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SEDIMENT TRANSPORT MODELING WITH ADVANCE HYDRAULICS SOFTWARE

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Abstract

This study investigates sediment transport dynamics in the Dognecea River, located in Caraș Severin County using MIKE 11. Numerical simulations were conducted to analyze sediment deposition, erosion patterns, and structural interactions. The sediment transport model considers multiple factors, including riverbed sediment characteristics, hydrodynamic conditions, and structural modifications. The sediment transport model has several applications, with variations in parameters such as study objectives, allocated resources, time scale, space, context of the study team, required accuracy, etc. The characteristics of the sediments in the riverbed are a necessary component to know for modeling sediment transport. It is proposed to collect additional sediment samples from the sediments of the layer. The samples obtained will be analyzed according to the size of the particles in the bed. To address sediment transport issues in the Dognecea River, advanced water flow modeling programs are used. Numerical modeling was performed using the MIKE11 software, incorporating hydraulic flow simulations to analyze sediment transport dynamics. Transport models can be used in the case of small alluvium, such as mud or clay, to non-cohesive deposited alluvium, such as boulders, small ballast and sand, but also mixed sediments. MIKE 11 provides several options for modeling the movement over time of alluvial transport, as well as structural changes in the riverbed. The results provide insights into alluvial transport behavior and offer solutions for mitigating sediment-related challenges such as riverbed clogging and erosion control. The findings demonstrate the effectiveness of MIKE11 in modeling hydraulic and sediment transport processes, making it a valuable tool for water resource management and flood risk mitigation.

Key words*: bed roughness, hydraulic modelling, sediment transport.*

INTRODUCTION

The Dognecea River, located in Caraș Severin County is affected by significant sediment transport processes. These issues impact infrastructure, water quality and flow parameters, necessitating advanced modeling techniques for effective management.

The Dognecea River originates in the Dognecea Mountains and flows through valleys and hilly areas, carrying alluvial materials, including loess deposits.

The upstream section is the built-up area, where the process of riverbed erosion manifests itself, this erosion threatens the stability of the county road, houses, as well as in the lower region of the village, where new households appeared in the area and the riverbed was completely clogged, which led to the overflow of the stream and the riverbeds.

Near the dam, built in 1750 to supply industrial water to the furnaces in Dognecea, sediment deposition occurs along the entire stretch from upstream to downstream, even starting from upstream to downstream, the sediments are deposited by transporting water to a depth of 265 m that causes erosion up to the rock, the banks being eroded, thus washing away the existing works, and the area presents phenomena of unconsolidated erosion. As a result of the floods, the existing works on the downstream section of the dam as well as the town hall are damaged. The masonry constructions have also been affected; the stone walls have been washed and the bridges destroyed.

Downstream, due to the low slopes and lack of excessive banks, the materials released from upstream are deposited downstream of the village. This leads to the accumulation of fine sediments that cause clogging and flooding of roads and households (Figure 1) (ANIF, 2024).

To mitigate flood-related damage, erosion protection measures have been implemented along the Dognecea River, aiming to stabilize the banks and safeguard the surrounding settlements. At the confluence with the Calina

River, upstream, the hydrograph of the Dognecea River has the following characteristics: route length 18 km, basin area 61 km, upstream altitude 420 mdM, downstream altitude 151 mdM, average altitude 388 mdM, average slope of 15%, convolution coefficient 1.27, forest area 4741 ha. In order to verify the capacity of the natural riverbed, transition calculations of the probability of exceeding Q5% flow were performed for determining the appropriate section sizing.

