The Nuntași Riverbed Hydraulic Distribution Vector Speed

Prof. PhD.eng. **Mariana PANAITESCU**[1], Prof. PhD.eng**. Fanel-Viorel PANAITESCU**[2]

[1] Constanta Maritime University,marianapan@yahoo.com

[2] Constanta Maritime University,viopanaitescu@yahoo.ro

Abstract: *In Romania, the current legislation provides normatives for knowledge, rational use, protection of water resources, and also organizes specific activities of defence against floods and supervises the quality of groundwater resources through prevention and control measures in case of accidental pollution.*
These things we pursue in this paper which aims the assessing and hydraulic modeling of surface water environmental risk.
All abstractions of groundwater in South Dobrudja must be protected against pollution by setting up hydro and sanitary protection zones, in order to ensure a better exploitation of groundwater resources. The most accurate method of determining protection zones is represented by mathematical modeling. Modelling gives a qualitative, sufficiently complete image of the free surface flows, as well as a satisfactory quantitative assessment. The paper present the modeling of the riverbed with environmental eroding risk in Dobrudja area with applicability on the lake basin Nuntasi using MIKE and ArcGis software.

Keywords: *riverbed, surface water, hydraulic modeling, environment, risk, lake*

1. Introduction

In Romania, the current legislation provides normatives for knowledge, rational use, protection of water resources, and also organizes specific activities of defence against floods and supervises the quality of groundwater resources through prevention and control measures in case of accidental pollution.
Dobrudja is composed of three major structural blocks namely: Dobrudja South, Central Dobrudja and North Dobrudja separated by faults Capidava -Ovidiu and Peceneaga - Camena (Fig. 1). More than 80% of Dobrudja appears to be siliceous rocks [1]. Dobrudja catchment area is very poor in own surface resources. Basically, they consist of several major rivers surface (so far there is no use in rivers due to low water flow permanently) and in coastal lakes and related Danube [2].

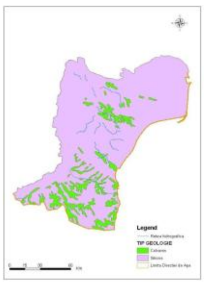

Fig. 1. Structure of Dobrudja bocks [1] **Fig.2.** DOBRUDJA hydrographic Basin [3]

The catchment area Dobrudja identifies 16 rivers with areas greater than 10 km², 18 natural lakes and four water storages that are larger than 0.5 km².
Dobrudja Basin consists of Seaside and streams tributary to the Danube River catchment area corresponding to Dobrudja (Figure 2) [3], [4].
To characterize a basin is necessary to know its characteristic elements-morphological variables of the watercourse system (Fig. 3). These can be divided into:

- Elements of hydrology and river network
- Geological features
- Features on vegetation.

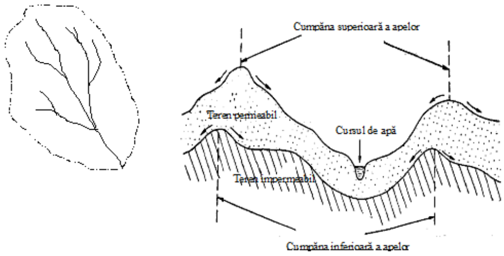

Fig.3. Hydrographic basin schema

Hydrogeologic basin represents the aquifer (underground), simple or complex, where the groundwater flows to surface to the same element drainage that can be a stream or a line of springs. Evaluation of the scheme of water flows is determined mainly by the knowledge of two categories of information: morphometry river system; hydrometric river system. Morphometric characteristics of the river system are expressed through: transversal profile of the riverbed; longitudinal profile of the riverbed; flashy stream.
Hydrometric data, obtained using methods and techniques is represented by the level of surface currents; surface currents speeds; surface currents flow. With these elements we represent the limnimetric key and the flow hydrograph.

2. Methods and research

Process modeling of flow and transport for free level aquifers involves the imposition of special conditions, especially due to variation in the free surface.
Basic equations of mathematical modeling of flow dynamics of non permanent surface water are based on the following physical principles: continuity equation (conservation of mass fluid respectively contaminant); equation of time (when fluid conservation, energy conservation (H. - J. Diersch, 2005) [5], [6]. General modeling assumptions are: incompressible fluid and homogeneous, two-dimensional flow, parallel throughout the riverbed slope small bed, small variations in the parameters of cross sections, the distribution date hydrostatic pressure [6].
Depending on the model attached flow modeling adds specific equations [6], [7].
Free level aquifers approach depends on the case - two-dimensional or three-dimensional. The usual method, preferred in hydraulic modeling, involves the calculation of free surface on a fixed network.
Solving numerical patterns of flow for whites erodible purpose engineering is based on the Finite Difference numerical integration of a system of algebraic equations, nonlinear rule.
Modeling the river bed with environmental eroding risk the following elements need to be studied:

