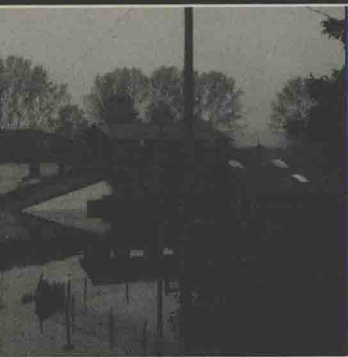

GEOMORPHOLOGY AND ENVIRONMENTAL IMPACT ASSESSMENT

MAURO MARCHETTI & VICTORIA RIVAS (EDS.)

Geomorphology and Environmental Impact Assessment

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Foreword

Most of the contributions of this volume were presented in Granada at a Special Symposium entitled: "Geomorphology and Environmental Impact Assessment" within the framework of the 6th Spanish Congress and International Conference on Environmental Geology and Land-use Planning.
The papers address some of the issues concerning the relationships between Geomorphology and Environmental Impact Assessment as mentioned in the first paper of this volume by Cendrero et al., although by no means all of them. They provide a good overview of a variety of methods and approaches, often of an interdisciplinary character and with an emphasis on the integration of geomorphological analyses into the general process of environmental evaluation.
The volume has been edited by two young researchers, Mauro Marchetti and Victoria Rivas, who have been collaborating in several research projects on geomorphological implication in the Environmental Impact and have acquired a considerable experience in this study sector.

A. Cendrero and M. Panizza

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Environmental Impact Assessment (EIA) is a very topical subject both for the implementation of considerably important engineering works and for territorial planning. As a consequence, nowadays many researchers are involved in this important scientific branch which is introduced more and more often as an indispensable procedure in the laws and regulations of several countries. The scientific contributions collected in this volume show how widespread this topic is geographically.

When a project is undertaken, there may occur several effects with environmental consequences. These effects may be direct or indirect, permanent or temporary, single or cumulative, short- or long-term. Not only are effects induced in the operative phase but also in the decommissioning phase (running down and dismantling).

Seldom are the effects on the environment sufficiently considered in the general planning. The operations and steps of Environmental Impact Assessment (EIA) studies are summarised in Figure 1 (Panizza 1995). When operations are functioning it is recommended that the degree of success of the predictions and impacts be evaluated as a guide to maintenance routines and future design. In the decommissioning phase it will be necessary to establish a new EIA, in order to predict the effects of the abandonment or dismantling of the plant (i.e. widespreading of pollutants, uncontrolled mine drainage etc.).

Although in some European countries EIA studies are compulsory, the geomorphological component is generally not assessed explicitly (Barani et al. 1995, Rivas et al. 1995, van Asch & van Dijck 1995). Generic considerations and geomorphological characteristics are however usually included in other environmental components (Watern 1990).

There are various reasons for the limited presence of geomorphology in EIA studies. First of all, geomorphology is not considered important by non-specialists. Many unmistakable and dramatic examples could be quoted to support this idea. The intense urban development of debris and alluvial cones in the Alpine region, or along the Blue River banks in China and in very many other examples all over the world, prove that man has a short memory with respect to processes which occur periodically, with varying return times, and cause risk situations for man and his activities.

Secondarily, non-specialists, but often also decision makers and the general public, tend to consider the landscape as a permanent set-up in a static equilibrium rather than the result of complex processes in a dynamic equilibrium which can also imply peaks of intense activity.

Furthermore up to not long ago earth science specialists showed superficial interest in the general environment. Only in the past two decades have new initiatives been carried out to improve our understanding of all the phenomena interacting in a natural environment and which, therefore, also influence geomorphological features. This has coincided with the growth of awareness among the general public that our geomorphological heritage must be preserved and that hazardous geomorphological processes which put human life and activities at risk must be assessed more accurately (Cooke & Doornkamp 1990, Panizza 1996).