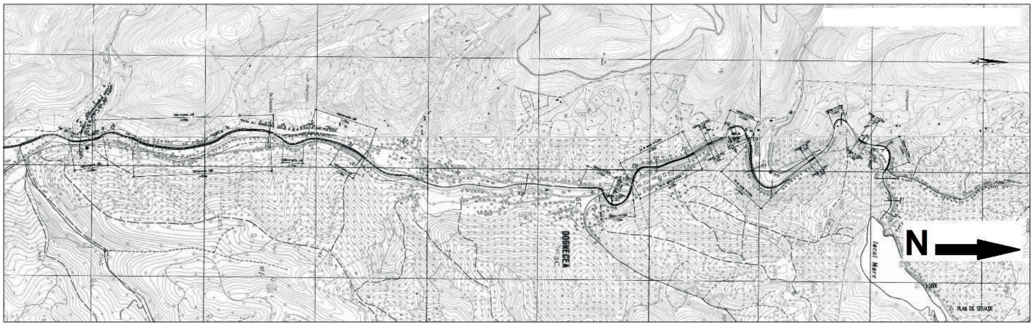

Figure 1. Plan view of Dognecea River

As a result, a remodeled, the remodeled section of the Dognecea stream was established between two predetermined trapezoidal points, which have a slope of 1:1.5 and 8 m wide at the base and a length of 2000 m.

Following the excavations, the resulting embankment material will be used for filing or lateral reinforcement, ensuring profile compensation across sections.

The weight of the stone retaining wall, L = 1000 m is applied in the major riverbed of the Dognecea stream (causing erosion and soil overload). Reinforcement bench with gabion boxes along a length of 1165 m with a section of 1.0×1.0×3.0 m, 1.0×1.5×3.0 m made of OB37 concrete steel frames, with a diameter of 16mm located at a distance of 1.00 m and OB37, with a diameter of 10 mm internally welded at a distance of 0.5 m, galvanized mesh with a size of 40×40 mm.

The foundation will be made on a bed of fascines 0.3 m thick and 3.0 m in length, and the boxes are filled with ballast of different sizes. The stone elements will be arranged similarly to plasterboard layers for enhanced load distribution. The cassettes are connected from all directions with OB steel (6 mm diameter), with a 2 mm gap (NARW, 2024).

The boxes are mounted on both banks of the stream to protect riparian roads, stabilize the riverbanks, and prevent sediment entrainment. These structures will also help reinforce existing constructions along the river. To mitigate bank erosion, gabion boxes will be applied on the fascines and a layer of earth on the calculation slope h = 2.0 m total length L = 2130 m. The studied section features a box gabion structure with the following dimensions of 1.0×1.0×3.0 m, the section is based on an elastic mattress with a thickness of 0.3 m and a free length of 1.0 m.

To achieve the required height, the transit flow measurements of the embankment were ensured by tilting the embroidery by 1.00 m from 0.30 m of broken stone for the drainage of aggregates to 0.15 m. Box gabions shall be at least 1.0 m thick.

The installation of gabion boxes will help achieve the following objectives the reduction of drainage tariffs, the reduction of the longitudinal slope and the stabilization of the riverbed.

This study aims to model sediment transport dynamics using MIKE 11 software to assess potential mitigation measures and improve flood risk management.

MATERIALS AND METHODS

The MIKE 11 program is a hydraulic modeling software designed to simulates water flow and level, water quality, sediment transport in rivers, canals, estuaries, sewage systems and different types of water systems. The MIKE 11 model was used to simulate unsteady flow and sediment transport, following methodologies similar to those applied in previous studies (Ivanescu et al., 2014), where MIKE 11-UHM and MIKE 11-HD were used for hydrodynamic modeling and runoff simulations. Connecting MIKE 11 can be integrated with GIS and ArcGIS enabling them to extract cross-sections, watershed contouring and which assist in risk assessment and mitigation. Flax to achieve these objectives or to be used as a forecasting tool. Hydrotechnical structures such as: spillways, canals/galleries, ridges, staves, pumps or control and regulation structures; or even the breaking of dams and dams (Huai et al., 2021).

Because of accumulation, we get a modeling dynamic that:

- Consider accumulation volume available in the canals and in the adjacent major riverbeds;
- Flood mitigation by delaying the peak of the flood, it allows a slow accumulation in the riverbeds Major;
- Allows water to retreat into riverbeds as flooding subsides.

