)$, and the output, $z(k)$. The measurement, $y(k)$, contains all the information on the state that is available, and may be used for regulating the system. The output, $z(k)$, the to-be-controlled output, is a variable that is relevant to the outside world. This variable need not be included in the measurement, $y(k)$.

In many cases the behaviour of the system is unsatisfactory. In such cases it is useful to look for a feedback controller that based on the measurements generates controls such that the resulting controlled system satisfies certain in advance given specifications.

In the first section we study the case without controlled inputs and we write the dynamics of the system as

$$x(k+1) = Ax(k) + Gv(k),$$

where A is a Jordan block corresponding to the eigenvalue 0 and the matrix G is based on the unit hydrograph of the system. In the second section we introduce the cotrolled inputs term, $Bu(k)$, and we investigate the closed-loop system using dynamic or static feedbacks and we end with some concluding remarks about the possibility of interconnecting multiple subsystems having this type of dynamics.

2. Systems without Controlled Inputs

We consider a river basin, S, having a unit hydrograph in n steps. We write the responses of the unit hydrograph in a matrix

$$G = \begin{bmatrix} g_1 \\ g_2 \\ \vdots \\ g_n \end{bmatrix},$$

and we aim to write the dynamics of the system as

$$x(k+1) = Ax(k) + Gv(k),$$

where $x(k)$ is the state vector at time k, while $v(k)$ represents the uncontrolled inputs of the system (precipitations) at time k.

We consider the case of an m hours rainfall, with intensities $v(k)$, ($k = 1,...,m$).

The discharge given by the unit hydrograph in this case is

$$g(k) = \sum_{i=1}^{k} g_i v(k-i), \text{ where } g_i = 0, \ \forall i > n. \tag{2}$$

The water that enters the system at time k influences the discharges at times k, $k+1$,..., $k+n-1$. We denote by $q_1(k)$, $q_2(k)$,..., $q_{n-1}(k)$, the water present in the system at time k which appears in the discharge at times $k+1$, $k+2$,..., $k+n-1$.

Setting $q(0) = 0$ and $q_i(0) = 0$ (when the rain starts, there is no surplus water in the system), from (2) we find the eqs.

$$\begin{cases} q(k+1) = q_1(k) + g_1 v(k), \\ q_i(k+1) = q_{i+1}(k) + g_{i+1} v(k), \ (i = 1,...,n-2), \\ q_{n-1}(k+1) = g_n v(k). \end{cases} \tag{3}$$

We introduce the state vector

$$x(k) = \begin{bmatrix} q(k) \\ q_1(k) \\ \vdots \\ q_{n-1}(k) \end{bmatrix},$$

which contains the total amount of surplus water that exists in the system at time k. With this notation, eqs. (3) become

$$x(k+1)=\begin{bmatrix} q(k+1) \\ q_1(k+1) \\ \vdots \\ q_{n-1}(k+1) \end{bmatrix}=\begin{bmatrix} 0 & 1 & 0 & \dots & 0 \\ 0 & 0 & 1 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 1 \\ 0 & 0 & 0 & \dots & 0 \end{bmatrix}\begin{bmatrix} q(k) \\ q_1(k) \\ \vdots \\ q_{n-1}(k) \end{bmatrix}+\begin{bmatrix} g \\ g_1 \\ \vdots \\ g_n \end{bmatrix}v(k),$$

or

$$x(k+1)=Ax(k)+Gv(k), \tag{4}$$

where A is a Jordan block of dimension n corresponding to the eigenvalue 0.

Using induction we find

$$x(k)=\sum_{i=0}^{k-1}A^{i}Gv(k-i-1).$$

3. Systems with Controlled Inputs

If in the studied river basin there exist hydraulic structures, then the measured discharges (or even the water that exists in the system and does not appear yet in the discharge) can be adjusted by introducing the control variable $u(k)$ which can be given by a dynamic feedback (or compensator) of the form

$$\begin{cases} w(k+1)=Kw(k)+Ly(k), \\ u(k)=Mw(k)+Ny(k), \end{cases} \tag{5}$$

which can be also seen as a dynamic linear time-invariant system, having the state variable $w(k)\in\mathbb{R}^{l}$, with K, L, M and N real matrices of dimensions $l \times l$, $l \times p$, $m \times l$ and $m \times p$, respectively. The index l is a nonnegative integer, and is called *the order of the compensator*. If $l = 0$, then the matrices K, L and M consist of zero rows and/or columns, and therefore do not appear in (5), so instead of a dynamic feedback, the controller is then referred to as a *static feedback*

$$u(k)=Ny(k).$$

The controlled system, also called *the closed-loop system*, obtained by the interconnection of (1) with (5) is described by the following eqs.

$$\begin{cases} x_e(k+1)=A_e x_e(k)+G_e v(k), \\ z(k)=H_e x_e(k), \end{cases}$$

where we have denoted

$$x_e(k)=\begin{bmatrix}x(k)\\ w(k)\end{bmatrix},\ A_e=\begin{bmatrix}A+BNC & BM\\ LC & K\end{bmatrix},\ G_e=\begin{bmatrix}G\\ 0\end{bmatrix},\ H_e=\begin{bmatrix}H & 0\end{bmatrix}.$$

The mathematical system theory develops several methods for the design of controllers such that the controlled system behaves in a prespecified manner, such as invariance, controlled invariance, conditioned invariance, disturbance decoupling, stability, etc. It turns out that the design of such controllers amounts to finding matrices *K, L, M* and *N* such that certain specifications are satisfied.

4. Conclusions

For small river basins with known unit hydrograph we can try to study the dynamics of the system writing it as a linear time-invariant system as in (4). If there exist feedback capabilities, we can use the tools provided by the mathematical system theory in order to design controllers such that the closed-loop systems behaves in a pre-specified manner.