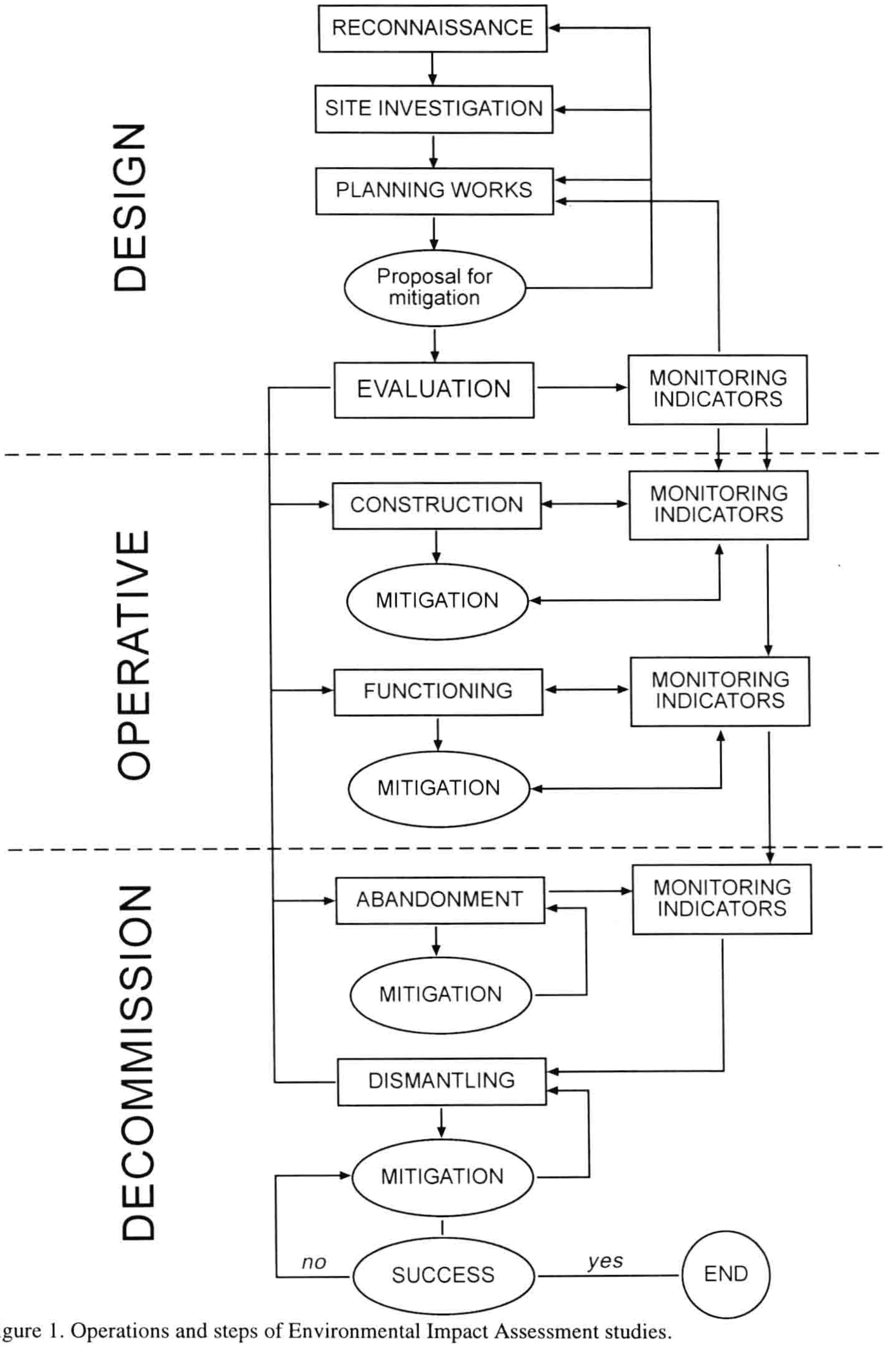

Figure 1. Operations and steps of Environmental Impact Assessment studies.

In a project financed by the European Union, the fields of research, the definitions and procedures to be developed for the introduction of the geomorphological component in EIA studies have been discussed (Marchetti et al. 1995, Panizza et al. 1995). In particular, three different geomorphological components have been identified and treated separately (Fig. 2).

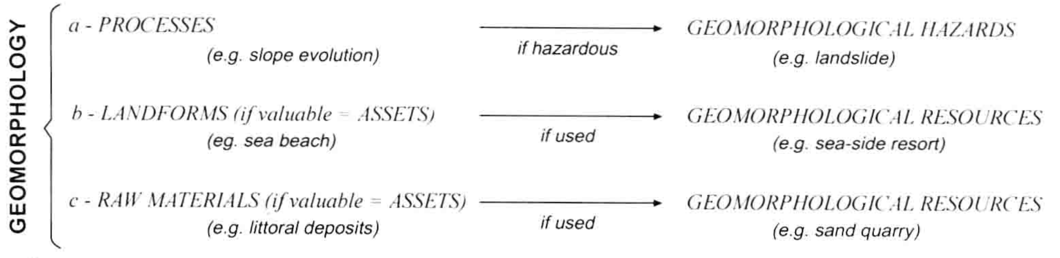

Figure 2. Main groups of geomorphological components.

