ZONAL STUDY FOR THE OPTIMUM PLACEMENT OF A PUMPED-STORAGE HYDROELECTRIC SUPERIOR RESERVOIR

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***Abstract**: Pumped-storage hydroelectricity is a type of hydroelectric energy storage used by electric power systems for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation in a superior reservoir.*

This paper presents a theoretical and practical solution on the above theme. The superior reservoir location needs to meet a series of terms listed by the general designer.

On the strength of the huge study area, the amount of the involved information, the task of merging the textual and spatial data and the way these above mix all together, the optimum way is to use the geographic information system (GIS) methods.

***Keywords:** GIS, theme map, 3D modeling, analyze.*

Motto:

"The drawing shows me at one glance what might be spread over ten pages in a book."

Ivan Turghenev – 1862
"Otsy i Deti (Отцы и дети)"rus. - Fathers and Sons

1. Introduction

The need for electric power is a modern matter. For this reason producing and supplying it involves complex technologies and infrastructures.

But what can be done if you have a peak of consumption at some time of the day. To put this simple, more energy must be produced, but must use a technology that is able to start production in "real time". One of these technologies is hydroelectric power but here are some drawbacks because a hydroelectric power plant can't deliver energy in drought seasons or if the reservoir level is at its minimum safe level.

One the other hand, at a national level, windmills can be used with the condition that air flow is available in that period.

So if this problem can be managed using the above solutions (although there are other more available - solar power etc.) what can be done if there is no demand for power in the national grid, there is significant air flow, or if there is a nuclear power plant that can produce a steady amount of electricity?.

Isn't there a way to "store" this extra power so that it can be available in a peak situation?

One of the answers for this question is Pumped-storage hydroelectricity. This method stores energy in form of gravitational potential energy by pumping large quantities of water from a lower reservoir to a superior reservoir using reversible pumps so when the need for electric power arrives, the pumps act as generators in a classic hydroelectric plant.

Usually the water is used from the reservoir of an existing hydroelectric facility.

The problem that comes out is to find a suitable place for the superior or upper reservoir. And here comes in handy the method that I propose using raster analysis of themed maps.

Fig. 1. Pumped storage hydroelectric facility

2. Introduction

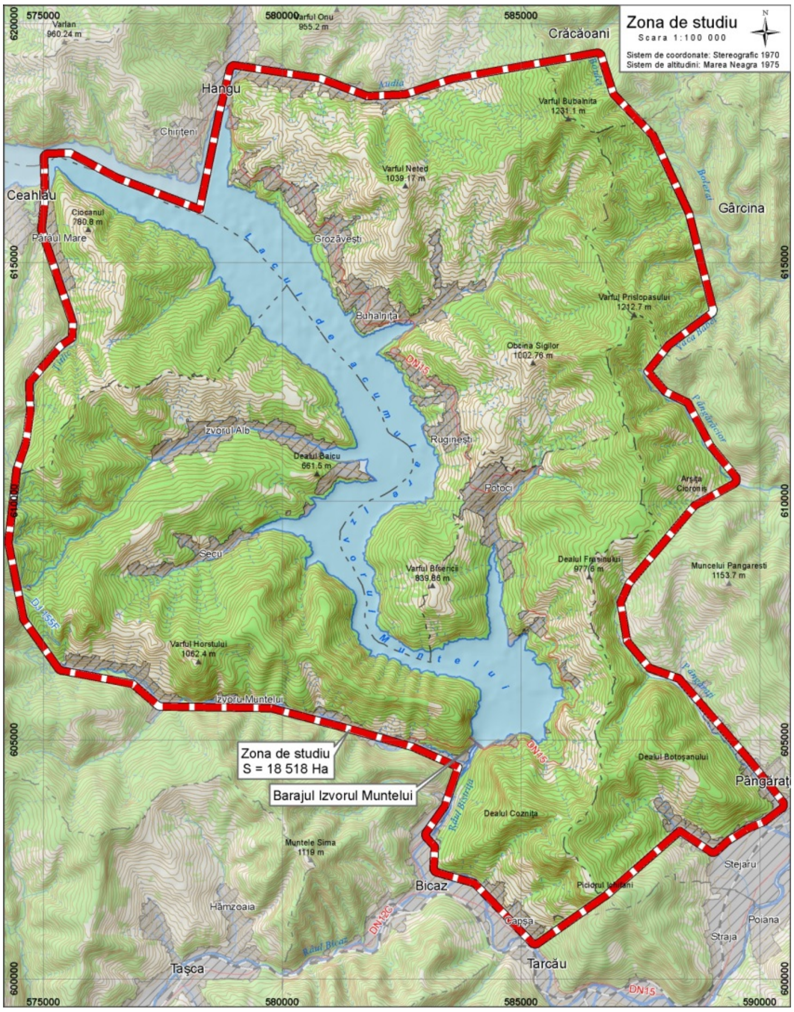

Fig. 2. Study area

The study area is located in Neamt county, just North of Bicaz city. It includes the area around the "Izvorul Muntelui" reservoir, running up just a few hundred meters above the nearest summits.