For larger river basins we can decompose them in subbasins and if for each sub-basin it is known the unit hydrograph, then we can write the dynamics of each sub-basin as in (4). The dynamics of the global system will then have eqs. similar to (4), with the matrix of the system having on its main diagonal the Jordan blocks corresponding to each sub-basin, but we will also have off-diagonal terms corresponding to the interconnections between the sub-basins.

Controlling such a decentralized system is more difficult than in the centralized case, since the design of a compensator has to take into account the decentralized structure and the communication between channels (sub-basins in this case). For example, in the stabilization problem for such a system the controller design eventually comes down to the location of the decentralized eigenvalues of the system matrix, which must not be fixed.

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MODELAREA SISTEMELOR HIDROLOGICE CA SISTEME LINIARE INVARIANTE ÎN TIMP DISCRET

(Rezumat)

În lucrare se introduce un model matematic pentru un sistem hidrologic, privit ca un sistem dinamic invariant în timp discret, de forma:

$$\begin{cases} x(k+1) = Ax(k) + Bu(k) + Gv(k), \\ y(k) = Cx(k), \\ z(k) = Hx(k). \end{cases}$$

În prima secțiune prezentăm câteva generalități despre sisteme dinamice invariante în timp, iar în a doua secțiune studiem cazul fără intrări controlate şi scriem dinamica sistemului sub forma (1), unde *A* este un bloc Jordan corespunzător valorii proprii 0 iar matricea *G* are la bază hidrograful unitar al sistemului. În a treia secțiune se introduce termenul intrărilor controlate *Bu*(*k*) şi se investighează sistemul închis folosind procedeul de feedback dinamic sau static, iar în ultima parte se prezintă câteva concluzii şi remarci despre posibilitatea interconectării mai multor subsisteme având acest tip de dinamică.

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CRITERIA FOR WASTE WATER TREATMENT TECHNOLOGIES

BY

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Abstract. The paper presents natural biological treatment systems (lagoons, constructed wetlands) that can be used to treat the waste water from small communities taking account of the four criteria groups which are considered as priorities in this study (aspects about technical, environmental, economic and social factors).

Key words: biotechnologies; developing countries; small communities; waste water treatment.

1. Introduction

Encouraging communities to be involved in determining the characteristics of projects and technologies that best suit their social-economic and environmental needs is one of the first steps in getting communities to become technologically self-sufficient (Murphy *et al*., 2009).

Knowledge about the perspectives that characterize each community and discharge point (number of inhabitants, surface available, climatic, geological and hydrological conditions, future prospects, benefits and impacts of the waste water treatment plant (WWTP) and other economic, social and environmental aspects) obtained through the survey of municipalities is very

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important. The answers to the survey could be subjective and hence qualitative and vague, however it is a valuable tool since it provides information about the territory and environmental that can be obtained only from local knowledge (Comas *et al*., 2003).

Normally, small villages in rural areas of developed countries are isolated and far from large natural or technical central sources of fresh water, pipelines and sanitation systems. In these cases small-scale, de-centralized, low-cost water and sanitation systems are needed (Faillance, 1990; Rheinlander & Grater, 2001).

In the Table 1 the list with the acronyms used in this study for each type of waste water treatment technologies is presented.

Table 1
Acronyms of the Technologies

Technologies	Acronyms
Septic tank	ST
Lagoons	LA
Vertical flow constructed wetland	VFCW
Horizontal flow constructed wetland	HFCW
Rotating biological contactor	RBC
Membrane bio reactor	MBR
Sequencing bath reactor	SBR

2. Selection Criteria for the Process of Treatment Technologies to be Implemented in Small Communities:

2.1. Technical Criteria

Technical aspects are mainly focused on evaluating the technology proposed and more appropriate as alternative (Schumacher, 1973).

a) *The required quality of the effluent according to the receiving environment*

The urban waste water provides different levels of treatment and final quality of the effluent. In practice if the discharge occurs in normal areas requires a level of secondary treatment (removal of the organic material and the containing of suspended solids) or primary in case of minor discharges (Ortega de Miguel *et al*., 2011).

b) *Number of the population*

Application of different purification technologies is recommended according with population ranges. The dark area (Table 2) reflects the range of population where the technology is recommendable (Ortega de Miguel *et al.*, 2011).

Table 2

Recommendend Implementation Range for Different Purification Technologies

Technology		Range of population (*i-e*)		
	50...200	200...500	500…1,000	1,000…2,000
ST				
LA				
VFCW and HFCW				
SBR				
RBC				

i-e: inhabitant equivalent

c) *Surface area and characteristics of the available land for construction of treatment plants*

Available surface area for the implantation of the treatment limits leads to the number of the technologies that are potentially applicable. Taking into account the characteristics of the land, a difficult excavation is possible; the larger is the volume of excavation required, will make the implantation more expensive and complex. The presence of shallow aquifers or the proximity of vulnerable areas can make unworkable the use of certain technologies that require deep excavation (Ortega de Miguel *et al.*, 2011).

d) *Origin and concentration of pollutants in waste water*

The presence of waste water can have negative consequences in the treatment and affects the quality of effluent and the characteristics of waste water generated in small populations (especially high concentration of contaminants) varies from one locality to another, depending at the local conditions (population, their habits, etc.) (Ortega de Miguel *et al*., 2011).

They can be applied as secondary or tertiary purification treatment to their capacity of adaptation to the level of contamination of sewage (Ortega de Miguel *et al*., 2011). If the concentration of BDO (biochemical demand of oxygen) is between 350...500 mg/L the waste water is heavy contaminated than the most efficient technology to use in this case is SBR and if the contamination of BDO is less than 150 mg/L the adequate technologies are the constructed wetlands (CW).

e) *Treatment versatility*

Variations in flow and concentration of pollutants throughout the day can be very pronounced in small populations because of the concentration of activity in a few hours throughout the day.