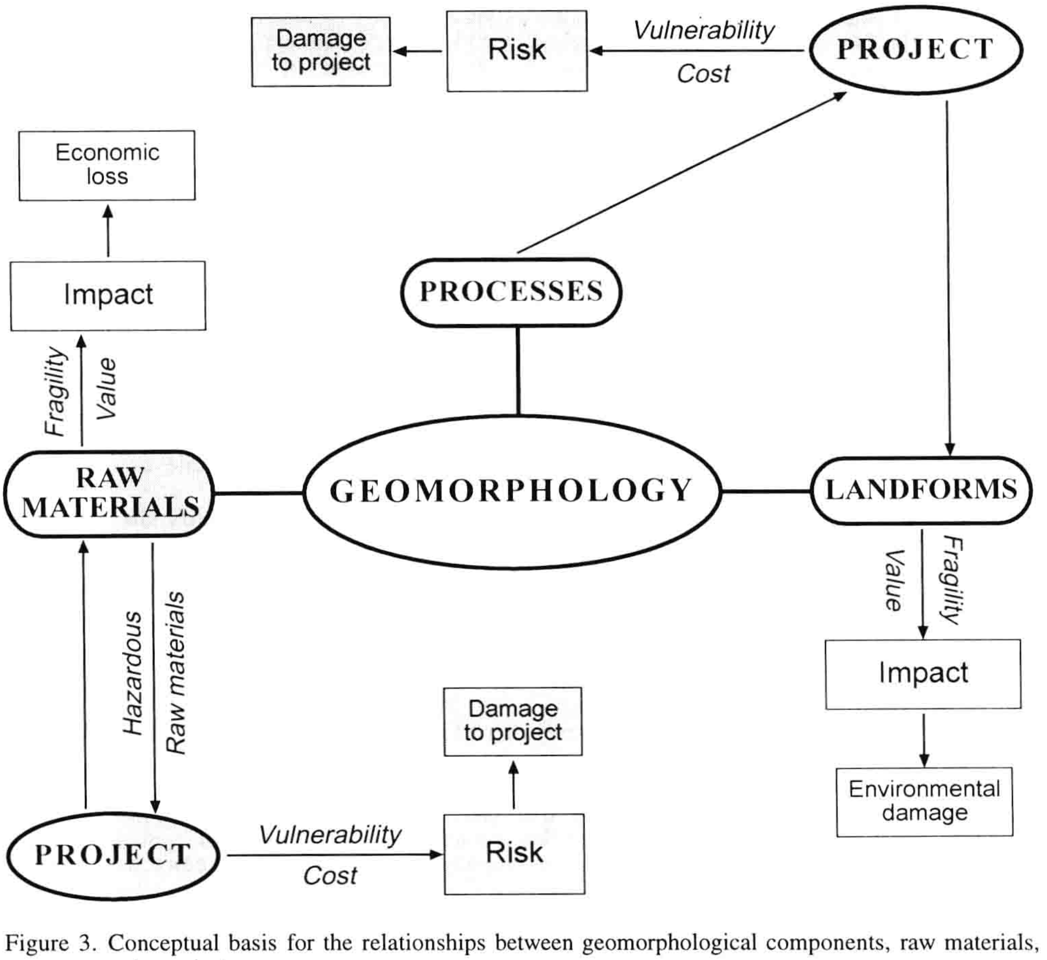

Figure 3. Conceptual basis for the relationships between geomorphological components, raw materials, processes and a project.

Figure 3 summarises the conceptual basis of the simplified relationships between these geomorphological components and a project.

These concepts have been presented in more detail by Cavallin et al. (1994) and Panizza (1995, 1996). It may be noticed that when processes are hazardous, they become geomorphological hazards and if they interfere with a project having its own cost and vulnerability, they may cause damage to the project itself. In this case natural geomorphological processes play an active role whereas the project plays a passive one.

When particular landforms are valuable, they are considered geomorphological assets, since they are characterized by a specific fragility and value, and these may be affected by a project. Landforms may be regarded as valuable assets not only on the basis of scenic, social, economic and cultural values, but also on the basis of other criteria related to the more general scientific concept of asset.

