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Landslide dams in Italy: analysis of main predisposing factors and damming susceptibility mapping

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Table of Contents

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Alkkammellaaaa!!!

Zalar Kalimor!!!!

ABSTRACT

Landslide dams result from the complex interaction, not yet totally understood, between river and slope dynamics. The study of past landslide dams and their consequences has acquired a significant relevance for forecasting and preventing their induced hydraulic risk on lives and property.

The main aim of this thesis was the study of the landslide dam phenomenon and design a useful and easy tools to assess the damming risk with spatial planning purpose.

The research started from the geomorphologic investigation of the Italian landslide dams and setting up an archive, updating previous studies on the same topic in smaller areas (Pirocchi, 1991; Ermini, 2000; Pacino, 2002), and integrating it through a careful literature review and cartographic and aerial photos interpretation. The collected data represents the wider example of systematic inventory in Italy, with almost three hundreds of cases selected from the Alps to the Southern Apennines, in Sicily. The research includes landslide dams occurred along the Cordillera Blanca mountain range, in Peru, to study the same phenomenon in a very different geographical, climatic and tectonic settings.

A morphological analysis of the collected data was performed to identify morphometric parameters that best define the formation process of a blockage. This analysis confirmed the validity of schematizations already developed by previous authors and new morphometric indexes, useful for forecasting and planning purposes, were proposed. In particular, encouraging result came from the formulation of the *Morphological Obstruction Index* (MOI) that allowed to perform a reliable analysis of dam formation and provided a good estimator to forecast a landslide blocking a river, from a geomorphic analysis.

In order to prevent part of the damages and suffer lower consequences related to landslide dam occurrence, an useful and practical tool was proposed, to predict which areas have a higher damming susceptibility and where preventive measures should be focused. Therefore a simple GIS methodology, useful as a forecasting and planning tool, was developed. This easy methodology, used on the Arno River basin, was able to assess with few data the damming predisposition, connected to existing landslides, and the probability of obstruction, by new landslides along a river network.

RIASSUNTO

Le frane di sbarramento sono legati all'interazione complessa, ancora non completamente compresa, tra la dinamica di versante e quella fluviale. Lo studio degli sbarramenti passati e delle loro conseguenze ha assunto una importanza significativa per la previsione e la prevenzione del loro rischio idraulico indotto sulle proprietà e la vita delle persone.

L'obbiettivo principale di questa tesi è stato lo studio dei fenomeni di sbarramento da frana e quello di fornire uno strumento utile e semplice da applicare per valutare il rischio di sbarramento con finalità di pianificazione territoriale.

La ricerca è iniziata con l'investigazione geomorfologica degli sbarramenti italiani e la creazione di un archivio, attraverso l'aggiornamento di studi precedenti in aree più piccole (Pirocchi, 1991; Ermini, 2000; Pacino, 2002) e l'integrazione, grazie a un'attenta ricerca letteraria e l'interpretazione cartografica e di foto aeree. I dati raccolti rappresentano il più ampio esempio di inventario sistematico in Italia, con quasi trecento casiselezionati dalle Alpi fino all'appennino meridionale, in Sicilia. La ricerca è stata estesa agli sbarramenti avvenuti lungo la catena montuosa della Cordillera Blanca, in Perù, per studiare lo stesso fenomeno in un contesto geografico, climatico e tettonico completamente diverso.

È stata eseguita un'analisi morfologica dei dati raccolti per identificare i parametri morfometrici che meglio definiscono il processo di ostruzione. Questa analisi ha confermato la validità delle schematizzazioni precedentemente sviluppate da altri autori e sono stati proposti nuovi indici morfometrici utili a fini previsionali e di pianificazione. In particolare, sono stati ottenuti risultati incoraggianti dalla formulazione del *Morphological Obstruction Index* (MOI) che permette di eseguire un'attendibile analisi sulla formazione di uno sbarramnto e fornisce un buono strumento di stima per prevedere l'ostruzione di un fiume da parte di una frana attraverso un'analisi geomorfologica.

Per prevenire parte dei danni e subire minori conseguenze legate al verificarsi di uno sbarramento, è stato proposto un utile e pratico strumento per individuare le aree con maggiore suscettibilità allo sbarramento, dove concentrare le opere di prevenzione. È stata quindi sviluppata una semplice metodologia GIS utile a fini previsionali e di pianificazione. Questo semplice metodo, applicato al bacino del Fiume Arno, ha permesso di valutare con pochi dati la predisposizione allo sbarramento, legata alle frane esistenti, e la probabilità di ostruzione del reticolo fluviale, da parte di nuove frane.

1 INTRODUCTION

Landslide dams are natural dams formed by slope movement that blocks a river channel. The obstruction can be complete or partial, but in all cases, an impoundment may be formed upstream. This causes a serious hazard for the involved river section and for the surrounding areas for kilometers, both upstream and downstream. For instance, the very recent (March 22, 2014) Oso mudslide reactivation that blocked the North Fork Stillaguamish River (Washington, USA), one of the worst landslide events of all time in USA history; it destroyed a village, killing forty-three people and causing extensive flooding upstream as well as blocking State Route 530 (Figure 1).

In upstream areas, rising waters blocked by the dam, can flood areas over kilometers, causing damage to properties and communication lines and artifacts. In downstream areas, landslide dam breach is linked to catastrophic events, such as anomalous destructive flood wave. Given that most of the human activity and main infrastructures are located in valley floors, consequences can be dramatic; especially in countries with high population density in mountain areas, such as Italy.

Figure 1 - The Oso (Washington, USA) mudslide occurred in March 22, 2014 (picture from www.nbcnews.com).

Sometimes these situations can be controlled through properly sized engineering works; when this is not possible, for lack of knowledge on the natural event and for technical limitations (related to available time and to size of the phenomenon), it can generate huge catastrophes. Being able to evaluate the stability and the obstruction likelihood of a dam is crucial in these cases.

For these reasons, the study of landslide dams and their consequences has acquired in scientific research, in the past decades, a significant relevance for prediction and prevention of flood risk on lives and properties (Schuster, 1986; Costa & Schuster, 1988).

Landslide dams are quite frequent in Italy, a country characterized by a broad climatic, geological and morphological variability. Nevertheless, their scientific study has only started after the Val Pola event in 1987 (Sondrio, Northern Italy), when a landslide threatened for months the survival of an entire valley. After such an impressive episode, the research on this topic received greater attention and a strong boost. Some authors conducted inventories of regional and inter regional areas (Pirocchi, 1991; Canuti et al., 1998; Pacino, 2002; Ermini & Casagli, 2003), with different degrees of detail.

According to some authors (Swanson et al.; 1986; Canuti et al., 1998; Ermini & Casagli, 2003; Dal Sasso et al., 2014) landslide dam behavior can be forecasted through geomorphological indexes. Said indexes are comprised of variables identifying the landslide (or the dam) and the river involved. These geomorphological tools have given encouraging results, showing great potential as assessment and forecasting tools. The knowledge of these events is, however, far from complete, since there are many contributing factors in determining their development and behavior over time.

A landslide dam, even when it does not evolve in a nefarious way, disrupts the lives of entire valleys. The restoration costs are often substantial and are of two categories: direct ones, e.g.: safety measures and infrastructure rebuilding; and indirect ones, more difficult to estimate, e.g: damage caused to industrial productivity or loss in real estate value.

The main purpose of this thesis is to propose some simple and effective tools to forecast the likelihood of a landslide obstructing a river and to evaluate the stability of landslide dams once they are formed.

The aims of the research can be summarized in three points:

1. The first step to properly characterize the phenomenon and to correctly develop tools to assess a landslide dam formation and its stability, in Italy and worldwide, is to carefully study past events.

   One of the main aims of this thesis is to develop a database that includes the largest number of landslide dam events, collected with a similar method to standardize data quality. The geomorphologic investigation on landslide dam events in Italy resulted in the widest systematic inventory, from the Alps to the Southern Apennines (Sicily).

   Geomorphologic parameters were determined through cartographic and aerial photos interpretation, or estimated via historic and bibliographic documents analysis. The data were gathered into a database, with easy-to-collect information, for an intuitive usability and future implementation.

   Many prehistoric entries are often linked to big seismic events (mainly in Southern Italy) or deglaciation events (mostly in Northern Italy). Ancient documents provide direct information for historic events, often describing catastrophic events as they really happened, but with emphatic and fictional elements.

   The study of landslide dams includes also events occurred along the Cordillera Blanca mountain range, in Ancash Province, Peru. This experience allowed us to study cases in a very different geographic, climatic and tectonic setting from Italy.
2. Additional geomorphological indexes are proposed to contribute to the description and definition of the issue. We presented reliable tools to best define the obstruction forming process, through a morphological analysis of the collected data. These tools are useful to accurately predict a landslide event blocking a river and to evaluate the landslide dams stability once they are formed.
3. Knowing where a landslide dam is more likely to form, can help to realize works for safety (cheaper than rebuilding costs) and devising a more efficient and conscious planning. This would reduce, or even eliminate, the catastrophic consequences of a river obstruction.

   The ultimate goal of this research is to propose a simple and effective methodology that can assess, quickly and with few data, the spatial distribution of predisposition and probability, or susceptibility to obstruction of river channels. The result is a mapping at basin scale of the damming predisposition, linked to existing landslides, and the obstruction probability due to new landslides along the river network. The method was applied on a test area: the Arno River basin.

To achieve these objectives, the research was divided in a number of interconnected stages, as shown in (Figure 2).

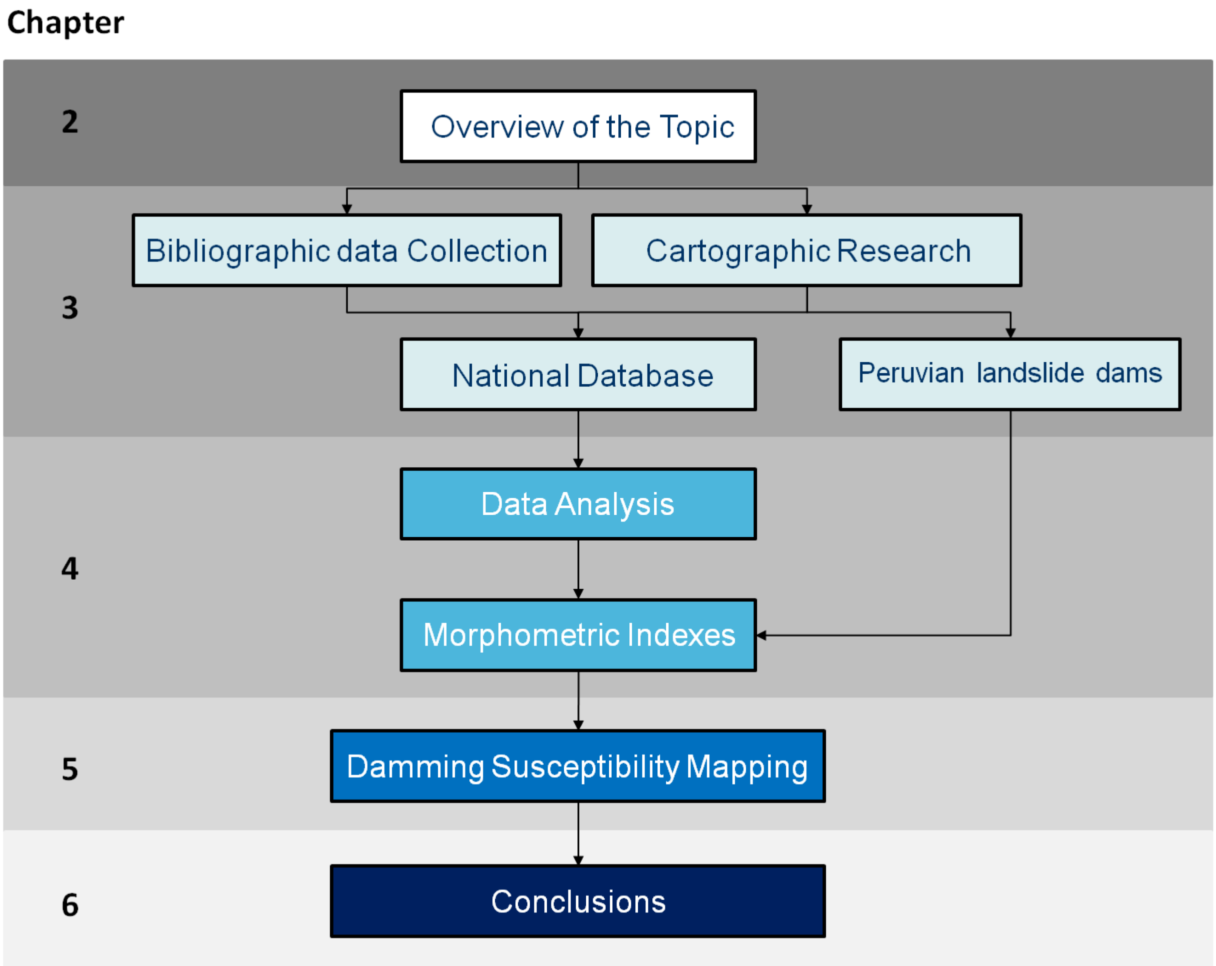

Figure 2 - Flow diagram showing the main phases of the research reported in the structure of the thesis.

For this reason, the thesis has been drafted with a particular structure: the findings of each stage are discussed in the corresponding chapter, instead of a single final chapter, since they are the basis for the following stage.

The outcome is a series of interlinked chapters, each containing materials, methods and results. Collecting morphological data on landslide dams in Italy helped creating a database, which, in turn, has been essential for the study of morphometric indexes and the formulation of two new ones. Thanks to these results, one of the indexes was exploited to develop a mapping methodology for damming susceptibility, that has led to encouraging results.

In addition to the *Introduction*, the thesis is structured as follows:

- *Chapter 2* contains a detailed review of the state of the art of landslide dams studies. A geomorphological classification of a natural dam, its main induced effects, the formation and collapse mechanisms are described.
- *Chapter 3* reports the data collecting phase. The literature and cartographic interpretation and morphometric data measure in Italy are described, and the obtained national database is illustrated. The research carried out in the Peruvian mountains is also described.
- *Chapter 4* contains the results of applying some of the main geomorphological indexes in literature, using the new database. Two new indexes, that can help to easy evaluate the formation and the stability of a complete blockage with few data, are presented and their reliability evaluated with Italian and Peruvian landslide dams.
- *Chapter 5* describes the main phases of the proposed mapping methodology, using one of the new proposed geomorphological index. The purpose is to assess the obstruction of a river network by reactivated or new landslides, by testing it on the Arno River basin area.
- *Chapter 6* summarizes the main findings of this thesis, in the inventoried cases, in the assessment of the formation and stability of a blockage, and in the damming susceptibility mapping methodology.
- *Chapter 7* contains the main references of this work, listed in alphabetical order.
- *Chapter 8* includes the Appendices with tables summarizing the data contained in the Italian and Peruvian database and some information about the Italian cases.

2 BACKGROUND AND STATE OF THE ART

The landslide dams topic is a discussed and studied subject by long time in the scientific literature (Emerson, 1925; Costa, 1985). The present chapter briefly reports the consolidated definition in the scientific literature about the term “Landslide Dam”.

In the following paragraphs the proposals for classification of these particular phenomena will be discussed and the current state of the art reported. It will be showed their behavior, evolution and impact on landscape and mankind. A limited series of known significant international and Italian historical landslide dams cases are also exposed.

2.1 LANDSLIDE DAMS

The term “landslide dam” identifies the natural blockages of river channels caused by slope movements (Casagli & Ermini, 1999). The blockage can be complete or only partial; in both cases an impoundment may be formed upstream. Complete blockages, remaining stable for enough time, originate landslide dammed lakes.

Landslide dams can be formed in every physiographic conditions. They commonly occur in narrow valleys, bounded by steep sheer rock walls and by uneven mountains where the mass in motion does not have space to disperse itself. In this places even modest volumes of displaced material can cause the formation of landslide dams. This is a typical scenario in active geological areas, characterized by volcanic activities, seismic events or post-glacial detension. In this environments large amounts of materials, as fractured or weathered rocks, are easily involved in landslide events.

It is very rare to see a natural dam in wide valley with soft morphology. Nevertheless where the river course digs sea and lake deposits, their damming can be determined by the triggering of rotational or translational sliding or liquefaction of active clays (Costa & Schuster, 1988).

Most of the recently occurred landslides are reactivation of movements that moved during periods of different climatic and geomorphological conditions from today (Canuti et al., 2004; Crozier, 2010; Tanteri et al., in preparation) (Figure 3).

At present, most of the landslides are dormant and covered by vegetation that, in some cases, makes the recognition of the phenomena quite difficult. These dormant slides, in which the strength parameters are reduced to values, close to the residual ones, can be reactivated by natural causes, such as rainfall or snowmelt, as well as man-made disturbance (Casagli & Ermini, 1999).

Landslide dams can be considered as geoindicator for climatic changes. This is due to the recovery of organic matter in the dammed lakes deposits, that can be dated via radiocarbon dating (Canuti et al., 2004; Soldati et al., 2004).

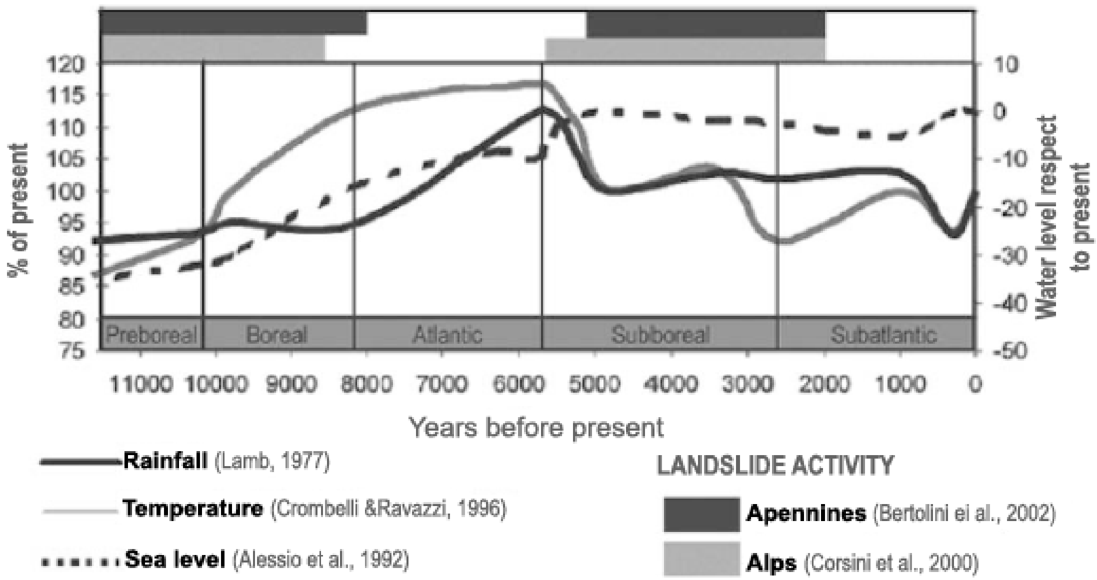

Figure 3 - Relation between the time of the temporal occurrence of landslides in the Apennines and Alps regions and Holocene climate (from Canuti et al., 2004).

The literature on landslide dams has been enriched for several centuries. In particular, well-documented studies about landslides causing blockage of the riverbed, with often catastrophic consequences, are frequent. Otherwise, those phenomena that had no impact on the urban and infrastructure fabric have been neglected, as those which lie outside the historical age.

Since the eighteenth century in fact we remember, among the many cases, the chronicles and the works of Ruberti (1787), Boccia (1804), Mercanti (1859), Almagià (1907) and the latest Lee & Duncan (1975), Nishizawa & Chiba (1979), Evans (1984, 1986), Schuster (1985), Soldati & Tosatti (1993), Casagli et al. (1995), Carotta (1997), Carulli & al. (2002), Irmler & al. (2006), Cencetti et al. (2011), Savelli & al. (2012, 2013).

There are not many methodological treatises on the subject: the main scientific references on a systematic classification of landslide dams have been drawn up by Swanson et al. (1986) and by Costa & Schuster (1988).

The most common genetic and geomorphological classification of landslide dams, drawn up by Costa & Schuster (1988), is based on data from 225 sample cases. The classification takes account the shape and size of the dams related to the size of the blocked valley (Figure 4) and can be a very helpful tool to start to know and understand landslide dams and for the interpretation of the evolution of these events.

There are six classes identified by Costa & Schuster (1988), five of which are completely dedicated to dams caused by landslides and one in common with the latter and those originated by glacial tongues.

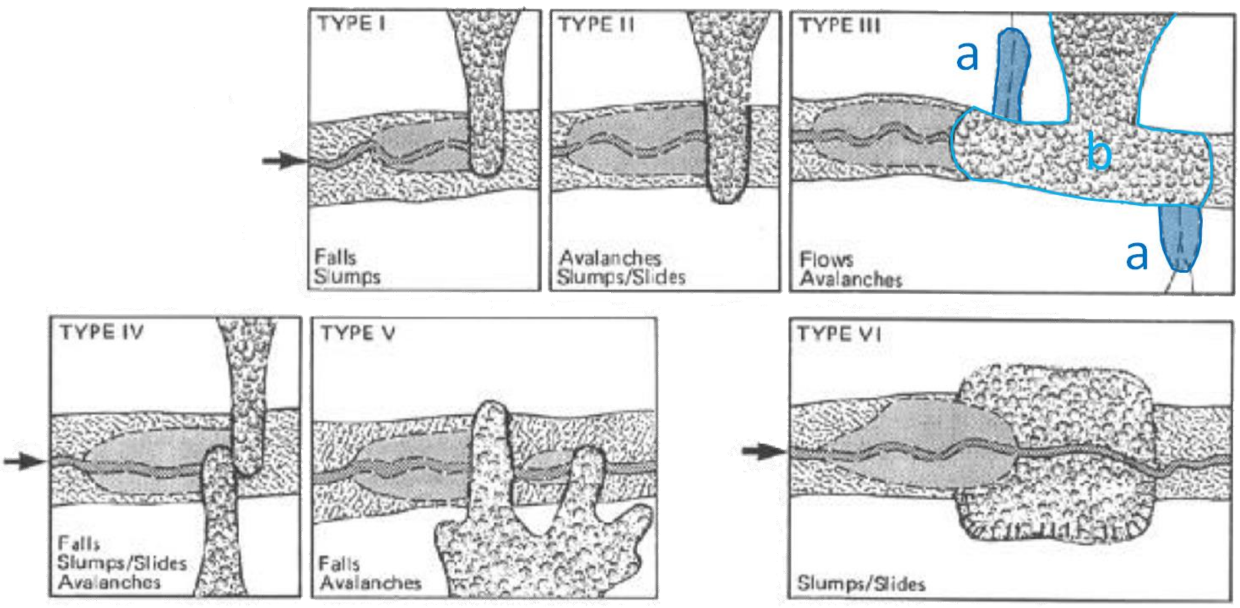

Figure 4 - Geomorphological classification of landslide dams (from Costa & Schuster, 1988 modified).

Type I: small dams relative to the valley size that can not reach the opposite slope. Barely is recorded the total closure of the stream and the lake usually is not formed. If it form it is small and shallow. The most commonly recorded effect is the deviation of the main course of the river.