The study area has roughly 18 518 Ha and covers partially six administrative territories.

3. Project requirements

The general designer asks for a suitable location on which a superior reservoir can be erected. This location must fulfill a set of conditions, listed below:
1. The site must not be within a protected environmental area;
2. The reservoir must be placed at a minimum of 450 m above the lower reservoir;
3. $k = \Delta H / Lca = 0,16$ parameter must be fulfilled, where ΔH is the height difference between the medium level of the lower reservoir and the upper reservoir location and Lca is the water path length;
4. The slope in the embankment area must be lower than 50%;
5. The site must not be in an area managed by ROMSILVA;
6. The village/constructed areas will be excluded;
7. The site must be on stable ground.

4. Theme maps

The principle of equal influence factors governs this analysis.

The study is based on the following data: 2008 orthophotos, 1:2000 and 1:5000 maps, "Natura 2000" protected environmental areas, "Map of natural landslide risk" - SC TOPOPREST SRL - 2012, data resulting from the 165/2013 law of terrain inventory.

Based on the above terms a set of seven themed maps will be drawn, each map will represent one of the conditions. The maps will be reclassified in raster format with 10m grid. In the reclassify stage the cells in the grid will have value 1 for favorable or 0 for unfavorable circumstances. Exception to this rule will be the "k" parameter raster grid cells, which will have values from 1-3 in favorable areas.

The maps and raster are drawn in ArcMAP using the following algorithm:

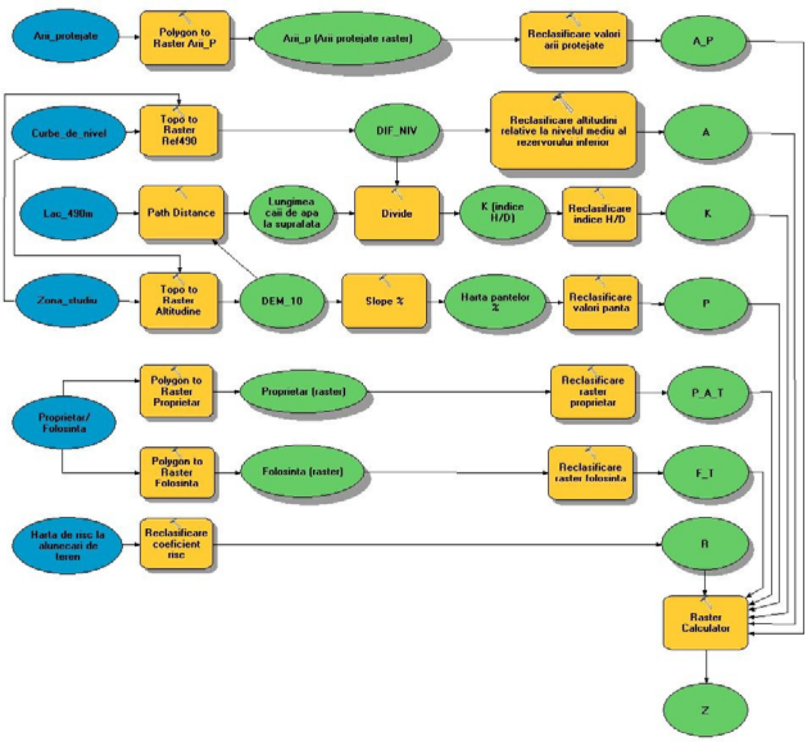

Fig. 3 - Logical scheme

With blue there are highlighted the initial data (left ellipses column), which are processed (left brown squares column) into intermediate raster form (middle green ellipses), reclassified (right brown squares) into final raster from (right green ellipses column).

The final seven rasters are named after the designer conditions, and each represents a theme map which illustrates that specific condition.
These theme maps are:

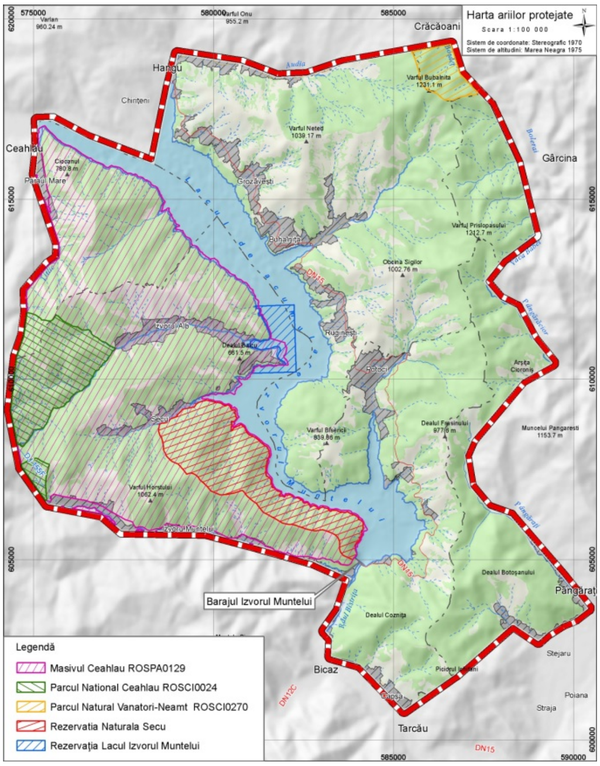

Fig. 4. Protected areas map

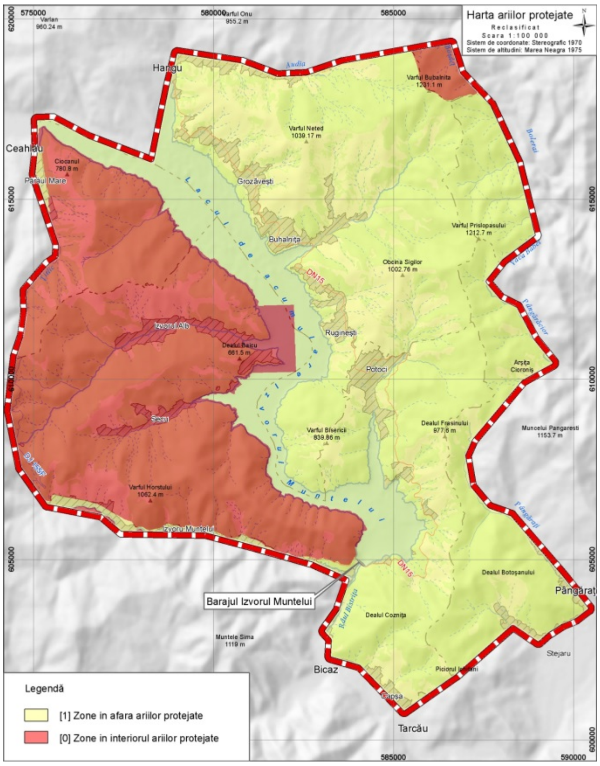

Fig. 5. A_P - protected areas

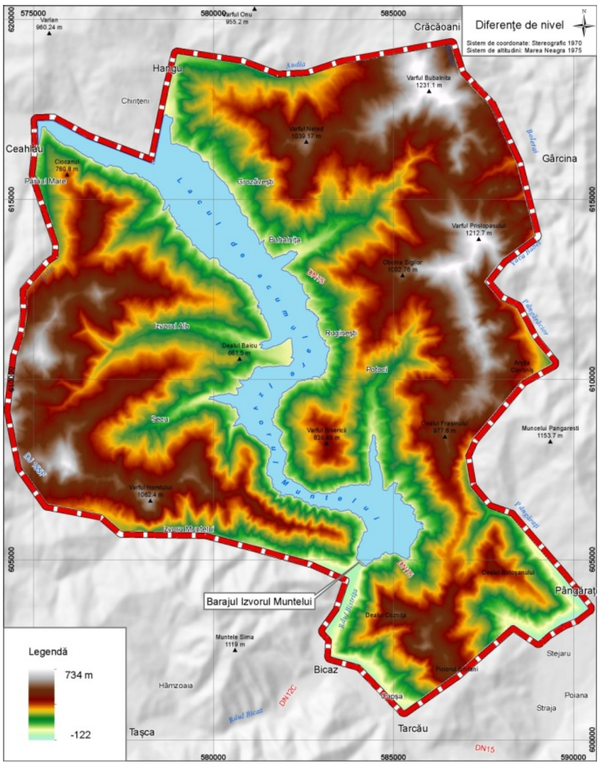

Fig. 6. Height above the lower reservoir

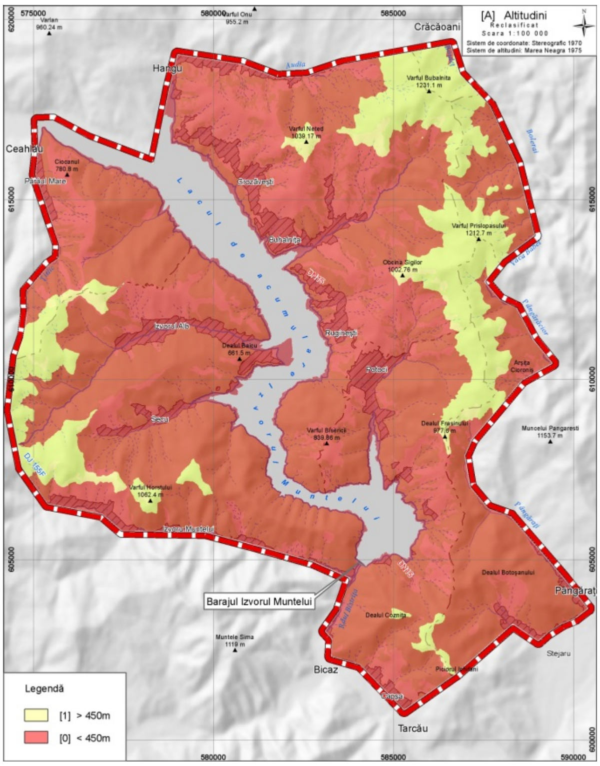

