INTEGRATED GIS DATA SET AND 3D ANALYSIS FOR ENVIRONMENTAL IMPACT ASSESSMENT IN THE CASTELFRANCO EMILIA AREA (MODENA PROVINCE, NORTHERN ITALY)

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Working Group TC VII-8

KEY WORDS: Digital database, Geographical Information System, Environmental Impact Assessment, Geomorphology, Castelfranco Emilia, Modena Province

ABSTRACT

This paper is prepared in the framework of a European project that aims at gaining a better understanding of the effects of transportation lines on geomorphologic processes and assets for preventing and mitigating risks and impacts.
In this work is presented a database sets in order to analyse an Environmental Impact Assessment (EIA) using Geographical Information System (GIS) and three dimensional (3D) techniques.
The study area is Castelfranco Emilia Municipality, which is located in the southern central sector of the Po Plain.
The study analyses three alternatives of the Bologna-Milano high velocity railway, which will crosses the territory of Castelfranco Emilia Municipality.
The environmental data considered (data on topography, lithology, geomorphology, hydrogeology and climate) have been introduced into the ILWIS Geographical Information System (GIS). Information was treated, and organised in different thematic maps. For each map a georeference database was created. The EIA analysis was also supported with 3D techniques through the software PC Raster (Dynamic Modelling Package) and Surfer TM.
A useful tool to storage and manage the geomorphological and geological data is elaborated in order to provide a decisional support to the decision-makers.

1 INTRODUCTION

This paper illustrates the study carried out in the Castelfranco Emilia area (Province of Modena, Northern Italy), (Fig. 1) to evaluate a set of geomorphological components that are indispensable in the Environmental Impact Assessment (EIA) in relation to a new transportation project. In fact, the Castelfranco Emilia territory will be crossed by a track of the high-speed Milano-Bologna railway, which is a part of a bigger project for the strengthening of the Italian railway system, projected and supervised by the engineering society of the Ferrovie dello Stato S.p.A.

The study was carried out in the framework of the GETS project (Geomorphology and Environmental Impacts Assessment to Transportation Systems) financed by the European TMR (Training and Mobility of Researchers) programme. The investigations in the GETS project are addressed to gain a better understanding of the effects of transportation lines on geomorphologic processes and assets.

In this paper the data set which is presented, concerns both the natural data related to the geomorphological characteristics of the area and the human intervention on it. The data set is structured in order to analyse the Environmental Impacts Assessment for three alternatives of the above mentioned high-speed railway track in the northern part of the Castelfranco Emilia Municipality, using GIS and 3D techniques.

2 GEOMORPHOLOGICAL AND GEOLOGICAL SETTING

The territory of Castelfranco Emilia is located in the southern central part of the Po Plain, in the Apennine fluvial system domain, the total surface is of 102.47 Km^2. Two rivers flowing northward cross the Castelfanco Emilia territory: the Panaro River along the western boundary and the Samoggia River along the eastern one. The morphological characteristics of the area are correlated to the evolution of the Panaro and Samoggia Rivers and their abandoned fluvial forms (Castaldini, 1989) and by the decreasing in texture of the alluvial deposits from south to north. In particular the decreasing of texture and plain slope, correspond, near Castelfranco Emilia, to the presence of natural water springs called 'risorgive', and to the change in the fluvial pattern of the Panaro River from a braided pattern to a meanderig one (Castiglioni et all, 1997).

The evolution of the river network in the study area was conditioned by the movements of the apenninic structures buried in the plain subsoil (Bertolini et all, 1982) and by intense changes in the climatic conditions during Middle–Late Pleistocene and Holocene (Cremaschi & Marchetti, 1995), which conditioned the fluvial actions of the Panaro and Samoggia River. The aggraded conditions during the last glacial maximum were substituted by erosive phases at the beginning of the Holocene. Then, new alluvial sediments, finer in size, were deposited in the distal part of the alluvial fans. These sediments, mainly clay, buried the gravel deposits of the Late Pleistocene. From 1950's also the human activity (quarrying and meander cuts) influenced the river pattern and the fluvial processes (Pellegrini et all 1979; Castaldini & Piacente, 1999).