The methods for identifying and evaluating geomorphological assets on a scientific basis may be subdivided into two phases: a) geomorphological survey and mapping; b) selection from geomorphological maps of those landforms that may be considered as assets. The implementation of a project can have a direct impact on geomorphological assets and cause environmental damage to them. In this case the natural component of the physical environment plays a passive role whereas the project plays a direct one.

The same remarks can be made for particular raw materials: when these are valuable, they are considered geomorphological assets and the interference associated with a project may produce a direct impact. In this situation there are some materials that may also be considered as hazards (i.e. salty soils, radioactive minerals, metastable sands, and so on). They may therefore create a risk for the project and produce damage to it.

Another reason which does not favour the introduction of the geomorphological component in EIA studies is the limited development of specific tools usable to quantify the assessment of the interactions occurring between landscape, geomorphological processes and human activities. There are basically two reasons for this. The first is that modern geomorphology is a very young branch of earth sciences in which a lot of instruments, already utilized in other disciplines, are only being introduced. The second and more important reason is that geomorphology is not a systematic discipline and the physical laws applicable in general cannot be used in a specific case but must be modified to respond to local causes, specific parameters and human activities which do not always correspond in different countries, and so on.

In some cases it is possible to use modelling or parametric approaches in order to predict the consequences of certain interventions (Amarù & van Asch 1996, Amarù et al. 1996, Rivas et al. 1996). However, in most instances, predictions may only be formulated by means of general, qualitative terms. This is in part due to the limited knowledge of the role of different factors in the development of geomorphological processes and in part to the fact that in most EIA studies the necessary baseline data are not available or cannot be obtained owing to limited time and/or resources.

The need to understand natural processes, on the one hand, and to identify the effects of potential modifications introduced by human activity, on the other, are the main goals of any EIA study. Several steps are required to carry out an environmental impact study, including: a) formulation of alternatives; b) impact identification; c) description of the existing environment; d) prediction and assessment of the impacts; e) selection of the proposed action from a set of previously evaluated alternatives.

In recent years, studies focusing on the role of spatial information systems in regional and urban planning have been carried out. These investigations required either the design and use of tailor-made information systems or of GISs which were particularly well suited for spatial modelling.

The characterisation of geomorphological impacts, resources and assets for environmental impact assessment should therefore be reconsidered. The approach is to facilitate computational procedures by means of geographic information systems. Spatial representation and spatial normalization are fundamental steps in the construction of a balanced framework for assessment, since their relevance extends far beyond the morphological area of environmental applications.

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Geomorphological impact assessment in the River Mincio plain (Province of Mantova, Northern Italy)

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ABSTRACT: This study deals with changes in the landscape caused by human activity in the past 40 years in the Province of Mantova in a sector of the River Mincio plain located between the morainic hills of Lake Garda to the north and the Mantova lakes to the south. The study includes the analysis of topographical maps and of aerial photographs taken in different years, and the compilation of geomorphological maps referring to the landscape features in 1997 and in 1955. The plain sector considered has been subjected to intense quarrying activities since the beginning of this century. The open quarries are classified as quarries exploited above the water table and trench quarries exploited below the water table. When no longer in use, the first-type quarries are reclaimed for farming after laying a pedogenised level of organic soil on their floor; the second-type quarries are abandoned or equipped for recreational fishing or in some cases used as occasional dumping sites. All these quarrying activities have caused significant landscape changes. Another aspect of human activities during the past decades concerns the construction of important artificial canals which, besides modifying the natural flow of both surface and sub-surface waters, have altered the natural morphological features of the areas affected. Urban development has also been responsible for important modifications in the landscape, especially in the vicinity of the main built-up areas. In this research a simple methodology for the assessment of the scientific quality of landforms was applied. The impact on the landscape is defined as the reduction in scientific quality due to the assessment of the deterioration produced by human activity. The study has shown that among the main human activities the most serious damage to the landscape has been caused by quarrying. The greatest impact, with over 50% loss of quality of the geomorphological assets, has occurred between Goito and Rivalta.

