M^3 (Monitoring, Management and Mapping) – tool for the solution of the conflict: "people and environment"

Z. Boukalová, V. Beneš & P. Kořán
Cross Czech, G-Impuls, Czech republic

Abstract

Natural disasters are typical examples of people living in conflict with the environment. Vulnerability of populated areas to natural disaster is partly a consequence of spatial planning policies that failed to take account of hazards and risks in land use zoning/development decisions. Thus it is important to combine knowledge, technology, M^3 and actors in the field of risk assessment and land use zoning to achieve effective natural disaster prevention and mitigation. Understanding geologic processes is essential to research fields, such as engineering, environmental management, land preservation and restoration, urban environment, soil and water pollution, soil erosion and landscaping.
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1 Monitoring, management and mapping

In recent years, due to more and more frequently occurring weather effects of extreme nature which cause disastrous floods, increased attention has been paid to two main issues, in the context of the conflict "people and environment":

- Inspection and maintenance of dikes and embankments.
- Risk mapping of natural hazards (floods) and spatial planning policies definition.

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1.1 Monitoring, management and maintenance of dikes

Inspection, monitoring, management and maintenance or remediation of dikes and embankments is very important task, in recent Europe. Our experience gained in the Czech Republic (projects IMPACT, FLOODsite, ARMONIA) shows that inadequate attention has so far been paid to the documentation of dike breaches and failures after extensive floods. Basic data on the reasons for, and the extent and course of dike breaches are missing in the majority of the cases. Exact data are seldom known, even from the recent disastrous floods in central Europe that occurred in 1997, 1998 and 2002. The data are often incomplete and of insufficient authenticity. However, it is evident that analyses of such information, followed by appropriate adjustments and repairs of the dikes, may significantly reduce the risk of occurrence of new dike breaches and failures. We particularly talk about those dike segments where the reasons for destruction were, for example, inappropriate dike structure, inappropriate material or reduced stream channel capacity due to clogging. Furthermore, after analyzing a database, it often turned out that dike breaches in these sections had occurred repeatedly.

Statistical analysis of dike breach parameters may also allow some important generalizations related to the causes and characteristics of breach in specific river basins (catchment areas). For example, it turns out that the prevailing reason for dike breach occurrences in Slovakia is liquefaction caused by seepages in the underlying beds. The main reason for dike failures in Hungary is overtopping. Entirely different mechanisms of dike breach occurrences of course require different types of preventive dike modifications.

At present, dike maintenance and preventive repairs are based on a system of visual inspection complemented by analyses of airborne or satellite photographs, or sometimes on slow intrusive methods (boreholes drilling etc.) results. Only rarely is the project documentation of dikes and embankments complemented by detailed information on structures and material properties, i.e. information acquired by engineering-geological investigation, drilling, laboratory tests of soils, etc. The reason for this is the considerable cost of such investigation and the large extent of the dikes. However, we believe that information on the nature of materials and basic dike structure is essential for efficient failure prevention. This particularly applies to old dikes for which construction documentation is missing. Furthermore, in some countries (for example, developing countries or countries of former East Europe) we may expect low quality of construction work that may contribute to dike breach when stressed (see Fig. 1).

It is in this area that a package of geophysical methods can be of particular value. Geophysical methods investigation and monitoring provide a continuous image of physical properties of a dike body and, furthermore, this type of investigation is relatively inexpensive. Last years, we concentrated on testing the possibilities of application of the following geophysical methods:

- **Geo-electric methods**

resistivity profiling (RP), self potential method (SP), multielectrode method (MEM), electromagnetic frequency method (EFM).

Figure 1: Example of inappropriate material in the core of a damaged dike.

- **Seismic methods**

shallow seismic method (SSM), seismic tomography (ST), multi-channel analysis of seismic waves (MASW).

- **Microgravimetric method.**
- **GPR method.**
- **Geomagnetic survey, gamma-ray spectrometric survey.**

Potential now exists to apply an innovation: a Geophysical investigation tool, which is based on generating electro-magnetic (EM) fields and mapping their propagation through soils and structures. The method finds perturbations in the EM fields arising from concealed boundaries or changed materials. Previous tools and approaches have shown limited effectiveness and poor data interpretation accuracy compared with conventional intrusive geotechnical investigation and description methods. Speed has been affected by the need to repeatedly remount transmitters and receivers.

The new technology, so-called Geophysical Methods Suite – GMS (using GEM-2 tool), could provide a breakthrough in an area of science in which infrastructure managers and engineers have been highly skeptical. Experience gained in the Czech Republic shows that the new technology GMS could support national government asset owners across Europe. The GMS is proposed to enable rapid, economic and repeatable identification of non-homogeneities (possible points of disruption) in line embankments and is especially promising for the identification of problem or weak spots in line embankments for water management and flood defense, where embankments could be subject to rupture under extreme hydrological conditions. Thanks to fairly fast and economical monitoring procedures it should also be possible to use the technology to facilitate the maintenance of line embankments in a state which should prevent leakage and ruptures. More, this technology should make it possible to check fairly long sections of line embankments in relatively short time (about 10 km per day), whilst maintaining adequate levels of precision.