Fig. 7. A - heights grater than 450 m

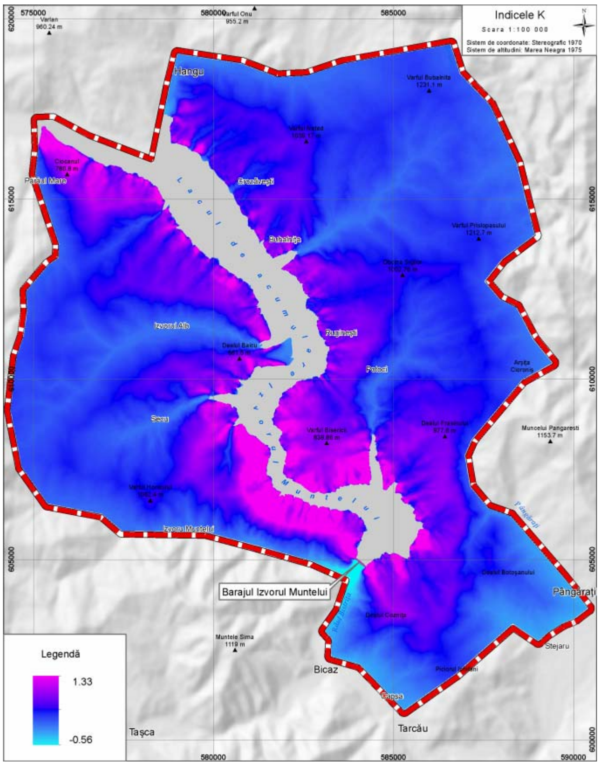

Fig. 8. K parameter distribution map

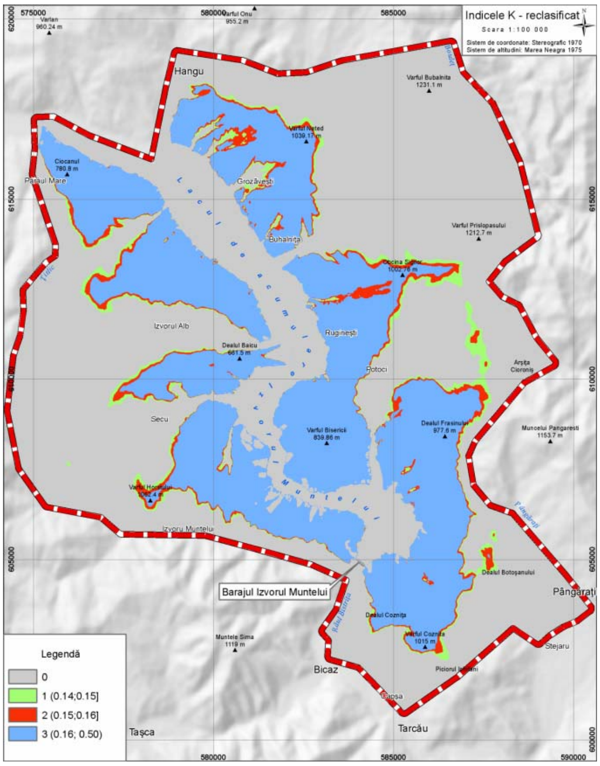

Fig. 9. K - parameter classes

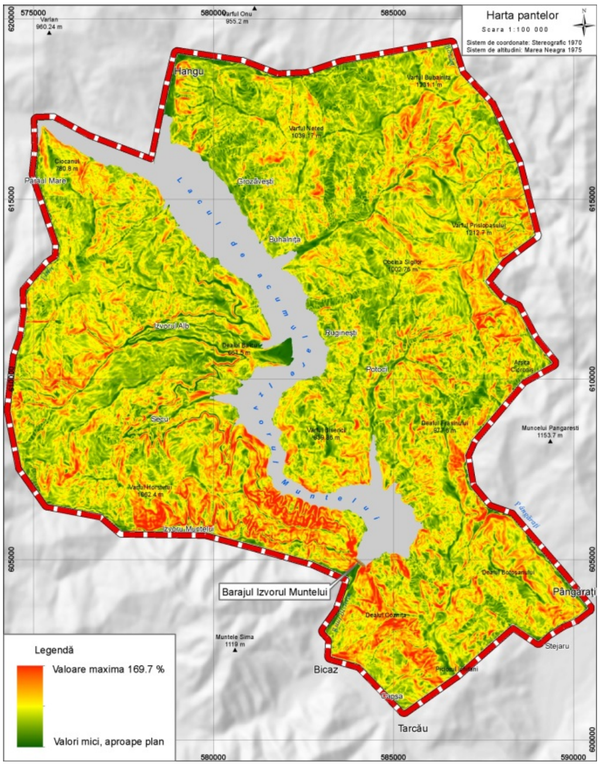

Fig. 10. Slope map