1 INTRODUCTION

This study deals with landscape modifications induced by human activity in the past 40 years in the Mantova Province in a sector of the River Mincio plain located between the Pleistocene morainic hills of Lake Garda to the north and the Mantova lakes to the south (Fig. 1). Studies performed in past years in the area of the central Po Plain have shown that the River Mincio Plain north of Mantova represents an area in which, more than elsewhere, human activity has played a fundamental role in modelling the physical landscape (Baraldi et al. 1976, 1980a, Baraldi & Zavatti 1990, Dal Ri 1991, Baraldi & Zavatti 1994, Castaldini 1994, Guzzetti et al. 1996, Castiglioni 1997a, b). Nevertheless, only in a few papers (Baraldi et al. 1980c, 1987) the problem of landscape degradation due to human activities has been considered. Therefore the aim of this study was to carried out a geomorphological impact assessment in the River Mincio Plain, north of Mantova. Since human impacts in the Mantova Province have assumed a great importance after the second world war, this study is based essentially on comparison between the morphological situation of the mid-1950s, as evidenced by maps and aerial photographs of that time, and the present-day geomorphological features determined on the basis of recent maps and aerial photographs as well as detailed field surveys.

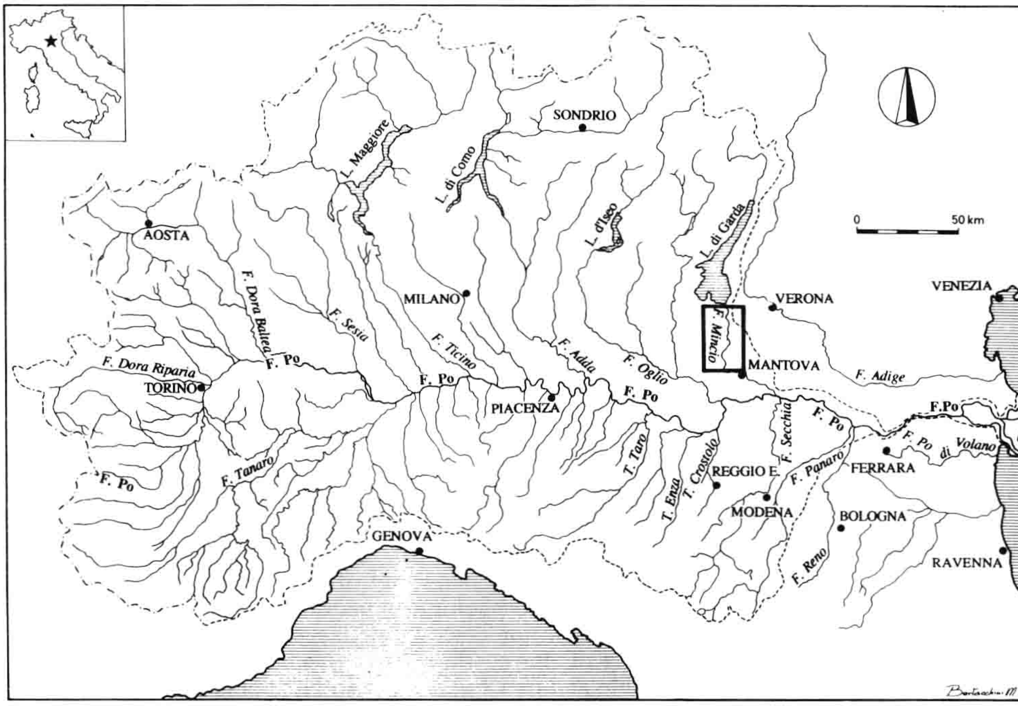

Figure 1. The Po River basin and the study area.

2 GEOGRAPHICAL AND GEOLOGICAL OUTLINE

The sector of the plain under study has an area of about 260 km^2 and belongs to the Po Plain which is the most extensive plain in Italy (approximately 46,000 km^2). The River Mincio, which is the main stream of the study area, is the collector between Lake Garda and the Po River, into which it empties after a course of about 75 Km (Fig. 1).

From a climatic point of view, the Po Plain is situated in a temperate zone (Type C, Koppen's classification). The study area represents one of the least rainy sectors within the Po plain with average annual rainfall from about 750 mm (in the foothill area) to 650 mm (in the Mantova sector), with seasonal peaks concentrated in the autumn and spring, and minimum amounts in the summer and winter (Baraldi & Zavatti 1994). As regards temperature, the data show a mean annual temperatures of 13-14°C (Baraldi & Zavatti 1994).