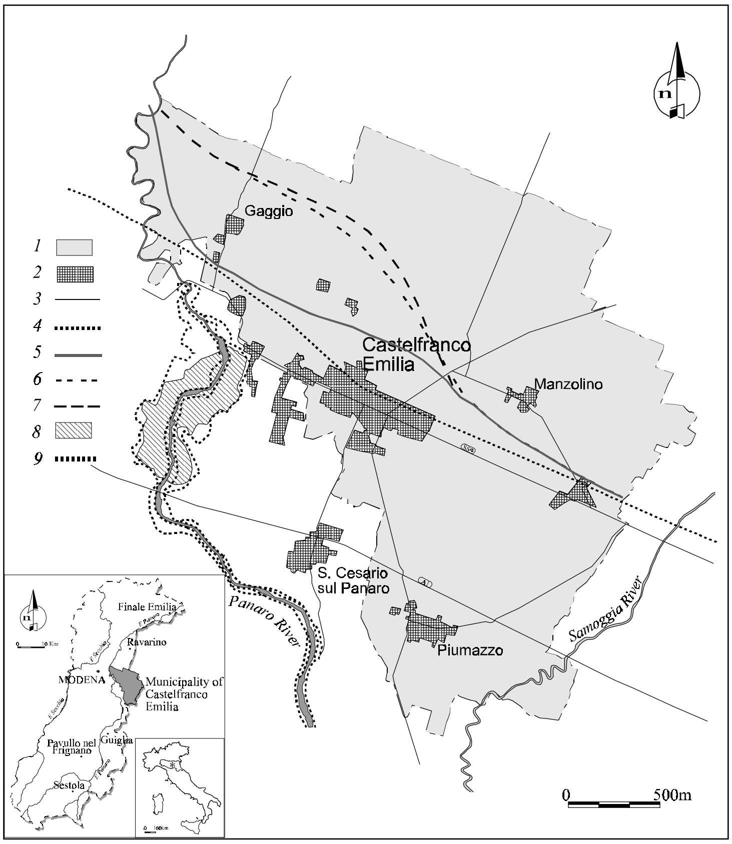

Figure 1. Location of the study area. 1) Municipality of Castelfranco Emilia, 2) built up area, 3) main road, 4) railway track, 5), 6), 7) alternatives tracks of the high speed railway project, 8) flow regulation system, 9) fluvial scarp.

3 DATA SET

3.1 Study methodology

The data set is structured to include the collection, the renovation, the modelling and the data analysis, for the evaluation of impacts and risks in the Environmental Impact Study of Castelfranco Emilia Municipality.

The environmental information (data on topography, lithology, geomorphology, hydrogeology and climate) and the data concerning human activity (quarry activity, infrastructures and the layout of the alternatives high-speed railway track) were primarily collected through bibliographical researches, aerial photo interpretations and field survey. In particular, very important has been the analysis through the interpretation of aerial photographs. The photographs examined included black and white aerial photographs taken in 1955 (scale 1:33,000 approximately), in 1973 (scale 1:16,000 approximately), in 1994 (scale 1:75,000 approximately) and colour aerial photographs taken in 1978 at scale of 1:20,000 approximately.

In a second phase, all these data were introduced into the Geographic Information System (GIS) ILWIS 2.2 and organised in different georeferenced thematic maps with a linked database. All maps have been realised in vector format (point maps, segment maps and polygon maps) with a coordinate system containing information about the projection (UTM), the datum (European 1950 - ED50), the datum area (Mean Europe), the ellipsoid (International 1924) and the zone (32). Then the vector maps were rasterised, with a pixel size of 25 x 25 meters and a georeference, with an affine transformation and a sigma error of 0,993 pixel. Every map has a domain (value, ID or class domain), a representation and an attribute table.

