**HazTOOL: A Geo-spatial System for Data Management, Modeling, Visualization, and Analysis within an Alpine Valley**

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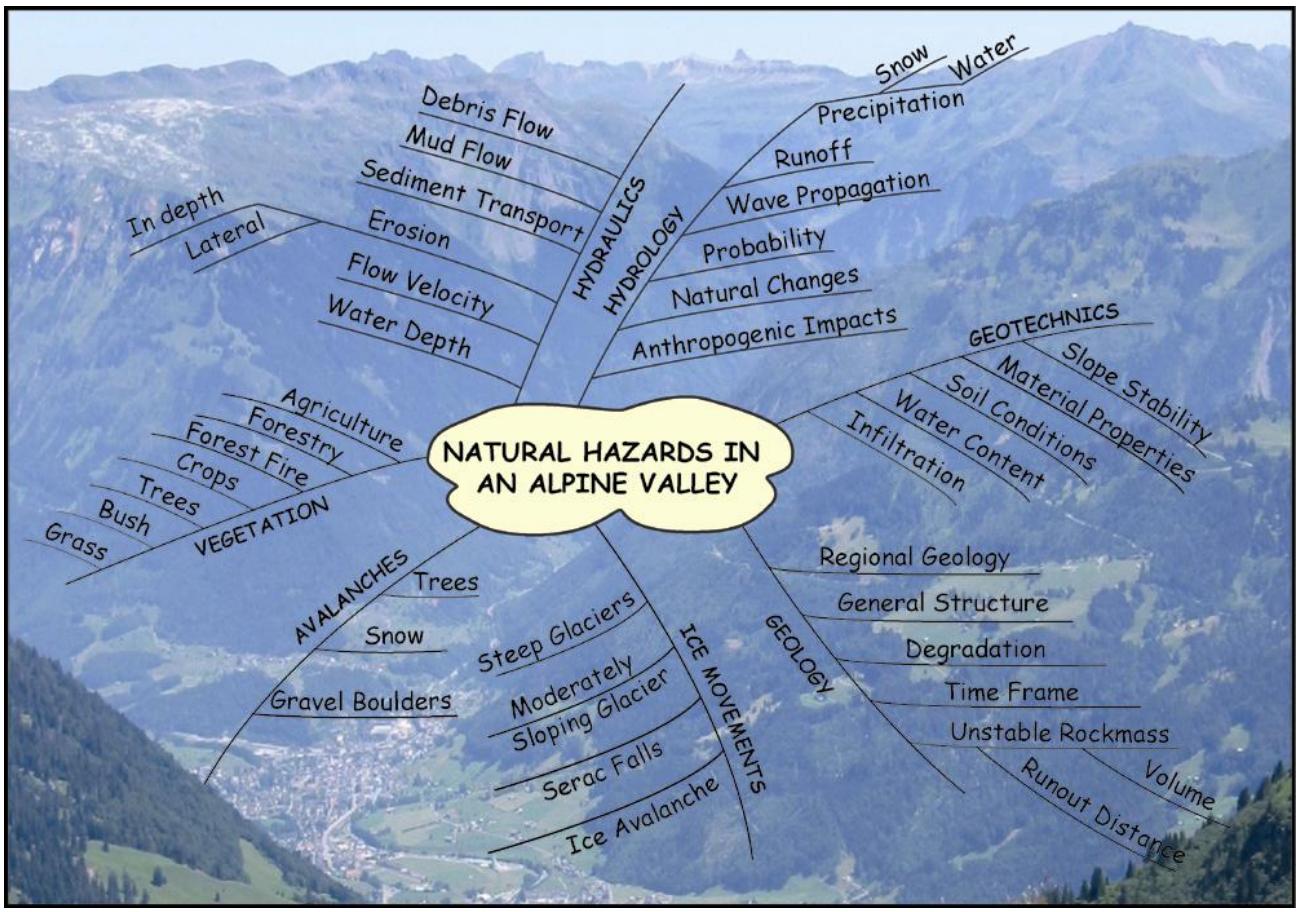
## 1. Introduction