From a geomorphological point of view, immediately north of the study area is located the morainic amphitheatre of Lake Garda corresponding to a hilly landscape (Fig. 2); here glacial deposits of the Upper Pleistocene crop out (Venzo 1965). Morainic remnants belonging to the Middle Late Pleistocene crop out to the west, near the River Chiese, with small relief emerging at a few metres height with respect to the surrounding plain (Cremaschi 1987). The plain in front of the morainic hills corresponds to the outwash plain (sandur) of the Upper Pleistocene deposited by the spills of the Garda glacier (Cremaschi 1987). The outwash plain, which is also called "Main level of the plain" (Petrucci & Tagliavini 1969, Guzzetti et al. 1996), is terraced by streams of Alpine origin such as the Chiese, Oglio and Mincio rivers. South of the outwash plain lies the alluvial plain of the Po, of Holocene age.

The study area comprises the outwash plain and the wide triangular depression (about 20 km from north to south and 8 km from west to east) cut by the River Mincio, north of the city of Mantova. The morphology of this depression is characterised by several scarps of varying height, mainly developing in a N-S direction and forming various orders of terraces of Holocene age. The natural morphology of the study area has been extensively altered by human intervention, especially quarrying.

At the southern edge of the study area are the Mantova Lakes, into which and out of which the River Mincio flows. These have an area of over 6 km^2 and a mean depth of 3.50

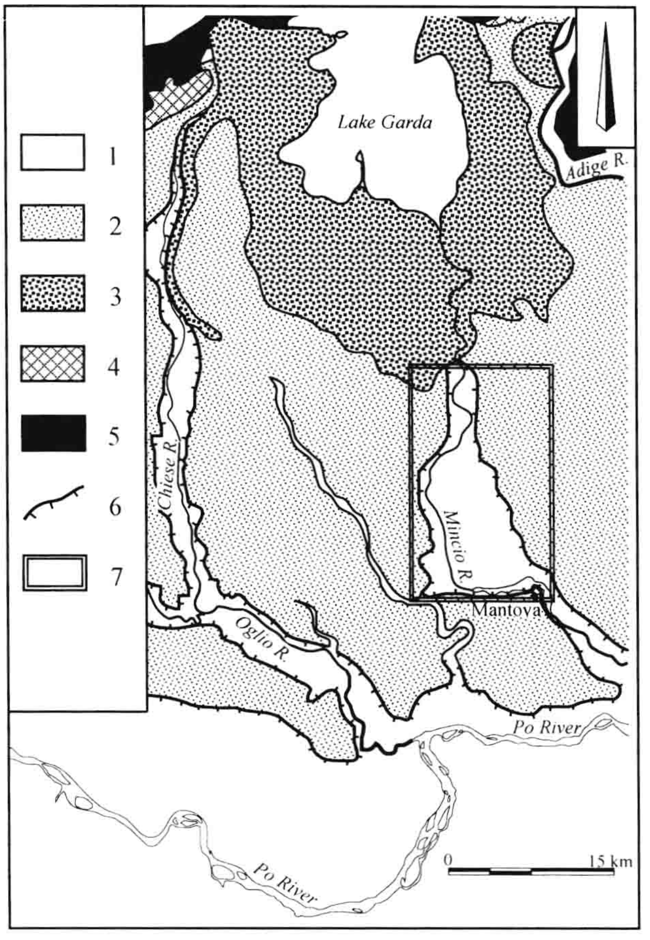

Figure 2. Geological-geomorphological sketch of the area between Lake Garda and the Po River. 1) Alluvial plain (Holocene), 2) Outwash plain (Late Pleistocene), 3) Morainic hills (Upper-Middle Pleistocene), 4) Fluvioglacial terraces (Middle Pleistocene), 5) Pre-Alpine reliefs, 6) Main fluvial scarps, 7) Study area.

m. They consists of three basins (Lago Superiore, di Mezzo and Inferiore) at different elevation.

The surficial deposits of the study area have a grain size constituted mainly by gravel; however, sandy, clay-silt and peat deposits also crop out.

From the deep-geological point of view, the study area lies on the "Pedalpine Homocline" which represents the continuation, within the subsurface of the Po Plain, of the homocline structure that characterizes the Alpine margin in the Lake Garda area. This structure dips regularly southwards from the Alpine margin as far as the Po River (see Pieri & Groppi 1981).