An analyse of the capacity of adaptation of the technology recommended to the changes caused by seasonal variations of the population is necessary. These changes may be for short length (week-ends) or long length (Ortega de Miguel *et al*., 2011) (Fig. 1).

Capacity of adaptation to hydraulic overloads		
–	0	+
VFCW	SBR/RBC/MBR	LA/HFCW

Capacity of adaptation to organic overloads			
– –	–	0	++
VFCW/HFCW	RBC/MBR	LA	SBR

Fig. 1 – Capacity of adaptation of the technology recommended.

f) *Climatology*

Temperature is the most important climatic factor and especially affects biological processes either in the treatment of waste water or sludge stabilization. Extensive treatments, when the water flow is completely subsurface (horizontal flow constructed wetlands), represent a greater protection against the cold weather while the lagoons are more vulnerable (Ortega de Miguel *et al*., 2011).

g) *Production and quality of generated sludge*

The generation of sludge represent factors to be considered in the selection process of the most adequate technology, each particular case sludge production complicate in lesser or greater extent the, management of waste water treatment plants (Ortega de Miguel *et al*., 2011) (Fig.2).

–	–	+	+	++
LA	VFCW/HFCW	RBC	MBR	SBR

Fig. 2 – Amount and frequency of the withdrawal of generated sludge.

h) *Complexity in the exploitation and maintenance*

Usually, the operation and maintenance are more complex on intensive technologies than in extensive technologies, by the increased presence of electromechanical equipment while the extensive often require more extensive greater workforce (Ortega de Miguel *et al*., 2011) (Fig.3).

– – – 0 0 + ++

LA	HFCW	VFCW	RBC	MBR	SBR

Fig. 3 – Complexity in the exploitation and maintenance and the level of electromechanical equipment.

2.2. Environmental Criteria

All technologies should minimize environmental impacts such as atmospheric emissions, water pollution, waste production, noise, land occupation and effects on the landscape (Garfi *et al*., 2011).

a) *Production of odours*

The purification of waste water is often considered an unhealthy activity and for this reason should be far away from the population (minimum 2 km). The main environmental impacts related to the treatment stations and a source of frequent complaints from the population is the generation of odours (Ortega de Miguel *et al*., 2011) (Fig.4).

– –	–	0	+	++
SBR	MBR[1)]/ RBC[1)]	VFCW	HFCW	LA

Fig. 4 – Potential of the generation of bad odours with septic tank as primary treatment.

b) *Noises*

The generation of noise at treatment stations usually comes associated with the operation of electromechanical equipment unless are soundproofed (Ortega de Miguel *et al*., 2011) (Fig.5). Noise is controlled by the indicator that measures the average number of decibels generated (dB/day).

– –	0	++
LA/VFCW/HFCW	RBC	SBR/MBR

Fig. 5 – Potential for noise generation.

c) *Landscape impact*

If small populations are located in rural or areas of high ecological value or with high quality landscaping, it is necessary to implement solutions that have a low visual impact (Ortega de Miguel *et al*., 2011).

Landscape impact considers the landscape changes because that can negatively affect people and nature (Garfi *et al*., 2011) (Fig. 6). The percentage of vegetation-covered soil that was considered in each alternative was taken into account (Riesgo & Gomez-Limon, 2006).

–	0	+
RBC/SBR/MBR	LA	VFCW/HFCW

Fig. 6 – Landscape impact.

2.3. Social Criteria

Social aspects permite to evaluate the solutions which have a positive or negative social impact on the small communities.

a) *Local participation and access*

Sometimes, rural communities are constituted by groups of agglomerated households very far from each other. Occasionally, different groups of people coexist in the same community, such as natives or minority groups (Garfi *et al*., 2011). Social values and cultural changes are likely to influence the type of technology that is appropriate for a specific country, community, or tribal context (Garfi *et al*., 2011). The aim of the local culture criterion is to ensure that local customs are respected, leading to public acceptance of the technologies and of the sustainability. Access to technology can be measured qualitatively by the percentage of the population who may be potential beneficiaries (Garfi *et al*., 2009).

b) *Migration*

A lack of water resources can force the poor population and especially that of rural areas to leave their communities and migrate to major cities (Garfi *et al*., 2011).

c) *Health*

Health refers to the possibility of improving the health of beneficiaries and reducing mortality due to diarrheal diseases in children under five years old. WHO stated that diarrheal diseases, which are the second leading cause of death at children under five years, are mainly due to the lack of safe drinking-water and improved sanitation (WHO, 2009a, 2009b).

d) *Public awareness and standard of living*

Public awareness on water, sanitation and hygiene issues considers the increase in people's consciousness in water and hygiene issues. Standard of living refers to the possibility of increasing beneficiary's income to improve their living quality (Garfi *et al*., 2011).

2.4. Economic Criteria

This section describes the economic aspects, considering the cost of the solution and the economic impact on beneficiaries.

a) *Costs*

The aim of the cost criteria is to determine the capacity of beneficiaries to pay for the implementation and maintenance of technologies. A common misconception is that an appropriate technology must be inexpensive or represent the 'least-cost' solution and this is not always the case. The most important consideration is that the cost should closely match the willingness and ability to pay of the technology users (Garfi *et al.*, 2011; Murphy *et al.*, 2009).

This criterion can be measured by analysing the communities' ability to pay, which has traditionally been evaluated by considering that households should not be obliged to pay more than 5% of their income for water services. Some biotechnological techniques are quite sophisticated but others are simple, cost effective and adapted to local conditions and resources of developing countries (Al-Ghuraiz & Enshassi, 2005).