Within the MIKE 11 software package, the MIKE Zero interface provides access to a range of modeling options.

Once in the actual numerical modeling phase, a program will be created. simulation (Simulation Editor - .sim11) that will be always kept open (valid for any type of work in MIKE 11), this is the main control center in MIKE 11. Access all the files necessary for running the program and their intercommunication.

The simulation editor also specifies the type of models that will be used and the simulation mode (permanent/non-permanent). The files used in the simulation will be added, depending on the type. The simulation we want to create. These will be:

- Network configuration;
- Cross sections data;
- Boundary conditions;
- Precipitation and runoff parameters;
- Hydrodynamic parameters;
- Advection/dispersion parameters;
- ECOLab parameters for water quality modeling;
- Time series data;
- Frost related parameters, etc.

The "Simulation" table within the simulation editor contains the initial conditions, the time step taken into account and aditional details regarding the simulation.

The period can also be calculated from here maximum simulation, based on the data entered the system; Time step can be entered as fixed, tabular or adaptive. Also, the time step can be set from seconds to days depending on the scale and precision required for the simulation. The difference between the start and end times of the simulation is proportional to the selected time step and the total duration of the model run.

In the "Start" section of the Simulation Editor, the system validates whether all input files are correctly set up. If any file is not marked in green, it is considered invalid, preventing the simulation from running. Once all files are validated (green indicators), the simulation can proceed, generating a text file ("Simulation") that can be edited in any text editor.

The Network Editor (.nwk11) defines the plan view, river network, and hydrotechnical structures. Users can upload graphical visualizations of the network, import saved files (e.g., JPEG, ASCII), and modify dimensions as needed. The interface also allows integration with MIKE 21 (DFS2) files, enabling overlaying and adjusting data layers (Hausler et al., 2019).

The hydrological network data can be modified within the network options settings, allowing users to select or deselect connected components dynamically. The river network is displayed graphically, enabling adjustments to nodes, river arms, and structures, while maintaining a record of all applied settings.

The tabular module provides a list of all digitized points in the model, which can be edited via the "Overview" or "Data Entry Panel". Users can import/export data from Excel tables for efficient data handling. In the Network Editor, the "Network" option facilitates watercourse discretization and node spacing, while the "Structures" option lists all hydrotechnical works, categorized by structure type and model settings.

Upon completing the simulation, a "Network" text file is generated, which can be edited in any text editor.

The Section Editor (.xns11) operates on a binary database, allowing multiple sections to be registered. Each section is identified by the river name (tributary), Topo identifier (Topo ID), and

route number (increasing downstream). Sections include:
- Raw data (X, Z coordinates, roughness markers);
- Processed data (hydraulic radius, storage area, width, and flow mode).

Users can modify node positions, rename sections, interpolate multiple sections, or adjust tabular data. The editor supports five common graphical markers affecting data calculations:
- Left bank pier;
- Low flow on the left bank;
- Left coordinate;
- Minimum riverbed height;
- Reduced flow on the right bank;
- Right coordinate.

Embankment markers define the active simulation area, and global modifications can be applied to both raw and processed data. Before running the simulation, a pre-check is recommended to ensure all sections are precalculated.

The Edge Conditions Editor (.bnd11) allows the inclusion of advection-dispersion and multilayer flow conditions, providing a structured panel for managing boundary conditions and simulation parameters.

The overview panel includes a description box (open, global, structures, closed), one for the type of condition (supply, levels, Q-h curves, bed level), one for for user identification and 3 for location (rich name, start (km), end (km). The specification panel contains a box for the type of download; one for the type temporal step (fixed, tabular, adaptive); one for values (used for editing time series) and one for information about the passage of time.

The conditions file, once created, can be modified with a text editor. The Time File Editor (.dfs0) is an editor and database for time series and communicates directly with the edge condition editor.

It can be viewed both tabular and graphically. Selected points in the view are drawn. The visualization is done only in the Time Series (TS) file.

You can also change or add/delete the type and units of time from here.

In the "Tools" menu, you can select the subset or the entire period of interest.