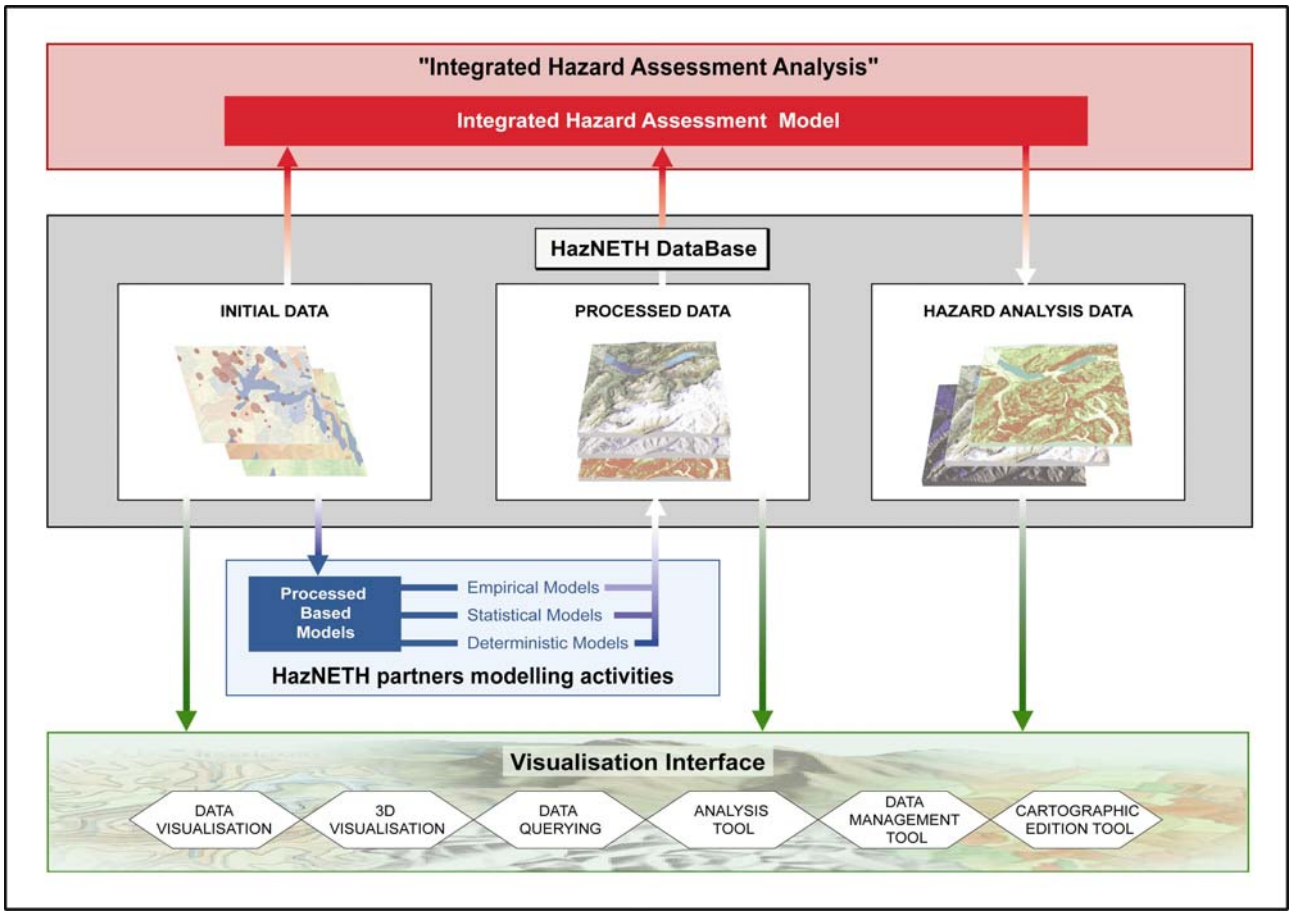
Switzerland is exposed to a wide variety of natural hazards especially happening in its alpine valleys (Figure1). Recent events, such as those occurring in Canton Wallis in October 2000, which included floods, debris flows and slope instabilities, or the avalanches in February 1999 lead to substantial loss of life and damage to property, infrastructure, cultural heritage and environment. As consequence came into view the necessity to move towards "*an integrated risk management and sustainable risk prevention culture*". Methods started to be developed and improved to define both the affected areas (by floods, debris flows, snow and rock avalanches, etc.) and the relevant parameters that make possible to define the static and dynamic loading of structures in these areas.