The origin of the Mantova Lakes can be traced to the deviation of the River Mincio at Grazie with resulting abandonment of its course along a paleobed southwest of Mantova. According to Baraldi et al. (1980a), Zanferrari et al. (1982), Slejko et al. (1987) and Panizza et al. (1988), this diversion is connected to activity of a buried tectonic structure (Mantova Lakes Fault or Mantova Line). Different explanations were, however, given by previous authors (see Cozzaglio 1933, Veggiani 1974).

3 METHODS OF STUDY

The study was conducted according to the following investigation phases:

1. Bibliographic research. Various papers were reviewed concerned with the geomorphology, geology, surface hydrography, hydrogeology and human intervention in the sector of the Po Plain comprising the study area.

2. Analysis on topographical maps. The maps examined comprise the following:

a) Regional Technical Maps (C.T.R.) of the Lombardy Region (scale: 1:25,000 and 1:50,000) updated in 1983;

b) Istituto Geografico Militare Italiano (IGMI) maps (scale: 1:25,000), 1885, 1912, 1935, 1954 and 1973 editions of the F. 62 Mantova.

3. Morphological analysis through the interpretation of aerial photographs taken in various periods. The aerial photographs examined include black and white aerial photographs to a scale of 1:33,000 (approximately) taken in 1955 and to a scale of 1:70,000 (approximately) taken in 1994, and color aerial photographs taken in 1981 to a scale of 1:20,000.

4. Processing of altimetric data. On the basis of the altimetric data reported on the C.T.R. of the Lombardy Region, a "Microrelief map" was prepared, i.e. an altimetric map with 1 m equidistance. The altimetric map of the area was handly made by tracing the contour lines on the basis of the altitude reference points of the C.T.R. of the Lombardy Region. However, the altitude reference points corresponding to human artefacts (e.g. roads, bridges, etc.) were disregarded, and the contour lines in the quarrying areas and former quarrying areas were not traced since their altimetric situation does not tally with the original one. In the northernmost part of the study area greater graphic clarity required that only the main contours with 5 m range be given.

5. Field survey. The field survey was carried out in order to verify the present-day morphology and to collect data on the lithology of surface sediments. Surface deposits were studied by a simple standardised field procedure where over a thousand samples were collected at depths ranging from 0.5 to 1 metre (immediately below the level affected by pedogenesis and reworked by agricultural operations). About one hundred samples were subjected to laboratory analysis for precise classification. This resulted in a "Surface lithology map".

6. Elaboration of geomorphological maps. On the basis of the above investigations, two geomorphological maps were prepared: one referring to the features in 1997 and one referring to the features in 1955.

7. Geomorphological impact assessment. The geomorphological impact assessment of the study area was performed essentially on the basis of comparison between the morphological features represented in the maps as indicated in the above mentioned point and by applying a methodology already employed in other areas of Italy (e.g. see Panizza et al. 1996b). Because it is one of the most noticeable point in this study, it will be explained in deep in chapter 8.

4 MAIN HUMAN ACTIVITIES IN THE STUDY AREA

From the early 1960s onwards, the province of Mantova was subject to intense economic development. This resulted in an intensification of the effects of human action upon the natural environment. These resulted in profound changes in the geomorphological features of the Mincio plain, and can be grouped under three categories: a) quarrying, b) hydraulic management, and c) urban development.

4.1 *Quarrying activities*

The study area is characterised by extensive deposits of gravels from ground level to a depth of 10-15 m (Baraldi et al. 1976). The petrographic features of the gravels are such as to render them of high commercial value: carbonatic, magmatic and metamorphic rocks outcrop in various percentages. The deposits of inert material consist of lithoid elements generally well selected, with granulometric classes ranging from pebbles to sands (Fig. 3).
In the Roman period, the pebbly-gravelly deposits, easily detectable, were used in the construction of important roads. Quarrying activities at artisan level are documented in the Mincio plain from the early 20th century (Belenghi 1908): already at that time the Rivalta quarries not only supplied inert material for the needs of the province, but also produced large quantities for the neighbouring provinces. It was not till the early 1960s that quarrying became an industrial activity. From then on, there was a large and consistent increase in the

amounts quarried (Fig. 4). Recent investigations (Baraldi & Zavatti 1990, Dal Ri 1991, Amministrazione Provinciale di Mantova 1996) have shown how the study area continues to supply more than 70% of the inert materials quarried in the province of Mantova, where more than 2,000,000 m^3 are quarried per year.