A typical example in Italy is the landslide of 1987 in the village of Mottacce (Figure 5, ID 53), in the Municipality of Subbiano (Arezzo), that, after destroying the provincial road and the railway for a distance 200 m long, stopped by blocking only half of the riverbed of the Arno River.

Figure 5 - The reach of river bed affected by "Le Mottacce" landslide (Arezzo, Italy), taken immediately after the occurring of the event (from Cencetti et al., 2011).

In some areas such cases are so frequent that they strongly affect the morphology of the river network and they represent the most distinctive geomorphological feature of the valley. In these cases the main watercourse form a series of loops that are not meander, at least not from the river dynamics point of view, but testimonies of many phenomena of deviation caused by landslides.

An obvious example of this conditioning is given by the stretch of the Reno River (Figure 6) in the Gaggio Montano Municipality (Bologna), where much of these landslides are in a state of dormancy for most part of the time except for periodic reactivations (Carboni et al. 2001).

Type I cases can be found in many part of Italy especially for the flow movements. Once arrived to the valley bottom, these mass movements considerably slow down their velocity, for the sudden decrease of slope, and they form a partial blockage.

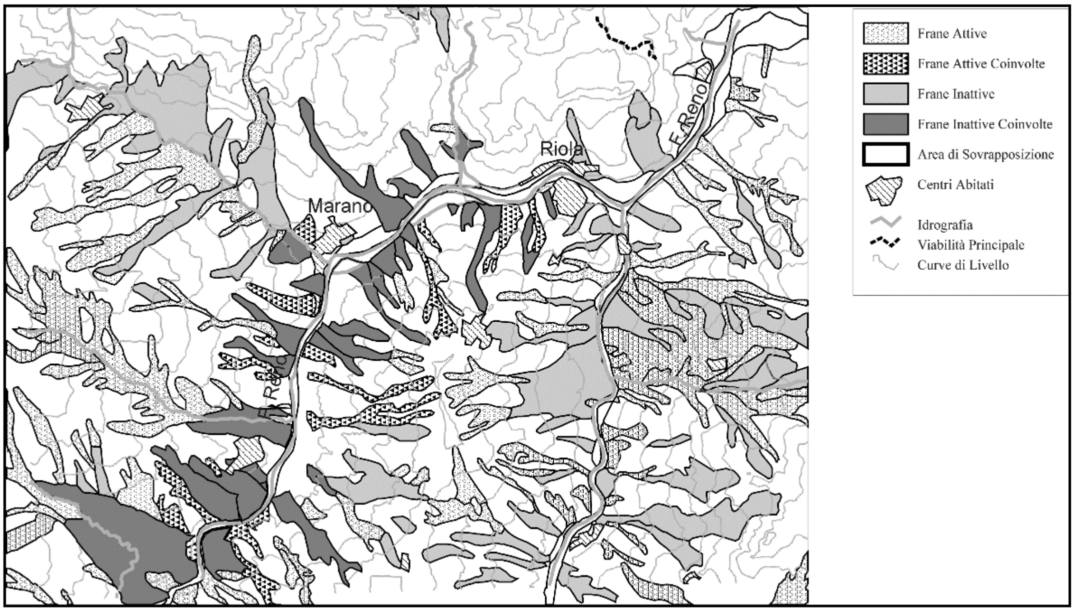

Figure 6 - Part of the basin of the Reno River, Municipality of Gaggio Montano (from Carboni et al., 2001).

Type II: larger dams, but still smaller compared to the valley dimensions. Some time they are able to reach the opposite side of the valley. Lake basins formed are potentially very dangerous because the narrow and long form of the dam. The step sides of the dam are also easily eroded by overflowing water.

These landslides can cause a total blockage of the stream, exploiting their inertial component, since they are often provided with high speed despite the relatively limited volumes of the involved materials. The small amount of materials, put in place by these landslides, is the most frequent cause of the instability of the dams that fall into this class.

They are one of the most widespread types of dam and they are usually formed by rotational or translational landslides.

An example in the Italian area can be represented by the landslide of Piuro (ID 144), Sondrio, in 1618 (Pirocchi, 1991) that involved the city of Plurs. The formed lake survived for few days breaking through the dam and overwhelming what the landslide had left unharmed. The disastrous event killed from 1.000 to 2.500 people approximately (Figure 7).

Figure 7 - Representation of Johann Hardmeyer, Zurich 1618, which shows the village of Plurs before and after the landslide.

Type II: this category includes very large dams. The collapsed materials are distributed both upstream and downstream from the release area, resulting in a blockage of lobed shape, at times with a "T" shape. Casagli & Ermini (1999) introduced a distinction in this class of classification, separating the phenomena in which the dam also affects the tributary valleys of the main one (**IIIa**) from those in which these are not involved (**IIIb**).

Oftentimes, in fact, a landslide does not exhaust his entire kinetic energy on the way to the valley and once collided on the side of the valley opposite to the landslide, still possesses a certain amount of motion that allows it to expand both upstream and downstream among the barred section. In certain cases the landslide continues to move even going back up the opposite side by a distance which may reach 20% of the drop in level.

The type III dam is one of the most widespread landslide dam.

Typical examples in Italy are Lama Mocogno (ID 15), Modena in 1879 (Pantanelli & Santi, 1895) e Val Pola (ID 115), Sondrio, in 1987 (Crosta et al., 2004; Pirocchi, 1991). The Lama Mocogno landslide, Northern Italy, is a reactivation of other events that had occluded in the same place, not always fully, the Scoltenna stream, a tributary of the Panaro. The most important event is definitely the one of 1879. The landslide led to the complete closure of the river, forming a lake of 4 km in length, which then disappeared for silting after few years. The big Val Pola landslide (Figure 8), Northern Italy, which took place July 28, 1987, was the more important calamitous event in the last few decades for the economic and social consequences that caused (Crosta et al., 2004). Also in this case it is the reactivation of an oldest landslide, whose crown area is still visible (Pirocchi, 1991). The landslide body blocked the valley bottom of the Adda River for almost 2 km long, going up the other side for about 250 meters (equal to about 1/5 of the difference in height of the drop).

However, not always the type III dams have so important sizes, as demonstrated by the landslide of Schiazzano (Parma, ID 74) of "only" about 30.00 m^3.

Figure 8 - Landslide dam of Val Pola, Sondrio, Italy, in 1987.

Type IV: those belonging to this category are very rare dams that formed for the contemporary fall of two landslides detached from opposite sides of a same valley. The accumulations of landslide may juxtaposed against each other in the center of the valley or overlap the front.

In Italy there are few examples of this type of landslide, like the Ossola landslide (ID 85) in Vallozzola (Parma) during the flood of 1977, the San Piero in Bagno landslide (ID 32), Forlì, in 1885 (Veggiani, 1995), or Chiotti Sant'Anna landslide in Castelmagno Municipality (ID 121), Cuneo, in 1966 (Merlo, 1969).

Also in the rest of the world this type of landslide dam is not so recurring. A good example is the LLanganuco Lakes in Cordigliera Blanca in Ancash Province, Peru, formed by the coalescence of two debris cones from the opposite valley sides (Figure 9).

Figure 9 - View of Llanganuco Alto dam, Ancash Province, Peru.

Type V: in this class we find multiple landslide dams formed by a landslide that, splitting it into multiple tongues, block the valley in more points. They are not very common, except in the case of river dams operated by tongues of glaciers. More rare is to meet them in the context of mass movements due to "common" landslides. They are not known in Italy.

Type VI: dams consequent to landslides in which the sliding surface passes below the river bed going then on the opposite side of the valley. The obstruction of the river is due to rising river bed, that creates a counterslope preventing the flow of water. The collapsed material transport is then minimum. The dam formed by landslide hardly reaches significant heights and in most cases even the lake will not form. For this reason, the risks of collapse are minor.

Such events are not very common but can occur during earthquakes of great intensity that trigger deep landslides. The lakes that form in these cases can be very long-lived, as the case of the lake formed by the Montelago paleolandslide, Ancona (ID 86). It disappear by silting after about 3,000 years (Savelli et al., 2013), but its memory has been witnessed by the place name "Lago" ("lake" in Italian) that can be found many times in the area (Figure 10).

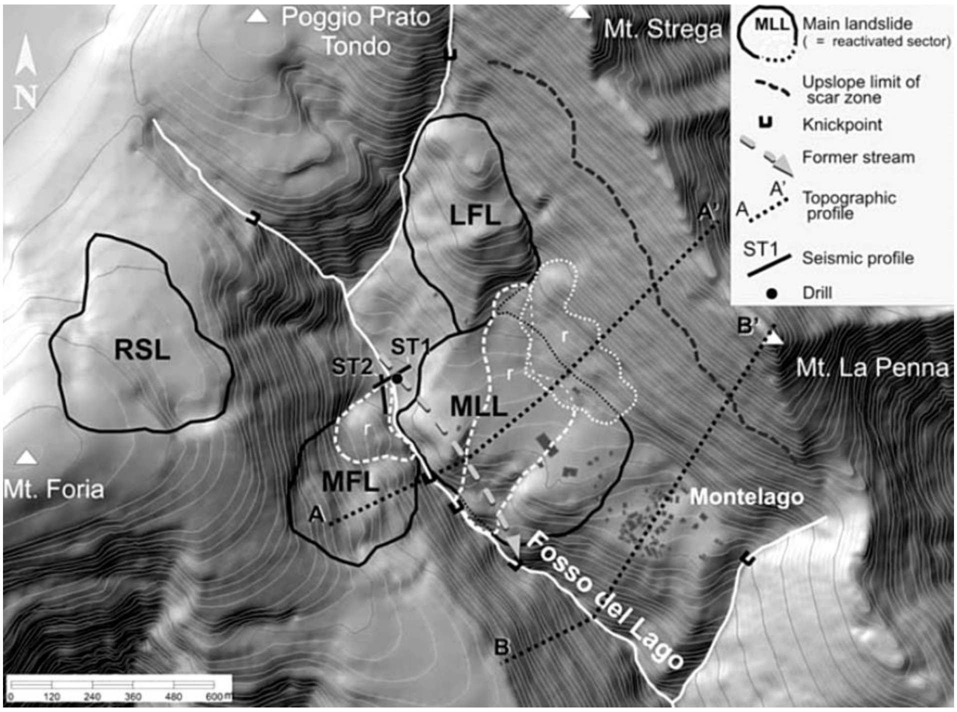

Figure 10 - Montelago Landslide, Ancona, Italy (from Savorelli et al., 2013).

According to Costa & Schuster (1988), landslide dam of type II are the most common and covers 44% of the cases, closely followed by the type III with 41%. The census conducted in the Apennines by Casagli & Ermini (1999) has led to substantially similar results, even if the most abundant dams are type III with 41% followed by type II with 34% (Figure 11).

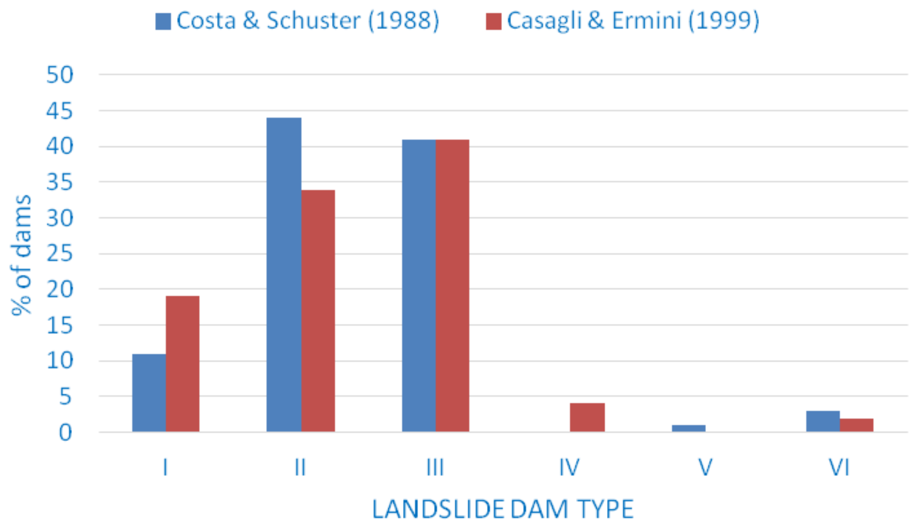

Figure 11 - Landslide dams type distribution (Costa & Schuster, 1988, in blue; Casagli & Ermini, 1999, in red).

Based on surveys carried out along the Argentine Andes, Hermann et al. (2006) found that in some cases landslide dams can make substantial changes in the river system, diverting the normal flow of water. This has resulted in the need to add new classes to the classification that are given below for the sake of completeness, although not represented in any of the reported cases in Italy (Figure 12).

Type VIIa: the dam forms a barrier that causes the development of a new drainage network, diverting the stream into an adjacent valley through the rock in place.

Type VIIb: the dam forms a barrier which deflects the course of water through the bedrock remaining in the same valley.

Type VIII: the dam is formed exactly where the drainage network can be diverted to another valley. In this case the paroxysmal event can be disastrous for both valleys, one for the overflow, the other for siphoning and subsequent flooding.

Type IX: the dam break causes a huge debris flow that can spread up to 60 km away (as in the case of the landslide Barrancas Valley in Argentina in 1914), whose terraced deposits can affect the flow of the tributaries located downstream of the dam.

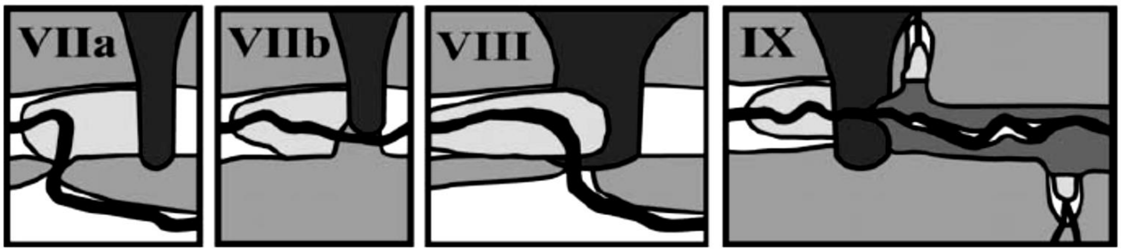

Figure 12 - Classification of landslide dam types VII – IX proposed by Hermanns et al. (2006) (from Hermanns et al., 2006 modified).

2.1.1 DAMMING MECHANISMS

A schematic sequence of the events occurring during a damming scenario is illustrated in the flow diagram of Figure 13. It is the result of experience gained by studying nearly 300 Italian landslides and researches made by other authors (Casagli & Ermini, 1999; Costa and Schuster, 1988; Ermini, 2000; Korup, 2005).

Whether the valley houses a mobile bed channel (an open valley) or a fixed channel, the result is mainly function of factors linked to the two main involved players, the landslide and the river: morphometric and kinetic characteristics (like volume and velocity) of the mass movement and hydraulic and geomorphological characteristics (like discharge and width of the valley) of the river valley.

Different scenarios may occur when a landslide threatens to get in a river valley. The damming of the valley will not affect at all the river bed (**A**) or can involve it, partially (**B**) or totally (**C**).

A) If the landslide can not reach the active riverbed of the channel, **no damming** occurs, and the damage that can be expected is connected only to the effect of the landslide.

B) If the landslide reach the active riverbed of the channel, but has no sufficient volume or velocity compared to the river discharge, may form a **partial damming** that narrow the outflow section of the water course. Immediately the stream will try to erode the foot of the landslide, trying to redress its condition, disturbed by the landslide that has reduced the area of the river cross section.

The result is a function of several factors: volume and size of the materials brought by the landslide, geomorphological characteristics of the barred riverbed, lithology of the slopes that form the valley, erosive capacity of the river.

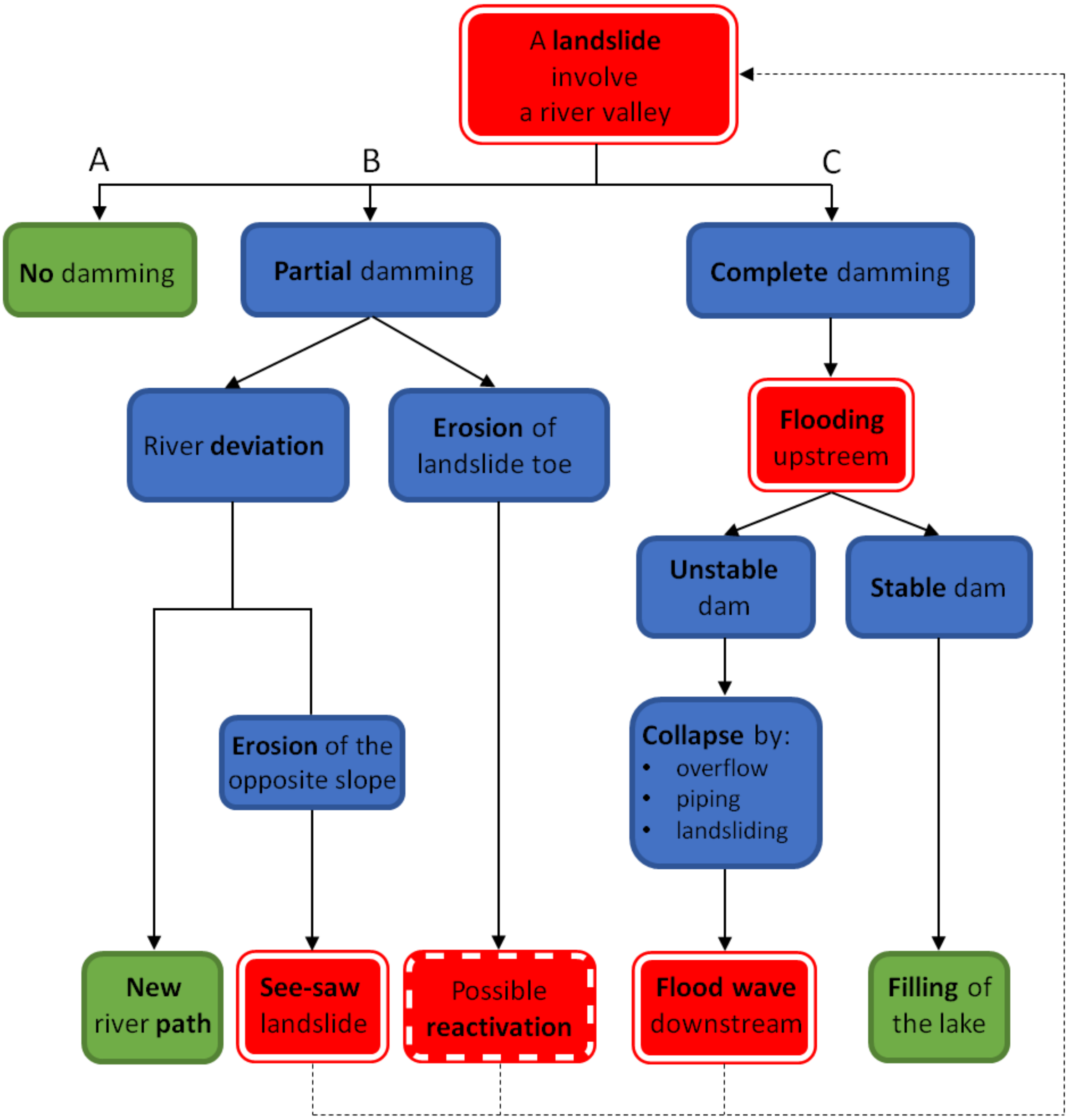

Figure 13 - Flow diagram of the different scenarios caused by a damming event.

If the stream has enough energy to **erode the foot of the landslide**, the latter is removed by increasing the solid load of the river. This establishes a condition of potential instability that could trigger future reactivation of the landslide. If it should happen, the scheme restart to the beginning.

If during the competition between the river and the landslide the latter win, **the river is diverted** and erosion is focused on the opposite side to the landslide. If the valley allows it, the river try to bypass the obstacle represented by the landslide. The only visible effect on the surrounding environment, in addition to those direct due to the landslide, is the deviation of the river path.

If the width of the valley is not enough, the river erodes the opposite slope to the landslide acting an undermining of the base. The consequent change of slope static equilibrium establish a potential instability situation. The trigger of another landslide leads back to the starting point of the scheme.

In rare cases, we can count more landslides triggered by a chain process. Elmi (1988) proposed to define these cases with the term of “See-Saw” landslides, just to emphasize the repetition of the phenomenon over time. In Italy an example was the case Castel dell'Alpi landslides (Bologna, ID 28) where five episodes of damming took place in historical times, alternating chronologically, three located on the right side and two on the left (Elmi, 1988).

In all of these processes lithological and geological-structural factors play an important role, in particular in the control of static disequilibrium situations that may evolve from a partial damming case.

From the geomorphological point of view and the evolution of the phenomenon, with the same boundary conditions, the ratio between the volume of the dam and the width of the dammed valley is determinant. In particular, low values of this ratio normally lead to the erosion of the landslide foot, while higher ratios lead to the diversion of the river.

C) If the landslide is able to totally obstruct a river valley, it form a **complete dam**. The first consequence is the formation of a lake. In upstream areas, raising waters blocked by the dam, can flood areas over kilometers.

Once the dam is formed, in some cases it can reach conditions of extreme stability and last for several years. In this cases, if the dam remains stable and resistant to erosion, the lake will survive until the sediments from the upstream rivers do not result in the complete **filling**.

Much more often, while the lake fills up, there is a very high risk situation due to the **collapse** of the dam. The dam may fail after a variable span of time depending on a number of factors such as volume, grain size and texture of the dam material, volume of the impoundment and river discharge. This risk increases of magnitude in mountain streams, because the geomorphological characteristics of the valley, often narrow and steep, that are arranged to a very fast fill (even a few hours).

Statistically worldwide most of the damages were reported in the areas downstream of landslide dams (Schuster, 2000), but this should not detract from the high risks that are associated even with the flood areas upstream of the dam.

2.1.2 COLLAPSE MECHANISMS

The collapse mechanisms for an unstable dam are well known and studied (Costa & Schuster, 1988; Schuster, 2000) and can occur in three ways:

- **Overtopping;**
- **Piping;**
- **Slope failure.**

The survey carried out by Costa & Schuster (1988) on a sample of 55 landslide dams, led to show that **overtopping** appears to be the most frequent cause of failure (over 92% of cases). The waters of the reservoir reaches the spillway height of the dam and trigger an erosion process, resulting in the formation of a channel on the downstream side of the dam. Sometimes the overtopping of the dam can be triggered by a wave of water caused by the fall of a landslide in the reservoir, like in the October 9, 1963, at Vajont dam (Pordenone, ID 184) when a massive landslide of more than 200 millions of m^3 of material cause a huge wave that destroyed the Longarone village and killed more than 2˙000 people (Figure 14).

