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# GIS UTILITY FOR HYDROLOGICAL IMPACT EVALUATION CAUSED BY DAMAGES OF WATER SUPPLY NETWORK IN RURAL AREAS. APPLICATIONS IN BAIJA MARE DEPRESSION

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**Abstract:** - *GIS utility for hydrological impact evaluation caused by damages of water supply network in rural areas. Applications in Baia Mare Depression.* Occurrence of a failure within the water supply network is an element of risk with important hydrological implications. Although at first glance you might think that a pipe diameter of only 20 cm can generate large effects, however, in case of significant damage or even burst pipe, a good part of high water flow in the pipe (approx. 25 m<sup>3</sup>/h on average in the Baia Mare) associated with a long duration of failure (several hours) may be in the drain area, impact on the local community. Regarding rural settlements, surface drainage allow a quantity of water retention tank underground infiltration but in many cases lack of a sewage system effectively contribute to increased negative consequences related to such damage (flooding farms, roads, crops compromise of flooding or drought in the event of damage to the hot water supply pipe and so on). This paper focuses on the role of Geographic Information Systems (GIS) to assess the impact of runoff induced by damages in rural areas. The study therefore spatial aspect, through GIS, on the one hand runoff along the flow path with the start point of the network fault location and view previous hydrological conditions of the terrain, and on the other hand the impact of runoff the rural community. Study area Dumbrăvița settlement located in Baia Mare Depression. This village is part of water supply system to the south and southeast of Baia Mare.

**Key-words:** GIS, hydrological impact, damage, water supply network, Baia Mare Depression.

## 1. Introduction

Following a failure in the water supply network the immediate hydrological impact on the local community is the interruption of water supply, sometimes the impact on residents subscribers, respectively household and economic activities undertaken by the affected village. However, the aspect that we wish to emphasize in this paper primarily relates to the impact surface fluid flow in terms of wasted water due to failures in the network, namely the danger of flooding of various areas of rural settlement.

In modeling the impact of hydrological disaster followed, usually following lines of research: modeling of water supply network, the water pressure in the pipes (Grise et al., 2001, Trépanier et al., 2006, Zhang, 2006, Văduva et

al., 2007, Capotescu, 2009, Ramesh et al., 2012), failure detection (Dong, Shinozuka, 2004) and modeling of pipelines damaged by analyzing the risk of failure (Andreou et al., 1987; Park et al., 2010) or modeling runoff and local flooding caused by damage (Zoppou, 2001, Amaguchi et al., 2012).

The study area is located in Baia Mare Depression and overlaps water systems connected with the Baia Mare in the south and southeast; case studies of this work will be done on the level of Dumbrăvița settlement [Fig. 1].

Water supply network of Baia Mare city and south and southeast of it comprises a total of 2230 sections of pipe. Of the 2230 sections of pipe situation in the rural settlements is as follows: Chechiș- 39 sections; Unguraș - 11 sections; Berința - 54 sections; Cărbunari - 42

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sections; Dumbrăvița - 95 sections; Groși - 51 sections; Rus - 81 sections; Sindrești - 33 sections. On pipe diameter, pipe network for water supply comprises the arteries with

diameters 200 to 800 mm, 100-150 mm pipe diameter (in some cases even lower) and branch pipes.