- Data location and description of the catchment area, applicable to Nuntasi;
- Data on power sources aquifer basin, applicable to Nuntasi;
- Balance river flows in the Dobrudja area for 1999, 2004, 2007 and 2010;
- Reporting to the climatologically normal space Dobrudja basin [8].
- Hydrometeorological regime for Nuntasi catchment area reported to Constanta County [8].

The analysis will be done for the creek Nuntasi and not for Lake Nuntasi.
Balance flow to the hydrographic area Dobrudja for 1999, 2004, 2007 and 2010 is shown in Table 1.

TABLE 1: Balance flow to the hydrographic area Dobrudja

Year	**Balance flows**	**Inlet flow [m3 /s]**	**Outlet flow [m3 /s]**
1999*[27]*	North boundary West boundary South boundary Black Sea Surface supplementary flow	- - - - 91 367.34	5417.58 7 869.45 17 98.06 60 800.55 -

2004	North boundary West boundary South boundary Black Sea Surface supplementary flow	- - -175.33 - 98 452.89	5923.72 8104.57 1945.27 67845.13 -
2007	North boundary West boundary South boundary Black sea Surface supplementary flow	- - -189.37 - 99 321.23	6123.48 8765.41 2006.39 69929.16 -
2010	North boundary West boundary South boundary Black Sea Surface supplementary flow	- - 143.28 - 39 987.25	2 320.63 4 248.47 8 579.01 24 998.52 -
TOTAL		329 636.69	286675.83

Supply aquifer - is mainly from rainfall and the loss of irrigation water systems.
Nuntasi Lake River Basin lies between 28^0 37''30' NV and 28^0 45' N-E and also parallel 44° 30 'latitude and parallel 44° 35' (Fig. 4)[9].

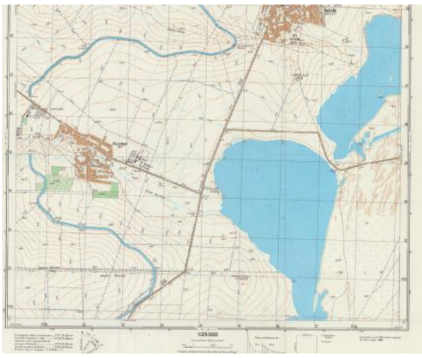

Fig. 4. Nuntasi River Basin [9]

Study of modeling assumptions are:
- flow-permanent, two-dimensional, parallel throughout the riverbed,
- incompressible fluid and homogeneous,
- slope small bed, small variations in the parameters of cross sections
- hydrostatic pressure distribution date [36].

The equations for the flow cross-section are the Saint-Venant equations (1), (2), (3), (4) and for along the riverbed flow, the turbulent flow equations, equation for turbulent kinetic energy (6), dissipation equation ε (7):

$$\rho \cdot Q \cdot dt - \rho \cdot (Q + \frac{\partial Q}{\partial x} dx) dt = \rho \cdot dA \cdot dx = \rho \cdot \frac{\partial A}{\partial t} dx \cdot dt \; ; \qquad (1)$$

where

$$\frac{\partial Q}{\partial x} = \frac{\partial A}{\partial t}, \qquad (2)$$

$$\frac{\partial Q}{\partial x} - B \cdot \frac{\partial h}{\partial t} = 0 \; ; \qquad (3)$$

and conservation of momentum equation (4)

$$\frac{\Delta M}{\Delta t} = \frac{\Delta(M \cdot U)}{\Delta x} + \frac{\Delta p}{\Delta x} - \frac{F_f}{\Delta x} + \frac{F_g}{\Delta x}; \quad (4)$$

where

M- total momentum; Δ(M.U) - momentum of flow debt; $\frac{\Delta p}{\Delta x}$ - hydrostatic pressure distribution; $\frac{F_f}{\Delta x}$ - variation of frictional force with riverbed; $\frac{F_g}{\Delta x}$ - contribution of gravity force on Ox axis.