3. Results

The following notations are used for facilitate the centralization of all the information concerning the technologies according with the selected criteria: *T*1 – the required quality of the effluent according to the receiving environment, *T*2 – population size to be treated, *T*3 – surface and characteristics of the available land, *T*4 – origin and concentration of pollutants in waste water, *T*5 – treatment versatility, *T*6 – climatology, *T*7 – production and quality of generated sludge, *T*8 – complexity in the operation and maintenance; *En*1 – production of odours, *En*2 – noise generation, *En*3 – landscape integration; *S*1 – local participation and access, *S*2 – equality and migration, *S*3 – health, *S*4 – public awareness and standard of living; *E*1 – costs.

Table 3
Legend

++	Very good
+	Good
0	Normal
–	Bad
– –	Very bad
ND	Not defined

Using the above mentioned notations and the legend from Table 3 the obtained results are concentrated in Table 4.

Table 4
Classification of Technologies According to the Selected Criteria

Technologies		ST	LA	VFCW	HFCW	RBC	MBR	SBR
	Technical							
	*T*1	0	0	+	+	++	+	+
	*T*2	0	++	++	++	++	ND	+
	*T*3	+	–	+	+	++	++	++
	*T*4	– –	–	–	–	+	–	++
	*T*5	ND	+	–	+	–	–	0
	*T*6	0	– –	++	++	ND	–	0
	*T*7	0	–	–	–	+	+	++
	*T*8	++	– –	–	0	0	+	++
	Environmental							
Criteria	*En*1	+	– –	0	–	+	+	++
	*En*2	+	++	++	++	0	– –	– –
	*En*3	++	0	++	++	– –	– –	– –
	Social							
	*S*1	0	0	0	0	++	++	++
	*S*2	0	0	0	0	0	0	0
	*S*3	+	+	+	+	+	+	+
	*S*4	+	+	+	+	+	+	+
	Economic							
	*E*1	+	++	+	+	+	–	– –
Total	+	10	9	13	14	14	10	16
	–	2	9	4	3	3	8	6

4. Conclusions

1. The most adequate waste water treatment for small communities should involve not just aspects of technical optimization, but also environmental, economic and social factors.

2. Elimination of pollutants and heavy metals is absolutely compulsory considering the human health and the environment.

3. Water treatment biotechnologies protecting the environment are less polluting and handle residual wastes more acceptable.

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CRITERII PENTRU TEHNOLOGII DE EPURARE A APELOR UZATE

(Rezumat)

Sunt prezentate sisteme de epurare biologică (lagune, zone umede construite) a apelor uzate din comunităţi mici, ţinând seama de o serie de criterii considerate ca fiind prioritare în acest studiu (aspecte tehnice, de mediu, economice şi sociale).

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APPLICATION OF “DIF” MATHEMATICAL MODEL TO SOLVING ADVECTION DIFFUSION PHENOMENA ON BAHLUEȚ WATER COURSE OF SPECIFIC POLLUTANTS RESULTING FROM THE TÂRGU FRUMOS WASTE WATER TREATMENT PLANT

BY

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Abstract. To study transport phenomena of pollutants during Bahlueț watercourse, affected in recent years by discharges of waste water, mainly from the Târgu Frumos treatment plant, we have achieved an advection diffusion modeling of pollutants discharged from the treatment plant mentioned it above, on a reach of the Bahlueț watercourse, with length of 5.3 km, bounded upstream of the discharge section of waste water into the Bahlueț watercourse and downstream by the water quality monitoring section of the Bahlueț watercourse called downstream Tg. Frumos. The case study was carried out using personal “DIF” model, developed in MATLAB programming software that uses a finite difference scheme of explicit type for integration of one dimensional advection diffusion equation.

Key words: “DIF” model; advection diffusion; Bahlueț; explicit scheme; transport of pollutants.

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1. Introduction

Ecological status of the Bahlueț water body is determined by discharges regime of constituents with concentrations above the maximum allowed from point sources (effluents of waste water treatment plants from agglomerations, from activities of industrial type, etc.) and the contribution coming from non-point sources of pollution (tillage management practices, regional policies on land use, effluent resulting from unorganized landfills from livestock, from urban landfills and industrial type, etc.) and to a lesser extent from the natural pollution of water resources under the action of climatic factors.

The main source of pollution of Bahlueț watercourse is the waste water treatment plant of the Târgu Frumos agglomeration. The Târgu Frumos agglomeration has a population of 14,572 and it has a sewerage network length of about 25 km, provided with the treatment plant with mechanical and biological treatment processes. This discharges a flow rate of approx. 53 L/s of treated water into the Bahlueț watercourse.

In 2012 were recorded exceeding of indicators: suspended solids, ammonia, organic substances (COD-Cr), total nitrogen, total phosphorus, hydrogen sulphide and total sulphide, although the treatment plant was refurbished in recent years.

Mathematical modeling of transport phenomena of pollutants in rivers is often complex due to the many factors that influence these phenomena: chemical processes, bio-chemical (such as processes of degradation/decomposetion of organic matter different variables expressed as BOD_5, complex processes of transformation of organic nitrogen to nitrite and nitrate forms), etc.

Transport processes of pollutants in water bodies are governed by the principle of mass conservation and laws that characterize the processes of advection diffusion (Fick's law), expressed as differential eqs. with partial derivatives of first order, second order, etc., depending on the considered area: one-dimensional, two-dimensional, etc. (Holzbecher, 2012).

Finite difference approximation of the partial derivatives are one oldest method for solving differential eqs., between those who had important contributions in this domain are: L. Euler, J. Fourier, C. Runge, a. o. (Thomas, 1995).

The debut of finite difference techniques used in numerical applications occurred in the 50s, and their development was simplified by the advancement of information technology and computers.

For eqs. with dependent variables in time the principle of these methods consist in replacing the partial derivatives from differential eqs. with equivalent expressions obtained from discretization fields (x, t) in space ($i - \Delta x$, i, $i + \Delta x$) and time ($j - \Delta t$, j, $j + \Delta t$). Intersection of these expressions are called *network nodes* (Stahel, 2012).