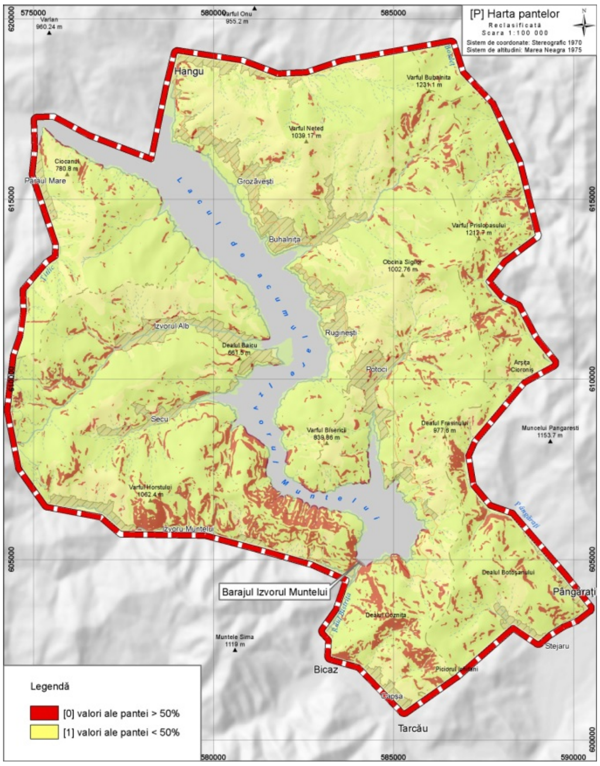

Fig. 11. P - slope lower than 50%

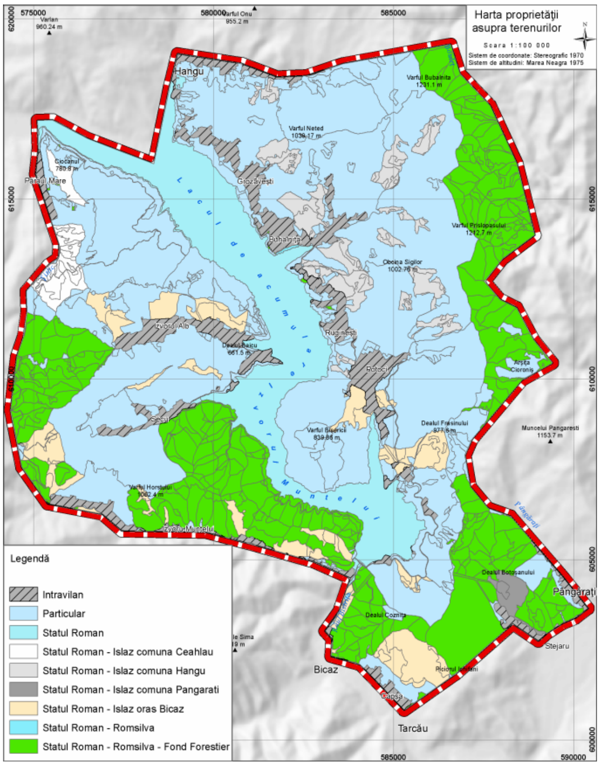

Fig. 12. Propriety map

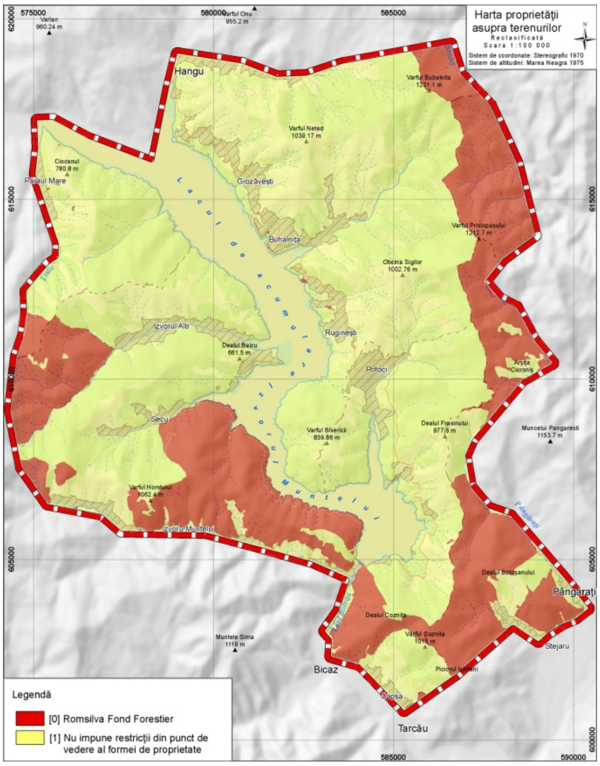

Fig. 13. P_A_T - propriety

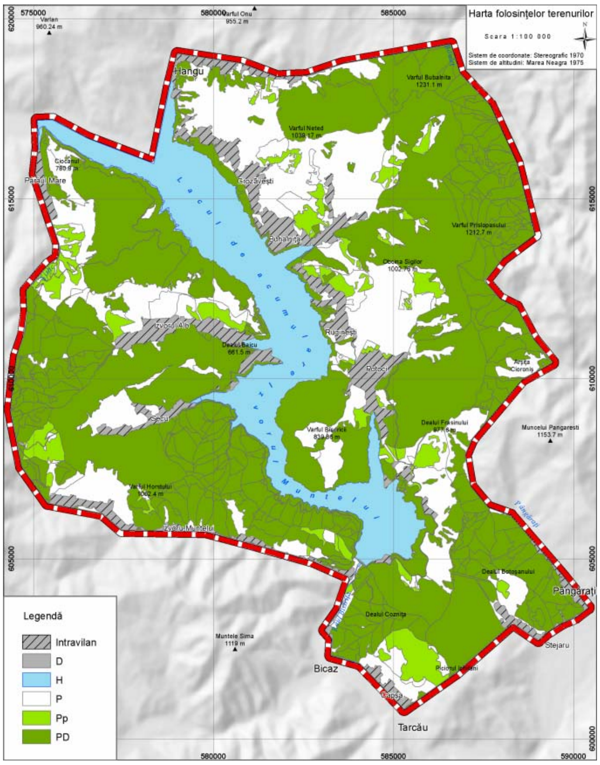

Fig. 14. Land use map