Some of the data have been also elaborated with 3D analysis with the support of Surfer TM and PC Raster (Dynamic Modelling Package) software.

3.2 Digital Terrain Model

In the study area, which is located in an alluvial plain, the difference in elevation is between 68 m and 26 m a.s.l., with a mean gradient of 0.32%; the slope decrease northwards.

The topographic maps of the municipality are from the new edition (1984) of the Emilia Romagna Technical Regional Map (CTR), at the scale 1:25,000. The format of these maps is a digital one, so the raster edition has been assembled, imported and georeferenced in ILWIS.

The microrelief of the territory was prepared by a hand made geometric method. The map was realised using 1 meter contour intervals. Automated treatment of the isolated elevation data would not produce a realistic model, representative of the natural topographic surface. This is due to the heavy conditioning of the human activity to the scattered points. Any interpolator is able to solve situations where the variables are homogeneous in space and time and it are not influenced by human conditioning.

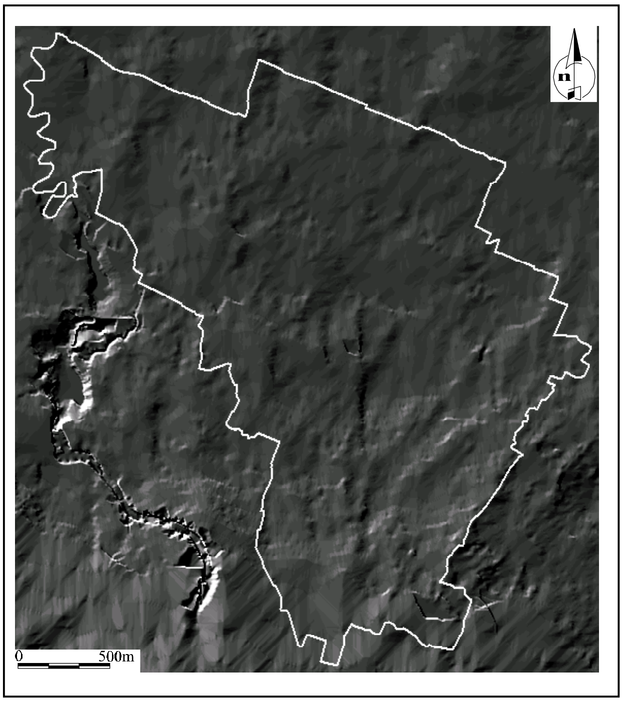

Figure. 2. Digital Elevation Model of Castelfranco Emilia area (pixel size 25 x 25 m).

The hand made microrelief has been prepared considering only the elevation points in natural conditions or introducing an evaluation of their naturalness. The areas affected by infrastructures, such as bridges, embankments, quarries, etc., have been discarded. So, the contour lines represent the natural topographical relief without influence of human modifications.

Then the contour lines have been digitalized and the obtained segment map has been rasterised and interpolated in order to obtain a new Digital Terrain Model (DTM), (Digital Elevations Model (DEM) (Fig. 2), slope model, in degree and in percentage and aspect model), with a precision of 0,001.

3.3 Surface Lithology

The territory is made up of alluvial deposits of Panaro and Samoggia rivers, variable in grain size from gravel to clay and with a thickness of more than one thousand meters. The surface lithology consists mainly of silt, with bands of sand and clay oriented mostly SW-NE, it is correlated to the paleo-drainage network. Mainly gravel lithology outcrops near the southern track of the Panaro River.