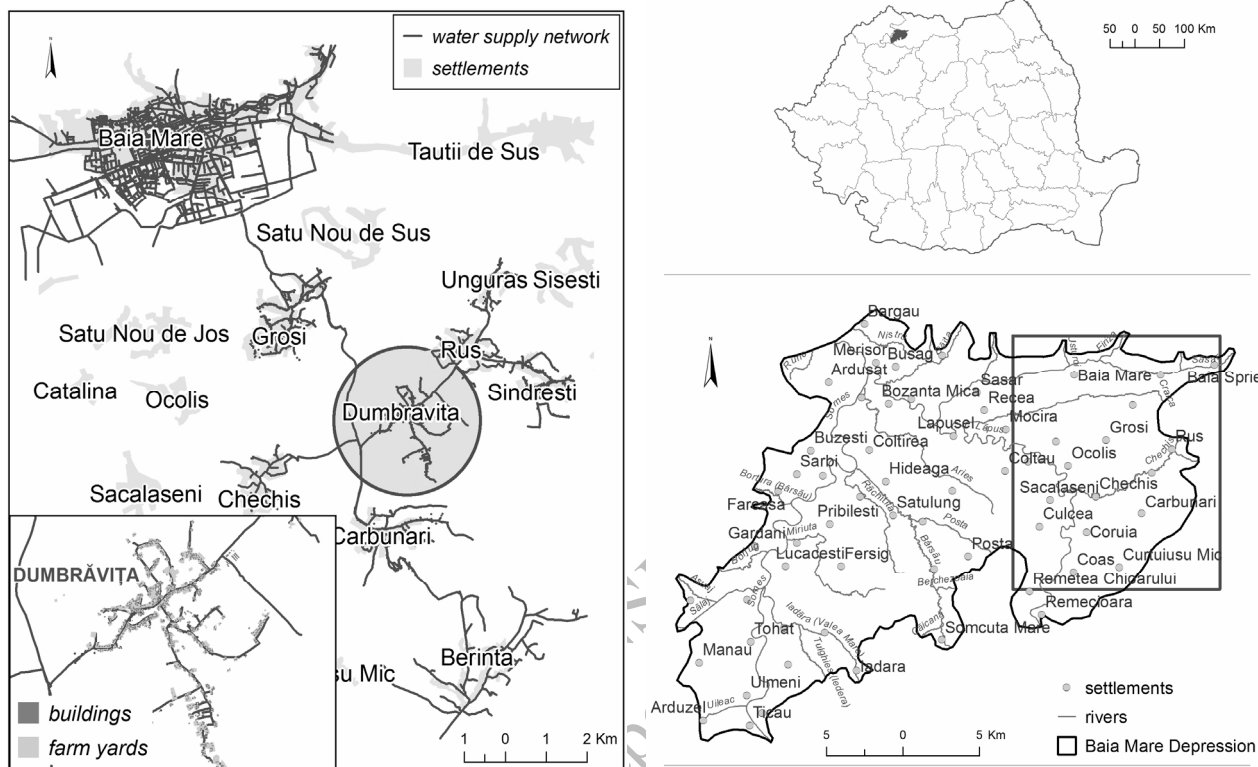


Fig. 1 Employment in the territory of water supply network and Dumbrăvița settlement

The main hydrological risk phenomena induced damage of water pipes are: **flooding of different areas of rural settlement** and **excess moisture of terrain**.

Several recent studies assessing flood damage if water pipes have been undertaken in urban areas of Baia Mare (Keller et al., 2009).

**Flooding homes and household annexes** constitute the greatest impact to be taken into account for damage to the water supply network in such areas as population concentration is highest. Of course, the highest exposure they have farms located closest to the location of the damage the pipe.

**Flooding of roads** is also a sensitive issue that could face the local community as a result of damage to the water supply network, especially for road sectors that connect with other locations. In such cases the question of accessibility in the local community and emergency (examples: medical emergencies; association with pipeline damage caused by

heavy rains flooding which necessitate emergency crews and so on).

Water loss caused by damage to the power lines can affect agricultural land categories primarily due to **excess moisture** (especially for areas with very low slope to delay or allow the transit volume of water discharged by pipeline damaged).

## 2. Database

GIS database required for simulating surface flow in an emergency water supply network and associated hydrological impact assessment consists of a large number of GIS layers on both the structure and the structure vector raster.

1. Vector polyline database includes:
  - **Water supply network** (with attributes on pipe type, pipe diameter).
  - **Contours** extracted from 1:10.000 topographic plans.

- **Hydrographic network** extracted from 1:10.000 topographic plans.
- 2. Vector polygon database includes:
  - **Plots** with different land use categories, derived from 1:10.000 topographic plans and land plans 1:5.000.
  - **Houses** and **household annexes** extracted from 1:10.000 topographic plans.
  - **Soils** derived from soil maps 1:200.000.
- 2. Vector point database includes:
  - **Rainfall stations** near Baia Mare Depression.
  - **Point elevation** extracted from 1:10.000 topographic plans.
  - **Branching points** of the water supply system.
  - **Failure points** selected for application of GIS methodology.