What is innovative about the proposed GMS? Having used the new tool to define the hot spots of an existing embankment system, detailed investigation, maintenance and renewal efforts can be concentrated in a cost-effective way on the critical parts of the embankments. The core part of the GMS is Dipole Electromagnetic Profiling with the unique brand new and innovative apparatus the GEM-2 (multi-frequency device).

In order to incorporate the geophysical methods into a complex of dike prevention and maintenance, we first have to identify the effects that can be monitored by these methods. Figure 2 illustrates an approach to incorporation of geophysical methods into a dike and embankments maintenance program. From the viewpoint of dike maintenance – dike breach, timing of the action is of central importance.

The breach formation itself takes place at a time scale of hours, max. a few days. A hazardous segment is evident, application of geophysical measurements is not assumed here. However, except for overtopping, the remaining defects mostly show somewhat hidden PRE-breach formation stage (for example, seepage through the underlying beds, repeated seepage at an increased water level, structure defects, etc.) which predisposes the point of future dike breach. This stage often lasts for even tens of years and is our area of interest for the application of geophysical methods.

The database of quick testing measurements, which is the basic component of the monitoring system (see Fig.2), provides a basic description of dike materials and structures, division of dikes into quasi-homogeneous blocks (i.e. dike segments showing similar geotechnical and physical properties). Productivity of measurement is rather high, based on the dike character ranging between 10 and 20 km of a dike per day. From the viewpoint of dike maintenance, these data are an appropriate complement to a visual inspection, allowing us to assess relative permeability of the dike material and its homogeneity and to detect subsurface distribution systems reaching a dike, etc. This allows us to more precisely identify problematic dike segments that are disturbed and weakened inside. All types of dike-testing measurements should be linked to GPS.

The GMS system: is composed of 3 basic building blocks:

Quick testing measurement – fast and cheap measurement for basic evaluation of the dike condition and homogenity within the whole river-basin. This method is also the core for repeated (monitoring) measurement. As a method for this purpose we suggest DEMP using multi-frequency tool (for example GEM-2).

Diagnostic measurement – detailed measurement of the eroded (non-homogeneous) sections aimed at finding hidden defects of the dikes. The method is based on the application of the set of geo-electric methods, especially multi-probe resistance method MEM complemented by another independent method based on the type of the defect searched for accordingly.

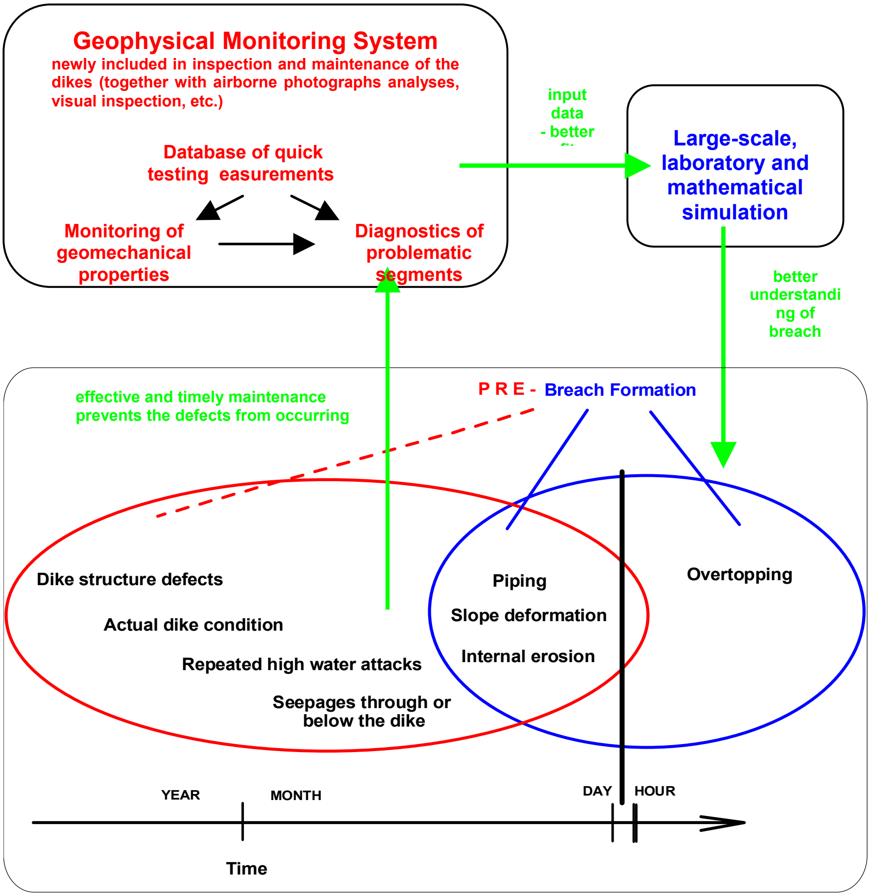

Figure 2: A diagram of incorporation of geophysical methods into dike maintenance.