Several techniques of solving, by a numerically way the finite difference schemes were developed by the following researchers: Crank Nicholson (in that case, the scheme requiring the imposition of initial conditions and boundary conditions), Dirichlet and Neumann or a combination of the two, in which case these conditions are called Cauchy conditions (Berbente *et al.*, 1997; Crăciun, 2007).

In this context, to study the transport phenomena by the advection diffusion of pollutants into Bahlueț watercourse from the Târgu Frumos waste water treatment plant, we designed a program for numerical computation of concentration- called "DIF", which is based on a mathematical model for solving one-dimensional eqs. with partial derivatives of advection dispersion in MATLAB programming software by integrating this eqs., using explicit calculation scheme with imposed initial and boundary conditions (Stahel, 2012; Popa 1998).

2. Investigation Method

2.1. Mathematical Proceeding

Differential eqs. that characterize the transport of a constituent, C, resulting from mass conservation eq. and Fick's law (Holzbecher, 2012) is:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial x} jC_x + \frac{\partial}{\partial y} jC_y + \frac{\partial}{\partial z} jC_z \mp S_i \,, \tag{1}$$

where: C is the constituent [M.L^{-3}]; jC_x, jC_y, jC_z – dispersive mass flow distribution in space on the three ortogonal directions, [M.L^{-2}.T^{-1}]; S_i – sources and sink of the constituent, [M.L^{-3}.T^{-1}].

Continuity eq. (1) shows that the amount of change variable, C, in time equals the sum of local mass flows.

Eq. (1) can be written as

$$\frac{\partial C}{\partial t} = \nabla jC \mp S_i \,; \tag{2}$$

the Fick's law

$$j = -D\nabla C, \tag{3}$$

means that diffusive flux is proportional to the concentration gradient with opposite sign, where D is the diffusivity or proportionality factor, [L^2.T^{-1}].

For multiphase systems, two changes occur in Fick's law (Holzbecher, 2012):

The surface through which diffusive flow occurs is only a part of the total area. It is assumed that the surface is reduced by the same factor as the volume.

Fraction of pore volume (for porous media) is considered as a factor measuring the active surface. Consequently in right term appears a coefficient, θ, for porous media.

A second correction occurs when there is a system consisting of several phases. Thus, diffusive cloud is longer, due to obstruction caused by multiphase system, the pathway of diffusive cloud depending by a factor, v, greater than the one, called the *extension factor* pathway. Fick's law becomes

$$j = \frac{1}{v^2} D_{\text{mol}} \nabla C , \qquad (4)$$

or

$$j = \tau D_{\text{mol}} \nabla C , \qquad (5)$$

where τ is the *tortuosity*.

For multiphase systems the gradient of concentration coefficient, D, is the effective diffusivity D_{eff} having the expression

$$D_{\text{eff}} = \tau\theta D_{\text{mol}} \;\text{ or }\; D_{\text{eff}} = \theta^m D_{\text{mol}} \;\text{ or }\; \tau = \theta^{m-1} , \qquad (6)$$

where θ is the forming factor that depends on porosity, $[T^{-1}]$.

When the advection is present, the diffusivity is major influenced by velocity of water, so

$$D = \tau D_{\text{mol}} + \alpha_L v , \qquad (7)$$

where α_L is a factor of proportionality between velocity of water and the dispersion, [L]; v – the water velocity, $[L.T^{-1}]$.

Thus, diffusivity consists of two parts: one is attributed to molecular diffusion, the other is attributed to flowing through porous media (Holzbecher, 2012; Popa, 1998).

From eqs. (2) and (3) for one-dimensional case and taking into account the advection process, we obtain

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2} - V \frac{\partial C}{\partial x} \mp S_i , \qquad (8)$$

where $V\,\partial C/\partial x$ is the advective term.

For the rivers and open channels case eq. (8) becomes

$$A\theta \frac{\partial C}{\partial t} = A\theta D \frac{\partial^2 C}{\partial x^2} - A\theta V \frac{\partial C}{\partial x} \mp S_i . \qquad (9)$$

If eq. (8) is divided to $A\theta$, then

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} \mp A^{-1}\theta^{-1}S_i\,. \tag{10}$$

To integrate the differential eq. with partial derivatives (10) we used a finite difference scheme of explicit type (Fig. 1), discretized on the spatial and temporal domain, (x, t). For temporal derivative we used a finite difference scheme with forward derivatives and for the spatial derivative we used a finite difference scheme with backward derivatives (Stahel, 2012; Berbente *et al*., 1997; Popa, 1998; Puşcă, 2011).

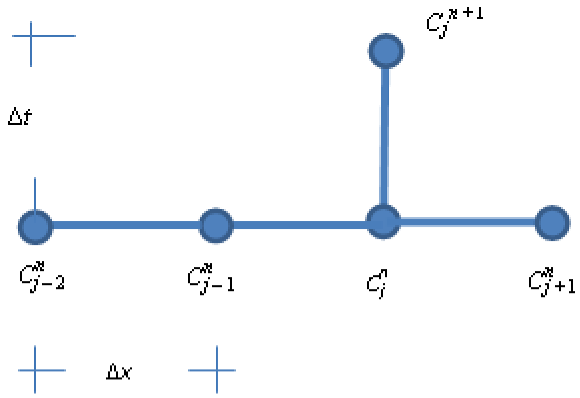

Fig. 1 – The finite differences scheme of explicit type.