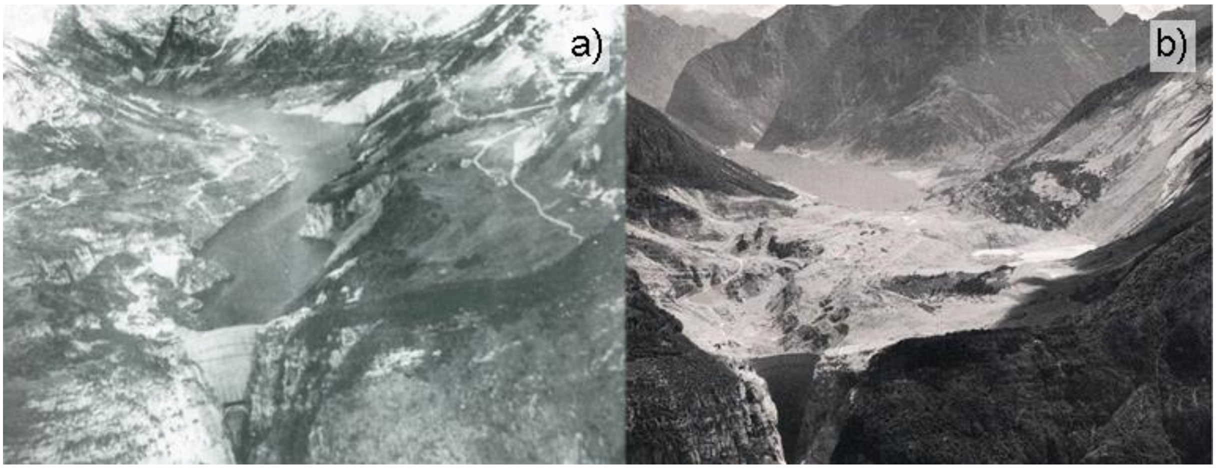

Figure 14 - Aerial views of Vajont valley (Pordenone, Italy), a) before, and b) after the disaster in 1963 (pictures from Wikipedia).

The breach deepens gradually within dam's materials towards the upstream side of the dam, causing it to collapse. The depth speed depends on the geotechnical properties of the materials making up the dam, the slope of the downstream and the volume of the upstream reservoir.

A landslide dam is often composed by unconsolidated or poorly consolidated heterogeneous materials. It is thus provided with porosity such as to allow the water of the reservoir to filter inside. The internal erosion process, triggered by the filtration of water through the blockage, determines the formation of an underground free path called "pipe", from which the term "**piping**" (Terzaghi, 1996). Within this free path the water flow is transformed from a filtration motion through a porous medium, to a current in pressure in a closed conduit. With the transit of the flow the dimensions of the duct are increased up to cause the collapse of the vault, with formation of a gap that widens and deepens rapidly in a similar way of the breakage by overflow.

The piping phenomenon is linked to the principle of effective stress proposed by Terzaghi (1996) to understand the behavior of the soil, that is a multiphase system consisting of particles, voids, and of pressurized water in the voids. The law of interaction between the various phases in the hydrostatic case is the following:

$$\boldsymbol{\sigma}' = \boldsymbol{\sigma} - \boldsymbol{u} = \boldsymbol{\gamma}'\boldsymbol{z} \quad (1)$$

where $\boldsymbol{\sigma}'$ represents the effective stress, calculated at the base of the immersed material, $\boldsymbol{\sigma}$ the total stress, $\boldsymbol{u}$ the neutral pressure, the volume weight of the immersed material, and $\boldsymbol{\gamma}'$ the investigated thickness of the immersed material. The importance of the principle of effective stress is that the behavior of the soil depends on the combination of the total stresses and neutral pressure and not by their individual values.

In the case of water filtration motion within the immersed material, it generates a pressure of filtration that, when is downwards, the effective stress increases and, when is upwards, the effective stress decreases. In this situation, the Terzaghi principle of effective stress will be given by the following equation:

$$\boldsymbol{\sigma}' = (\boldsymbol{\gamma}' \mp \boldsymbol{iz}\boldsymbol{\gamma}_{\boldsymbol{w}} \quad (2)$$

where γ_w is the weight of the water volume and $\boldsymbol{i}$ the hydraulic gradient.

When the filtration pressure increases to cancel the effective stress, the soil does not bear any load and the soil particles without cohesion are removed and carried by the water in motion. This results in the liquefaction of the immersed ground. The hydraulic gradient by which this occurs is called *critical hydraulic gradient* $\boldsymbol{i_c}$ and every time it is reached or exceeded, the piping phenomenon occurs. Generally this erosion phenomenon occurs in the lower part of the dam, where the critical hydraulic gradient is reached because the high hydrostatic pressure.

The piping phenomena does not occur if the material is composed even by a part of clay or silt, because even low levels of cohesion can stop the erosion of the soil and not allow the expansion of the pipeline. Perhaps this is the main reason why siphoning is so rare in the case of collapse of landslide dams.

A landslide dam with upstream and downstream vestments characterized by high slope and with high internal pressure, can be subject to failure of one, or both, of the two facings of the dam body that can collapse for **slope failure**, under the action of the force exerted by the hydrostatic load of the upstream reservoir.

This is an eventuality that is rarely observed, since the materials that constitute the dam body are distributed in a dynamic way, according to their angle of repose, and is generally linked to other processes. A variation within this group could be the complete collapse of the dam, which has never been directly observed, although it could occur with dams formed by quite loose materials. The direct observation of these phenomena is extremely difficult because they occur in very short time after the dam formation and often in inaccessible mountainous areas and characterized by high gradients. A good esemple can be the collapse of Matthieu landslide dam in Dominica, West Indies, that occurred in the middle of the night in a rural area with no inhabitants, 14 years after its formation. Landsliding on the face of the landslide dam was not directly observed but available evidences were consistent with this hypotesis (De Graff et al., 2010; James & De Graff, 2012).

2.2 MAIN EFFECTS INDUCED BY LANDSLIDE DAMS

Landslide dams are composites and complex phenomena. Composites as occur from the interaction between two different environments, the valley and the slopes. There act two morphogenetic processes, the river and the gravitational movements.

Complex because their consequences, both on the environment and on the human activity, are of dual nature. Indeed, to clearly understand them, the risk of landslide and especially the hydraulic risk have to be analyzed and taken into account. Moreover, the effects propagate through space (on-site, upstream and downstream) and time (a dam may fail after a few hours, but even after many centuries). Furthermore, the potential damage related to the formation of a dam is not limited only with the direct effect due to the landslide, which already can be catastrophic itself.

One example is the dam of Borta (Figure 15, ID 119), Udine (Northern Italy), whose landslide destroyed the village with the same name in 1692 causing hundreds of dead (Montandon, 1933). However, reports of landslides that cause deaths and devastation can be continuously founded in the world.

Figure 15 - Picture of the XVII century of the Borta landslide (Udine, Italy) (from V. Joppi Library, Udine).

It is important to highlight that the greatest danger starts after the fall of the landslide, following the damming of the river. By now, the landslide body and the stream become two closely linked entities, in close dependence on each other, forming a single system.

The most immediate effect, resulting with the blockage of the valley, is the formation of a lake upstream of the landslide dam, in a more or less long time, according to the flow of the water course and the morphology of the valley barred. The flooding of the upstream areas involves risk to human activities, the lines of communication and artifacts. The economic damage can be substantial, water can submerge entire villages and floods make the infrastructures useless, while the threat of losing lives is usually reduced. In order to forecasting, is very important to identify the potential flood area in advance, evaluating the growth speed of the water based on height of the dam itself, the morphology of the ground and by the amount of discharges. In this way it is also possible to calculate when the lake will overflow, reaching its maximum volume. This prediction, however, can be invalidated by various factors, such as sudden and exceptional weather conditions, that are often trigger of other additional landslides.

An example is the lake formed in 1987 in Val Pola (ID 115), Sondrio, whose growth rate was calculated in 40 cm per day. Instead, after very intense precipitation, the water level of the lake grew up to 4 m per day (ASC, 1987).

When a landslide cut off a watercourse, it interferes with the delicate balance between erosion and sedimentation. Thus, for the upstream section of the river, a new level of local basis is created. So, into the reservoir there is a sudden increase of the deposition for the drastic reduction of the carrying capacity of the current. The stream start to deposit material, beginning from coarse to fine, and the river tends to restore a uniform longitudinal profile.

A typical Italian example is the Alleghe Lake (ID 116) in the valley of the Cordevole Stream, Belluno, which clearly silted and significantly reduced its size and its volume during its life time. At its formation in 1771 it measured 4 km long and 52 m deep. Currently it measures 1˙500m long and 15 m deep (Pirocchi, 1991).

An example of completely filled dammed lake, whose burial deposits are engraved in many points, is located along a left tributary of the Irminio River, opposite the town of Ragusa, Southern Italy (Nicoletti et al., 1998).

The effects are more catastrophic downstream of the dam. The greatest risk is the possibility that the landslide body collapses, causing rapid and sudden emptying of the lake, with the onset of an anomalous flood wave that have devastating effects on the downstream area. In Biasca, Switzerland, in May 20, 1515, the flood caused by the emptying of a dam of debris formed two years earlier caused 600 deaths.

After the sudden and rapid overflow of the landslide dam, the retained water exceed the barrier, deposits their solid load, increases its speed triggering a quick erosion process that causes the complete collapse of the dam. This event occurs at different times depending on the discharge of the stream, the size and the geotechnical characteristics of the dam body.

The sudden release of water, for the failure of the dam, then is followed by the formation of a flood wave that propagates in the valley with serious risks to people and artifacts.

To understand the magnitude of this event consequences is useful to recall the history of the Kummersee Lake located just north of Merano (Figure 16, ID 118), Bolzano (Northern Italy). In 1401 a landslide comes off from the Monte Ganda, formed by metamorphic rocks, and blocks the Passirio River. A lake about one kilometer long and more than 50 m deep forms behind the landslide. It is called "*Passeier Wildsee*" (Wild Lake of Passiria) or "*Kummersee*" (Lake of the Accident). During the span of its life, the lake overflows several times, often without serious consequences (Walcher, 1773; Montandon, 1933; Elsbacher & Clague, 1984; Pirocchi 1991). In 1419, however, after the collapse of a large portion of the dam, a flood wave mixed with water and debris overwhelms the small villages along the Passirio River up to the city of Merano located 25 km away. There were over 400 deaths and incalculable damage. Repeated reactivation of landslides from Monte Ganda allowed the lake to survive and it continued to cause severe damage in 1512, in 1572, in 1721 and in 1772. After the last two episodes, which caused extensive damage, some works to reduce the risk of flooding were carried out as directed by the professor of mechanics at the University of Vienna, J. Walcher. In October the 22, 1774, for an error to the operations supervisor, the waters of the lake, raised by the violent rains, poured into the spillway destroying all the works carried out and headed violently downstream.

Figure 16 - Lake Kummersee (Bolzano, Northern Italy), oil-painting of XVIII cent. (from State Museu Meran Archive).

The lake was emptied completely in less than 12 hours, bringing death and destruction to the valley up to Merano. After this wave the lake is not reformed anymore, witnessed only by the wide flat stretch of the river bed, but the Ganda Mounain still continues to move. One day the Kummersee could still be talked about.

There are many worldwide examples of catastrophic landslide dam failure.

On August 25, 1933, an earthquake of magnitude M=7.5 near Diexi, Sichuan Province, caused the formation of three landslide dams with a maximum height of 160 m on the Min River. The three lakes behind the dams merged into a large lake because of the continuous inflow of water from upstream and the higher elevation of the most downstream dam. The dam was overtopped 45 days later, and a flood of water rushed down the valley for a distance of 250 km, killing at least 2˙500 people (Sichuan Seismological Bureau, 1983; Xu et al., 2009).

The flood wave transit can become even more devastating if the liquid flood wave turns into debris flow. Thus, the landslide dam failure can be the trigger of a channeled debris flow. The extraordinary discharge of the stream, that have strong availability of eroded solid material in the riverbed, can bring about extraordinary intense solid transport phenomena (Walder & O'Connor, 1997; Gattinoni, 2000). When a debris flow landslide overran a riverbed from the beginning, the evolution of the phenomena is mainly about on the relationship between volume and viscosity of the involved materials. Usually the mass movements with low velocity can not reach the opposite slope and often, when they come into the riverbed, are further liquefied by the river. In this cases they don't form a dam, but they quickly spread downstream with often extremely devastating effects.

Other secondary processes can be generated by the formation and subsequent collapse of a landslide dam, like the trigger of additional landslides in the lake for water level lowering of the lake basin, or in the downstream valley, for the foot erosion produced by the transiting flood wave (Elmi, 1988).

The most catastrophic collapse documented in the literature is the case of the landslide dam of Indus River in 1841. After an earthquake, during the winter between 1840-1841, a landslide movement interested the Nanga Parbat Mountains and caused the complete obstruction of the Indus River creating a lake 305 m deep and 64 km long. In June 1841 the overflow occurred and the dam were rapidly dig to its complete collapse. The lake emptied completely in 24 hours propagating a flood wave 30 m high up to Attok city, 400 km downstream from the point where the dam was formed, hundreds of villages were submerged with thousands fatalities (Mason, 1929; Costa, 1985).

From human losses point of view, the most catastrophic event occurred after the dam landslide failure in historical times, took place in China's Sichuan Province in June 1, 1786, after an earthquake with a magnitude of M=7.75 (Dai et al., 2005). The earthquake triggered numerous landslides, one of which blocked the Dadu River, forming a temporary lake. The dam was about 70 m high and the lake formed had a surface of 1.7 km^2. By 9 June the lake had started to flow over the dam and in 10 June an aftershock caused the dam to suddenly collapse. The flood that resulted from the landslide dam failure reached the city of Leshan on 11 June, causing collapse of part of the city walls. The destructive effects of the flood continued downstream at Yibin and Luzhou, with an estimated 100˙000 people being killed overall along a path of about 300 km.

3 RESEARCH DATA: LANDSLIDE DAMS DATABASE

The data collection was the first and main part of this study on landslide dams. In the first part of this chapter the archive of Italian landslide dams realization is proposed.

As mentioned in the Introduction (Chapter 1), the prevalence of archives at different scales, local, regional or interregional, with different level of detail, imposed the need for a single database with national scale that would gather the larger number of known cases distributed throughout the Italian territory. The research, structured in several stages, was very challenging, especially during the retrieval of bibliographic data because the lack of historical information and the assessment of their degree of objectivity in order to standardize the quality of the data. Then, the data collected in the database, essential to further researches, are presented.

Finally in the last part of the chapter, the experiences abroad in Peru, realized to develop a comprehensive and different approach to the topic and to help the assessment of the Italian cases, is also described.

3.1 DATA COLLECTING

The census work has led to the acquisition of 291 cases, filed in person or from sources very different for the quantity and quality of the information provided. The complete list of the Italian landslide dams is located in the Appendices (Chapter 8) at the end of the thesis.

Data collected were assembled in a single database with friendly and intuitive structure containing all the collected cases. Such a treatment has been preferred in order to privilege the usability and also has significant advantages for a future implementation. In fact, the database structure is very slim and the retrieval of data is easy because can be taken also by samplers without experience on the field, maintaining as much as possible the quality of data.

A major problem, in the treatment of archive data in Applied Geology, came from the subjectivity and sensitivity of the individual sampler. Sometimes, in fact, some less obvious cases, characterized by altered morphology and recorded by improvised chroniclers, which recorded only a part of the information, have not been stored for not reducing the quality of the rest of the archived data.

In order to standardize the data collection, the cases surveyed whether they were from, (from other archives or checked/discovered more recently), have been reported following a census sheet of landslide dams proposed by Casagli & Ermini (1999), derived from a similar one introduced by Amanti et al. (1996). The sheet include all the most important parameters of the landslide, the blockage, the dammed stream and the lake. It has been modified a bit and is divided in two sides, as shown in Figure 17.

The first side of the sheet is dedicated to the description in space and in time of the landslide and geomorphologically characterized. The second side, strictly dedicated to the dam and the hydraulic section affected by the landslide, allows a complete classification of the phenomenon of the dam, that is characterized by geomorphological, geotechnical and hydrological-hydraulic point of view.

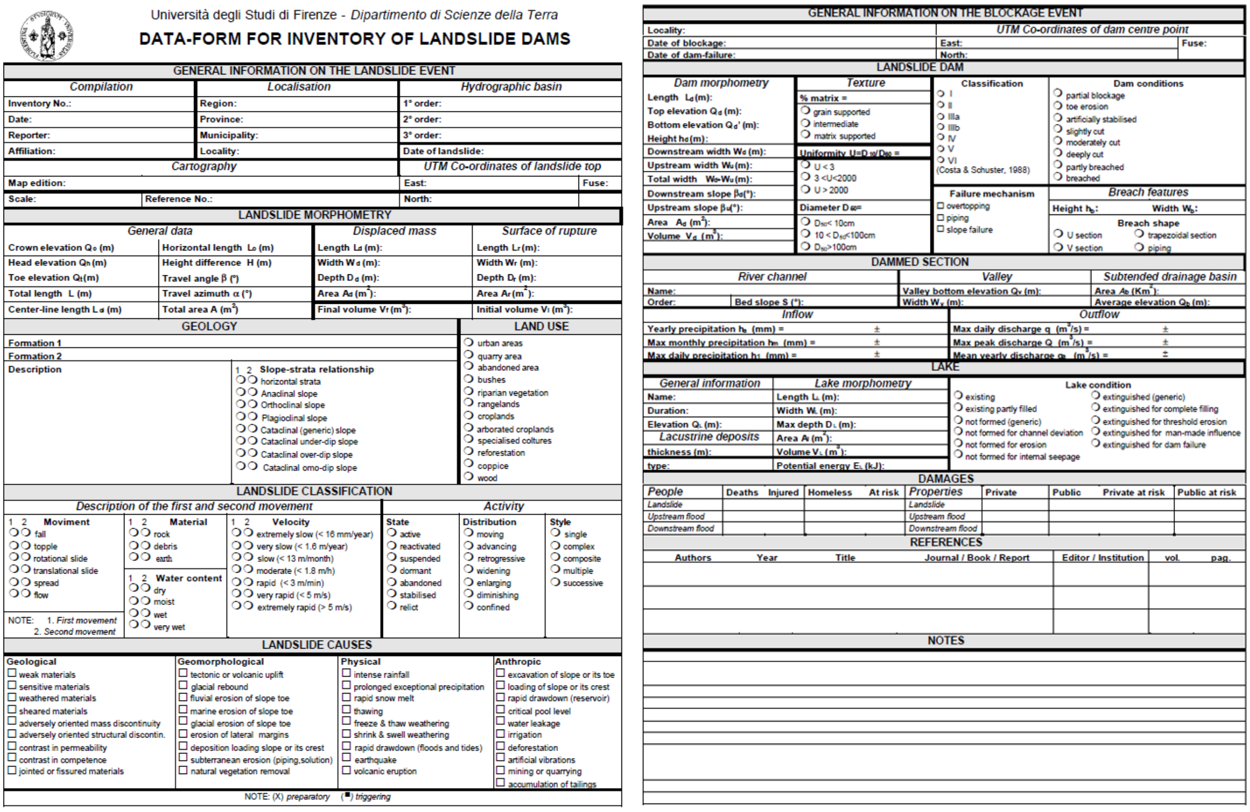

Figure 17 - Both sides of the data-collection sheet with the parameters for the description of landsliding, dam, lake, stream and drainage basin (from Casagli & Ermini, 1999).

The sheet represent one event and reactivations are events in their own right that must be recorded in one other sheet. When, during the census, dam events realized by the same landslide at different times were founded, only the best documented events were included.

In order to make the census as much objective as possible, the descriptive fields and the note field on the sheet are only a small and limited part and the fields to single or multiple choice are favored.

For most of reported cases it was not possible to collect, in the literature or directly obtained, data relating the granulometry of the dams materials, although of great importance for the characterization of the dams stability (Costa & Schuster, 1988; Pirocchi, 1991; Ermini et al., 2006). It could not be possible, indeed, to collect laboratory data for all the Italian cases in just three years because of the huge number of reported cases and the large extent of the country.

Moreover, the measurement of the particle size and texture of a landslide are an operations anything but objective and presents several difficulties. The main limitation is operational. The typical granulometric/texture analysis, performed by sieving or digital photography techniques, employ samples of a few kilograms of material or small photographic strips taken at the surface. We can hardly consider the data obtained by these techniques as dimensionally representative of landslide body, which instead is formed by particles ranging from few microns up to tens of meters in size and often have considerable internal heterogeneity, with horizontal and vertical clear changes in particles sizes.

Even if we manage to get a complete granulometry measurement and a comprehensive characterization of the texture of the dam, is still extremely difficult (and arbitrary) to decide which is the right size that best fit with the result of the analysis and can express numerically.

3.1.1 PREVIOUS ARCHIVES AND BIBLIOGRAPHIC RESEARCH

The implementation phase of an Italian database of landslide dams has led to an intensive bibliographic research and, when were missing in the texts from which we learned the events, acquisition of geological and morphometric data.

The confluence of the previous archives of the smaller size made by other authors in a single database was an important part of the PhD activities.

Some authors have already made the archives of landslide dam for other nations in the world. These include the archive for New Zealand (Korup, 2003), which includes about 250 dams, the Swiss (Figure 18) made up by Bonnand et al. (2006), with 31 cases and the Chinese, which has even 1239 cases (Peng & Zhang, 2012), 257 of which formed during the earthquake of May 12, 2008, in Wanchuan (Xu et al., 2009).

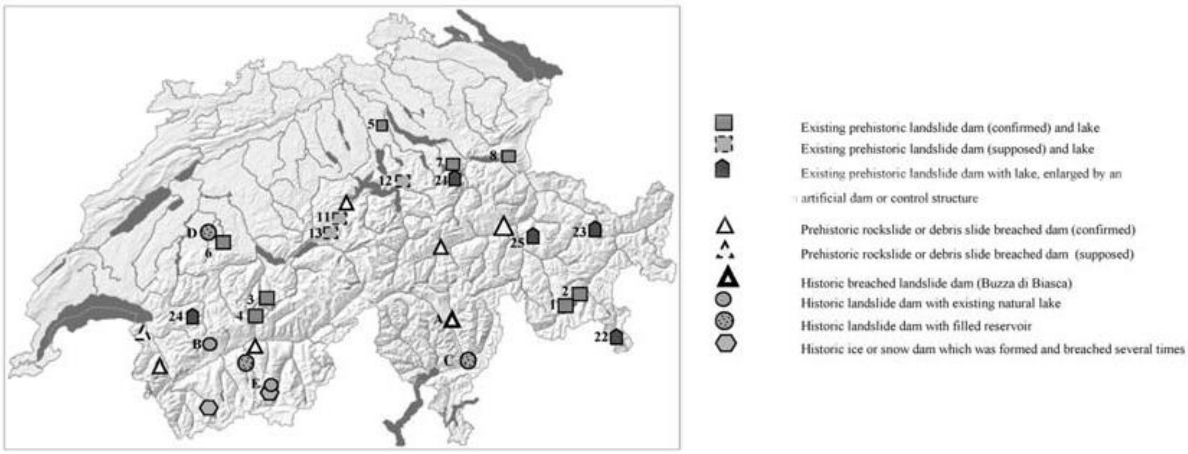

Figure 18 - Map of landslide dams in Switzerland (from Bonnard, 2006).