A detailed surface lithological map was elaborated on the basis of field samples and bibliographical data (Gasperi, 1987; Gelmini et all, 1988; Fazzini et all, 1976). The surface lithology data taken from bibliography were digitalized and imported in ILWIS in different

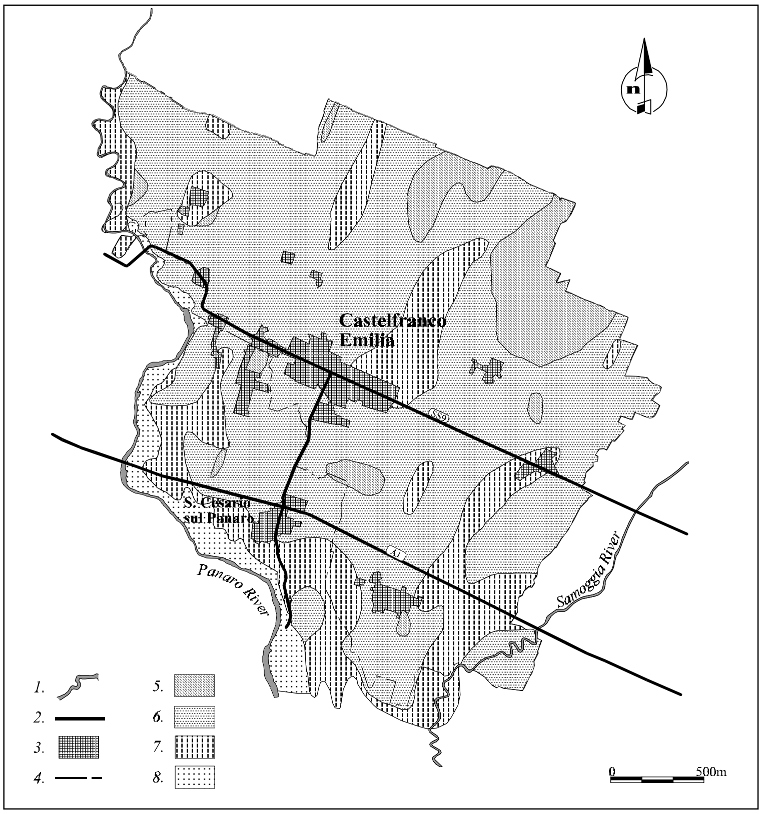

Figure 3. Surface litological map of Castelfranco Emilia area. 1) River, 2) main road, 3) built up area, 4) boundary of Castelfranco Emilia Municipality, 5), mainly clay, 6) mainly silt, 7) mainly sand, 8) mainly gravel.

layers. Through the overlap of these layers, incongruent areas have been identified in which a detailed field survey has been done. Lithological samples, taken with a hand drill at a depth between 1 to 2 m from the topographical surface beneath the soil, have been defined directly in the field as particle size classes, using the technique of the harmonic thread (Gasperi & Gelmini, 1976). Many of them have been tested in laboratory with particle-size analysis. The locations of the field samples were introduced in the GIS as a lithological point map and the results of sample analysis were introduced into the database as attribute table. On the basis of these data, a polygon map of the lithological surface has been created and classified in four classes: mainly gravel, mainly sand, mainly silt and mainly clay (Fig. 3).

3.4 Geomorphology

The geomorphological characteristics of the area are mainly the result of the evolution of Panaro and Samoggia rivers. The geomorphological information has been obtained from field survey, aerial photo-interpretation and bibliographical researches. The geomorphological landscape is mainly characterised by alluvial fans, and traces of abandoned river bed (at plain level as well as ridges), (Fig.4). They testify the transition in the plain from a braided system, in the southern sector, to a meander pattern, in the northern sector. Other geomorphological features are the fluvial scarps near the present Panaro River and the natural springs to the east of Castelfranco Emilia. The fluvial ridges, one to two meters high, are parallel to Panaro and Samoggia rivers in a N-S mean direction. In the northern sector some depressed areas are also in evidence. Fluvial ridges and depressed areas have a great importance both to recognise the geomorphological evolution of the area and to assess the flood hazard. In fact the knowledge of these morphological characteristics of the plain permit to assess both the confining of foods (fluvial ridges flank) and the flooded area (depressed areas). Geomorphological data contain also forms connected with human activity such as quarries, built up areas and a flow regulation system. The geomorphological elements have been divided into three different maps: point, segments and polygon map.