The elevation data was exploited to generate a raster dataset with resolution of 10×10 m including: **Digital Elevation Model** (MNT), Slope, Aspect, Flow Direction. Digital Elevation Model was used also for defining vector polyline Flow Path (the location of the damage to the lowest elevation in the basin).

Later, after the calculation of runoff, the length of this vector polyline resizes obtaining actual length of flow path. Spot database on daily rainfall rainfall stations for the stereo was valued daily values of precipitation, resulting in the precipitation raster daily scale with resolution of 10×10 m. This information was needed to analyze the hydrological conditions of the land prior to a possible failure, the analyzed period 07.05.2010 - 16.05.2010.

### 3. GIS methodology

#### 3.1. GIS methodology for computation of surface runoff generated by failure pipe

The main steps which make up computation methodology pipeline leak caused by damage are:

1. Generate the vector GIS database parameters necessary spatial analysis on previous hydrological conditions of terrain: water supply network, elevation, soil, land use, precipitation. This database was obtained either by editing techniques or automatically by importing techniques based on coordinates x, y.
2. Generate, using the spatial analysis

methods (spatial interpolation functions, digital elevation model derivation functions), the raster layers of the physical-geographical (DEM, slope, slope direction, precipitation) needed to assess the hydrological conditions of the terrain.

3. Generate raster layers on Antecedent Precipitation Index (API), Antecedent Moisture Conditions (AMC), Curve Number (CN) and the maximum potential retention (S). This step is based GIS implementation classical methods of assessment runoff.

It is therefore primarily about **API index** developed by Kohler and Linsley, 1949, through which the water supply is studied taking into account rainfall land the day t (Pt), water supply API previous day (API-1) and a parameter dependent on the physico-geographical terrain (k) (Chevalier, 1983, Beschta, 1990). **CN index** developed by USDA-SCS, 1972, of the ability of infiltration-runoff based on soil texture, soil hydrologic class, land use, **antecedent moisture conditions** (AMC) was used to assess the **maximum capacity retention** (S).

4. Generate raster layers on coeficientului soil water saturation on the results of API index and maximum potential retention S (Crăciun, 2009).

5. Generate Flow Direction raster and defining flow path having as origin damaged pipe, using ArcHydro **Flow Path Tracing** module.

6. Data extraction on maximum capacity retention and saturation coefficient for each cell along the flow path. Flow calculation is made considering cells arranged along the flow path as a string "n" reservoirs supplying successively downstream cells after infiltration excess capacity.

#### 3.2. Application of methodology

Calculation methodology presented in the previous section was applied to the village Dumbrăvița, considering the time of the accident on the 15/05/2010 with two scenarios of damage to pipelines (Avarie 1 and Avarie 2) [Fig. 2].

In the first phase were analyzed hydrological conditions of the terrain (interpolated rainfall, water supply API, the maximum retention coefficient of saturation).