In Italy some archives have already been realized and they include information about the dams occurred in specific regional or interregional geographic areas. The most important and complete studies were used to compile the final database. Their study areas of investigation are: Pirocchi (1991), the Apennine area and the north of Italy; Ermini (2000), in the central and northern Apennines; Pacino (2002), in Sicily. Each of them reports a large number of fully described and morphologically characterized cases of river damming for their area of study. The cases listed by Ermini (2000) and Pacino (2002) were collected using both the same data collecting sheet proposed by Casagli & Ermini (1999) as sampling tool.
These databases have been extensively revised in the framework of this thesis, checking each of these cases, updating, correcting and completing them with the information that were missing, also with specific researches. The realized research has allowed the updating of the databases both with new cases of damming occurred in each area after their draft and with episodes that were not considered before by the authors.
At the same time as the study of cases reported by these authors, there was a large work of bibliographic research, scientific and not, to gather more information and news relating to possible cases of historical or prehistoric landslide that produced the damming of a stream of water with the formation of a lake basin. Data acquisition is the central phase and more prolonged in time of the whole thesis. The research was indeed focused on the river damming

occurred mainly during historical times. In these cases, information and relevant contemporary chronicles are more easily available related to important events and it is easier to correctly reconstruct the sequence of the events. The retrieval of these sources has been possible also thanks to the collaboration of some local governments (municipalities, provinces and other public structure for the government of the territory), although a small number of those contacted.

In the census, however, we collected also cases occurred in the prehistoric era with available datings, mainly carried out by the radiocarbon method (procedure followed in the case of S. Martino di Castrozza, ID 179, in Siror Municipality, or Sutrio, ID 191, in Alta Terme Municipality), or even phenomena preserved to such an extent as to guess their nature and the reconstruction of their evolution. Especially, the reference is to all those cases of damming as prehistoric Campo di Grevena (ID 177,Figure 19), Trento (Northern Italy), that were characterized by evident morphologies, from the analysis of aerial or cartographic images or on the field, and so much unaffected by erosion to assume that their morphologies had changed very little.

Figure 19 - View of the ancient landslide of Campo di Grevena, Trento, Northern Italy (picture from GoogleEarth).

In order to collect new data, the bibliographic research did not stop at mere reconstruction of historical chronicles, in which the events describing the formation and evolution of a landslide damming are reported, but also involved the whole scientific, geological and geomorphological information of the area where the landslide occurred.

The studies on the instability in Italy and related archives of the AVI Project, *Aree Vulnerate Italiane* (Italian Vulnerable Areas), (Guzzetti et al., 1994) have been of great interest and usefulness. The AVI Project was commissioned by the Minister for Coordination of Civil Protection at the GNDCI - *Gruppo Nazionale per la Difesa dalle Catastrofi Idrogeologiche* (National Group for Defense from Hydrogeological Disasters), with the purpose to carry out a census of areas historically affected by landslides and floods. The archive contains historical information on landslides and floods that took place during the 20th century in Italy and was updated until 1996. The database contains information of more than 22˙000 landslides.

To carry out the research were consulted both scientific texts and social and historiography chronicles, both of historical and recent era.

The chronicles of newspaper are very useful because they often report events with great detail. Especially in the most recent cases, during the days immediately following the event, plenty of news and information can be found, often accompanied by pictures taken at very close and different times (Figure 20). With the availability of all exits of the newspapers reporting the event, it is possible to collect the descriptions written by local reporters often the day after the landslide. They often point to the sensationalism and drama of the event losing details and important information, because they have no familiarity with the description of natural phenomena.

Figure 20 - Newspapers reporting chronicles of landslide dam events and their consequences (among which Vajont, Val Pola and Val D'Ossola, Northern Italy).

In the following weeks are instead collected the more useful opinions expressed by the experts, who usually perform inspections and reports in the following days.

After the collection, the information that allowed the detection and identification of a case of obstruction were further completed with various survey techniques. Because the over-extension of the national territory, primarily for practical and time reasons related to the large number of reported cases, it was possible to carry out a field survey only for a small part of the many recorded cases, in order to combine academic study with direct experience of the problem.

For all cases, however, an investigation through photo-interpretation and study of maps was carried out. It allowed us to collect most of the morphometric data relating to the landslides characterization. Especially for the study of the dams that occurred in more recent times, Google Earth software was very useful to use, in particular for the possibility of the aerial imagery archive consultation, like for the case of the Scascoli landslide reactivation (ID 72), Bologna (Figure 21).

Figure 21 - The Scascoli case (ID 72), Bologna, before and after the landslide reactivation (pictures from GoogleEarth).

This tool, combined with the 3D view of the ground (Figure 19), has allowed, through the comparison of images acquired in different times, to understand and reconstruct the evolution of a landslide dam (as the Costantino lake silting, ID 97, in Reggio Calabria, Southern Italy, showed in Figure 22) and its consequences on the upstream and downstream area.

Figure 22 - Evolution from 2005 to 2012 of silting up of Costantino Lake (ID 97), Reggio Calabria, Southern Italy (pictures from GoogleEarth).

3.2 THE ITALIAN DATABASE

The landslide dams, resulting from the census stage of the research, were geo-referenced and collected in a GIS. The Figure 23 shows the results of georeferencing, the map of distribution of Italian landslide dams, through a cartographic base corresponding to the projection UTM (Universal Transverse of Mercator).

At first glance, it is possible to immediately notice a higher concentration of cases in the Alps and the northern Apennines than in the southern part. Although the map of slope instability in Italy (Progetto IFFI (*Inventario dei Fenomeni Franosi in Italia*) ISPRA - *Dipartimento Difesa del Suolo-Servizio Geologico d'Italia*, 2006) would let believe that this distribution has a real correspondence, this should not mislead (Figure 24).

The distribution of dams collected in Italy is obviously affected by the studies conducted so far about this issue and also the morphological evidences that each event left on the territory. For this reason we are reasonably sure that we are aware of most of the sizable cases occurred in historical times in Italy, but also that many others were not detected. However, there are some inconsistencies, in terms of number of cases existing between one area and another.

Figure 23 - Geographical distribution of Italian landslide dams, according to three evolution classes.

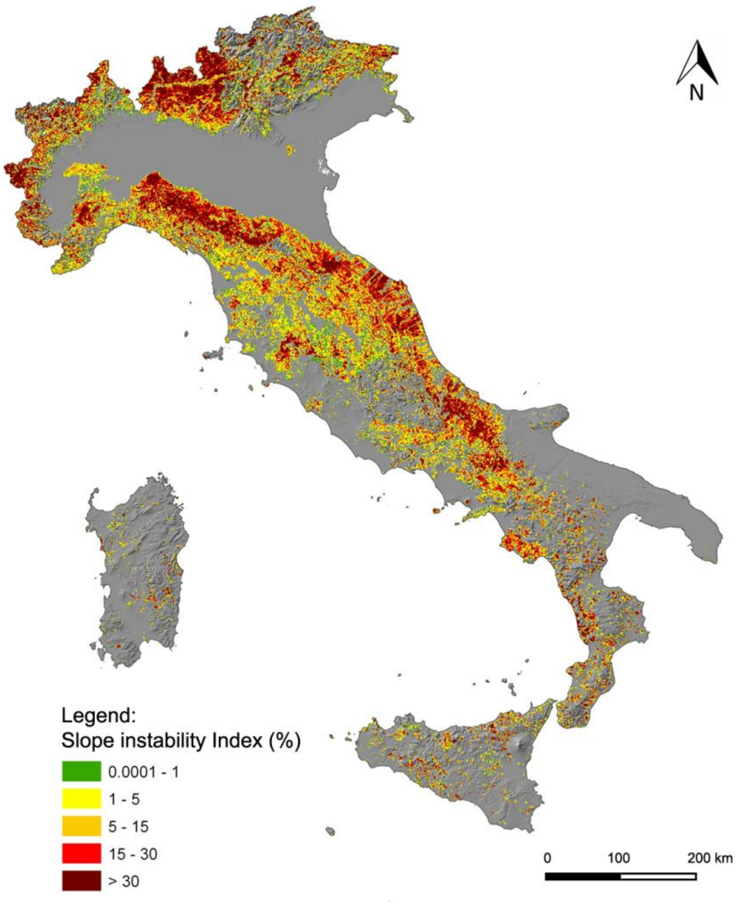

Figure 24 - Map of slope instability of Italy (from Progetto IFFI (Inventario dei Fenomeni Franosi in Italia) ISPRA - Dipartimento Difesa del Suolo-Servizio Geologico d'Italia - Regione/Provincia Autonoma...., 2006, modified).

This distribution difference is mainly the result of two factors. First of different morphological and hydrogeological characteristics of the different geographical areas, which control the formation of a dam and then a different preparation to obstruction of the enviroment. Secondly, the quality and quantity of references founded. Except for Sicily, in fact, the number of sources about events located in the southern Apennines is lower compared to the northern and that sometimes it was not possible to exactly identify where it was located the described landslide dam.

In general, the more the bibliographical data is related to an event distant in time (and of small size) and the lower the accuracy of the data and the morphologic evidence left. A bibliographic case that clearly illustrates this possibility is represented by the seismic event that shocked all southern Italy in February 5, 1783, with particular intensity in Calabria Region. The earthquakes caused more than 31˙000 victims and real devastation in the territory.

Countless were the landslides, including several oversized which destroyed entire villages dragging them downstream. Rivers were diverted or dammed, with the formation of at least 215 lakes (Figure 25), as reported by Ruberti (1787):

"[...] Until now are known two hundred and fifteen of them. But to understand in one shot their extension and the place we will split up all the Plain area, where they are spread, in seven districts, and also the lakes in big, medium and small. We will consider as big those that are 1˙500 palms long; as medium those that are not so long but at least 500 palms long; as small those are less long that 500 palms. [...] Fourteen of first order, thirty-five of second order, and one hundred sixty-six of third order. [...]"
[1 palm = 26,5 cm].

"[...] *Sono dunque i noti finora duecentoquindici. Ma per comprendere ad un colpo d'occhio la loro estensione, ed il sito, divideremo tutto il suolo della Piana, nel quale essi sono sparsi, in sette ripartimenti; come anche i Laghi stessi in grandi, mezzani e piccioli. Intenderemo per grandi quelli, che saranno nella massima loro lunghezza da sopra i palmi 1˙500; saranno mezzani quelli, che non eccedono questa misura in lunghezza, ma superano quella di palmi 500; si diranno finalmente piccioli quelli, la cui lunghezza non eccede i detti palmi 500. [...] Quattordici di primo ordine, trentacinque di secondo ordine e centosessantasei di terzo ordine.* [...]"

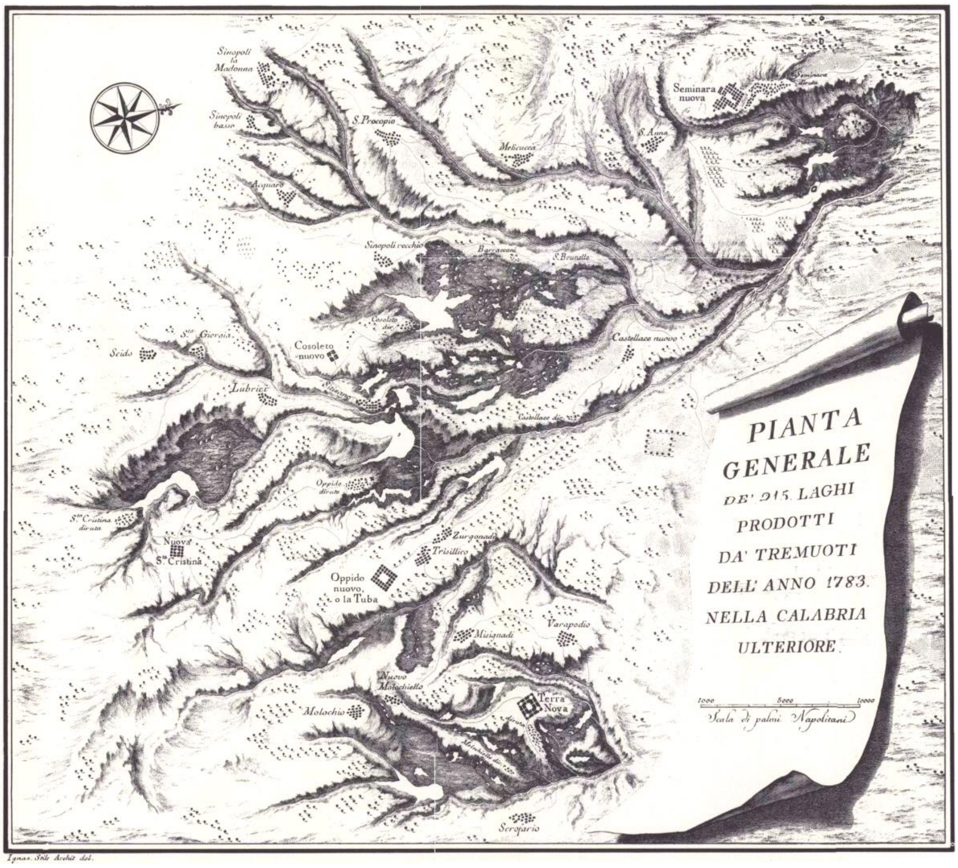

Figure 25 - Map of the 215 lakes formed by the earthquake of 1783 in Calabria, Southern Italy (from Sarconi, 1784).

Unfortunately it was possible to identify with certainty only about ten of the dams on the Calabrian territory product by landslides of larger size. The other approximately 200 dammed lakes produced by gravitational movements of lower dimensions were not detected by the lack of sufficiently obvious forms in the current morphology. A careful reading of the chronicles describing these lakes (Ruberti, 1787; Vivenzio, 1788) has allowed to understand that many of these were not the result of a river obstruction but were instead water basins located along counterslopes within the landslide.

The same difficulty generally occurs to identify Type I dams, according to the classification proposed by Costa & Schuster (1988), which occurred not very recently. Indeed landslides that fail to completely block a river valley generally have a small volume (compared to the river discharge) and their morphologic evidence is erased in a short time by the erosive capacity of the water course. It must taken into account also that most of the landslide dams of this type, precisely because of their small volume, produces no social alarm on the territory and therefore it is not reported from any source. So we can assume that this kind of landslide into the riverbed are much more frequent than those known.

As shown in Figure 26, the lower volume possible to measure was about 10^4 m^3 and this lower boundary is fully represented by Type I dams. Also, most part of almost 20% of all the landslide dams stored, which we couldn't evaluate the volume, belong to Type I. Can be assumed that at list a part of this dams had a scant volume, even lower than 10^4 m^3. So this can be considered as the minimum volume that can cause any kind of detectable effect on the valley and the river dynamic.

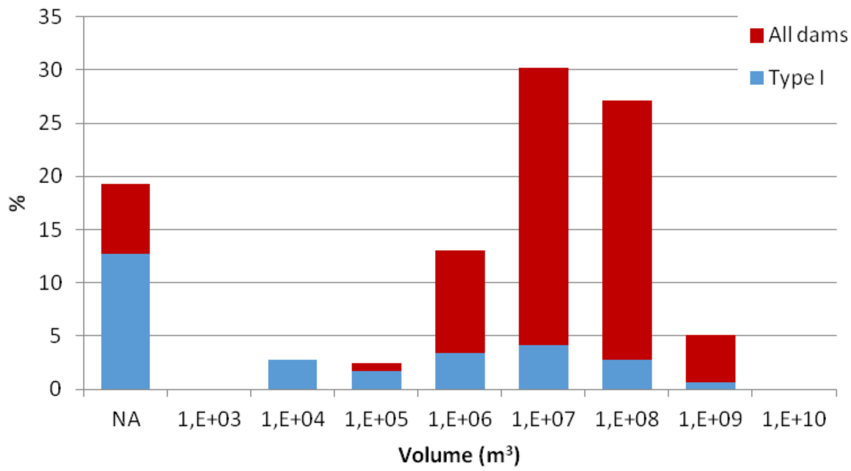

Figure 26 - Volumes distribution of landslide dams collected in Italy. The part of them represented by Type I dams (according to the classification proposed by Costa & Schuster, 1988) are highlighted in blue. (NA = Not Available).

3.2.1 DATABASE STRUCTURE

The new database is primarily the result of the acquisition and the study of the archives related to the damming lakes of other Authors (Costa & Schuster, 1991; Pirocchi, 1991; Ermini, 2000; Pacino, 2002) and derived from the information obtained through survey using a data collecting sheet (Casagli & Ermini,1999).

The structure of the database is easy in order to privilege intuitive usability. It is formed by 57 information fields easy to collect and measure that can be gained by staff without any specific competence in matters.

The data can be gathered into six groups, according to the type of information they provide, as shown in Table 1.

	Information	unit	Description
Localization	ID	[ ]	Unique Identification Number of the Landslide
	Locality	text	Local name where damming occurred
	Municipality	text	Italian Municipality where damming occurred
	Province	text	Italian Province where damming occurred
	Region	text	Italian Region where damming occurred
	UTM E, N crown	[ ]	Coordinate of the Landslide crown (WGS 1984-UTM)
	UTM E, N dam	[ ]	Coordinate of the Landslide dam (WGS 1984-UTM)
News	L.-damages	text	Direct Damages caused by the landslide
	u-damages	text	Upstream Damages caused by the rising water
	d-damages	text	Downstream Damages caused by the outburst flood
	Bibliography	text	Bibliographic references about the event
	Note	text	Additional note or information
Landslide	Movement	text	Landslide movement classification (Cruden & Vernes, 1996)
	Velocity	text	Velocity classification of the Landslide (Cruden & Vernes, 1996)
	v	[m/s]	Velocity measure of the landslide (Cruden & Vernes, 1996)
	Material	text	Landslide material classification (Cruden & Vernes, 1996)
	Lithology	text	Lithology classification of the landslide
	Water c.	text	Water Content classification of the landslide (Cruden & Vernes, 1996)
	H L.	[m]	Altitude difference between higher and lower part of the Landslide
	α	[°]	Steepness of slope opposite to the Landslide
	β	[°]	Steepness of Landslide slope
	L L.tot.	[m]	Total length of the Landslide
	L L.body	[m]	Length of Landslide body
	Wmax	[m]	Maximum width of the Landslide
	Wmin	[m]	Minimum width of the Landslide
	D_{rf}	[m]	Thickness of the Landslide
	S L.	[m^2]	Surface of the Landslide
	V L.	[m^3]	Volume of the Landslide
	Trigger	text	Trigger mechanism of the landslide
	Prev. activations	dd/mm/yyyy	Previous Activations of the Landslide before the damming event
Dam	Date of damming	dd/mm/yyyy	Date Of Damming
	Date of failure	dd/mm/yyyy	Date Of Failure of the dam (if any)
	d type	[ ]	Classification of the dam (Costa & Schuster, 1988)
	L d	[m]	Length of the dam
	W d	[m]	Width of the dam
	H d	[m]	Height of the dam
	S d	[m^2]	Surfece of the dam
	V d	[m^3]	Volume of the dam
	Q d	[m] a.s.l.	Altitude of the spill way (above sea level)

	Information	unit	Description
	d condition	text	Dam Condition
	Evolution	text	Evolution of the landslide dam
	Type of Failure	text	Dam failure mechanism (if any)
Stream	**Main Basin**	text	Name of the main basin
	Dammed R.	text	Name of the dammed river
	Wvalley	[m]	Valley Width
	Subt. S	[km^2]	Surface of the basin subtended by the landslide dam
	S	[°]	Steepness of river bed
Lake	**Lake name**	text	Lake Name
	L lake	[m]	Length of the lake
	W lake	[m]	Width of the lake
	D lake	[m]	Depth of the lake
	S lake	[m^2]	Surface of the lake
	V lake	[m^3]	Volume of the lake
	Q lake	[m] a.s.l.	Lake altitude (metres above see level)
	h of Lac.dep.	[m]	Height of lacustrine deposits (if any)
	Lake life time	text	Life time of the dam (hours, days, mounths, centuries)
	Lake Condition	text	Lake Condition

Table 1 - Italian Landslide dam Database structure.

We think unnecessary to dwell for long time on the description of each data entered into the database, because their understanding should be obvious. A clearer graphic representation of geometry and morphometric parameters of the landslide and the dam can be found in Figure 27.

Below is a briefly description of the six groups of information and in the following paragraphs we will describe some essential parameters with more detail.

- **Localization**: in these fields are present all data about geographical position of the landslide (both the crown and the dam) and other information useful to its localization and identification. The first field is an unique *Identification Number* (ID) useful to univocally identify each landslide dam.
- **News**: containing a description of the consequences (damage to property or fatalities) of the landslide, the lake (upstream) and of the flood wave (downstream). In this section are also listed the references of the data sources about the event.
- **Landslide**: here a number of information useful to landslide characterization are listed. Both general descriptive data (like landslide material and trigger), morphometric and volumetric data are collected. We use the landslide movement classification, material,

and water content, proposed by Cruden & Vernes (1996). The velocity assessment used method is explained in a later section.

- **Dam**: as for the landslide, in these fields many information, both descriptive, morphometric and volumetric, useful to dam characterization are reported. Also some information about the dam condition and event evolution are provided.

  For the *Dam Condition* ten option are available:

  - Partial blockage: if the obstruction of the riverbed caused by the dam is not complete;
  - Toe erosion: if the landslide's foot is eroded by the stream;
  - Artificially cut/stabilized: the landslide dam is cut/stabilized thanks the human work;
  - Slightly/moderately/strongly cut: the dam is eroded in different extent, with small, medium and big intensity;
  - Not cut: the dam has not been cut yet and it is fully intact;
  - Breached/ Partly breached: the dam completely/partly collapsed.

  There are three possible *Type of Failure* mechanisms, already described in the Chapter 2:

  - Overtopping;
  - Piping;
  - Slope failure.

  The *Evolution* possibility are described widely below.

- **River**: containing the main parameters of the stream, the watershed area above the dam and the valley itself, as its width.
- **Lake**: containing the main morphometric parameters of the lake, if formed, and details on its evolution.

  For the *Lake Condition* eleven option are available:

  - Not formed (generic)/for erosion/for infiltration/for deviation: the lake did not form; is possible to specify the cause (for erosion, infiltration or deviation);
  - Existing/existing partly filled: the lake still exist/but can be partly filled;

- Extinguished (generic)/for man-made influence/for spillway erosion/for filling/for dam collapse: the lake no longer exist; is possible to specify the cause (man-made influence, spillway erosion, filling or dam collapse).