You can zoom in on the area of interest (zoom) or move the area (pan).

Files of type * DFS0 (TS) can be created from a blank document or from a ASCII document.

You can also create hydrograph files for projects in the Time Series editor Developed.

The HD Parameter Editor (.hd11) contains the initial conditions and resistance data.

The table of initial conditions includes the local conditions superimposed on the global ones, the values specified globally, local values (strings), etc. The initial conditions will set the water level to the first step of time.

The lateral resistance factor in the section applies to the overall values or locally. If lateral resistance is specified as the value, then the file in question will be ignored. The resistance of the bed results from the overwriting of local values over the global value, along the course.

The local approximation can be solved for an entire sector or only for a part of it. Kinematic or diffusive waves can be associated with fast channels without shaking. In this editor, additional results will be given to the default constants in the simulation (which will create an additional editable file with the name from "Simulation" and the extension "HDAdd"). All other panels in the editor can be used for more advanced use of MIKE 11 (DHI, 2021).

These are the interconnection editors, required by MIKE 11 for the creation of all numerical modeling projects. The MIKE 11 program is created by DHI Water•Environment•Health, Denmark, to solve the Saint-Venant equations, the basic component of the model was used in the simulation, i.e. the hydrodynamic module (HD), which contains a 6-point Abbott-Ionescu default scheme with finite differences (Lagos et al., 2024).

MIKE 11 was created to make detailed modeling of gate and dam openings, special treatment of floodplains, road overflows, bridges, rivers.

The program has the ability to use vertically integrated, diffusive, kinematic, or fully dynamic momentum and mass equations. Types of limits include Q-h relationship, water level, resistance factor, flow rate, wind field, dam failure. The limit of the Q-h relation can only be applied to the downstream limit. The water level limit applies to the model either downstream or upstream. The flow limit applies in the same way as the water level limit, either downstream or upstream, and can also be used at the lateral tributary flow (flow). To describe the leakage, lateral flow is applied.

MIKE 11 is a well-known program since the beginning of its use, that could be operated through an efficient interactive menu, menu sequencing and systematic layouts.

The latest generation of the "classic" MIKE 11 has been developed - version 3.20, which usefully uses the experiences and features of the "classic" era with the Windows-based user interface, including calculation speed and graphical editing.

In many applications around the world it has been used over time, among its main areas of application being flood mitigation analysis and design, dam failure analysis, flood forecasting today, improvement of channel and reservoir sources, sediment transport and morphological studies, ecological estimates of water in rivers and wetlands, saline intrusion into estuaries and rivers (Merz et al., 2021).

The MIKE 11 program has a variety of options for modeling morphological changes and sediment transport dynamics in the riverbed (Lee et al., 2021).

RESULTS AND DISCUSSIONS

Numerical flow modeling was performed using MIKE 11, which proved effective for unsteady flow simulation with MIKE 11-HD. Figure 2 shows the model layout, and Figure 3 presents the channel cross-section profiles based on topographic surveys.