Applying the above scheme, the terms of eq. (10) can be written

$$\frac{\partial C}{\partial t} = \frac{C_j^{n+1} - C_j^n}{\Delta t}\,, \tag{11}$$

$$\frac{\partial^2 C}{\partial x^2} = \frac{C_j^n - 2C_{j-1}^n + C_{j-2}^n}{\Delta x^2}\,, \tag{12}$$

and

$$\frac{\partial C}{\partial x} = \frac{C_j^n - C_{j-1}^n}{\Delta x}\,. \tag{13}$$

Applying relations (11),..., (13), eq. (10) becomes

$$\frac{C_j^{n+1}-C_j^n}{\Delta t}=D\frac{C_j^n-2C_{j-1}^n+C_{j-2}^n}{\Delta x^2}-V\frac{C_j^n-C_{j-1}^n}{\Delta x}-A^{-1}\theta^{-1}S_i \quad (14)$$

or

$$C_j^{n+1}=C_j^n+D\frac{\Delta t}{\Delta x^2}\left(C_j^n-2C_{j-1}^n+C_{j-2}^n\right)-V\frac{\Delta t}{\Delta x}\left(C_j^n-C_{j-1}^n\right)-A\Delta t\theta S_i. \quad (15)$$

We introduce following notations:

$$A=D\frac{\Delta t}{\Delta x^2},\ B=V\frac{\Delta t}{\Delta x},\ P=\theta\Delta t,\ S_i=C_j^n,\ A=\frac{Q}{V}. \quad (16)$$

After grouping terms, eq. (15) becomes

$$C_j^{n+1}=(1+A-B)C_j^n-(2A-B)C_{j-1}^n+AC_{j-2}^n-\frac{V}{Q}C_j^n\frac{P(\theta)}{\Delta t}. \quad (17)$$

The unknown term of eq. (17) is C_j^{n+1} from the current time *n* + 1 which is calculated using known terms of the eq., on computing time, *n*, in space node, *j*, and neighboring nodes, *j* – 1, *j* – 2 (the C_j^n, C_{j-1}^n and C_{j-2}^n values) (Popa, 1998; Puşcă, 2011).

2.2. Initial Data

To running the "DIF" model is required setting hydraulic parameters characterizing flowing regime in the Bahlueț watercourse, the quality parameters of Bahlueț watercourse and initial parameters of Târgu Frumos effluent treatment plant.

1° *Hydraulic parameters*

a) The Bahlueț water flow rate, average annual flow of the Bahlueț watercourse for the period 2007... 2011, varies between 0.083 m^3/s (in 2007) and 0.296 m^3/s (in 2011).

b) The Târgu Frumos WWTP effluent flow –0.050 m^3/s.

c) The Bahlueț watercourse velocity: Bahlueț watercourse velocities are ranged between 0.23...0.89 m/s (Păduraru, 2012).

d) Longitudinal dispersion coefficient determined according to

McQuiveys relationship (Chapra, 1996):

$$D = 0.05937 \frac{Q}{S_f} B\,, \tag{18}$$

where: Q is the water flow rate, [L^3T^{-1}]; S_f – slope energy line; B – wetted bed width, [L]; $\theta = f(P)$, with

$$P = \left(c_i - c_p \rho_p\right) \frac{\partial \theta_s}{\partial t}\,, \tag{19}$$

$$c_p = \frac{k_L S_i c_i}{1 + k_L c_i}\,, \tag{20}$$

here: P is a factor characterizing diffusion in porous media; c_i – the concentration of a chemical species, [ML^{-3}]; c_p – concentration diffused through the pores of multiphase media, [ML^{-3}]; S_i – the sorption coefficient, [L]; k_L – Langmuir's constant, [L^3M^{-1}]; ρ_p – density of chemical species, [ML^{-3}]; θ – loss factor by chemical reaction or formation factor, [T^{-1}].

2° *Concentrations of selected pollutants* in the discharge section of the treatment plant effluent into the emissary (Table 1).

Table 1
Initial Data for Running the "DIF" Model

Type of constituent	Maximum Concentration mg/L	Injection time min.	Longitudinal dispersion coefficient m^2/s	θ, [T^{-1}]
NO_3^-	10.03	600	5	0.03
Total P	0.43	600	5	0.03
Total Zn	0.01455	600	5	0.03

3. Results

a) Simulation of NO_3^- (nitrate) pollutant transport on the reach with a length of 5,300 m; the result are represented in Figs. 2 and 3.

By modeling the advection diffusion processes we obtained maximum concentration of 8.85 mg/L NO_3 after a transport time of approx. 380 min, the values of NO_3 concentrations from the monitoring program of Bahlueț watercourse in the Târgu Frumos downstream section (Fig. 4) are between 11.40...17.20 mg/L, higher than the value obtained by applying "DIF" model.

The differences can be attributed to the contribution of non-point pollution because Bahlueț watercourse bed is bordered mainly by agricultural land use.

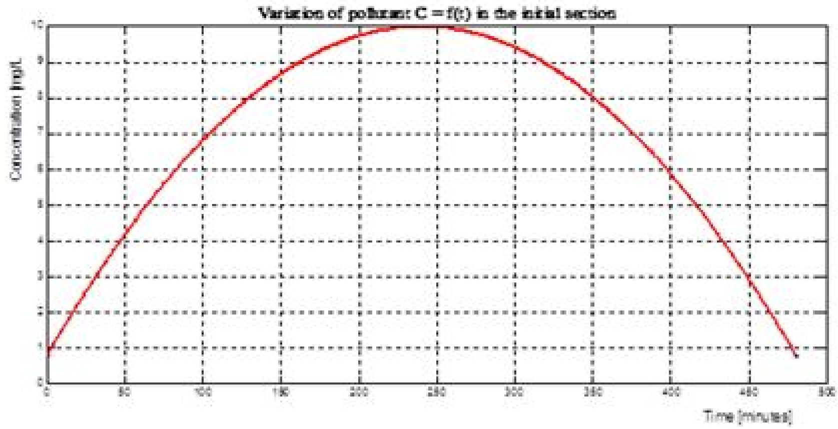

Fig. 2 – Variation of the NO_3 concentration in the initial section.