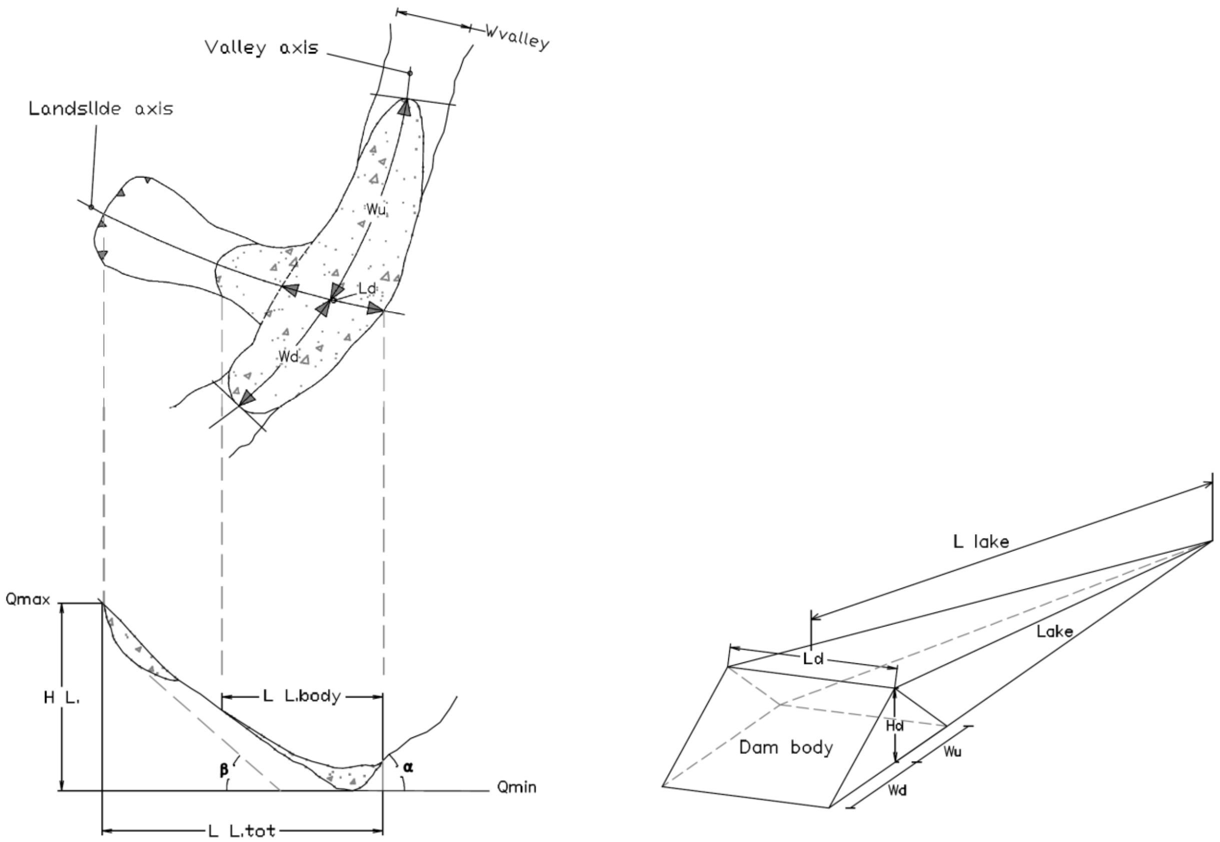

Figure 27 - Landside dam geometry and morphometric parameters, see Table 1 for symbols correspondence (from Pirocchi, 1991, modified).

Landslide velocity

With the same other boundary conditions, the speed of a landslide can be the discriminating parameter to decide the formation of a dam. This statement is broadly supported in all studies directed to the analysis of the process of construction of a natural dam (Swanson et al., 1986; Casagli & Ermini, 1999; Ribaldi, 1999).

It is not easy to define landslide velocity. It can be calculated by direct measurements, that can be on surface or deep down, or throw a reconstruction after the event.

The surface movement can be assess with the classic monitoring techniques for landslide: with topographical tools (also with GPS), or with extensometers, to directly measure the relative change of position of the landslide compared to something believed to be still. Also radar interferometry techniques (satellite and ground based) has been strongly applied for studies regarding terrain deformations induced by natural and anthropogenic phenomena. This techniques can provide the millimetric movements of the ground based on interference pattern resulting from the comparison of two or more radar images of the landslide taken in different moment (Fruneau et al., 1996).

The deep monitoring of the landslides is developed throw inclinometers that can also be equipped with an extensimeter cable. All these instruments measure displacements that can be properly processed in average speeds based on the time interval between two measurements. The smaller the time interval used, the more measurement will properly approximate the instantaneous value of the speed of the landslide. Because of obvious practical limitations, however, these techniques are much more useful the lower the speed of movement of the landslide.

Often, however, movement triggers unexpectedly, immediately reaches the valley floor and such data are not available, so the reconstruction of the speed of a landslide is quite difficult. This is true particularly with the events that occurred in the past or for extremely fast movements and these two cases include most of the dams.

Of great help for many of the landslides investigated in this thesis indeed it was been the classification of landslide velocity based on the resulting damages originally proposed by Hungr (1981) and then adopted in the formulation of Cruden & Varnes (1996). These authors have established a relationship between the speed of a landslide and the produced damage, combining different levels of damage with different speed thresholds of the landslide that produced them, with a logical scheme similar to the one followed for the formulation of the Mercalli scale for the analysis of earthquakes intensity. The scale of Cruden & Varnes (1996) identifies seven classes of damage and the same number of speed ranges, as shown in Figure 28.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evacuation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
	Extremely SLOW			Imperceptible without instruments; construction POSSIBLE WITH PRECAUTIONS

Figure 28 - Mass movement classification based on velocity of displacement (from Cruden and Varnes, 1996, modified)

The speed scale drawn up on the basis of the damage caused by landslides proved to be very useful because direct measurements of the speed of landslides are very difficult to acquire for the events of the past, unlike what occurs for the damages.

Also the historical landslide archive in fact (Almagià, 1907; Catenacci, 1992; Guzzetti et al., 1994) report in great detail the damage caused by landslides, especially when they have caused the complete destruction of villages and killed many people.

Dam Evolution

Particular attention was paid in the "Evolution" information field of the database to the definition of different types of evolution that a damming event can meet. In a forecast analysis in fact the evolution of a phenomenon is the only dependent variable, so it is therefore important to define what types of evolution can affect a landslide dam. Based on the analysis of collected cases and on studies in the literature (Ermini 1997; Canuti et al., 1998; Casagli & Ermini 1999; Rosati, 2000) six dam cases can be defined:

1. Not formed;

2. Breached hours/days/months/years;
3. Partly breached;
4. Stable – filled lake;
5. Stable – existing lake;
6. Man-made influence;

1. Not formed: in this class are included all partial damming events that cause river deviation and narrowing of the valley section, without the formation of a pond. Most of the dam cases collected in Sicily are not formed dams.

2. Breached hours/days/months/years: these are all the landslide dams failed with a catastrophic collapse for overtopping, piping or slope failure. The dam may fail after a variable span of time, from few hours to thousands years, depending on a number of factors of the landslide, the lake and the river such as volume of the dam, potential energy of the impoundment, discharge and stream power.

3. Partly breached: the term is related to the landslide dams that have suffered a gradual erosion of the dam, with partial emptying of the upstream lake, up to the complete extinction. Landslide dams can be slowly dismantled after their formation within a span of time ranging between a few months to several years. Unlike the previous evolution type, this one is normally a consequence of several overtopping events which produce a partial breach. The breach usually initiates at the toe of the dam and progressively deepens and propagates upstream. The deepening and the migration of the breach occur gradually without catastrophic events. The speed of the deepening can be very slow due to a process known as self-armouring (Nouth, 1990) consequently the removal of the finer material of the barrier. The outflow channel, that deepens slowly within the dam body, is covered and protected by the coarser fraction of the landslide materials.

4. Stable – filled lakes: in some cases landslide dams can reach conditions of so good stability that can last for many years. In these cases, in which the dam remains stable and resistant to erosion, landslide dammed lakes can be extinguished through filling. Several cases of complete filled lakes are located in the Apennine and in Sicily because of the erodible nature of the outcropping rocks in the watershed. The deposits of the older cases are cut by more recent river dynamics.

5. Stable – existing lakes: in this class are included all stable landslide dams that originated dammed lakes still existing. Several cases, even if have had an evolution globally characterized by stability, still have an element of potential danger linked to the presence of the lake basin. For this reason a part of the existing dammed lake have suffered an human influence in order to make sure of their complete stability. There are many cases of landslide dam in Italy that led to the formation of beautiful natural lakes: for instance the Alleghe Lake (ID 116), Belluno, in Alps (Montandon, 1933) as showed in Figure 29, that formed in 1771, and the older Scanno Lake (ID 68), L'Aquila, in Abruzzo Region (Nicoletti et al., 1993). The knowledge of the rates of filling of an impoundment is of central importance for estimating the sediment-production rates in a drainage basin for planning purposes. Landslide dammed lakes provide precious chances of direct measurement of sediment yield.

Figure 29 - View of the Alleghe, Northern Italy, Lake from the Est side.

6. Artificially controlled: the term refers to all natural dam cases where human intervention was decisive in determining the evolution of the phenomena. The main actions that can be adopted in order to control the evolution of a landslide dam can be divided into the following (Casagli & Ermini, 1999):

- Measures to prevent the formation of the blockage as, for example, the excavation of the landslide toe or deviation of the channel;
- Dam stabilization measures in order to limit the possibility of slope failure and to control internal seepage. This strategy has been adopted in some cases where natural

landslide dams have been reinforced and used as constructed dams, for example the Quarto di Savio dam (ID 31), Forlì.

- Measures to prevent overtopping and breaching through reduction of the lake level. These consist of pumping, construction of spillways over the dam or along the dam flanks over stable slopes, excavation of tunnels inside the dam or into the bedrock.

An example of how to intervene to remove a dangerous situation is the Contrada Torazza (ID 224), Catania, Southern Italy, landslide dam formed on the Alcantara River close to Randazzo (Catania) and Santa Domenica di Vittoria (Messina) in 1996. The first operation was aimed at control the level of the formed lake using some water pumps. Later it was decided the removal of the accumulation of landslide with the digging of a channel in order to prevent the failure of the dam by overtopping of the water (Ferrara & Pappalardo, 2000).

The analysis that will be presented in the following chapters are based on the measured parameters of dam cases occurred in Italy and the study of their evolution. In order to achieve one of the primary goals of this thesis to develop a tool that can provide indication on the possibility of a landslide to block a river, it was indeed necessary to group the recorded cases so as to be able to fulfill these needs. The six different classes of possible evolution for landslide dams previously described were subsequently grouped into three classes, in order to operate analysis that have a more immediate comprehension and can be used with forecast perspective.

a) Not formed: cases of partial damming of a stream where are not occurred formation of a lake basin upstream of the dam. Both upstream and downstream consequences and damage are not serious.

b) Formed-unstable: the landslide led to the formation of a lake basin which remained for a variable span of time until the collapse of the dam occurred with the release of part or all of the impounded water. The damage upstream and downstream of the dam can be catastrophic and depend on the speed of filling and the dimensions of the lake. The larger these values and the more damage.

c) Formed-stable: the landslide caused the complete blockage of the stream and the consequent formation of a lake basin. It remains preserved for a certain period of time until now, or it extinguished for filling. In some cases, the dam has suffered overtopping episodes and felt some damages, but however is not collapsed. In all cases the dam is characterized by a global condition of stability.

This operation of reclassification was quite easy in most of the cases, but sometimes, in particular when the human action was decisive, it was more complicated. Sometimes was preferred to exclude from being processed cases that, even if well documented, could lead to erroneous conclusions to their natural evolution because of the human action.

3.3 PERUVIAN LANDSLIDE DAMS

As part of this research, the study has been extended to landslide dams cases that occurred along the Cordillera Blanca mountain range, in the Huáscarán National Park, Ancash Province, Peru. The study in the foreign country, carried out thanks to the help and the collaboration of Prof. Vít Vilímek of the Charles University in Prague (Czech Republic), has been realized to improve the point of view on the topic, otherwise potentially restricted by the Italian experience. In fact, this experience has allowed to study the same phenomenon, the landslide dams, in a very different geographical, climatic and tectonic settings compared to Italy. This, in addition to extend the knowledge on the subject and to develop a more complete approach, also made possible to verify, in a very different part of the world, the validity, and evaluate the effectiveness, of the relationships observed on Italian cases, using the Peruvian cases as further proof of the fact.

The Cordillera Blanca (Spanish for "White Range") is part of the highly tectonically active Andes range, formed by collision of Cocos, Nazca, Antatic and South American lithosphere plates. It includes 33 major peaks over 5˙500 meters high in an area 21 kilometers wide and about 200 kilometers long. The highest mountain in Peru, Nevado Huáscarán (6˙768 m a.s.l.), is located here. The Cordillera Blanca forms the NE boundary of the valley of the Santa River (Figure 31), which has been affected by many historical natural disasters (Klimeš et al., 2009).

Within the high glacial valleys of the Cordillera Blanca there are many thousands of glacial lakes of different sizes that have produced many devastating Glacial Lake Outburst Floods (GLOFs) (Vilímek et al., 2014). The most important, which is the most destructive GLOFs in the world, is represented by the flood of May 31, 1970. A landslide of rock and ice, triggered by a strong earthquake off the Pacific coast, fell from Nevado Huáscarán into the lake of the Llanganuco valley, causing a sudden overflow. The water, rock and ice wave that was unleashed traveled more than 14 km in less than 3 minutes (Carey, 2005), completely burring the Yungay city and other smaller villages with about 18˙000 fatalities (Figure 30).

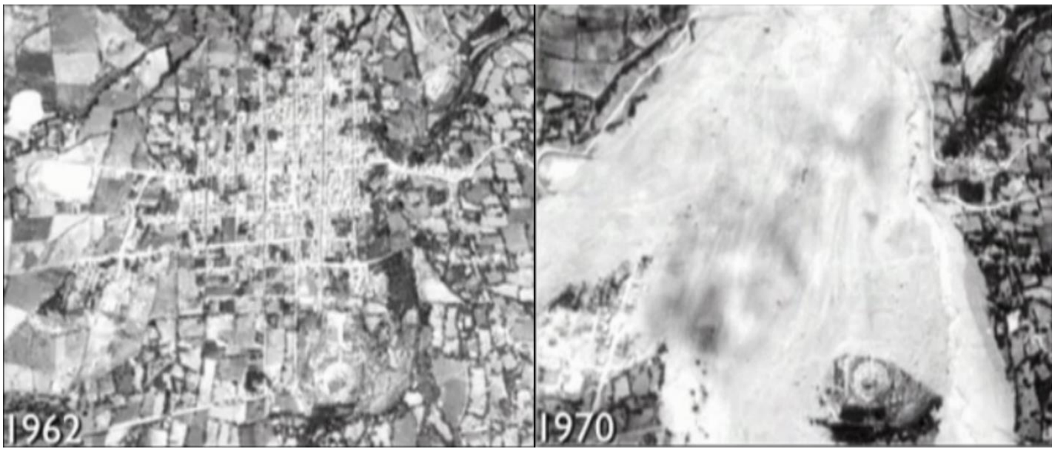

Figure 30 - Peruvian village of Yungay (Ancash Province) in 1962 and after 1970 disaster.

In the Cordillera Blanca Mountains is also possible to find some landslide dam or the traces of extinct lakes. A total of 24 cases have been identified (Figure 31), but it was possible to realize a field survey just for four of them (as Llanganuco Lakes, shown in Figure 32), because the hard access conditions to the area due to the high mountains.

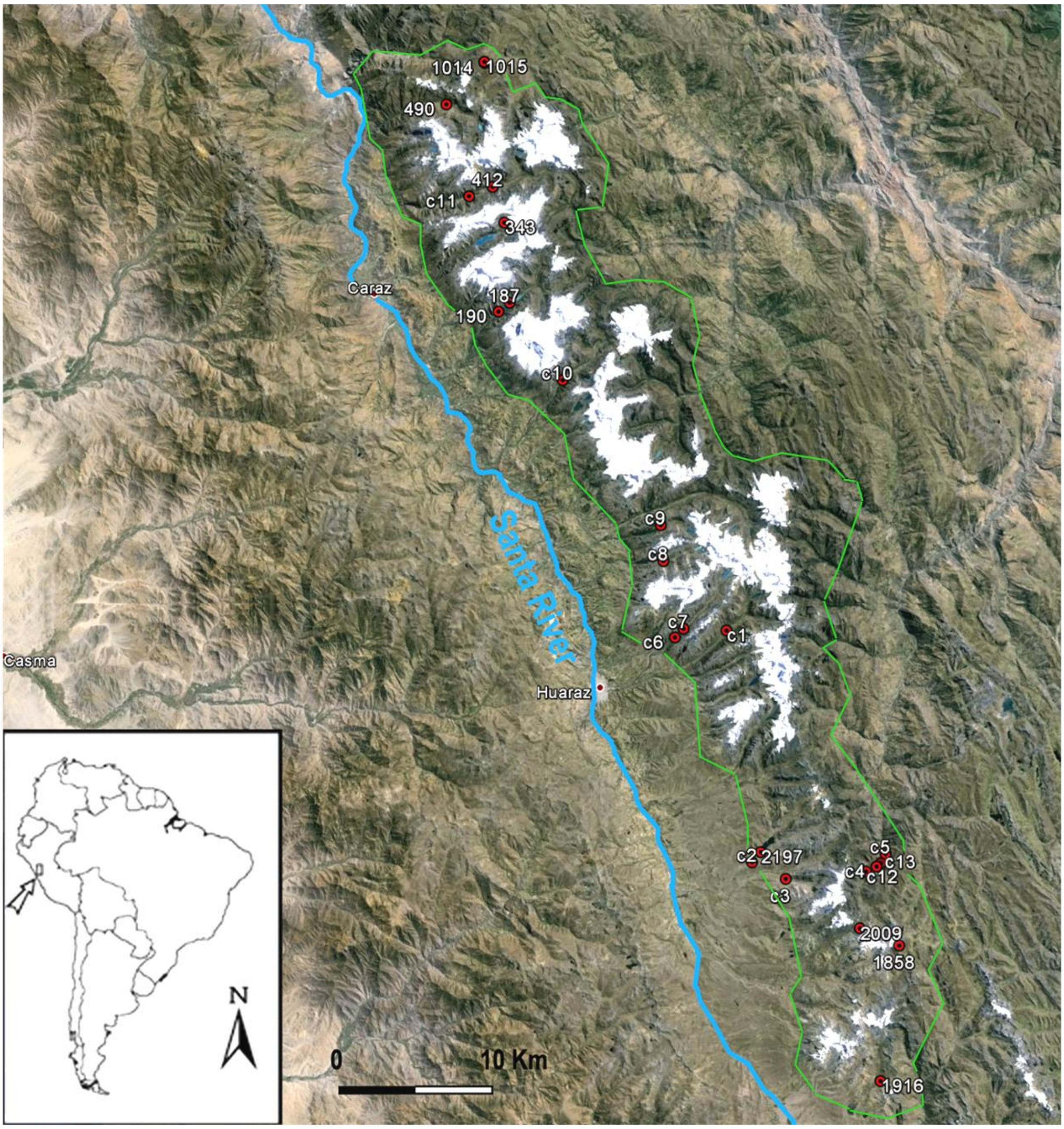

Figure 31 - Map of Cordillera Blanca mountain range (green line) showing the landslide dams collected in Peru (red dots) and the Santa River path (blue line).

To compensate for the lack of references related to single events in Peru, a wide maps research and an interpretation of images and aerial photos was carried out. This was possible thanks to the full cooperation of the staff of the ANA - *Autoridad Nacionale del Agua* (National Water Authority) in Huaràz, the Peruvian national structure with control function of the glacial lakes, and their chief Marco L. Zapata that allowed full access of their archive and library. In these structures, it was possible to consult a large number of maps, aerial photos, technical reports and official documents concerning the lakes in Cordillera Blanca.

Like the Italian cases, in Peru we measured all the morphometric parameters of the landslide, the dam, the valley and the lake (if present). The Peruvian landslide dams parameters and all the information discovered during the stay in Huaràz were collected together in a single archive. Some cases came from the Database of glacial lake outburst floods (Vilímek et al., 2014). Their "*Locality*" name and geographic position is the same of the Database of glacial lake. The new ones, discovered during the various investigation along the Cordillera Blanca, have an "*Locality*" composed by a progressive number forerun by a "c". The complete list of the Peruvian landslide dams is located in the Appendices (Chapter 8) at the end of the thesis.

The foreign experience was very useful also because, as will be shown in the next Chapter, the parameters of the Peruvian cases have been used to test and verify the analysis and the indexes realized with the Italian cases. As they belong to a really different region, from the climatic, orographic and geologic points of view, they can work like a "control group" in order to be sure that relationships found between the parameters of the dams are not due to chance or local Italian conditions, but reflect the natural laws that describe the internal balance in all the landslide dams in the world.

Figure 32 - Pictures of Llanganuco Lakes, Ancash Province, Peru: a) ID P2, "Laguna Baja" or "Chinanqocha" (Low or Female Lake) 3˙850 m a.s.l. (2014); b) ID P1, "Laguna Alta" or "Orqonqocha" (High or Male Lake) 3˙860 m a.s.l. (from Zapata, 1971).

4 DATA ANALYSIS

In the previous parts of the thesis has been described how the landslide dams cases, that form the knowledge base of this study, were collected and their different backgrounds. The starting point is represented by the cases collected in the Alps by Pirocchi (1991), in the Northern Apennines by Ermini (2000), in Sicily by Pachino (2002). These have been completed with new acquisitions and joined together to form the database of landslide dams drawn up on a national scale.

Whilst without the presumption to have collected all cases in Italy, the one presented in this thesis is the single most complete collection of Italian landslide dam cases.

This Chapter will discuss the considerations and processing carried out on data collected cases. Strom (2013) states that some studies base their analysis and statistical reports on data collected at regional or mountain system scale and for this reason they can’t be used in different geographic or climatic contexts. The data that constitute this database come from all over Italy and include within them the whole climate, lithological and morphological variability along the national territory, so their characteristics are therefore not strictly conditioned by local specific features. Calculations derived from them can therefore be considered valid at least in whole Italy and the Mediterranean area.

Some geomorphologic indexes, suggested by other authors and newly developed, are proposed in this Chapter, using parameters easy to collect. To verify their validity and extensibility in geographic areas with climatic and geological characteristics distinctly different, analysis performed on the Italian database were eventually applied also to the cases surveyed along the Cordillera Blanca in Peru.

The final aim of the data processing stage was to find, according to the cases observed in the past, the best parameters, relations and indexes useful to characterize and distinguish the river valleys with higher damming probability. This will be the key step in the development of a tool on damming susceptibility useful for forecasting and planning purposes.

4.1 ITALIAN LANDSLIDE DAMS CHARACTERISTICS

In Italy landslide dams, like landslides in general, are always highly widespread phenomena. In Figure 33 is shown, on this subject, the landslide dams occurred during the last thousand years dated through bibliographic data or with research on historical evidence. In the figure a significant increase in cases of natural dam can be observed from the beginning of the XVIII century, in the middle of the period known in literature as the "Little Ice Age" (between the mid-sixteenth and mid-nineteenth century). During this period, strong advances of the alpine glaciers fronts and episodes of freezing of the main streams occurred, like for the Arno River in Florence.

This “rise” of the landslide however can be only partially explained by this climatic oscillation.