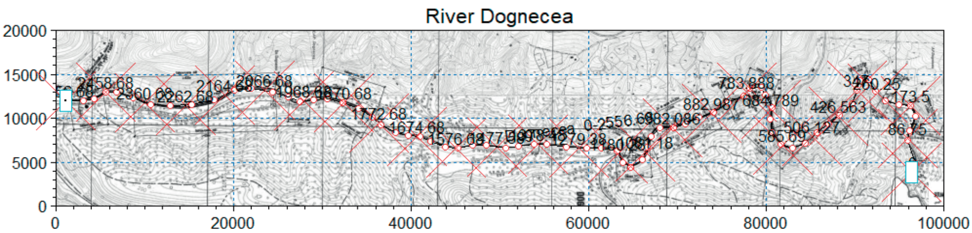

Figure 2. Plan view with the network model

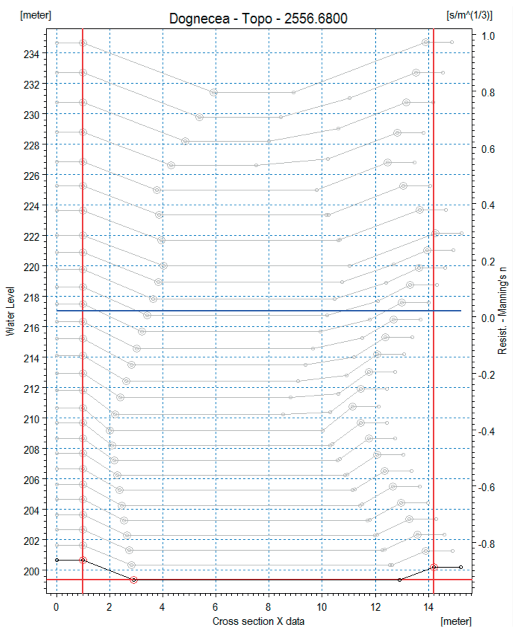

Figure 3. Cross sections

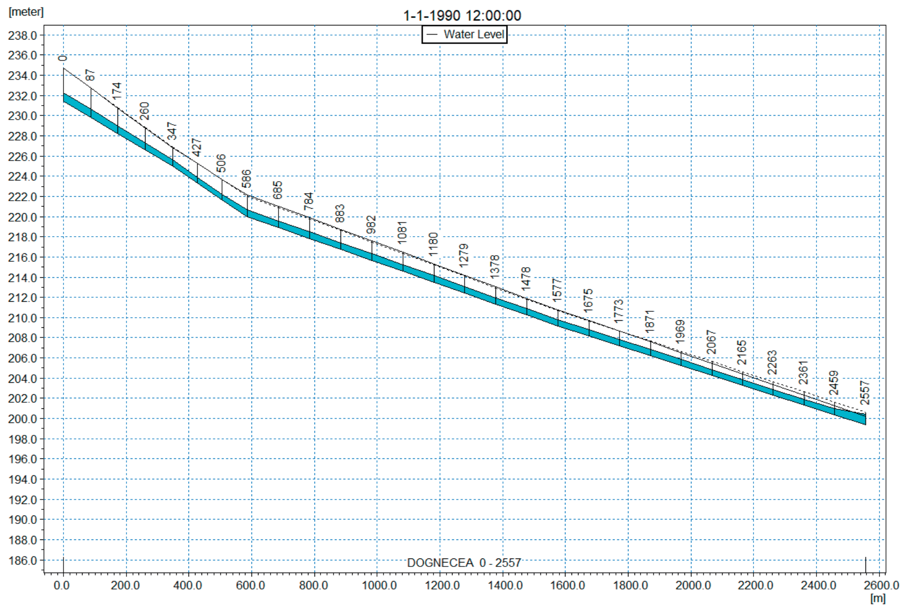

Figure 4. Water Level in longitudinal profile

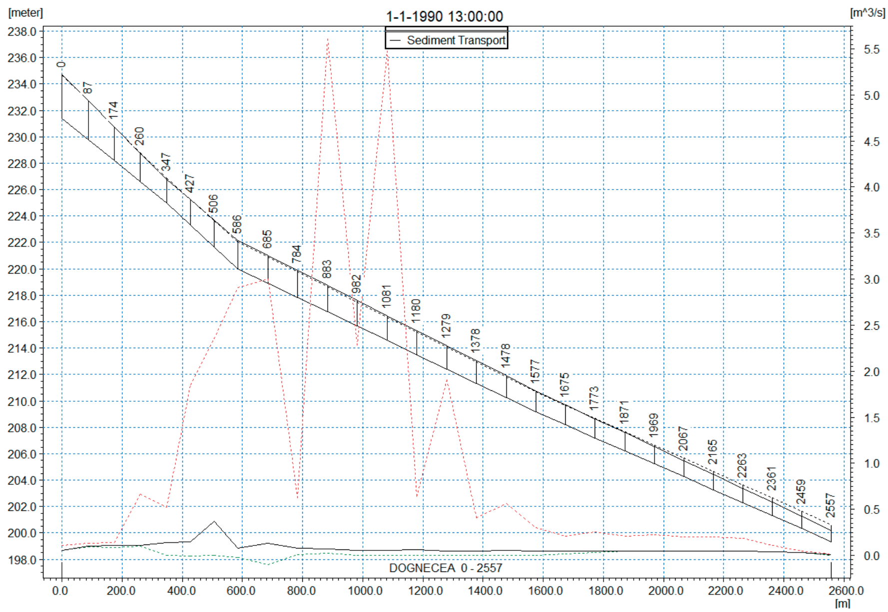

Figure 5. Sediment transport in longitudinal profile

According to the introduction of the data or the limit conditions formulated, the upstream flow at chain 0 is constant Q 19.9 mc/s the downstream flow at chain 2556, the key to the curve of the downstream river sector (Biali et al., 2022). Following modeling with the MIKE11 program, the longitudinal profile of the existing canal was obtained (Figure 4).

The downstream boundary condition is important in terms of alluvial flow in a morphological and dynamic model between sediment transport, bed level, hydrodynamics and plane shape changes, and another condition is the simulation time which should be as long as possible. (Damian et al, 2022).

The following boundary conditions are required: the boundaries of the sediment beds in the riverbed and the level of displacement of the alluvial at the limit. The first applies when it is considered with a certain precision that the riverbed remains at the same level as the upstream limit. The second applies if it is accurately known for alluvium transport (e.g. zero transport) (Grozav et al, 2018).

According to the formulated boundary conditions or data, the sediment flow upstream to chain 0 and downstream to chain 2556 is 0.

The MIKE 11 ST module simulated sediment transport dynamics along the canal, showing variations in transport rates over time. The longitudinal profile (Figure 5) highlights areas of significant sediment accumulation and erosion, which are critical for understanding flood risks and designing mitigation strategies.

The results from the sediment transport model show the variation over time across the entire river section of erosion and deposition, which aligns with the expected results (Najafi et al., 2021).

There are areas with higher erosion in zones where the river slope changes, while higher deposition occurs in areas with a lower slope.

Over time, if the deposited sediments are not removed, they will reduce certain river sections, decreasing the river's water discharge capacity, ultimately leading to an increase in water levels, which will negatively impact flood control.