**Figure 1.** A synthesis of different phenomena acting as natural hazards within an alpine valley is done in the picture below.



A platform for geo-spatial hazard and risk information system, comprising graphical and numerical geo-spatial data, aerial and satellite images, geo-referenced thematic data and real time monitoring feeds is being developed by the Research Network on Natural Hazards at ETH Zurich (HazNETH). This will allow researchers to build efficient systems for handling, pre-processing, and analyzing the existing huge and variable data sets from different natural hazards data as well as different natural environments in the Swiss region. The final product will be a geo-spatial hazard and risk information system (Figure 2).

**Figure 2.** The general scheme of the HazTOOL system




A major aim of this technical development is also to provide a versatile tool not only accessible to experts with GIS knowledge, but also to other experts, decision makers such as emergency organizations, public authorities and even politicians. To this end a second kind of access and interface to the data and the results of analyses will be developed, based on the versatile concept of Atlas Information Systems (AIS). The potential of such AIS lies in the integration of adapted GIS functionality as well as visualization and multimedia technologies, offering better information access and a versatile palette of presentation tools in 2D, 3D and 4D (time) without the necessity to acquire special GIS knowledge. The application will be used as an additional tool for risk and emergency assessment, as well as for planning purposes.

## 2. The geo-spatial system for data management, modeling, visualization, and analysis (HazTOOL)

### 2.1. General Frame

Three main steps will be followed in order to create the information system: the spatial database development, an integrated hazard procedure design, and a web data query and visualization tool-set. The geo-spatial database including the entire set of natural hazards phenomena occurring within an alpine valley will offer a platform to study the existing hazard assessment methods and will allow the analysis and combination of various hazard parameters in relationship to phenomena. Spatial distributed data and time series will be used to improve the hazard procedures and to derive new methods. Torrent streams and debris flows phenomena were chosen to be analyzed as a first step. In parallel uncertainty analysis in hazard assessment will be developed.

These three steps could be identified with the following three main research directions:

A. Data analysis, representation and database development
B. Integrated natural hazard assessment method and data modeling tools
C. Multimedia information system for natural hazard analysis "HazTOOL"

The first direction deals with the need of managing the huge amounts of related data used in natural hazards assessment. To solve this first task a spatial database integrating the entire set of input and output data is currently developed (Direction A). However, important issues of combining hazards and their effects are to be solved: deriving new methods where the existing hazards could show intrinsic interaction, developing user-interfaces for hazard parameter quantification, and uncertainty analysis of data and methods.

Another main direction (Direction B) is to perform a detailed investigation, which is directed towards a qualitative and quantitative hazard assessment for interrelated phenomena: torrent streams and debris flows, with consideration of related hazards such as soil and rock mass movements, and floods hazard.

The third direction (Direction C) described in this paper, complement the first two and consists in the design of a multimedia-based geo-spatial hazard and risk information system which comprises graphical and numerical geo-spatial data, visualizations, images, the thematic data and at a later stage real time monitoring data. The central idea is to provide a versatile tool that is not only accessible to experts with GIS experience, but in user-friendly versions also to decision-makers (e.g. politicians and civil protection authorities).

### 2.2. Multimedia information system for natural hazard analysis "HazTOOL" (Direction C)

The different hazard, environmental and topographical data layers will later be integrated in the innovative concept and user-friendly technique of the mentioned Atlas Information Systems (AIS) in a multimedia environment on an Internet platform. The major focus in the proposed research work must be laid on the definition of meaningful and useful hazard related GIS functions and their embedding in a user-friendly and intuitive workflow. The concept of the multimedia environment will contain the following features: functionality groups (general functions), thematic navigation, spatial navigation and orientation, visualization functions, and GIS-functions. A high interactivity will enable for active participation in a multimedia environment thus affording an adequate

immediate response. The development of a graphic user interface with a structured but flexible layout using a functional screen segmentation will enable an easy access to information.