The differential equation of flow is (5):

$$\frac{\partial Q}{\partial t} + \frac{\partial(\alpha \frac{Q^2}{A})}{\partial x} + g \cdot A \cdot \frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 A \cdot R} = 0, \quad (5)$$

where

Q- fluid flow [m^3 /s]; h-depth of water in riverbed [m]; C- Chézy coefficient (C=1.R1/6/n); n- Manning coefficient, roughness; A-cross area [m^2]; R-hydraulic radius [m].

The equation for turbulent kinetic energy (6) and dissipation equation ε (7) are

$$\frac{\partial}{\partial t}(\rho_m k) + \nabla \cdot (\rho_m \bar{v}_m k) = \nabla \cdot \left(\frac{\mu_{t,m}}{\sigma_k} \nabla k \right) + G_{k,m} - \rho_m \varepsilon; \quad (6)$$

$$\frac{\partial}{\partial t}(\rho_m \varepsilon) + \nabla \cdot (\rho_m \bar{v}_m \varepsilon) = \nabla \cdot \left(\frac{\mu_{t,m}}{\sigma_\varepsilon} \nabla \varepsilon \right) + \frac{\varepsilon}{k}(C_{l\varepsilon} G_{k,m} - C_{2\varepsilon} \rho \varepsilon); \quad (7)$$

where mixture density ρ_m consist of several phases (α_i........ α_N), with density ρ_i (8), speed vector $\bar{v}_m$ (9), component concentration z, $C_{l\varepsilon}$, k- permeability tensor, μ-cinematic viscosity, ε -phases volume fraction α (10)

$$\rho_m = \sum_{i=1}^{N} \alpha_i \rho_i; \quad (8)$$

$$\bar{v}_m = \frac{\sum_{i=1}^{N} \alpha_i \rho_i \bar{v}_i}{\sum_{i=1}^{N} \alpha_i \rho_i}; \quad (9)$$

$$\mu_{t,m} = \rho_m C_\mu \frac{k^2}{\varepsilon} \quad (10)$$

Turbulent kinetic energy generated on speed gradient will be done by formula (11):

$$G_{k,m} = \mu_{t,m} \left(\nabla \bar{v}_m + (\nabla \bar{v}_m)^T \right) : \nabla \bar{v}_m \quad . \quad (11)$$

Mixture density will be (12)

$$\rho_m = \sum_{i=1}^{N} (\alpha_i \cdot \rho_i) \quad . \quad (12)$$

Mixture speed will be (13) $$\bar{v}_m = \frac{\sum_{i=1}^{N}(\alpha_i \cdot \rho_i \cdot \vec{v}_i)}{\sum_{i=1}^{N}(\alpha_i \cdot \rho_i)}. \quad (13)$$

Turbulent viscosity is done by formula (14)

$$\mu_{t,m} = \rho_m \cdot C_\mu \cdot \frac{k^2}{\varepsilon}, \quad (14)$$

where C_μ is a constant.
So, turbulent kinetic energy which is generated on speed gradient will be (15)

$$G_{k,m} = \mu_{t,m}\left(\nabla\vec{v}_m + (\nabla\vec{v}_m)^T\right) : \nabla\vec{v}_m. \quad (15)$$

For the flow modeling we select a sector and we will note the geometric and hydraulic parameters and related to this sector, the settling flow diagram by hydraulic modeling [10]. In our case, the modeling will be done by using software MIKE 11 [11].
Flow stability is required for the convergence of the solution achieved by modeling, given the initial conditions and the approximation by finite differences that need to be consistent.
Explicitly provided stability is the number Courant (16) [10], where Cr <1.

$$Cr = (\sqrt{g \cdot D} + v) \cdot \frac{\Delta t}{\Delta x}. \quad (16)$$

Boundary conditions of the flow are:
- discharge flow upstream of the control section, downstream
- tributaries flow
- condition for convergence solution-end flow, Q = 0
- water depth, h (1 ÷ 2.3) m
- weather-wind, currents
- conditions for Q / h downstream flow (never upstream).

There was used information provided by operating with ArcGis software (Fig. 5), software MIKE Zero (Fig. 6) and Nuntasi topographic map of the basin (Fig. 4).