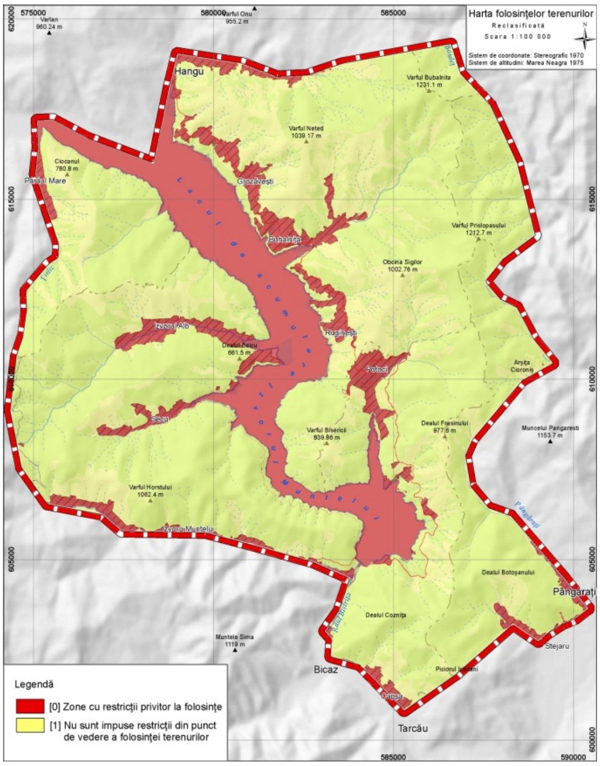

Fig. 15. F_T - land use

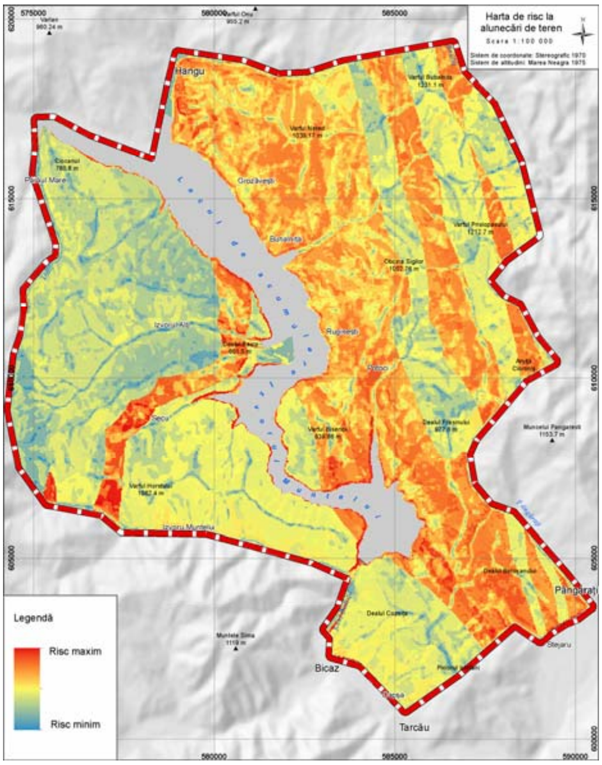

Fig. 14. Map of natural landslide risk

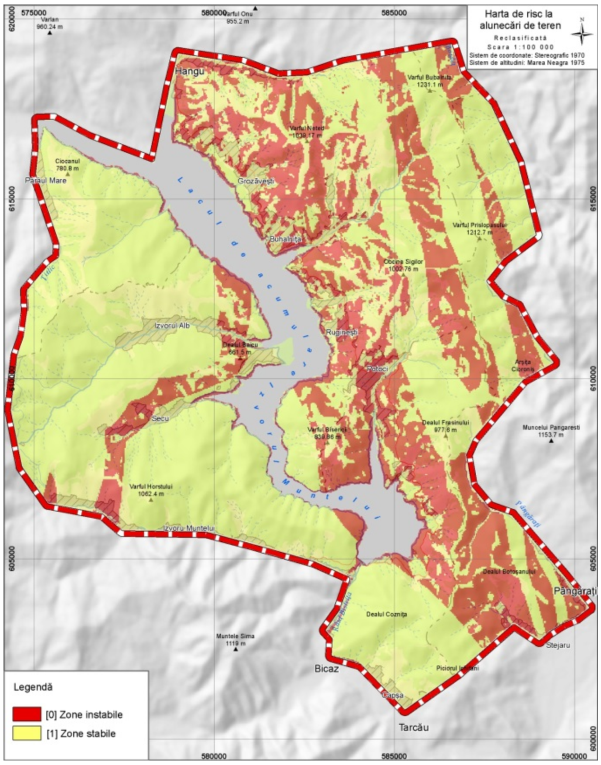

Fig. 15. R

The theme maps are processed into Z map using the formula:

Z = A_P * A * K * P * P_A_T * F * R

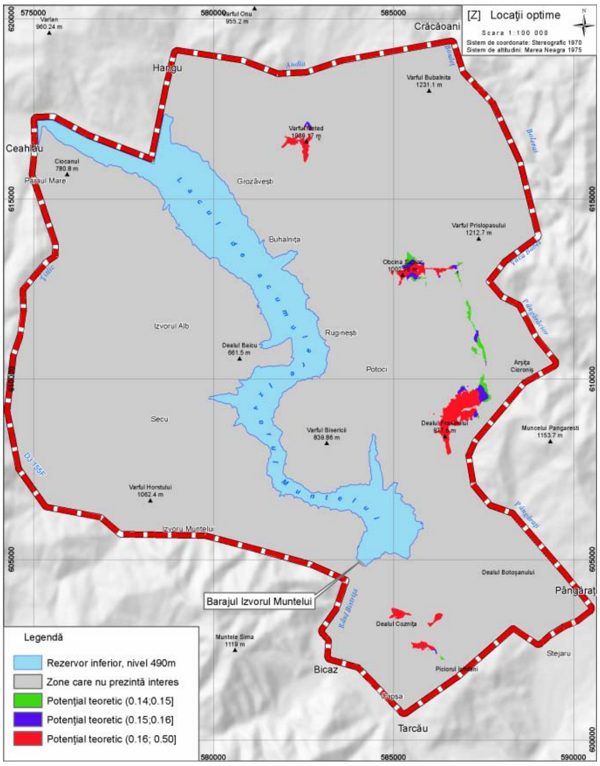

Fig. 16. Z - potential classes in favorable zones

5. Results

In the above map (Fig 16) there are shown the grid cells that accomplish all the seven conditions and are not strictly homogeneous areas.

Here comes the human factor, and after the map is stripped of small areas, we can show the true favorable compact locations in form of a final map:

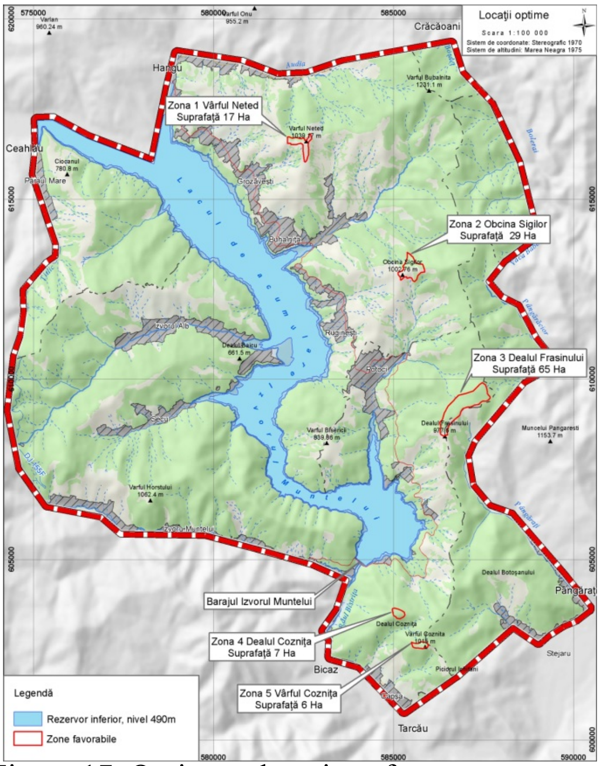

Figure 17. Optimum locations for an upper reservoir

This process has been automatized in ArcMAP using ModelBuilder.