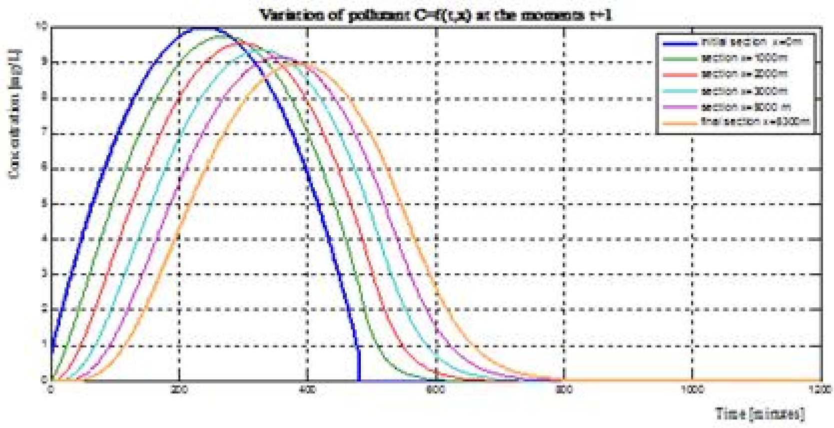

Fig. 3 – Variation of the NO_3 concentration in downstream sections of the reach chosed for simulation.

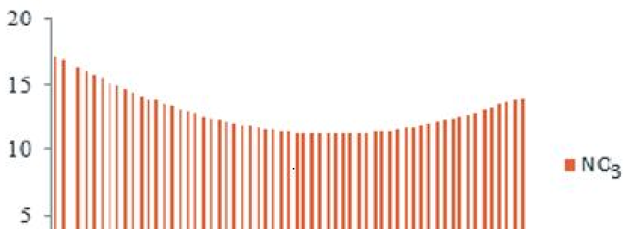

Fig. 4 – Variation of the NO_3 concentration in downstream sections in Târgu Frumos monitoring section of a Bahlueț watecourse.

"DIF" model at this stage does not take into account the contribution of non-point pollution.

b) Simulation of Total P (total phosphorus) pollutant transport on the reach with a length of 5,300 m; (Figs. 5 and 6)

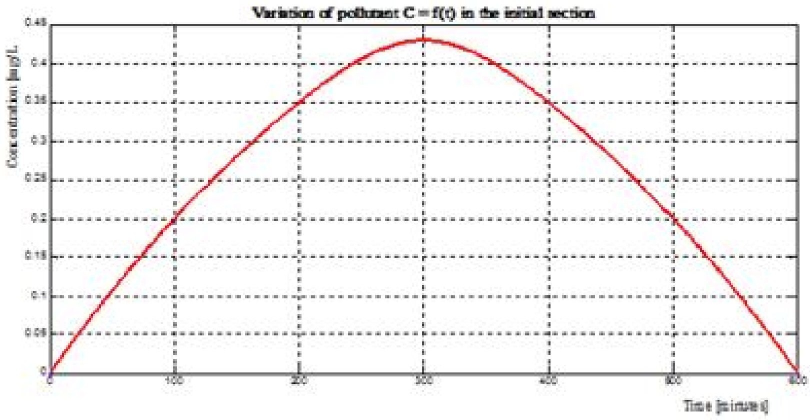

Fig. 5 – Variation of the total P concentration in the initial section.

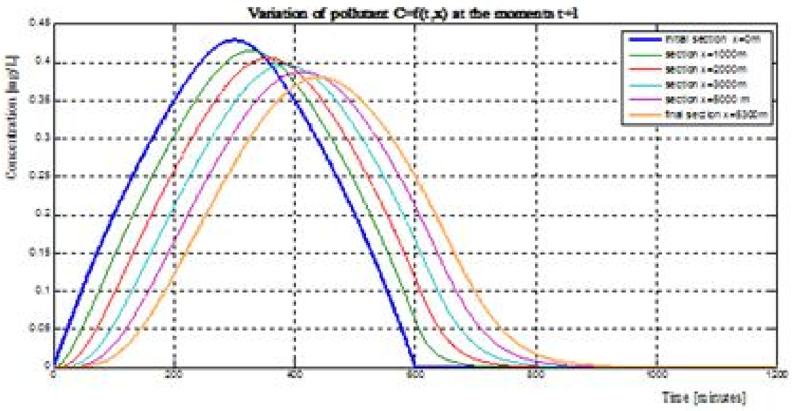

Fig. 6 – Variation of the total P concentration in Târgu Frumos in downstream sections of the reach chose for simulation.

By modeling the advection diffusion processes, we obtained a maximum value of Total P concentration of 0.383 mg/L after a transport time of approx. 450 min, the values of Total P concentrations from the monitoring program of Bahlueț watercourse in the Târgu Frumos downstream section (Fig. 7) are situated between 0.26...0.550 mg/L so that the obtained value by applying of "DIF" model is included in this range.

c) Simulation of Zn pollutant transport on the reach with a length of 5,300 m (Figs. 8 and 9).

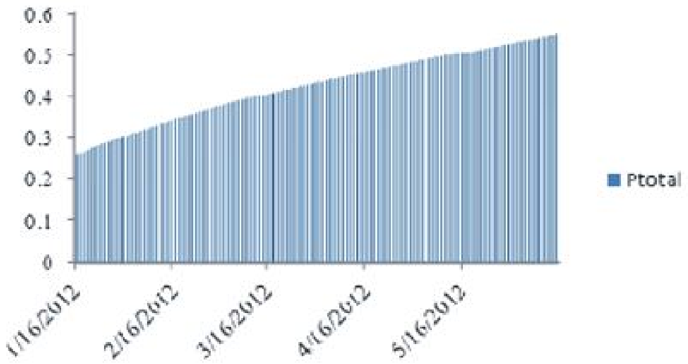

Fig. 7 – Variation of the total P concentration in Târgu Frumos monitoring section of a Bahluet watecourse.