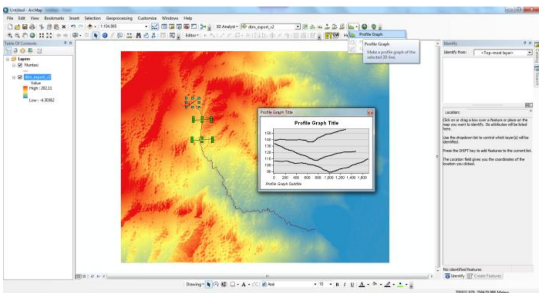

Fig. 5. Location Nuntasi River Basin on ArcGis [35]

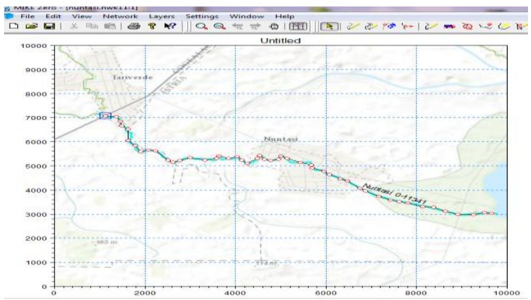

Fig. 6. Nuntasi basin topographic map-MIKE [36]

Based on topographic data, initial hydraulic data and data obtained by graphic-analytical and also the limnimetric key of Nuntasi riverbed using MIKE 11 software was simulated a flow specific to a situation of flood in 2007 and compared to the level of 1999 (Fig. 7).

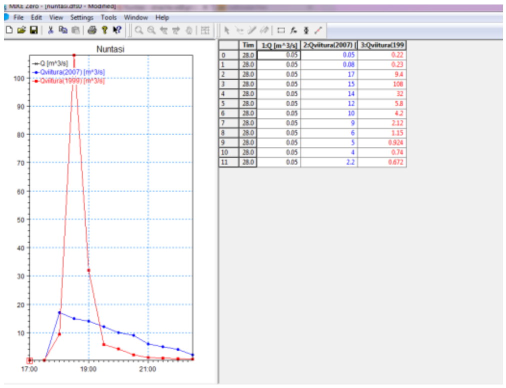

Fig. 7. Flow simulation for two discharge flow (flood in 1999 and 2007).

3. Results and interpretations

Varying flow was analyzed from downstream to upstream along the length of 14 km of the river course. We used first the ArcMap program's related information to determine files of the Nuntasi river’s spatial route (Fig. 8).

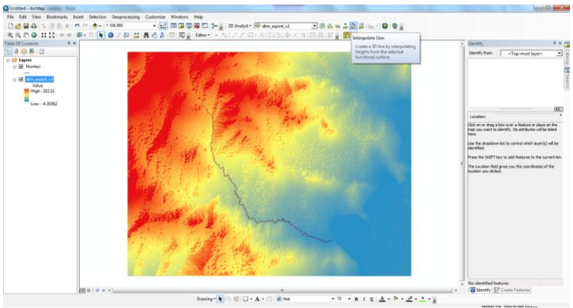

Fig. 8. Shapefile with the plan river route of Nuntasi

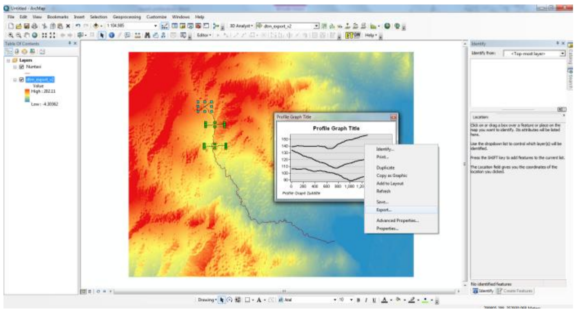

Fig. 9. Digital Terrain Model for framing Nuntasi river

With this information was passed to achieve digital terrain model to fit Nuntasi River (Fig. 9). Subsequently, was used ArcGIS software to extract cross sections of the course of the river. With this information entered into the program MIKE 11 resulted files giving details of the actual flow section of the river wedding party. The final results of modeling with MIKE 11 program are plotting and maximum rates for the flood of 2007 (Fig. 10) and flow profile along the riverbed Nuntasi (Fig. 11).

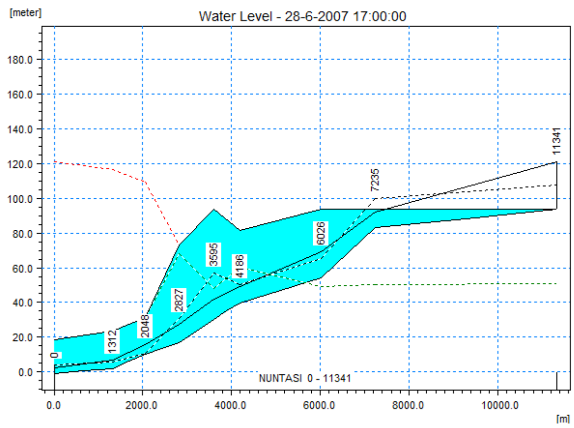

Fig. 10. Shares riverbed for flood in 2007.