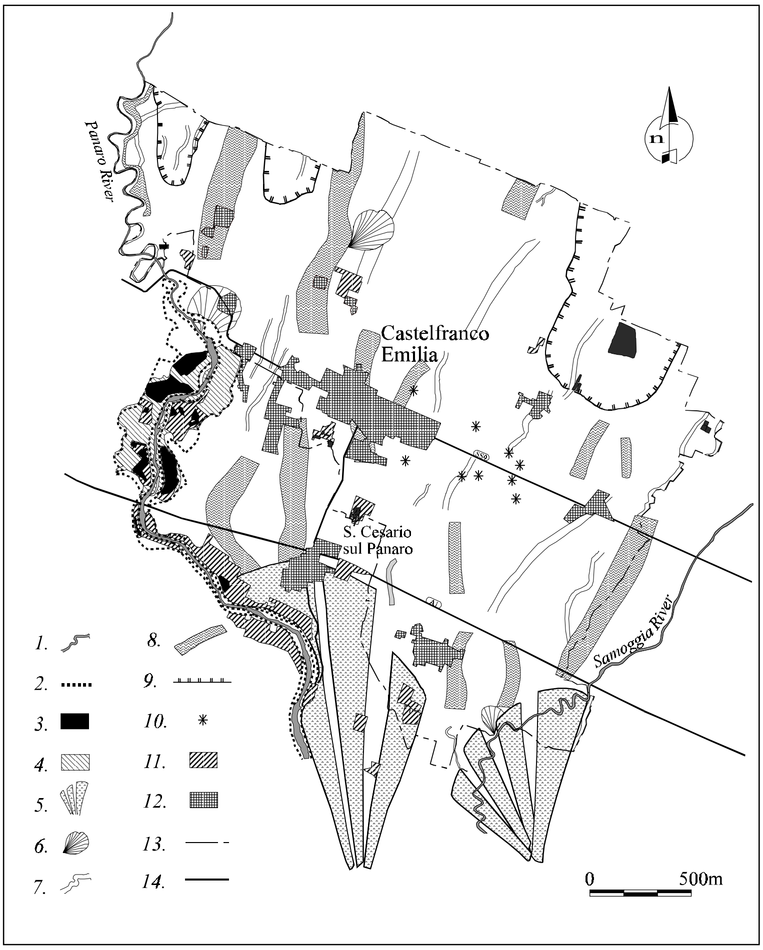

Figure 4. Geomorphological map of Castelfranco Emilia area. 1) River, 2) fluvial scarp, 3) bodies of water, 4) flow regulation system, 5) alluvial fan, 6) crevasse splay, 7) paleoriver, 8) fluvial ridge, 9) boundary of depression, 10) spring area, 11) quarry, 12) built up area, 13) boundary of Castelfranco Emilia Municipality, 14) main road.

From the geomorphological maps the more relevant geomorphological assets have been selected, (natural springs, abandoned meanders, etc.), after which a map of the Site of Geomorphological Interest (SGI) was elaborated. For the evaluation of the intrinsic quality of these sites and the evaluation of the impacts on them a methodology based on the degree of knowledge, expert knowledge and extent has been elaborated (Giusti & Gonzalez Díez, in print).

3.5 Hydrogeology

The hydrogeology of the Castelfranco Emilia plain is influenced by the distribution of the surface lithology and the geometry of the alluvial bodies in the subsoil. Particularly important are the apenninic rivers and their linkage to the freatic level. The freatic level from south to north becomes more superficial and rises to the surface near Castelfranco Emilia (Fig. 5) as testified by natural springs. The trend of piezometric level is more irregular.

Measurements of the different hydrological layers have been performed through the drillings, for the piezometric level, and the roman wells, for the freatic level; also a collection of hydrological data from Local Administrations (Regional Agency for Environment and Municipality of Castelfranco Emilia) have been collected.

The large amount of data has been collected and stored in ILWIS, as point map; data have been transferred to Surfer and interpolated using a kriging interpolator to reconstruct the 3D freatic and the piezometric surface of Castelfranco Emilia area.