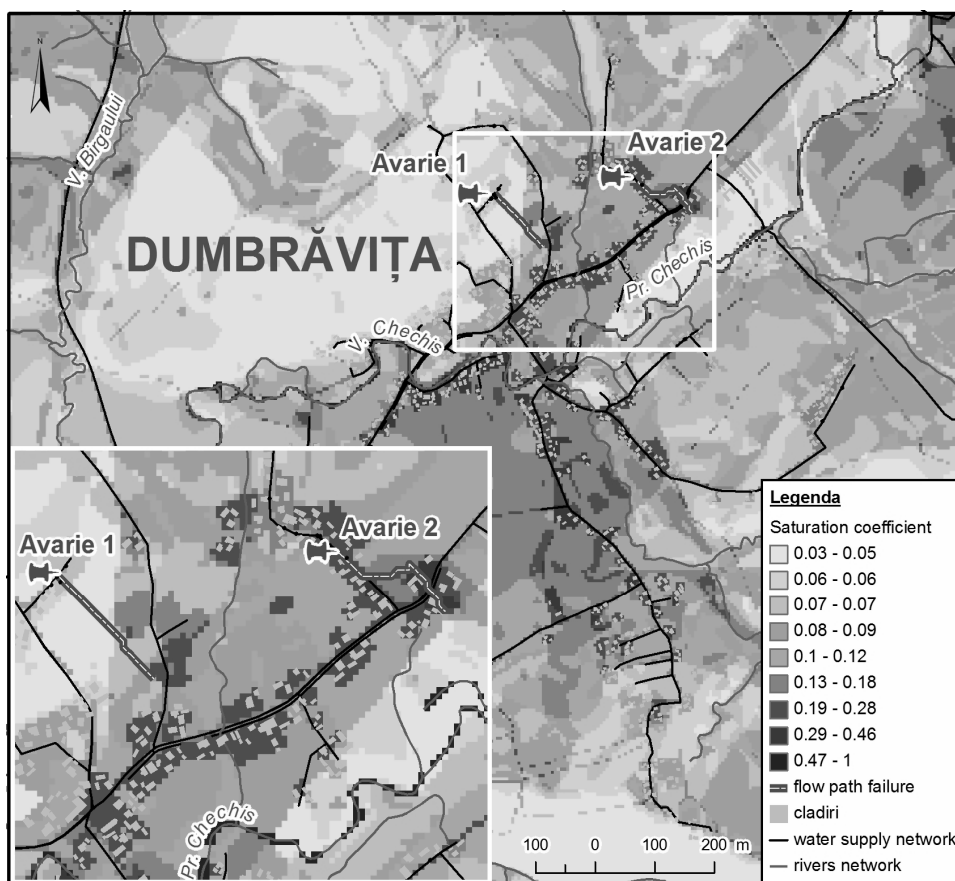


Fig. 2 Water saturation coefficient map and location of damages (15-05-2010)

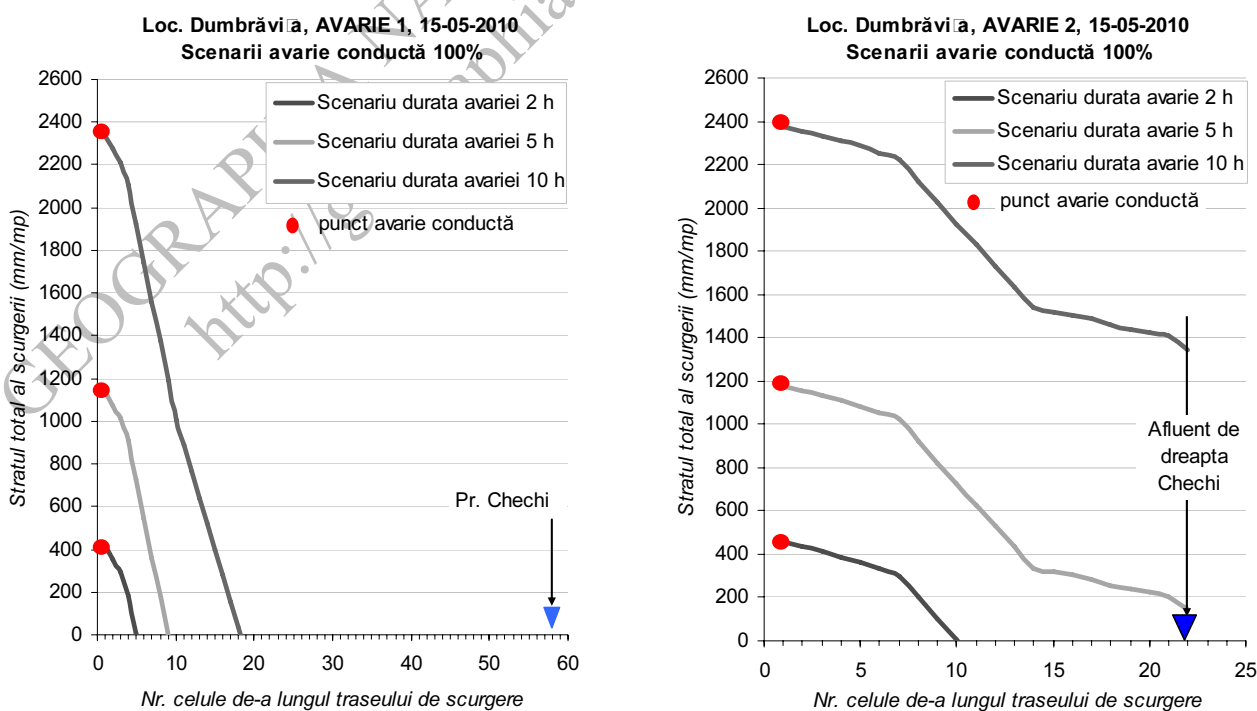


Fig. 3 Results of surface runoff along the flow path for different scenarios of the fault. Hypothesis: Water damage causes loss of 100% of the average volume of water carried by pipeline

In [fig. 2] we present the water saturation coefficient map which can be observed on most of the territory, low soil water saturation for the day 15/05/2010. Saturation coefficients from 0.4 to 0.5 can be found only if beds and floodplains of watercourses or built village (farm yards) on land with low slope.