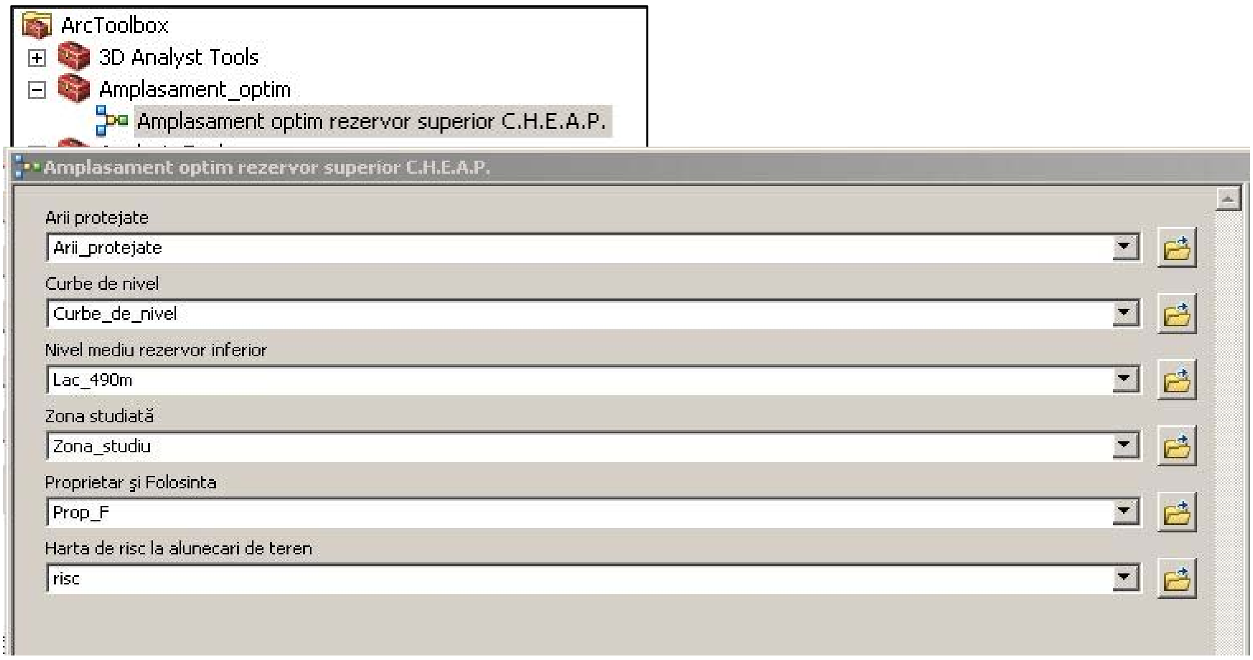

Figure 18. Application input panel

6. Conclusions

Initial data quality will reflect in the final product.

All the initial approximations will merge and amplify and will alter the final suggested area.

This study is a rough prospective solution to the given task.

Because of the above reason, this study is just the first phase in finding the truly best location for the upper reservoir. The next step is to do field work, on site prospections such as geological studies, land survey, environmental impact analysis owner identification etc.

The advantage of this method is that it reduces the study area to small feasible areas, reducing time and money for larger area studies and expeditions.

Using the application specified at point 5. this study can be applied to any region, regardless of the location and area, only with the condition that the input data be standardized according to the application specifications.

This solution can be adapted if the initial task list is modified.

This method has been confirmed by on site study and area 3 has been validated as a location for the upper reservoir that will serve a pumped storage hydroelectric plant.

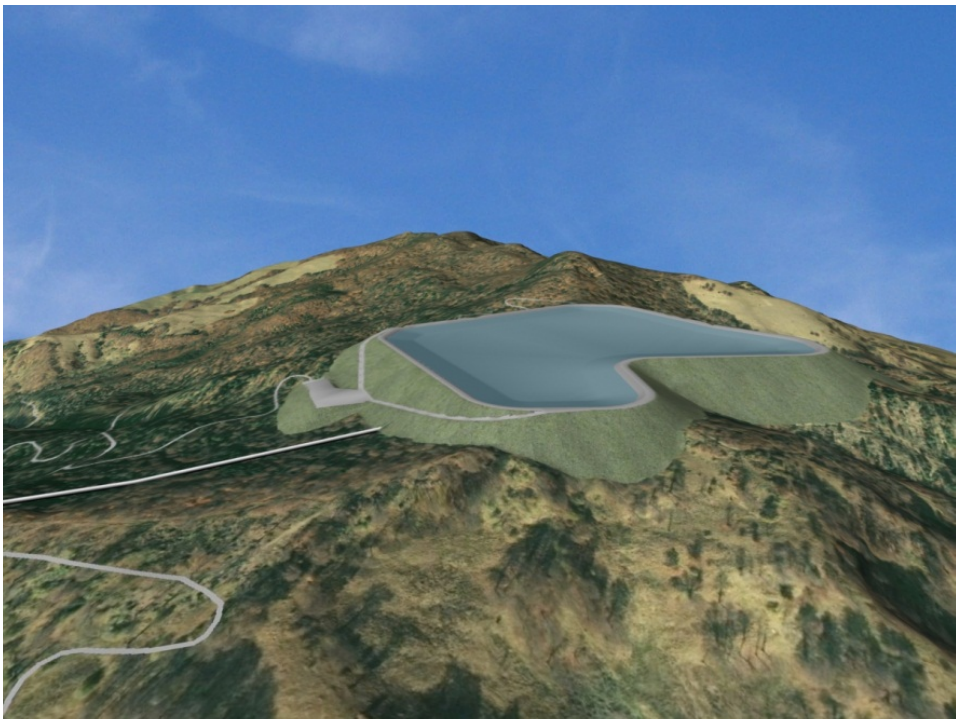

Figure 19. Area 3 - proposed upper reservoir 2.8 Mm^3

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15. *Source: http://www.energystorageexchange.org/projects/4*