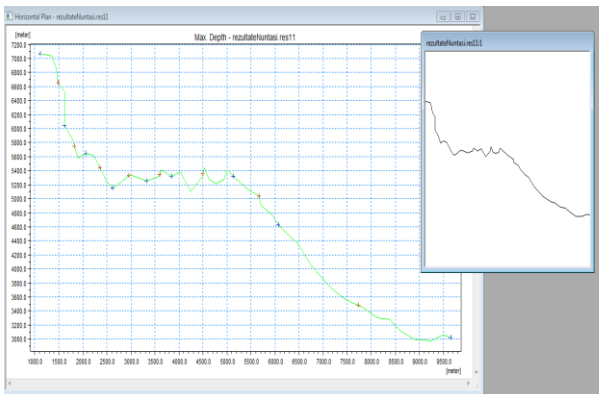

Fig. 11. The final flow speed along the riverbed

On the length of Nuntasi river was represented the allowance variation of the riverbed, the distribution of the velocity vector for related shares initially introduced in the program.

4. Conclusions

One of the risk factors is represented by the floods. For studying the flow in the Nuntasi riverbed eroded with environmental risk were analyzed elements: location and description of the hydrographic area, data sources feeding the aquifer basin data sources feeding the aquifer basin balance flows to the hydrographic area Dobrudja for 1999, 2004, 2007 and 2010, reporting to the climatologically normal catchment area Dobrudja; hydro meteorological regime for the guests catchment area reported at Constanta County; morphological and morphometric elements of the bed of the guests; Nuntasi riverbed proper flow modeling.
Building the model accordingly to Nuntasi basin riverbed assumed the existence of a stage modeling that was done with the program MIKE 11 situation of 2007, to a forecast of rainfall for a period of 14 hours, the hydrograph basin Nuntasi, based on rainfall intensity curve; then there is simulated the flow along the river, indicating the distribution of speeds of flood related natural hydrograph.

Acknowledgement

Thank you for supporting Romania DHI Company using ArcGis and MIKE 11, especially Mrs. Director Maria Cheveresan and Mr. Mihai Valentin Stancu, Hydro technician engineer.

References

[1] M. Ielenicz, I. Săndulache, "Romania - Platteaus and Hills" (România - podişuri şi dealuri), University Publishing House, Bucharest, 2008;
[2] D. Scradeanu, A. Gheorghe, "General Hidrogeology", chapter "Natural factors supply and underground waters regime" (Hidrologie generala, cap. Factori naturali ai alimentarii si regimului apelor subterane", Technical Publishing House, Bucharest, pp. 1-42, 2014;
[3] http://www.rowater.ro/daDobrudja/, "Planul pentru prevenirea, protecţia şi diminuarea efectelor inundaţiilor în spaţiul hidrografic Dobrudja-Litoral", slides, sl.9, 2012;
[4] M. Panaitescu, F.V. Panaitescu, "Hydraulics. Theory and applications", Nautica Publishing House, Constanta, 2011;
[5] I. Mircea, "Modelarea curgerii apei subterane prin acviferul cantonat în calcarele sarmaţiene din DOBROGEA DE SUD" (Modeling of groundwater flow through aquifer garrisoned in the sarmathian calcars in SOUTHERN DOBRUJA), Bulletin AGIR, nr. 3, pp.113-116, 2013;
[6] *** Hydro-Informatics, Modelling tools MIKE 11, Part 1-Introduction, IHE 2001-2003;
[7] *** "Bulletin on risk assessment: Risk assessment as an aid to dam safety management", I.C.O.L.D., 102 p., 1999;
[8], http://www.isuDobrudja.ro/wp-content/uploads/2016/03/Planul-de-Analiz%C4%83-%C8%99i- Acoperire-a-Riscurilor-al-jude%C8%9Bului-CONSTAN%C5%A2A-2015.pdf, "Planul de analiză şi acoperire a riscurilor al judeţului Constanţa", pp.14-20/83, 2015;
[9] Archives of M.A.N., R.S.R., Military Topographic Directorate, 1981;
[10] I.A. Enache, "Modeling of flows components of the waters from Dobrudja – Seaside Hydrographyc Basin" (Modelarea componentelor scurgerii apelor din bazinul hidrografic Dobrogea-Litoral), Bachelor's thesis, Constanta, 2014;
[11] R. Courant, K.O. Friedrichs, H. Lewy, "On the partial difference equations of mathematical physics", Math. Ann. vol.100, 1928.