The water levels from the initial results were compared with measured levels in several sections. To correct the differences, the roughness values were adjusted in certain river sections until values close to the measured ones were obtained. After validating the model regarding water movement, the sediment transport model was then run.

The calculation of the transport capacity of non-cohesive sediments, the morphological changes and the transformation of the alluvial resistance in relation to a water system can be done with the MIKE 11 program.

The input data for the properties of non-cohesive sediments are:

- Diameter of sediment grains;
- Data for graded ST;
- Transport model;
- Calibration factors;
- Bed level without cleanliness;
- Passive branches;
- Predetermined distribution of sediments in nodes.

CONCLUSIONS

This study applied a one-dimensional hydraulic model to simulate unsteady flow using the MIKE 11 software.

The MIKE 11 model demonstrated several advantages easy to view and extract results analyses, short simulation time, accurate hydraulic description in flowing waters/channels of hydrotechnical structures.

The MIKE 11 program presents a complex and efficient modeling and design system in various engineering applications, water sources, water quality management and planning, extraordinary flexibility, speed, as well as a very easy use of the program.

The core of the MIKE 11 modeling system, the hydrodynamic module (HD) forms the basis for almost all modules, including water quality, flood forecasting, advection spread, as well as alluvial displacement modules of various sizes and non-cohesive.

The MIKE 11 model successfully simulated sediment transport, identifying key areas of erosion and deposition. These insights are valuable for improving flood risk assessment and designing effective river management strategies.

However, one-dimensional models have limitations, particularly in capturing complex flow interactions in floodplains. Future research should consider integrating 2D or 3D hydraulic models to improve accuracy in predicting morphological changes and extreme flood events.

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