Measurement of geotechnical conditions – geophysical measurement to monitor geomechanical conditions of eroded dike sections. For the analysis of dikes geomechanical characteristics; especially seismic methods and micro-gravimetry will be used.

The GMS asset lies in the possibility of objective evaluation of dike homogeneity and condition. Geophysical methods are suitable supplement for current methods of checks (visual check, aerial and satellite pictures analysis). Monitoring function of GMS lies in the analysis of relative changes of geophysical parameters. GMS database construction requires so called initial stage and so called following check stages.

Initial stage of GMS is based on quick testing measurement of dikes within the whole area of the river-basin and following diagnostics measurement of selected problem sections. These checks result in complex evaluation of dikes condition in the river-basin including the suggestion of the necessary repairs. Special selected sections may be checked using measurement of geotechnical condition.

Check stages are planned for the dikes which are constructed to protect some place against high water level (flood protection). In Europe, the check stage should be carried out after 3 years at the latest without the reference to flood conditions. Check stages may of course be carried out based on agreement at whatever times according to the needs of the dike owner/caretaker, e.g. in limited time setting during floods. The check stage includes repeated quick testing measurement and comparison of the acquired data with the data from previous stages (when using the results to eliminate the influence of climatic conditions). Thanks to analysis of repeated measurements we are able to locate time unstable anomaly areas which often coincide with the places where the dike ruptures occur. The check stage can be supplemented with diagnostic measurement if needed.

The GMS system success is largely based on narrow co-operation between geophysics specialists and dikes caretakers. They have large quantity of information which can help in making the geophysical measurements interpretation much more precise. Without mutual trust and communication the GMS database program has no meaning.

1.2 Mapping of natural risks and hazards

The implementation of flood risk assessment procedures for spatial planning in order to prevent and mitigate floods in urban areas is very important issue. From October 2004, the project ARMONIA is trying to find right solution regarding the implementation of multi-risk assessment procedures for spatial planning in order to prevent and mitigate natural disasters in an urban environment. The main objective of the project is to provide guidelines for EU standards on the harmonisation of data, methodologies and maps related to all main natural hazards acting on urban areas, incorporating consideration of climate change impacts.

ARMONIA seeks to achieve outcomes that can mitigate the adverse effects of natural phenomena through joint effort of the scientific community, technology experts and users. The target is not only a scientific output, but a measurable impact on policies/practices for disaster mitigation initiated within the period of the project, which fits with Europe's goals regarding sustainable development in supporting environmental and security policies by facilitating and fostering the timely provision of quality data, information and knowledge, developing tools and improving management practices.

Disaster management in Europe currently suffers from following main reasons: There is no common shared strategy at European level for the prevention and mitigation of natural disasters, mainly when dealing with the integrated and combined impacts of natural hazards on modern society, including secondary social effects. Main important initiatives are on regional or national levels. As disasters are often affecting several countries with heavy transboundary effects (as for example the floods 2002), there is important to support common multidisciplinary EU activities focused on prevention and mitigation of natural disasters.

There is the need for a modern "disaster science" which can better deal with the complexity of reality in Europe (taking into consideration dynamic systematic interactions). The common accepted "natural and induced technological disaster management cycle", including stages of prevention, mitigation, preparedness, response and recovery is a theoretical view that is usually marginally working in practice: the synergic interaction and implication of various hazards and risks are missing. A new approach for the harmonization and further development of all component of the disaster cycle is needed.

The effective use of available technological tools in the field of disaster management by end users is not common in many European countries, especially in some of the new member states. More, the sustainable hazard mitigation programmes addressing both the short and long term consequences of their implementation in a holistic manner have not been adequately included in the agenda of European research, end users and stakeholders.

The project ARMONIA should bring the important outputs and solve the issues as harmonisation of different risk mapping processes for standardizing data collection/analysis, monitoring, outputs and terminology for end users and optimisation of methodologies for hazard/risk assessment for different types of disastrous events. More, the project will suggest the design of a harmonised decision-making tool for applying hazard and risk mitigation in spatial planning and optimisation of a guideline on natural hazard mitigation in the context of the EU Environmental Assessment Directive (2001/42/EC), till end of year 2007.

Human and economic losses due to natural disasters continue to increase world-wide. The high importance of disaster reduction policies was stressed at the UN-World Conference on Disaster Reduction (January 2005, Kobe, Japan). As a consequence there is a need to integrate knowledge, technology and actors and to update state of the art into a disaster management approach that reflects the complexity of the modern society in a realistic way.

2 Conclusions

There is an urgent need for better disaster and vulnerability reduction support actions, in the catchment scale. In order to achieve overall management of water resources, at river basin level in particular, it is of prime importance for decision-makers (Directors of River Basin Organizations and Administrations, Basin Committee members, representatives of Local Authorities and associations of users) to have easy access to comprehensive, representative and reliable information, at all relevant levels. The M^3 (Monitoring, Management and Mapping) tool, adapted on the modern society would be the best start to find realistic and end users friendly “disaster and vulnerability reduction support actions” in the context of the conflict: “people and environment”.

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