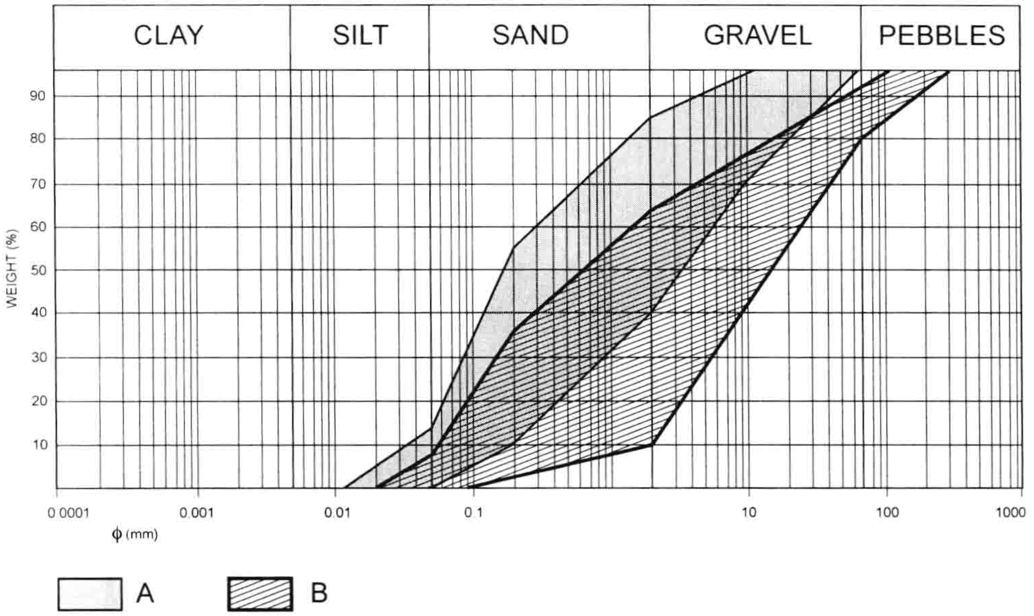

Figure 3. Range of the granulometry of the inert materials quarried in the Mincio River plain: A) Southern area between Goito and the Lakes of Mantova, B) Northern area between Pozzolo and Goito.

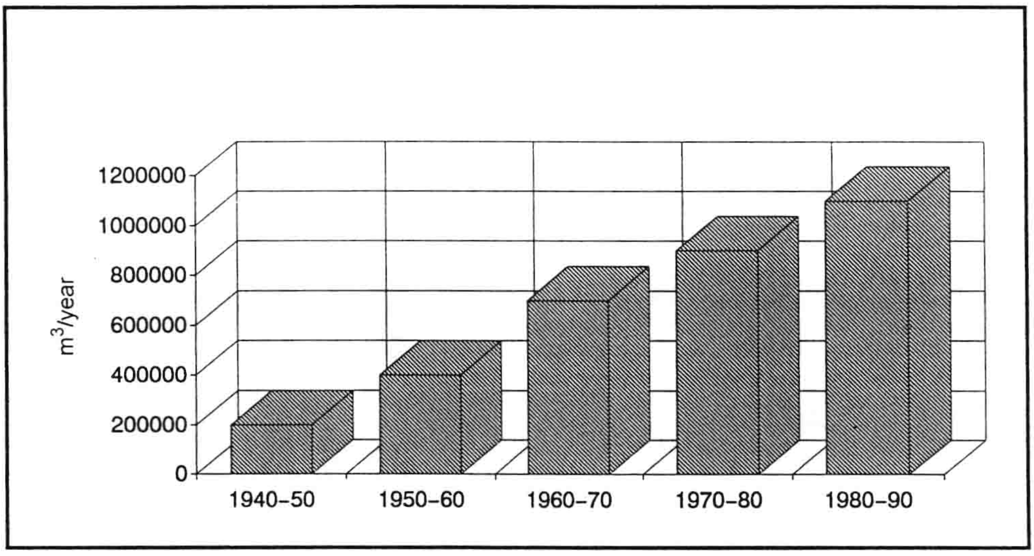

Figure 4. Quarrying activity in the Mincio River plain between 1940 and 1990.

The open quarries are classified as (Baraldi et al. 1980a): a) quarries exploited above the water table, b) trench quarries exploited below the water table (Fig. 5). The quarries of the first type are exploited only a few metres below the original ground level and in any case down to about 1 m above the level of maximum excursion of the water table. When no longer in use, these quarries are reclaimed for farming after laying a pedogenised level of