Visualization within the proposed system environment will be guided primarily by quality aspects of cartographic design and a high degree of interactivity. To achieve these goals, visualization is treated as a bottom-up data-driven process, controlled by a set of rules and constraints. Whenever available, the data is included in its original form, thus enabling the user to access original as well as derived data (such as changes, percentage etc.) by applying simple built-in spreadsheet calculations. Relying largely on data, maps can potentially be modified by the user in numerous ways. Unlike with GIS or mapping systems, the multimedia atlas will also prevent the user from creating useless or even wrong maps. 2D visualization refers to topographic and thematic map design and the portrayal of the map elements in different contexts under dynamic situations. The types of maps to be displayed in the atlas are: topographical base maps, statistical and other kinds of thematic maps such as raster- and vector-based maps. Where appropriate, a combination from a number of given map layers and thematic variables can be chosen. Modifiable color scales or layer transparencies are additional visualization/analytical functions that support individually designed maps or focus on characteristic spatial patterns. Specific expert modules allow alternative symbolizations. Scale-dependent symbol size generation is used in order to reduce the number of hidden symbols when zooming in.

Additionally, given data classifications can be dynamically changed. Functions for the display of variations in time will be implemented for visual inspection or for analytical purposes. Animated time series show processes in time and can be created on any of the regional aggregation levels and from any area of interest.

The envisaged system will also play a central role in the future activities of the HazNETH consortium. Only such an open, advanced analysis and visualization system which is independent from commercial products will be flexible enough to match the needs arising from the planned projects of the partners: The following steps and demands can be anticipated: 1.) Implementation of a common GIS data model for combined natural hazard analysis and correlation, 2.) data quality aspects, 3.) further extension towards multi-scale models, 4.) ease of access to data and analysis functions, 5.) further development of web mapping capabilities, including seamless web maps and temporal modeling, 6.) 3D modeling and cross-section/volume visualization of phenomena (surface and underground), 7.) integration of multidimensional, multi-thematic real-time data, on-the-fly creation of queriable, high quality web maps and information systems, 8.) modeling of standard decision chains of users (agencies, offices, administrations, etc) in order to strengthen decision support systems in the field of natural hazards.