Further calculation was performed for each cell runoff point along the flow path considering three scenarios regarding the duration of damage (2h, 5h, 10h). In fig. 3 presents results on the flow chart for the two cases of damages where the explosion would take place pipe (100% water loss, approx. 24 m<sup>3</sup>/h water flow in the pipe as it is in the study area).

The average discharge of water in pipes of 24 m<sup>3</sup>/sa was obtained from measurements made in the study area. Office Water Loss in SC VITAL, Baia Mare conducted a series of campaigns to measure water discharge in different strategic points in the city and in rural water taken from the water operator SC Vital SA.

Thus, in 2011 conducted a water operator

range of flow measurement campaigns as follows: input flow Sighetul Marmației city, main water plant outputs Baia Mare, Grivița reservoirs, Crăciunești settlement.

#### 4. Results of hydrological impact to rural community

In this chapter we turn therefore attention to the following lines of analysis: the impact on households (farm yard, house, household), the impact on road and rail routes, impact on crops. We present an example in [Fig. 4] records categories of land likely to be affected by flooding or excess moisture for the two scenarios from the village Dumbrăvița damage if pipes burst and the duration of such failure for 10 h.

[Table 1] presents an overview of the number of houses and household annexes, number of tracks, number of agricultural parcels and usage thereof affected by runoff in case of damage in the two selected points



Fig. 4 Map parcels and households affected

Table 1. Household, roads and agricultural land likely to be affected by excess moisture or flooding in case of damage to the water supply network for different scenarios regarding the degree of fault and fault duration

Damage	Damage level of pipe	Damage longtime	Number of farm yards	Nr. of houses / annexes at risk	Road sectors at risk	Agricultural parcels at risk	Landuse category
Avarie 1	50%	2h	1	3	1	-	-
		5h	1	3	1	2	1 arable, 1 orchard
		10h	1	3	1	2	1 arable, 1 orchard
	100%	2h	1	3	1	2	1 arable, 1 orchard
		5h	1	3	1	2	1 arable, 1 orchard
		10h	1	3	1	2	1 arable, 1 orchard
Avarie 2	50%	2h	3	4	1	1	1 fâneată
		5h	3	4	1	3	1 arable, 2 meadow
		10h	7	9	2	4	2 arable, 2 meadow
	100%	2h	7	9	2	4	2 arable, 2 meadow
		5h	7	9	2	4	2 arable, 2 meadow
		10h	7	9	2	4	2 arable, 2 meadow

## 5. Conclusions

The main risk hydrological phenomena induced damage of water pipes are flooding various areas of rural settlement and excess moisture analysis.

The impact analysis of damage to water supply network was based on a study using GIS and hydrological conditions of the land surface runoff generated calculation of water losses due to network failures. Subsequently, database

query over land and buildings in the rural village studied were prepared reports on areas at risk for different scenarios of the fault or degree of fault of the pipe [Table 1].

[Table 2] is a summary of the impact of fluid (total elapsed layer and land affected by runoff) at different distances from the location of the damage, taking into account where the pipe burst and a duration of 10h damage.

Table 2. Report on runoff caused by damage and land affected in the event of a pipe explosion and damage duration of 10h (15.05.2010)

Damage	Flow length	Total runoff depth (mm/m <sup>2</sup> ) distance of "x" from the location of the damage point					Landuse category at risk
		20 m	40 m	60 m	80 m	100 m	
Avarie 1	236 m	2274	2107	1741	1375	1010	
		households, farm yards	households, farm yards, arable	arable, orchard	households, farm yards, arable	arable, orchard	
Avarie 2	256 m	2377	2331	2286	2221	2024	
		households, farm yards, road	households, farm yards, road	households, farm yards, road	road, meadow	meadow, arable	

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