3.6 Flooded and subjected to water stagnation areas

The Modena plain, including some areas of the Castelfranco Emilia Municipality, is a territory subject to flooding hazard, as witnessed by several flood events that occurred during the last centuries. A detailed study of the Panaro River floods has been carried out through searching historical catalogues on archives, public authorities offices, research agencies, research project and scientific reviews, in order to localised these events (e.g. Moratti, 1988; Provincia di Modena, 1996). Over the bases of the polygon maps on these historical events, of pluviometric data and of the analysis of the physical characteristics of the territory has been realised in ILWIS the map of the areas flooded and subjected to water stagnation.

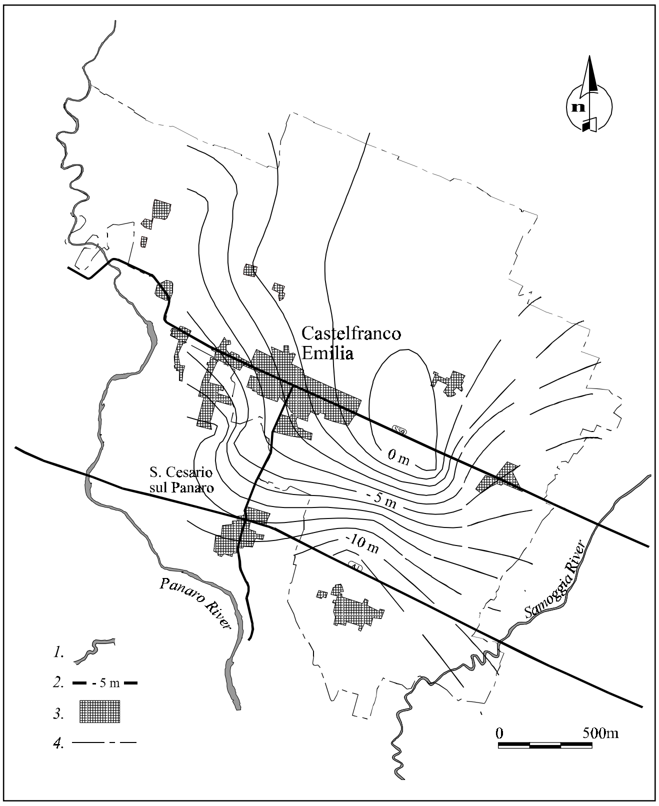

Figure 5. Hydrogeological map of Castelfranco Emilia area. 1) River, 2) deep of freatic livel, 3) built up area, 4) boundary of Castelfranco Emilia Municipality.

After the construction in the 1985 of a flow regulation system, that was completed in 1999 (total surface of 3,5 Km^2, total volume of 24 million m^3), for regulation of the Panaro River peak floods, no flooding events have occurred. For details on the flood hazard see Bertens et all (in print).

3.7 Infrastructures and railway track

The data set is also comprehensive of maps concerning the human infrastructures (roads, railway, embankments) and the projected transportation lines; these maps have been elaborated through aerial photo interpretations and field survey.

On the basis of the collected data also the three alternatives of the high-speed railway track that will cross the northern area of the Castelfranco Emilia Municipality have been investigated. The alternatives should be realised on embankments except when they cross the Panaro River, where they are on bridges. These lines with a radius of curvature of 3,500 m should permit the train to gain a maximum speed of 250 km/h.

4 DISCUSSION AND CONCLUSION

The data set, realised to manage the geomorphological environment of Castelfranco Emilia territory, is considered of great help in order to create a useful tool for the evaluation of impacts and risks in the Environmental Impact Study.