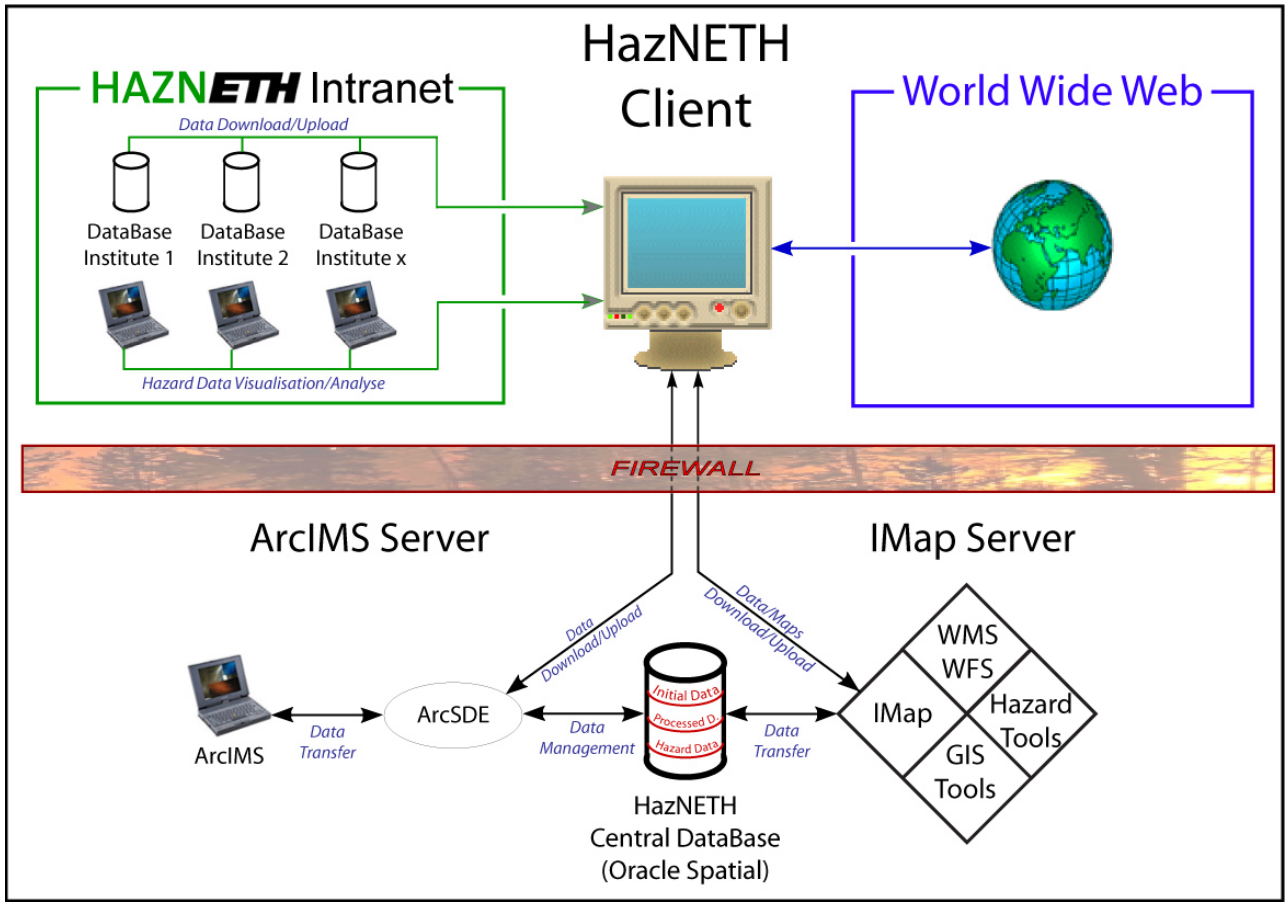
### *HazTOOL proposed scheme*

Diverse methods, tools, and software are used to store, analyze and display the natural hazards data: maps, geometric data as well as time series, laboratory results, and metainformation are stored in a distributed database (Oracle Spatial).

The delivering of dynamic maps and data via the Web is done via ArcIMS (ESRI). This tool supports multimedia, layers, database management, client-side information entry and geospatial information sharing.

A specific server (IMap) is being developed in order to provide a dedicated Natural Hazards GIS tool on the web. The general proposed scheme could be seen in Figure 3.

**Figure 3**. The study design scheme proposed for HazTOOL implementation.




***Data and Server Standards***

HazTOOL will try to follow the current tendency of Community Environmental Policy overseen by INSPIRE (Infrastructure for Spatial Information in Europe) concerning the spatial data and data server harmonization through the establishment of integrated spatial information services, based upon a distributed network of databases, linked by common standards and protocols to ensure compatibility.

To overcome the growing amount of heterogeneous data that are stored in diverse formats and in diverse databases the following Open GIS Consortium (OGC) and ISO specifications and standards will be followed:

OGC standards:
- Web Map Service standard (WMS)
- Web Feature Service standard (WFS)
- Web Coverage Service standard (WCS)

ISO standards:
- ISO 19115: Metadata standard
- ISO 19139: Metadata Implementation Specification standard
- ISO 19136: Geographic Markup Language (GML) standard

## 3. Future developments

Potential damage in Switzerland constantly increases, because man moves into areas that are more risky, and the worth of the installations is constantly increasing. A profound basis on which the necessary decisions can be made is necessary.

The described research will provide a knowledge base and network, as well as a detailed interdisciplinary data set to be used for future calibrations of nation-wide or other local hazard and risk assessment projects, aiding local communities with an easy-to use web-based client software in their operations. This approach is not only seen as a seed project and pilot study to Swiss hazard and risk assessment research, but also to provide an easy-to-use tool for future cost-effective hazard assessment and response operation by local as well as government authorities. In times of crisis, time is sometimes lacking to consult experts immediately, and if called their turnaround time for recommendations will be faster, more precise and possibly even more accurate by the availability of such an integrated hazard assessment tool (HazTOOL) with rigorous quality and uncertainty control.

The final software product and its planned sequential updates would be easily implemented into federal and cantonal government agency operations concerned with Swiss geotechnical and risk inventories, hazard assessment and disaster relief, or cantonal environmental offices. Other versions may eventually be made available by to be defined means to international and foreign national agencies, such as UNEP (United Nations Environment Program), or through Swiss foreign aid and disaster relief agencies.

This project is not only relevant for Switzerland. The results are also highly relevant to all other countries of the European alpine region, as well as other mountainous areas: the Himalayas and the Andes experience similar problems. The result of this project can also be transferred to these regions.