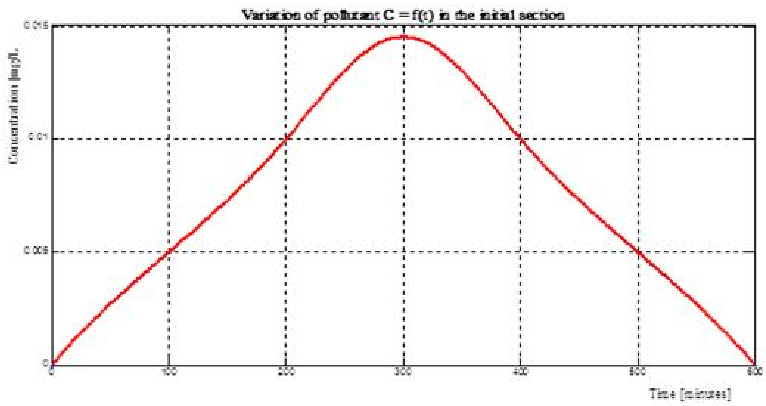

Fig. 8 – Variation of the total Zn concentration in the initial section.

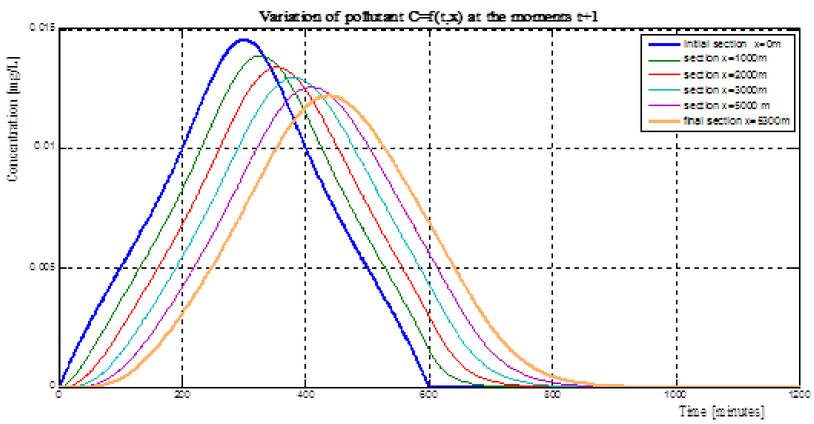

Fig. 9 – Variation of the total Zn concentration in downstream sections of the reach chose for simulation.

By modeling the advection diffusion processes, we obtained a maximum value of total Zn concentration of 0.0132 mg/L after a transport time of approx. 457 min, the values of total Zn concentrations from the monitoring program of Bahlueț watercourse in the Târgu Frumos downstream section (Fig. 9) are situated between 0.0121...0.01455 mg/L, so that the value obtained by applying the “DIF” model is included in this range.

4. Conclusions

1. By applying the numerical model computing “DIF” in finite differences with the integration scheme of explicit type we obtained close values of the modeled pollutants to the values of existing monitoring so that „DIF” model can be validated.

2. By the case study carried out on a reach of the Bahlueț watercourse using existing mathematical expressions in the engineering literature and by the “DIF” model that we have created, we highlighted the impact it has the effluent of the Târgu Frumos treatment plant to the ecological potential of Bahlueț water body in particular way and generally the effluents of the waste water treatment plants impact has on the natural emissaries. Thus, the mathematical and numerical “DIF” model can also be used in other water bodies in similar conditions, to estimate the advection diffusion processes of pollutants in water resources.

3. The “DIF” model can be used with good results in case of accidental pollution production, when is necessary to evaluate the risks of pollutants discharged into natural emissaries on the water uses facilities from the downstream and the conditions from the field does not allow for strict monitoring of quality receiver.

Basically, knowing the concentration of the pollutant at the point of injection to the rivers and some hydraulic elements of the water body the different scenarios can be make regarding the propagation times of the pollutant wave on the downstream sections (the length between sections of the variation calculated pollutant can be modified to a greater accuracy), the assessment occurring at interval of few minutes. Thus, the best strategy of action may be adopted to limit the effects of accidental pollution.

4. The “DIF” is also useful for obtaining more accurate data on water quality studies, the basin forecasts, water quality synthesis, may contribute to the plan of management of the river basins and water management studies.

5. Thus, “DIF” model is part of the methodology which can be used in ecological potential monitoring of water bodies according to the Water Framework Directive 2000/60 / EC.

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APLICAREA MODELULUI MATEMATIC „DIF" LA SOLUŢIONAREA FENOMENELOR DE ADVECŢIE DIFUZIE ÎN CURSUL DE APĂ BAHLUIEŢ A UNOR POLUANŢI REZULTAŢI DIN STAŢIA DE EPURARE A ORAŞULUI TÂRGU FRUMOS

(Rezumat)

În scopul studierii fenomenelor de transport a poluanţilor in cursul de apă Bahlueţ, afectat în ultimii ani de evacuările de ape uzate provenite în principal din staţia de epurare a oraşului Târgu Frumos, s-a realizat modelarea advecţiei difuziei unor poluanţi evacuaţi din staţia de epurare menţionată anterior, pe un tronson al cursului de apă Bahlueţ, cu lungimea de 5,3 km, delimitat amonte de zona evacuării în emisar şi în aval de secţiunea de monitorizare a calităţii apei pe cursul de apă Bahlueţ, aval de Târgu Frumos. Studiul de caz a fost efectuat cu ajutorul modelulul original „DIF", elaborat în mediul de programare MATLAB, ce utilizează o schemă cu diferenţe finite de tip explicit pentru integrarea ecuaţiei diferenţiale cu derivate parţiale unidimensională, a advecţiei difuziei.