The study on the Castelfranco Emilia area has produced a database containing many geomorphological data. These types of data are very useful to individuate the interactions between man and environment (Fig. 6). In particular it is possible to distinguish two situations: impacts and risks (Panizza, 1992; Cavallin et all, 1994). During a previous European Project entitled ‘Geomorphology and Environmental Impact Assessment’ in the framework of the Programme ‘Human Capital and Mobility’ these complex relations have been investigated to elaborate a methodology to insert geomorphological research in the assessment of the Environmental Impact (Marchetti et all, 1995). In this paper, the above mentioned methodology the EIA of three alternatives of the project concerning the high-speed railway track in the Castelfranco Emilia Municipality is studied in depth.

The main impact of the proposed alternatives is defined on geomorphological assets. They are identified on the basis of the methodologies proposed by Panizza et all (1995) and by Rivas et all (1997) and modified by Giusti & Gonzalez (in print) for the evaluation of their intrinsic quality. Geomorphological assets are selected starting from the digital geomorphological maps, taking into account the scale of the asset. The assets are classified on the basis of three independent categories (processes, paleogeomorphological examples and examples of evolution). These categories are dimensioned using normalised parameters as extent, degree of knowledge and expert knowledge. Particularly valuable geomorphological assets are the natural springs to the east of Castelfranco Emilia and the abandoned meanders of the Panaro River at the western boundary of the area. The distribution of these forms will permit the assessment of the eventual impacts.

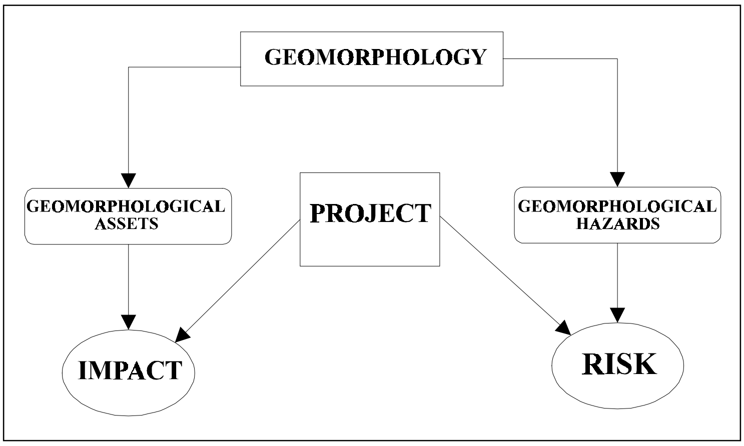

Figure 6. Interactions between geomorphology and project (from Panizza, 1996, modified).

The main risk for the project and the surrounding settlements is due to the flood events and to areas subjected to water stagnation. Due to the concomitance of geomorphological processes, lithological factors and the superimposition of the railway track, some areas are subjected to water stagnation. This is evident for the three alternatives, so the water stagnation is conditioned by the projected railway.

For the assessment of the areas subjected to flood hazard, a model has been prepared with the PCRaster Modelling Package, which considers past discharge, the past levee failures, the microrelief, the geomorphology, the soil permeability due to the soil texture and the human infrastructures (i.e. main roads, quarries, levees, etc.) (Bertens et all, in print).

This kind of study has more than one advantage. The first is to make aware the local administration of the importance to have a complete database on the environmental characteristics of its territory. In fact all these data will be delivered to the Municipal Administration of Castelfranco Emilia, which is building its own Geographical Information System.

All environmental data in the near future will be accessible to interested people. Every datum can be handled and updated in a simple way.

The data set will be interactive with other database both from the same municipality (e.g. economic data) and from Administrations of higher hierarchical level (e.g. Regional Administrations).

At the end it is necessary remember the general objective of the Training and Mobility Programme (TMR) which founded this research. The main scope is to improve the mobility of the researchers involved in the network. So, in the development of geographical database of the Castelfranco Emilia area, besides italian researchers a number of young researchers from Netherlands and Spain Institutions were involved.

ACKNOWLEDGMENTS

The financial support for the study was provided by the European project: ‘A European Research Network for the Application of Geomorphology and Environmental Impact Assessment to Transportation Systems (GETS)’, (contract ERBFMRXCT970162), Local Co-ordinator of the Modena and Reggio Emilia University, Prof. M. Panizza.

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