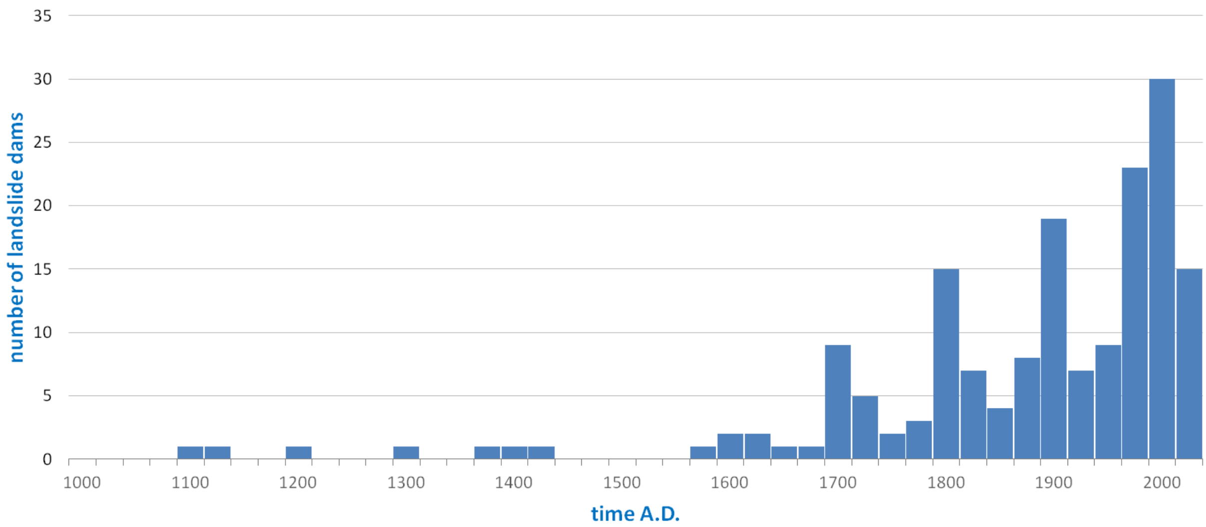

Figure 33 - Temporal occurrence of the inventoried cases during the last thousand years.

Canuti et al. (2004) show in Figure 34 an increase in the general landslides during the last five centuries which partly attributed also to a peak in cutting of forests in the same period.

As mentioned in Paragraph 3.2, the historical documents useful to assist in identification of blockage events begin to be more frequent, widespread and best preserved to this day only in recent centuries, probably due to the spread of printing in the fifteenth and sixteenth centuries. Diffusion of information in the twentieth century, in fact, led to gather information on nearly 90 landslide dams cases in the last century.

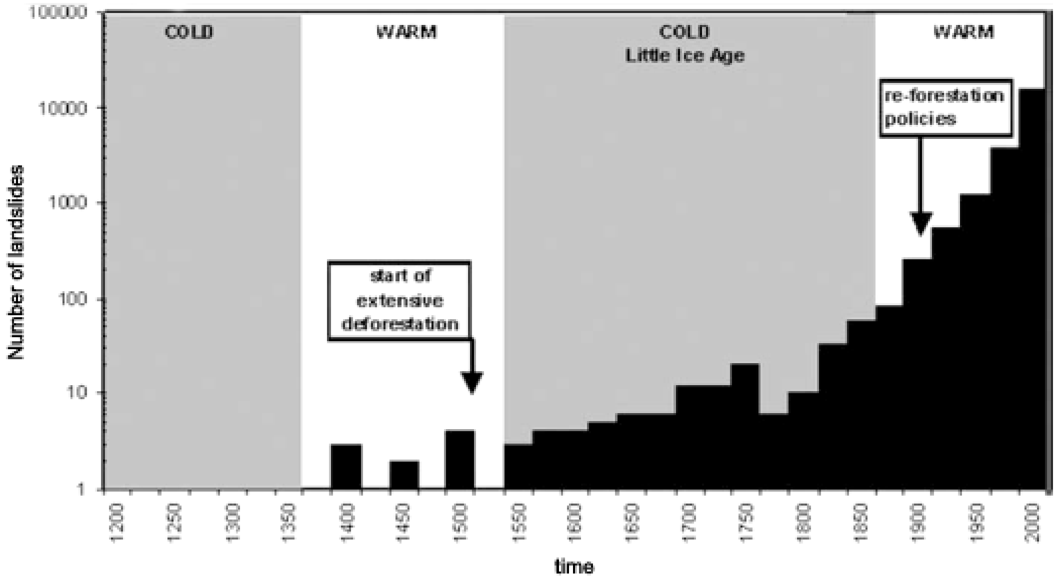

Figure 34 - Temporal distribution of landslide events in Italy compared with the main climatic periods in the last eight centuries (from Canuti et al, 2004).

Some of the cataloged dams instead are dating back thousands of years ago during the Holocene. Many data coming from lakes, formed behind landslide dams accumulating organic material, offer the possibility of dating landslides through radiocarbon method. Radiometric dating provides estimates the age of the deposits and thus indirectly of the landslide that caused the emplacement. Some examples are the paleo-lakes of Forni di Sotto (ID 188), Udine (Northern Italy), and Montelago (ID 86), Ancona, Central Italy. The presence of vegetal remains in layers of silt and clay deposits at Forni di Sotto, in Friuli Venezia Giulia Region, has allowed to determine the age of the lake, and therefore also the age of the landslide, between 9˙770 and 9˙930 years BP (Martinis, 1985). Even in the case of Montelago, in Marche Region, radiometric dating and pollen analysis of lake sediments have allowed to date the beginning of the deposition approximately 8˙990-8˙550 years BP (Savelli et al., 2013).

In Italy, as in the rest of the world, in some cases during history landslide dams have caused so big disasters that their consequences were mentioned by the local people for centuries. In Table 2 major catastrophic events that have affected the Italian territory and the their consequences are collected. As described in Chapter 2, the devastating effects of a landslide dam can occur directly on site due for the landslide itself, upstream for the rising of the impounded waters and downstream for the failure of the dam sudden emptying of the formed reservoir. It is important to note that the number of damming cases which resulted in casualties (and their absolute number) has declined in the last century, despite the number of recorded events is increased.

ID	Locality	Year	Landslide damages	Upstream damages	Downstream damages	Fatality
77	Castello di Serravalle	1279	A Romans castle destroyed			500
118	Kummersee	1401			-1419 some villages destroyed, -1503 Merano's walls destroyed, -1512 Merano's tower demolished, -1572 Merano's walls destroyed again, -1721,1772,1774 destruction of some Merano's buildings	400 ? ? ? ?
144	Piuro	1618	City of Piuro (Plurs) buried	Countrysides flooded		1200
113	Antrona	1642	Androna village buried	Flooded 40 houses and farms		93
42	Boesimo	1690	Destruction of 4 farms	Countrysides flooded		10
119	Borta	1692	Borta village destroyed			166
47	Montignoso	1717			Capanne village destroyed	?
116	Alleghe	1771		Flooded some houses close to Caprile village		52
31	Quarto di Savio	1812	Destruction of 4 houses and a church	Countrysides flooded		18
186	Antelao	1814	Taolen and Mareana villages destroyed			250
38	Lizzano	1814	Lizzano village and a bridge on Lima River destroyed	Modenese Road flooded		?
117	Val Vanoi	1825		Flooded 36 houses of Ponte hamlet	Destruction of Remesori village	52
142	Crodo	1834			Destruction of 46 houses of Crodo village	12
49	P.ve S.Stefano	1855		P.ve S.Stefano village flooded		4
100	Caridi	1873		Countrysides and some farms flooded		15
173	Colma di Barbiano	1891	Destruction of 13 houses at Colma village			39
171	Chiusa	1921		Flooded Chiusa village, railway		20

ID	Locality	Year	Landslide damages	Upstream damages	Downstream damages	Fatality
				damaged		
141	S. Giovanni	1958			Destruction of some buildings of S. Giovanni village, railway and main roads damaged	13
115	Val Pola	1987	Santonio Morignone, Morignone, Poz, Tirindè, S.Martino and part of Aquilone destroyed			29

Table 2 - List of major damage related to landslides dam in Italy.

The severity of the consequences of a landslide dam comes directly from the evolution of the dam after its formation. The analyzes presented in the following paragraphs are based on the observation of the cases occurred in Italy and the examination of their evolution.

The three main evolution classes (not formed, formed-unstable, formed-stable), summarized from the six evolution types described in the Chapter 3, were an useful classification tool to distinguish the wide range of possible dams, grouping them into sets with similar characteristics and behavior. The processing shown in this Chapter were made considering this subdivision with three classes.

The result of the division of the collected cases into evolutionary classes does not show a clear dominance of one class over other (Figure 35). The formed-stable dams are the most frequent with 39% of the cases, closely followed by the not formed dams with 32% and than by the formed-unstable with 28%.

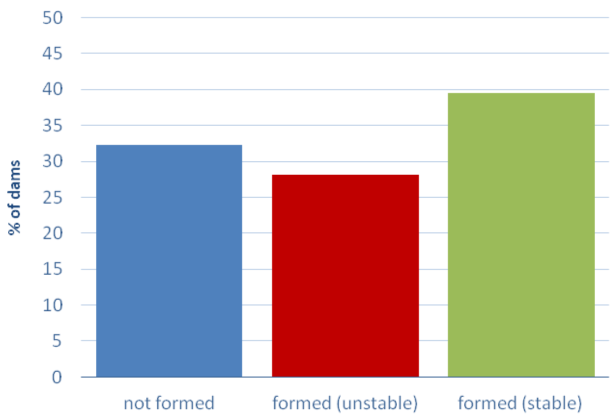

Figure 35 - Distribution of the evolution of landslide dams.

According to the landslide dam classification proposed by Costa & Schuster (1988) between the censed dams in Italy shown in Figure 36-a), the most common are the type II representing 41% of the total amount. Follow landslide dams of type I with 28% and of type III with 23%. Much less frequent are the blockages of type IV and VI, respectively with 4,5% and 3,5%. In Italy were not surveyed dams of type V.

The percentages about the landslides dams surveyed as part of this thesis differ somewhat from those submitted by Casagli & Ermini (1999) and Costa & Schuster (1988) (see Figure 10). While the most frequent type of blockage, represented by type II of landslide dams, is in agreement with that observed by Casagli & Ermini (1999) in the Northern Apennines, the percentage about type I is very higher (28% against 19% for Casagli & Ermini, 1999 and 11% for Costa & Schuster, 1988). Type II and type I of landslide dams in whole Italy overcome even those of type III, that in Casagli & Ermini (1999) and Costa & Schuster (1988) were the second most frequent blockage.

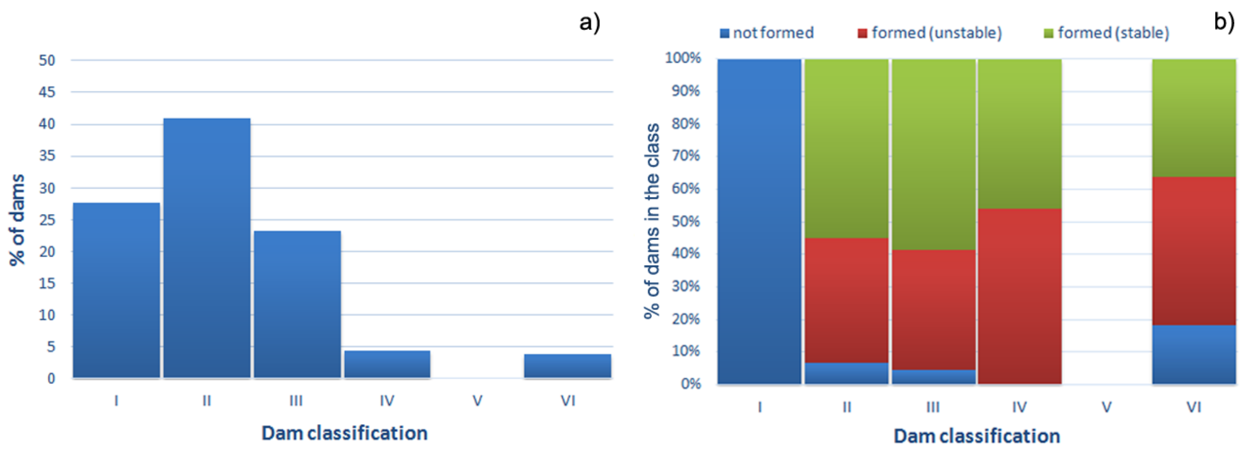

Figure 36 - Classification of landslide dams in Italy a) according to Costa & Schuster (1988) b) and their evolution classes distribution.

As regards their evolution in Figure 36-b) we can observe that not formed class represent 100% of the dams of type I, as is to be expected, and between 10 and 20% of types II, III and VI, while they were not found among type IV.

The formed-stable blockages are the most representative class among the landslide dams of type II and III with 55-60% of the cases, while among the landslide dams of type IV and VI the formed-unstable blockages are more recurring with about 50%.

As just described above, it is not possible to asses, from the examined cases, that there is a specific dam type with a clear effect on the final stability of the dam, once it is formed.

In the histogram of Figure 37 it is shown the division of the landslides based on the type of landslide movement that originated the dams. The used classification for the landslide movement is the one proposed by Cruden & Varnes (1996) that divide the landslides in six different kinds of main motion plus one complex. The term “complex” is referred to the style of a landslide characterized by two or more main movements combined in time or in space.

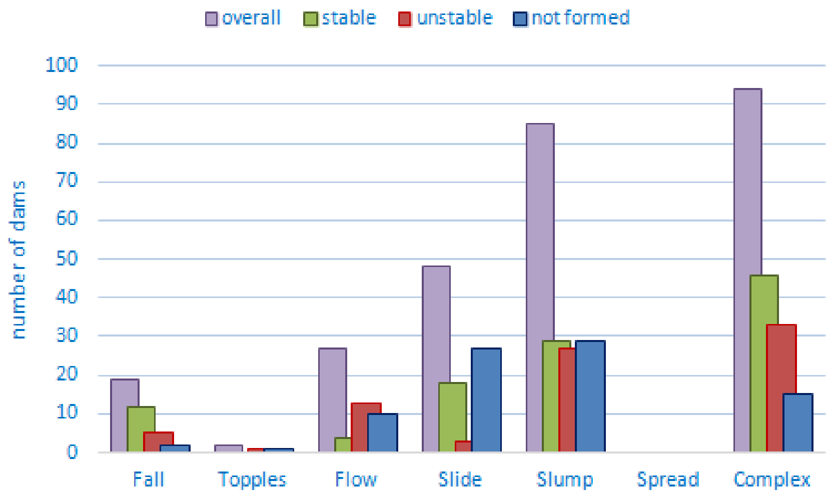

Figure 37 - Types of landslide movement compared with the evolution of the dam in Italy.

In the census it is possible to find five main types of movement that are, even outside of the particular category of landslides that cause damming, the most widespread that can be found in Italy. The landslides classified as complex are the most common and usually are the result of a first movement consisting of a translational and/or rotational slide of debris and/or rock, that evolve in a second movement classified as flow of debris and/or rock. Very common throughout the territory are also individual rotational and translational slides. Stable blockage of river courses rarely are formed by flows, falls or topples, because the volume of the involved materials in this movements usually is small and unlikely visible traces of the landslide remain, especially for flows. Between the landslides that originated the obstruction of a stream there are no reported lateral spread.

According to other studies concerning worldwide landslide dams (Costa & Schuster, 1988; Ermini & Casagli, 2003) it can be observed that the most recurring landslides movements types in the world in the formation of a river blockage are: translational and rotational slides of debris and/or rock, flows of earth and/or debris, falls of rock and/or debris and complex landslide movements, starting from slides and evolving in flows.

From the point of view of the evolution of the dam in Italy, most part of landslide classified as fall (63%) and complex (48%) resulted in formed-stable dams and just a fraction of these landslides (10% for falls and 16% for complex landslides) did not realized a complete obstruction. Instead, a small part of the landslides classified as flows formed a stable dam (just 15%), while most formed dams were stable only for a short period of time (48%) or not formed at all (37%). The slide, translational or rotational, have a completely different evolutionary behavior. The rotational slide are almost equally distributed in not formed, formed-unstable and formed-stable, and most part of the translational movements are not able to realize a complete obstruction (56%), but if they got it the dam is often stable (37%).

Also this time, the classification of the movement of the landslide is not able to distinguish a clear evolutionary trend, positive or negative, of the dam, identifying a type of motion that can block a stream with greater probability. Thus in general each type of landslide can result in not formed, formed-unstable or formats-stable dam. The only reliable information we can draw from these distributions are that the rockfalls form in most cases (63%) stable dams and, on the contrary, that the landslides classified as flows produce almost always potentially unstable dangerous dams (48%) or not formed dams (37%). The reason of this behavior could be the fact that, for falls, most of the volume of the landslide contribute to the formation of the dam body, with a positive impact on stability, while often, for flows, the geotechnical characteristics of not consolidated materials involved and the small volume of the landslide have a negative contribution to the formation and the stability of the dam.

4.1.1 LONGEVITY AND TRIGGER CAUSES

An important characteristic for purposes of civil protection and assessment of the damage caused by landslide dams is the endurance of the dam body over time, especially in the short term. Most landslide dams fail by overtopping or piping shortly after their formation (Costa and Schuster, 1988), typically in conjunction with the first serious hydraulic emergency situation faced by the dam. Many deterministic models (Dal Sasso et al., 2014; Ermini & Casagli, 2003) investigated this type of emergency situations as main aim and assessed the short-term stability of dams formed.

Figure 38 shows the dam longevity curve constructed using all the available data.

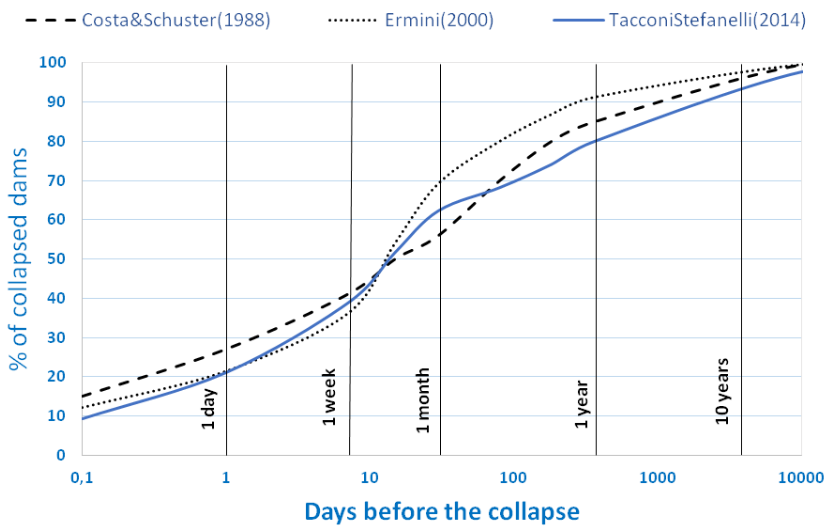

Figure 38 - Survival time before the failure of landslide dams.

If the data related to the longevity of the dams in this thesis are compared with those collected by other authors, it is possible to show some differences. As shown in Figure 38, even if 65% of the censed cases in Italy are failed within one month of their formation, in agreement with what reported by Costa & Schuster (1991) and Ermini (2000), about 20% of the total was stable for over a year and almost 10% for over 10 years (with double percentage than reported by Ermini, 2000). The complexity of an articulated system, as the landslide dam, composed by the impounded water basin and the involved river network, display therefore a wide variability in the data.

From the analysis of past cases emerged that there are barriers that remain stable for decades and then suddenly collapse when it was believed that they were stable. These events often cause extensive damage because all precautions and alert conditions were removed, as happened for the case of Kummersee lake (ID 118), Northern Italy (Pirocchi, 1991), or the Matthieu lake in Dominica, West Indies (James & De Graff, 2012), collapsed 15 and 14 years after the formation respectively. The former reached the city of Merano located 25 kilometers away, causing 400 casualties, with a wave of mud and debris, while the latter, hopefuly, did not result in fatalities or injuries because it occurred in the middle of the night in a rural area with no inhabitants, despite significant property and infrastructure damage.

In order to obtain indications for the formation of a natural dam and its stability, we investigated the causes that triggered landslides originating the collected dams. We chose to group the triggering causes of landslide dams in the following main groups, representative of the variability found in Italy:

- snow fall or melting;
- fluvial erosion;
- heavy rainfall;
- anthropic causes;
- earthquakes.

The Figure 39 shows the distribution of the trigger causes for the Italian landslide dams, although 127 cases of the database are not included because not known or certain. Just over half (52,4%) were provoked by seismic events and approximately another third (32,5%) by heavy rainfall events. The remaining part is divided in fluvial erosion with 10,8%, snow fall or melting with 3,0% anthropic causes with 1,2%.

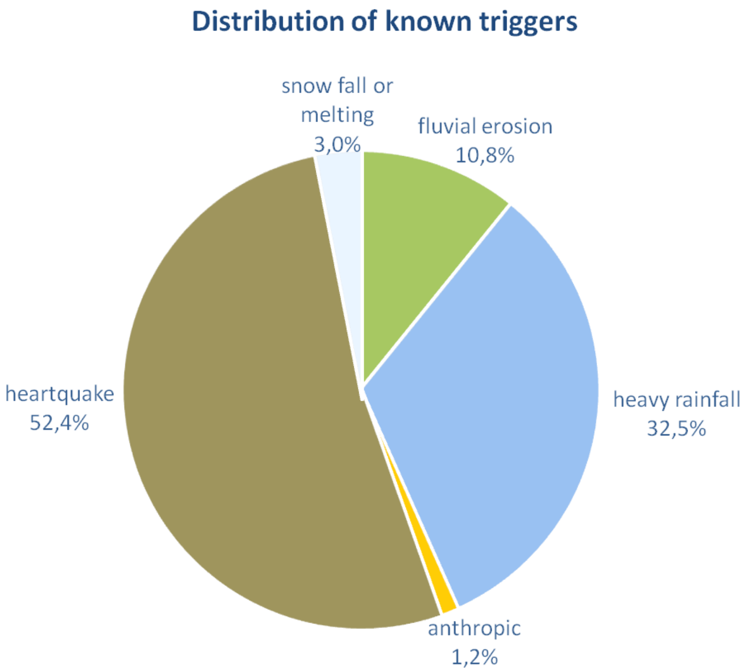

Figure 39 - Subdivision of the inventoried landslide dams, according to the known trigger.

It is important to go further into detail with these data and wonder about the spatial distribution in Italy of the trigger causes of landslides dams, because they reflect a different distribution of geological environments in Italy. If the national territory is divided from north to south in Alps, Northern Apennines and Southern Apennines, as shown in Figure 40-a), almost all of the dams caused by seismic events are placed in the Southern Apennines. In fact about 76% of 101 landslide dams surveyed in southern Italy with known trigger are caused by big high magnitude earthquakes (Figure 40-b)), especially between the seventeenth and twentieth century in Sicily and in Calabria, for the previously mentioned catastrophic seismic event of 1783.

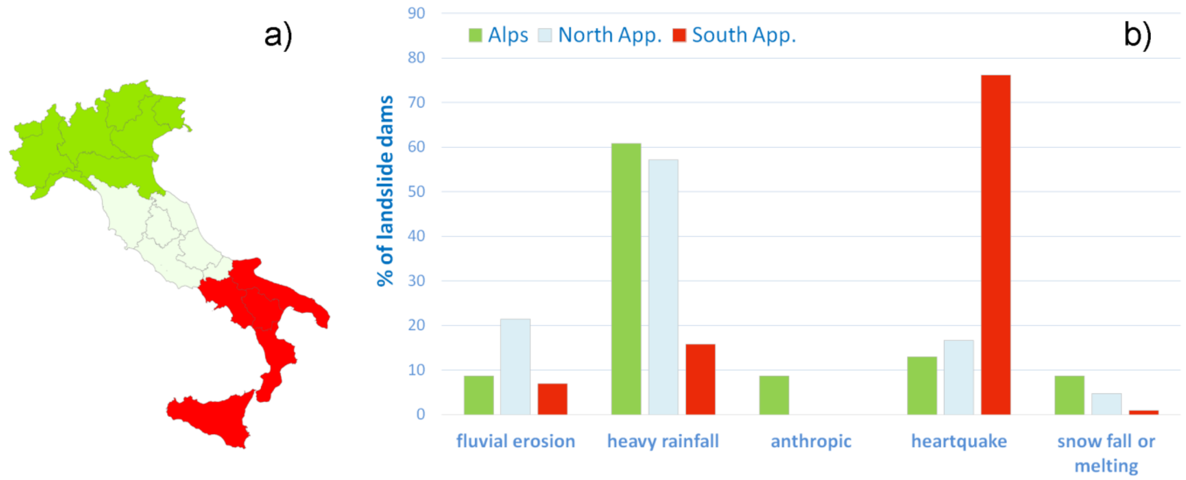

Figure 40 - a) Division of Italian territory in Alps, Northern Apennines and Southern Apennines regions; b) Distribution in the three Italian regions of the triggers of movements that formed a landslide dam.

The landslide dams caused by high magnitude earthquakes are among the most destructive, not only for the synergic contingency of the effects due to the earthquake, because can involve huge volumes of material. Among these, the best documented in the world are the earthquake caused by the famous event in 1906 in San Francisco, USA, with a magnitude of M = 8.2 (Keeper, 1984), the one in Wenchuan Region, China, in 2008 with a magnitude of M = 8.0 (Xu et al., 2009) which caused more than 1˙200 landslides and among these 257 generated the obstruction of a river, the one in Usoy, Tagikistan, in 1911 with a magnitude of M = 7.5 (Ambraseys & Bilham 2012) which generated the biggest natural dam in the world with 2.4×10^9 m^3 of rock, the one in Ancash Province, Perù, in 1970 with a magnitude of M = 7.9 which buried the town of Yungay with almost 20˙000 casualties (Keeper, 1984), and the event in the Madison Canyon, USA, in 1959 with a magnitude of M = 7.1 (Hadley, 1978).

In northern Apennine area and along the Alps instead more frequent trigger causes of landslide dams are the intense rainfall, with 61% and 57% respectively. This difference with the southern Apennines highlights once again how Italy is representative of a large diversity of climatic and geological environments. Alps are glaciated areas with very energetic elevation, with accentuated gradients. The Northern Apennines is characterized by highly variable morphology and over 3000 mm of annual rainfall (ISPRA, 2013), while Southern Apennines are areas with very less rainy climates and tectonically active, characterized by much higher seismic activity.

It is also important to go into detail of the single categories of causes triggering landslides to check if they carry some type of control on the final evolution of the phenomena. In Figure 41 are shown the evolution classes of the inventoried landslide dams according to the cause that triggered the landslide movements. The unstable dams are clearly prevailing between landslides caused by intense rainfall events and melting snows, reaching 56% and 60% of the singles categories respectively. Those caused by river erosion are equally distributed between not formed and formed-unstable, with 39% each and 22% formed-stable. In Italy the landslides caused by earthquakes usually do not produce dams (58% of cases) because in most of cases they involve small volumes of material. During earthquakes of higher magnitude the volume of triggered landslides is much greater and in this case 27% of dams formed are stable, compared to 15% of the unstable. This is the only one category where the number of stable dams is more than unstable dams.

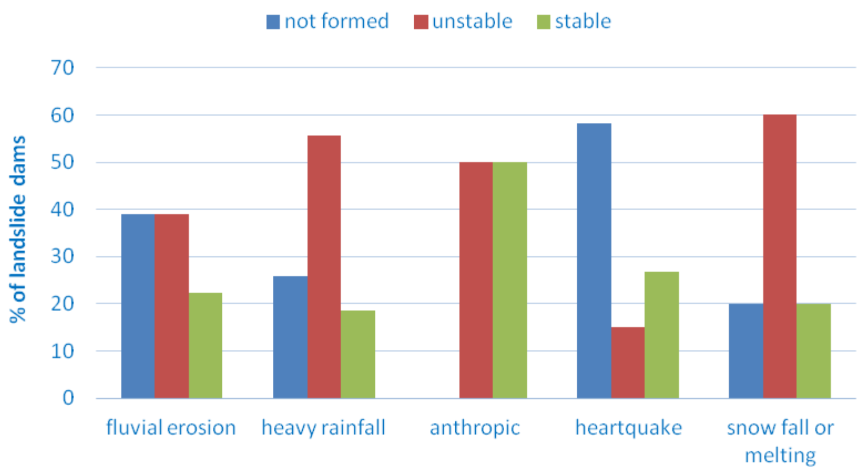

Figure 41 - Evolution of the inventoried landslide dams, according to the cause that triggered movement.

It is often stated that the dams occur almost exclusively in hilly or mountainous areas. This statement seems to be confirmed from the distribution analysis of the dams quotas in Figure 42. Indeed, more than 90% of all cases happened in Italy occurred at altitudes higher than 200 m above sea level.

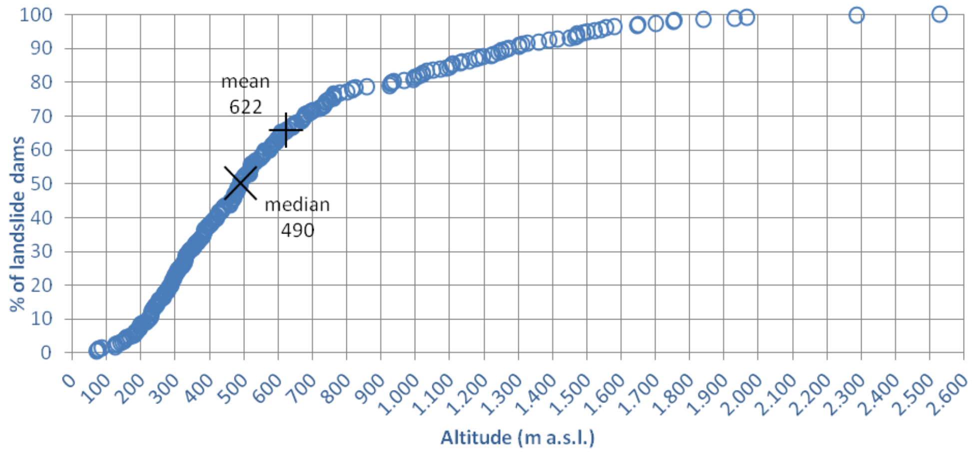

Figure 42 - Altitude distribution of the inventoried landslide dams.

4.2 GEOMORPHOLOGICAL INDEXES

A complete understanding of the damming phenomenon can not be detached from the systematic comparison between the parameters describing the dam, with those identifying the watercourse.

In this paragraph some relationships from the literature are reviewed in order to schematize, from the main geomorphologic point of view, the possibility of formation and evolution of landslide dam. In particular, a series of morphometric indexes are analyzed in attempt to describe, using data easy to retrieval, a physical phenomenon that, as pointed out on several occasions, is in itself very complex. Within these schematizations, the construction of an index is usually the consequence of a comparison between two chosen variables, one relative to the landslide and the other to the concerned watercourse. In this way the concept of the meeting between the world of the landslide and the dam, mentioned in Chapter 2, are described and ideally summarized.

The use of morphometric variables, in the description of a natural process, it is a quite common practice in the application of earth sciences, such as in all the branch of quantitative geomorphological analysis.

The chosen indexes analyze variables introduced in previous sections and a critical reading of their results allows to evaluate the representativeness of the considered variables. This process also allows to evaluate which parameters best represent the event, in addition to have a practical use for forecasting purpose.

4.2.1 BLOCKAGE INDEX

The possibility to form a dam and its general stability are the object of the "*Blockage Index*", BI, defined by Swanson et al. (1986) and Pirocchi (1991). According to the explanation given by these authors, they assume that the volume is the variable that best identifies the dam, while the hydrographic surface subtended by dam is the parameter that best describes and summarizes the characteristics of the watercourse and the basin affected by the occlusion.

The index proposed by Swanson et al. (1986) and Pirocchi (1991) relates the logarithm of the volumes of landslides in m^3, V_l, with the subtended hydrographic surface in km^2, A_b, as a function of the stability of the dam.

From his investigation, on a sample of 11 cases of landslide dam in Japan, Swanson (1986) has realized a bilogarithmic diagram and detected two distinct fields: one related to the unstable dams and the other to the stable ones. The same procedure was applied by Pirocchi (1991) for 93 dam cases in the Alps. The bilogarithmic diagram build on the base of these cases is divided in three fields by two straight lines which approximate the upper limit for the field of unstable dams and the lower limit for the stable dams. Between the two lines was introduced a field of uncertain determination.

Canuti et al. (1998), starting from the study realized by Swanson et al. (1986) and Pirocchi (1991), proposed an analysis that differs from the previous ones because it takes into account only the material that really contributes to the formation of the dam, V_d, while other schematizations considered the entire volume of the landslide, V_l. Thus the formulation of the Blockage Index proposed by Canuti et al. (1998) is expressed as follows:

$$BI = \log\left(\frac{V_d}{A_b}\right) \tag{3}$$

where V_d is the dam volume (m^3) and A_b the catchment area at the point of blockage (km^2).

Inside the uncertain determination area Canuti et al. (1998) introduced a further division (Figure 43): an unstable field, which is the range of the diagram where the cases of unstable dams are dominant, and uncertain evolution field, which is the range of the diagram where both stable and unstable dams are present.

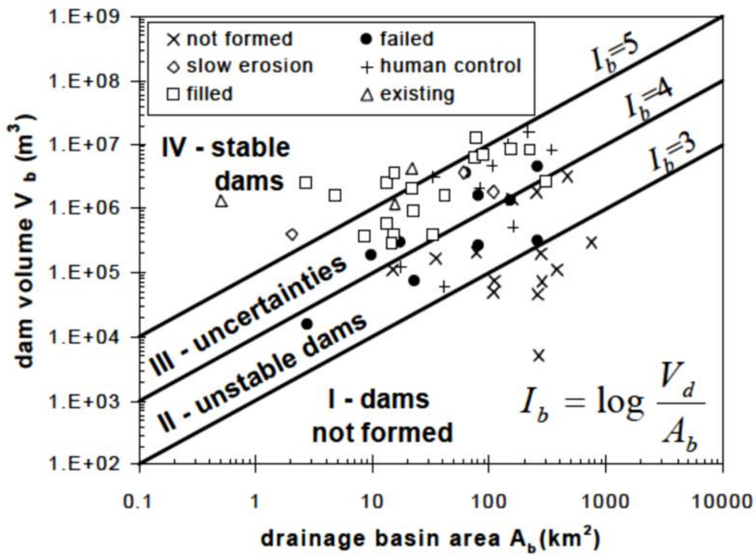

Figure 43 - Landslide dam volume versus drainage basin area distinguished by type of evolution in Northern Apennine (from Canuti et al., 1998).

The application of the Blockage Index as formulated by Canuti et al. (1998) can distinguish discreetly cases collected in this thesis and its results are shown in Figure 44. Three different domains of existence can be recognized as follows:

a) **Stability domain**: BI > 5,40. Here there are mainly dam cases classified as "filled" or "existing". In this field fall also one case of formed-unstable dam.
b) **Uncertain determination domain**: 3,00 < BI < 5,40. In this area there are stable, unstable and not formed dams.
c) **Not formed domain**: BI < 3,00. This is the sector of the diagram of not formed dams. In this field fall also two cases of formed-unstable dams.

The uncertain determination area wasn't subdivided in the uncertain evolution and the unstable fields because inside it the not formed landslide dams are distributed throughout the field, preventing a clear separation.

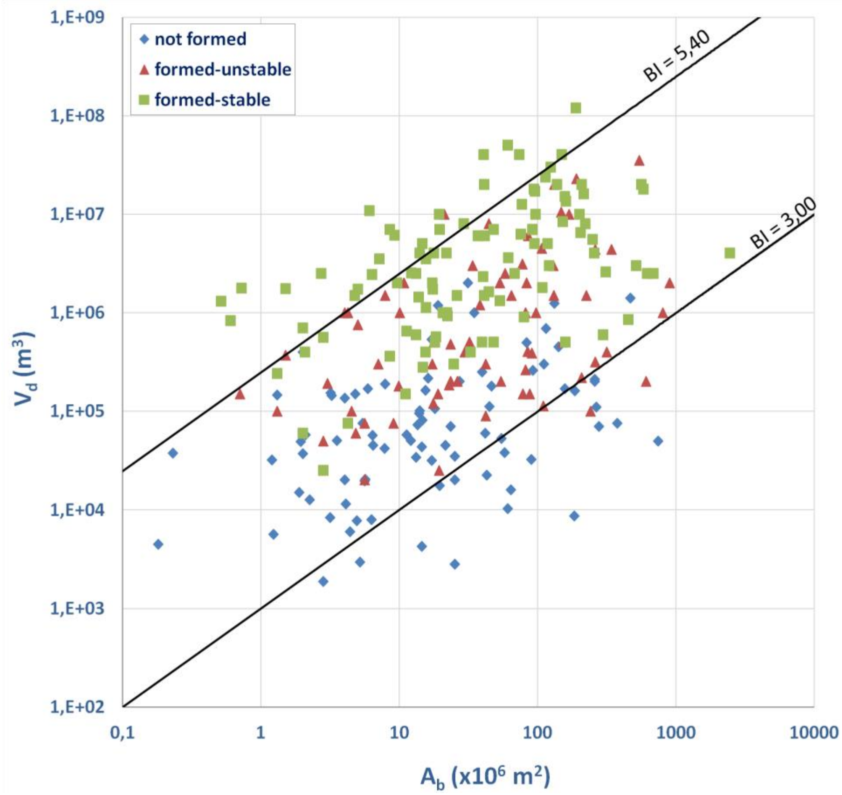

Figure 44 - Ratio between landslide dam volume and drainage basin area (Blockage Index, according to Canuti et al. (1998)) for the inventoried landslide dams, distinguished by type of evolution.

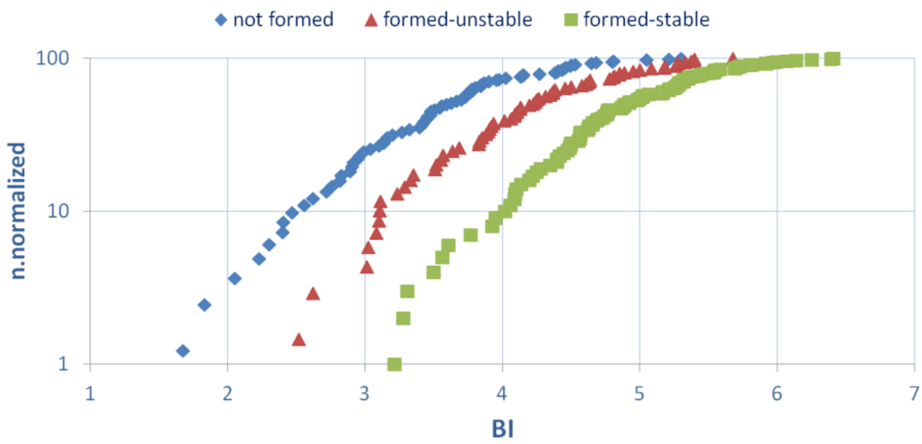

Figure 45 - Blockage Index values distribution of the inventoried landslide dams according to the three evolution classes.

The diagram in Figure 45 reports the distribution of the collected cases. It can be used for forecasting porpoise both to define the possibility of dam formation by a ongoing landslide and to determine the stability of an already formed landslide dam. To define the possibility of formation of a dam with a forecasting use, it is necessary the prior formulation of a reasonable volume of the landslide.

Instead, the analysis of a dam stability already formed on a river with known volume is more immediate. In these cases it is sufficient, in fact, to perform the comparison between the two parameters, which define the index, without initial assumptions.

The reliability of the diagram is greater in its marginal areas, while in the central part, in which fall most cases, there is a strong uncertainty. In general, with the increase of the value of the index, the dam will evolve toward a state of greater stability. Thus, landslides with larger volumes or with smaller watershed result more easily in to conditions of stability.

4.2.2 ANNUAL CONSTRICTION RATIO

According to a study proposed by Swanson et al. (1986), when a landslide reaches the end of the slope, the blockage possibility depends on the speed of the movement compared with the width of the valley. In this study, taking into account some sliding landslides in Japan, is proposed the ”*Annual Constriction Ratio*”, ACR, defined by the ratio between the two factors that have the greater control on the process of dam formation, the landslide velocity and the width of the dammed valley.

As explained in Chapter 3, in most of the events it was not possible to directly measure the landslide velocity. It was, however, made a fairly accurate estimation of the landslide movement speed using the scale proposed by Cruden & Varnes (1996), like the seismic intensity scale of Mercalli, based on the observation of the reported landslide affects.

The ACR proposed by Swanson et al. (1986) was reversed from its initial formulation in order to have a result which has the unit of time as dimensions. This formulation is better suited to describe a quantity that expresses the duration of a process. The index equation can be expressed as follows:

$$ACR = \log\left(\frac{W_v}{v}\right) \tag{4}$$

where W_v is the width of the dammed valley (m) and v the landslide velocity (m/s).

In a diagram, made by an index with a such formulation, the formed-unstable and formed-stable dams can not be distinguished, but actually are overlapping.

The diagram in Figure 46 shows the trend of the ACR Index, expressed by the logarithm of the ratio between the width of the dammed valley, W_v, and the landslide velocity, v, for 117 of the censed cases.

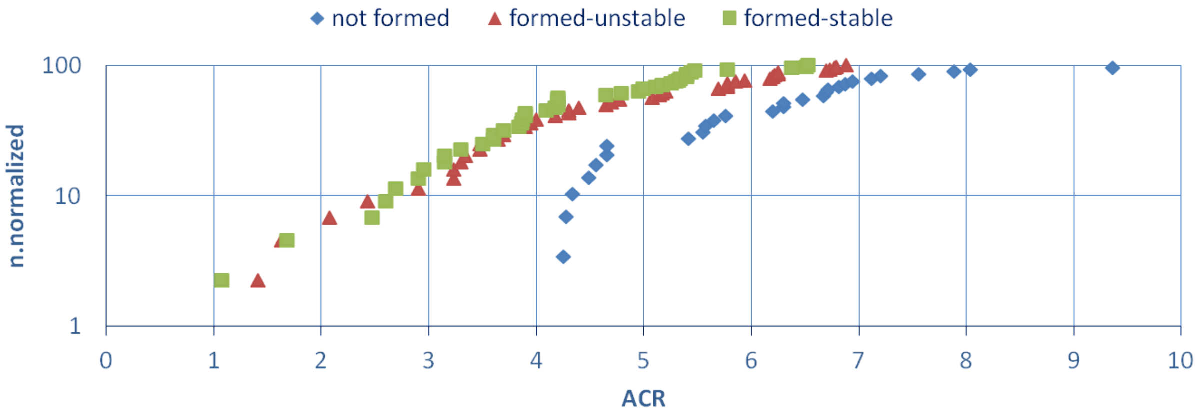

Figure 46 - Annual Constriction Ratio (Swanson et al., 1986) values distribution of the inventoried landslide dams according to the three evolution classes.

The trend of the data on the diagram show that with the increase of the value of the index the possibility of a moving landslide to blocks a stream decreases, while increase the number of not formed dams. It is not easy to establish some threshold values in the diagram which can be useful for forecasting purposes. In the figures three main domains can be separated as follows:

a) **Formation domain**: ACR < 4,26.
b) **Uncertain domain**: ACR > 4,26 > 6,88.
c) **Non-formation domain**: ACR > 6,88.

Unfortunately only a small part of the cases have value of ACR < 4,26, the lower limit of not formed dams, and ACR > 6,88, upper limit of formed cases (unstable and stable). In a big area in the middle of the graphic there is a overlapping zone where lie a large part of the not formed, formed-unstable and formed-stable cases.
Without other indications, however, it is possible to apply this graphical method to have a fast estimation, which has most reliability in the extreme areas.

4.2.3 DIMENSIONLESS BLOCKAGE INDEX

Through the systematic comparison between the variables that identify the river with those the dam, Ermini & Casagli (2003) tried to describe the phenomenon of damming through the formulation of a dimensionless index.

Developed processings involves a work of merging of variables in order to hold in a single expression many contributions coming from each factors who rule the evolution of a damming process.

The attempt is to propose a different dimensionless formulation of the Blockage Index, BI. The new formulation is named "*Dimensionless Blockage Index*", DBI:

$$DBI = \log\left(\frac{A_b \cdot H_d}{V_d}\right) \tag{5}$$

where H_d represents the dam height (m), V_d the landslide dam volume (m^3) and A_b the catchment area (km^2).

As previously stated, the volume is the parameter that best identifies the dam and with the increasing of the volume usually increase also the global stability. However, from a physical point of view, dam height is an important variable to assess the stability of a landslide dam against both overtopping and piping failure mechanisms. Indeed, if the increase of the volume involves only an blockage height increase, it should not be interpreted as an improvement in stability. At the contrary, in the overtopping mechanisms it influences the steepness of the dam vestments and consequently the velocity of the overtopping waters and the erosivity, while in the piping mechanisms, it controls the position of the water table through the dam and in particular its hydraulic gradient (Ermini & Casagli, 2003).

This index does not consider not-formed or partial dams, because the height of a partially damming case is subjective and could mislead. So its use is mainly aimed to the prediction of a formed dam stability.

The results of the application of the Dimensionless Blockage Index to 173 of the inventoried landslide dams have been represented in the diagrams of Figure 47 and Figure 48. In the figures three main domains can be separated as follows:

a) **Stability domain**: DBI < 2,43.

b) **Uncertain domain**: 2,43 < DBI < 3,98.

c) **Instability domain**: DBI > 3,98.

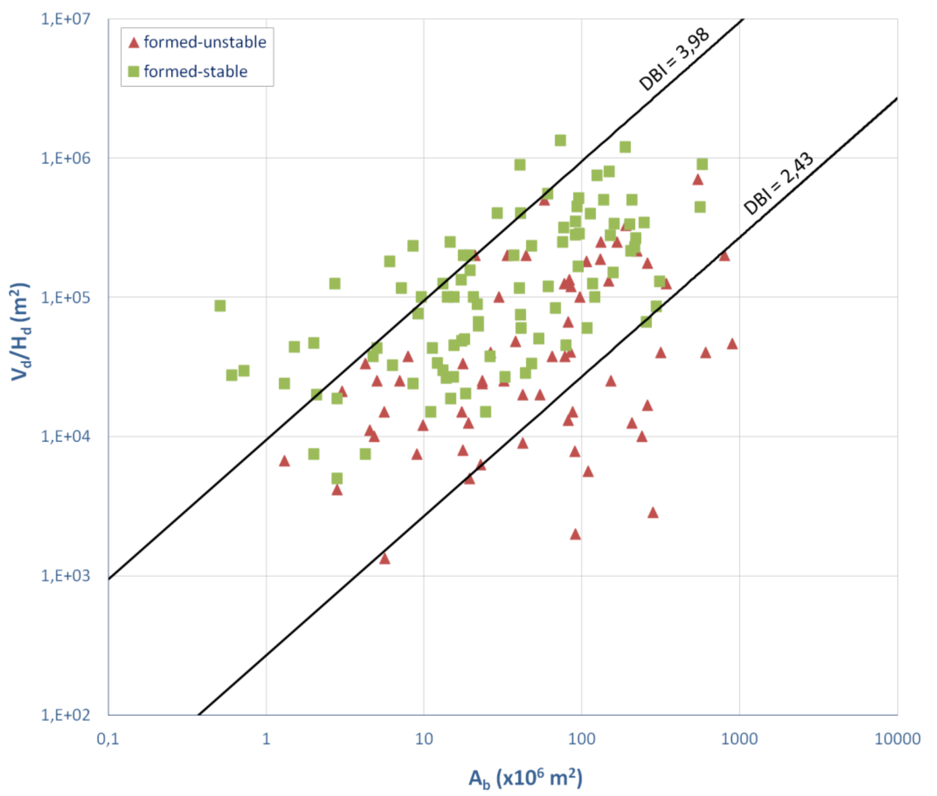

Figure 47 - Landslide dam volume and dam height plotted versus drainage basin area (Dimensionless Blockage Index, according to Ermini & Casagli (2003)) for the inventoried landslide dams, distinguished by type of evolution.

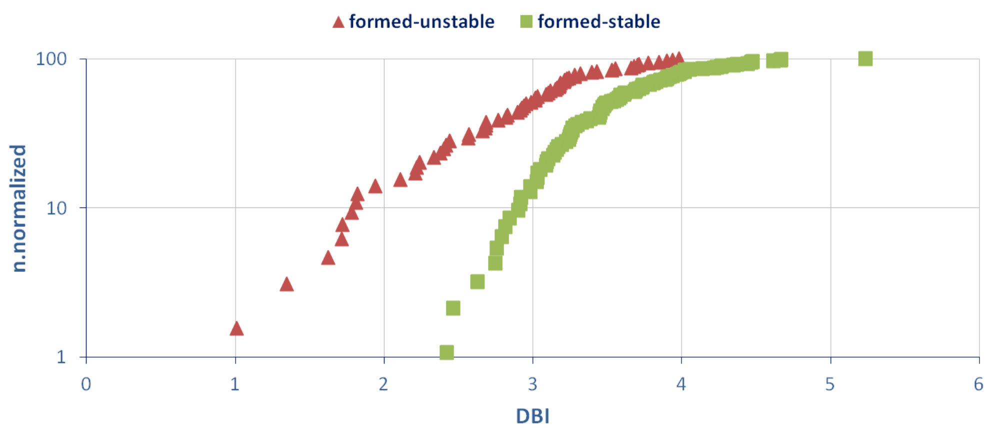

Figure 48 - Dimensionless Blockage Index values distribution of the inventoried landslide dams according to the three evolution classes.

The uncertain domain is wider compared to the one proposed by Ermini & Casagli (2003), as shown in Figure 49. In fact the two limits that identify the different domains for the latter authors were DBI = 2,75 for the stability domain and DBI = 3,08 for the instability domain. The higher variability of data in landslide dams inventoried for this thesis, due to the higher number of cases compared to the study of Ermini & Casagli (2003), may explain these differences. In the formulation of their Dimensionless Blockage Index, in fact, Ermini & Casagli (2003) take into account 84 landslide dams, even if worldwide. The graphs are more reliable in their marginal areas, because even in this case the central area of "uncertain definition" is very broad and includes most of the reported cases. Despite this, the index can be as useful tool for carrying out preliminary forecasting on landslide dams stability.

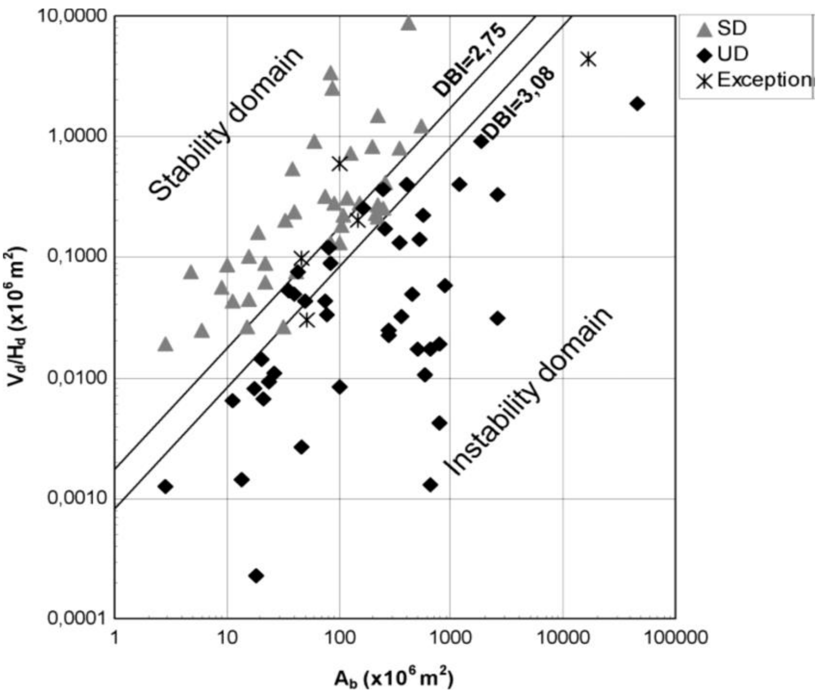

Figure 49 - Results of the dimensionless blockage index for 84 events inventoried worldwide by Ermini & Casagli (2003).

4.3 NEW GEOMORPHOLOGICAL INDEXES AND DATA PROCESSING

In previous paragraph some important morphological indexes, among the most important ones in the description and understanding of a process of damming, were introduced and studied. The analysis of these studies allowed to investigate and learn about the evolution of damming event and the parameters that better influence the phenomenon.

Starting from the considerations and the results of the empirical analysis on the inventoried dams, is possible to asses that the evolution of damming phenomenon is framed as a process with scale invariance. Dams can form starting from the smallest forms of channeled runoff, up to the bigger rivers that cross the world. In the archive presented in this thesis there are dams with volumes ranging from a few thousand cubic meters up to the hundreds of millions of cubic meters and rivers with catchment areas of variable extension, from a few to thousands of square kilometers. Also the other variables, which describe both stream and dam, are characterized by a comparable wide variability. Whatever the investigated scalar context, the final evolution of a damming process is always and only the result of the comparison between all the factors connected to the dam-landslide, with those relating to the watercourse.

Once the investigated natural phenomenon is known and the factors that physically determine its development are identified, it is possible to find relationships that can describe the possible formation of a dam and forecast its evolution.

It is not easy to define the absolute importance of individual factors. Almost all identified cases have some unique features, hard to compare with others.

In this paragraph some attempts to describe the damming phenomenon are proposed, with the formulation of new geomorphological indexes. Once again, the indexes were realized through the systematic comparison between the parameters describing the river and the landslide.

In the expression of the indexes at the numerator there are variables related to the barrier and at the denominator those who idealize the stream. In this way the two factor of the expression are kept separate in order to graphically underline the influence of each on the final results.

It is not always useful to merge together too many variables related to landslide or to the river. Often, even if it is known that they are important as individual factors, their actual relative weight and their mutual influence it is not really known. It was therefore avoided to combine too many parameters (Dal Sasso et al., 2014) to formulate new simple morphometric indexes that were effective in describing the phenomenon. These indexes are designed to meet a basic principle, an easy and fast data collection, which is considered as being crucial during emergencies.

4.3.1 MORPHOLOGICAL OBSTRUCTION INDEX

It was previously stated that the more important parameter related to the landslide, from which depends the possibility that the dam is formed, is the volume of the landslide material. The histogram of Figure 50 shows the volume distribution of the recorded landslide dams according to their evolution. In this simple diagram is immediately obvious the landslides trend to instability or non-formation with small volumes, while for large volumes the persistence of the dam prevails.

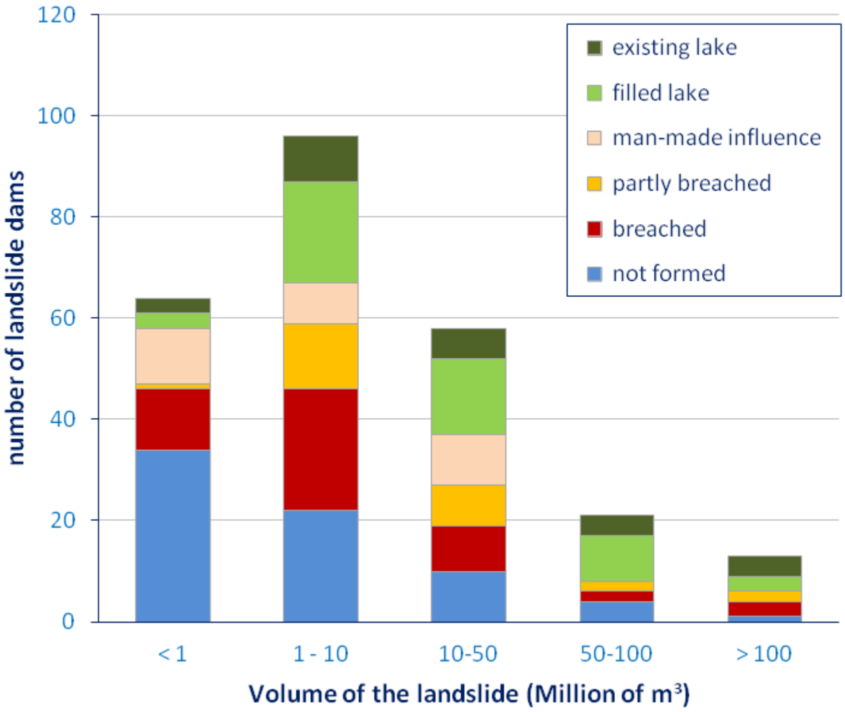

Figure 50 - Distribution of landslide dams volume according to the evolution classes.

One of the most important factor relating to the river, to determine if a landslide does or does not occlude a valley and form a natural dam, also in relation to the volume of the landslide, is the width of the valley affected by the phenomenon (Swanson et al., 1986). It is also evident intuitively that a narrow valley with steep slopes needs a landslide with relatively small volume to operate the complete blockage of the stream. Moreover, as shown in Figure 50, assuming the same width of the valley, the larger the volume of the material collapsed and the greater the stability of the dam formed.

Starting from these considerations and in an attempt to improve previously analyzed studies, an analysis of these two important parameters was carried out, taking into account the whole inventoried Italian database.

From geomorphic analysis, encouraging results were reached through the definition of the "*Morphological Obstruction Index*", MOI:

$$MOI = log\left(\frac{V_l}{W_v}\right) \tag{6}$$

where V_l represent the landslide volume (m^3) and W_v the width of the dammed valley (m).

The results of this investigation have been represented in the distribution diagram of Figure 51, that can be utilized for forecasting purpose. The collected cases are divided in three different domains of existence, that can be recognized as follows:

a) **Non-formation domain**: MOI < 3,00. The landslide it is not able to block the valley and it evolves in a not formed dam.
b) **Uncertain determination domain**: 4,60 < MOI < 3,00. In this area the evolution of the dam is uncertain because, even if it is formed, it can evolve in the sense of instability and collapse. For values between 3,00 < MOI < 3,83 if the dam is formed it will be unstable. For values 3,83 < MOI < 4,60 the formed dam can be also stable, but still persists the possibility of not formed and formed-unstable dam.
c) **Formation domain**: MOI > 4,60. The valley is certainly blocked. Even if the density, and so the probability, of formed-stable dams is higher, however the dam can still evolve in situations of instability.

In the diagram the uncertain determination domain is in the shady red area, bounded by two dashed lines, a red one and a blue one.

The red dashed line is named "***Non-formation straight line***" and is the lower limit for the formed dams.

The blue one is named "***Formation Straight line***" and is the upper limit for the not formed dams.

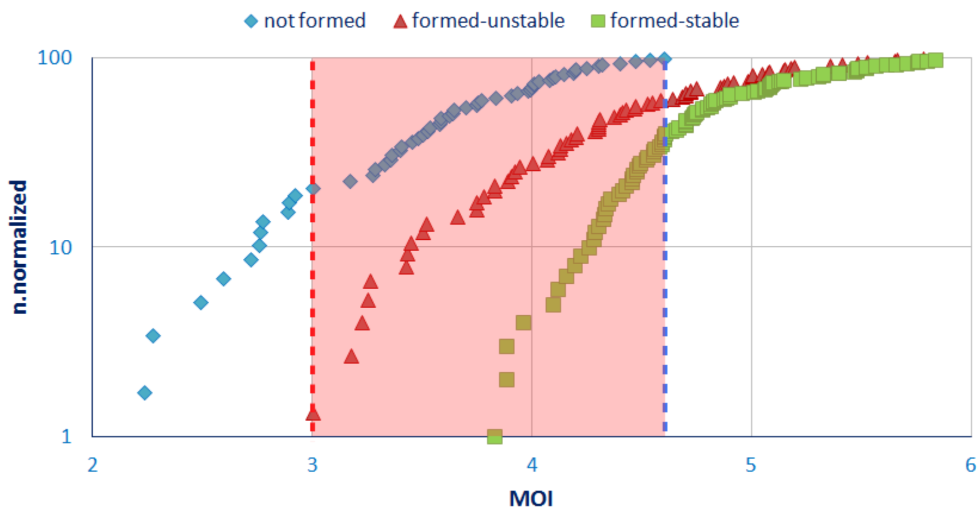

Figure 51 - Morphological Obstruction Index values distribution of the inventoried landslide dams according to the three evolution classes.

The same result is shown in the bilogarithmic diagram of Figure 52, where landslide volume, V_l, and width of the dammed valley, W_v, are plotted. In the diagram formed dams were not distinct between stable and unstable to better show the three previously described domains of dams formation and the two lines that divide them.

The red dashed **Non-formation Straight Line** divide the Non-formation and Uncertain evolution domains and below the there are no formed dams. Its equation can be expressed as follows:

$$y = 2.4 \cdot x^{2.3} \tag{7}$$

where *y* represent the landslide volume (V_l) and *x* the width of the dammed valley (W_v). This volume value is the minimum landslide volume of formation for a dam, less than a landslide certainly does not produces complete river blockages and is named the ***Non-formation volume***, ***V_l'***.

The blue **Formation Straight Line** detach the Uncertain evolution and the Formation domains. Over this line there are only formed dams and it is expressed as follows:

$$y = 3162 \cdot x^{1.5} \tag{8}$$

Where the y value represent the landslide volume (V_l) and is the boundary landslide volume above which the river valley is certainly dammed. This volume value is named the ***Formation volume***, ***V_l''***. The x is the width of the dammed valley (W_v).

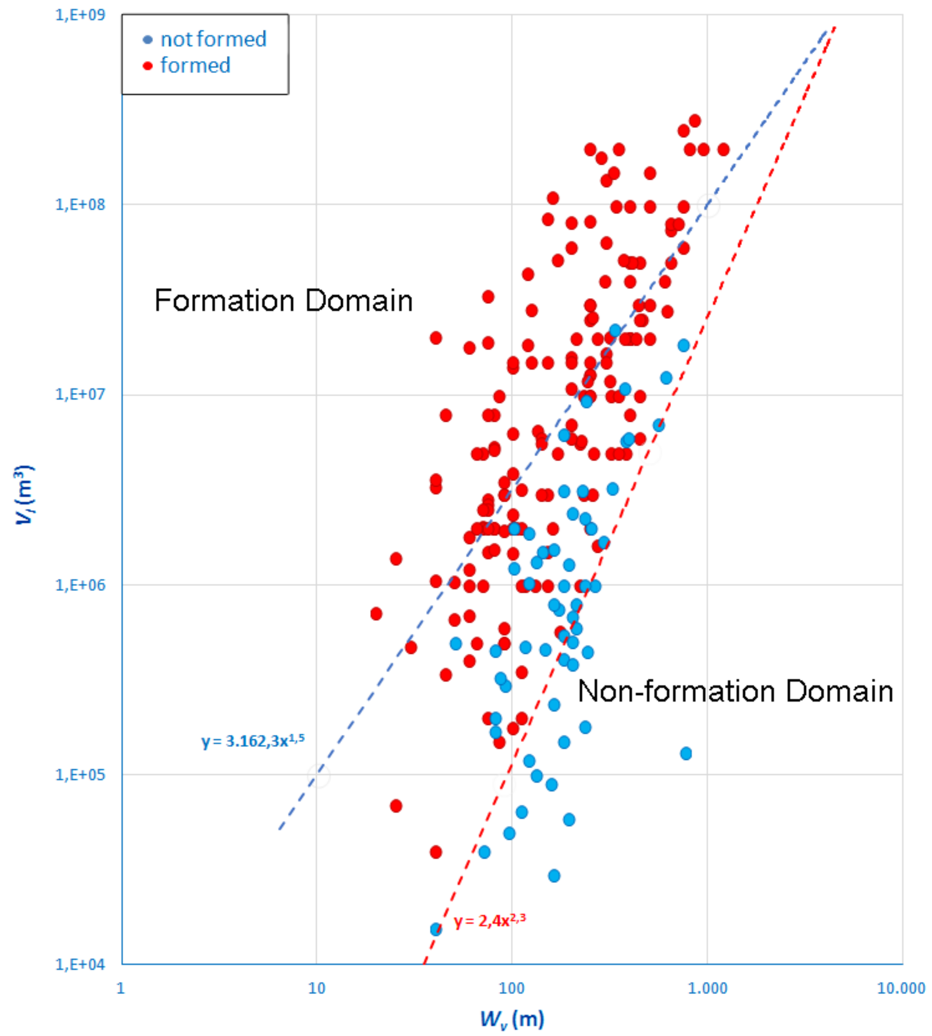

Figure 52 - Ratio between landslide dam volume and width of the dammed valley for the inventoried landslide dams, distinguished in formed and not formed.

To be sure about the significance of the information obtained from the ratio between the volume of the landslide, V_l, and the width of the valley, W_v, the data relating to the three main evolution classes shown in Figure 51 were undergo to a simple but effective test of statistical significance, the *t-test*.

The t-test takes into account two populations of data at a time from a zero starting hypothesis that the distribution of data within the two groups is equal to each other and the observed difference can be attributed to chance.

The t-test can be expressed as follow:

$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \tag{9}$$

where:

$\bar{X}_1$ = Mean of first set of values;

$\bar{X}_2$ = Mean of second set of values;

S_1 = Standard deviation of first set of values;

S_2 = Standard deviation of second set of values;

n_1 = Total number of values in first set;

n_2 = Total number of values in second set.

The upper part of the ratio is simply the difference of the two averages, while the lower part measures the variability or dispersion of the data.

The *T* value obtained have be compared in a table of significance of *T*, imposing a risk level (called *alpha*) commonly equal to 0.05. Being a statistical test, the result will be the probability *P(t)* that 95% of the data verify the hypothesis. Thus, the lower the *P(t)* value, the greater is the statistical difference between the two populations. Conventionally two populations are considered statistically distinct if the *P(t)* value is less than 0.1 for an *alpha* equal to 0.05.

The Table 3 show the results of the t-test for the ratio of landslide volume and the width of the valley carried out between the three classes of dam evolution. These low values confirm that the three groups of data are statistically distinct and their distribution has no difference attributed to chance.

T-test result (MOI) Alpha = 0.05		
Not formed - Unstable	Not formed - Stable	Unstable - Stable
t = -4.2477 P(t) = 2.0331 E-05	t = -5.5336 P(t) = 6.5369 E-08	t = -2.4559 P(t) = 7.5224 E-03

Table 3 - T-test result of the Morphological Obstruction Index between the three classes of dam evolution.

The formulation of the Morphological Obstruction Index allows to perform a reliable analysis and provides a good estimator to forecast the formation of a natural dam by a landslide.

In the diagram of Figure 52 one case is characterized by an evolution that apparently disagrees with the domain where it is placed. This "exception" is the Grappallo landslide (ID 2), Piacenza (Northern Italy), that during 1888 has not formed a complete blockage even if it is placed in the Formation domain. In this case local factors, an extremely wide and flat valley (more than 300 m broad) and the lithology (mainly sands and clays), prevail in determining its evolution.

Despite this, the index was able to predict the behavior of 218 landslide dams and it should therefore be interpreted as a tool for carrying out preliminary forecasting on formation of landslide dams.

4.3.2 Hydromorphological Dam Stability Index

In order to define the landslide obstruction possibility of a valley and its stability, another morphometric index able to quantify the result of the potential erosive energy of the stream and the resistance offered by the landslide has been drawn up.

The river dynamics as a modeling agent of the landscape is a process that moves forward by leaps, according to flood peaks of the river. As for other parameters, it was not possible to obtain the values of discharge for each single stretch of river affected by obstruction because the extent of the whole Italian surface. In addition, the real discharge value is not an easy and fast information to be obtained. According to some authors (Bagnold, 1966; Baker & Costa, 1987; Dalla Fontana, 2005) the "stream power" can be used to describe the flood ability to modify the landscape with greater efficiency than the single value of stream discharge. The stream power value should be considered as a basic indicator of the energy of the stream, easy to use and obtain in the absence of precise data (Petit et al., 2005).

The stream power (Ω), which represents the work that a river may do, is expressed by Watt/m and presented as follows:

$$\Omega = \rho \cdot g \cdot Q \cdot S \tag{10}$$

with ρ the fluid density (in kg/m^3), *g* the acceleration due to gravity (in m/s^2), *Q* the discharge (in m^3/s), *S* the local longitudinal slope of the stream (m/m, which may be approximated by the slope of the channel bed). The stream power can be differently formulated on topographic base assuming the area of the upstream dam basin as representative of the discharge of the stream (Stock & Montgomery, 1999; Cavalli & Grisotto, 2005; Petit et al., 2005) in the following simple form:

$$\Omega = \mathrm{A_b} \cdot \mathrm{S} \tag{11}$$

where A_b is the drainage basin area.

This expression can be used to describe the river potential energy and compared with the most significant parameter of the landslide in order to obtain the "*Hydromorphological Dam Stability Index*", HDSI, expressed as follows:

$$HDSI = \log\left(\frac{V_l}{A_b \cdot S}\right) \tag{12}$$

where V_l is the landslide volume (m^3), A_b the catchment area at the point of blockage (km^2) and *S* the local longitudinal slope of the channel bed.

The distribution diagram in Figure 53 shows the result of the application of the Hydromorphological Dam Stability Index to the collected landslide dams.

Following this characterization three main domains can be highlighted as follows:

a) **Instability domain**: HDSI < 5,51. The landslide it is not able to form a stable dam. Even if it blocks the valley, the dam is unstable;

b) **Uncertain Determination domain**: 5,51 < HDSI < 7,67. In this area the evolution of the dam is uncertain. Even if the blockage is complete, it can be unstable and collapse;

c) **Stability domain**: HDSI > 7,67. The valley is certainly blocked and the dam is stable.

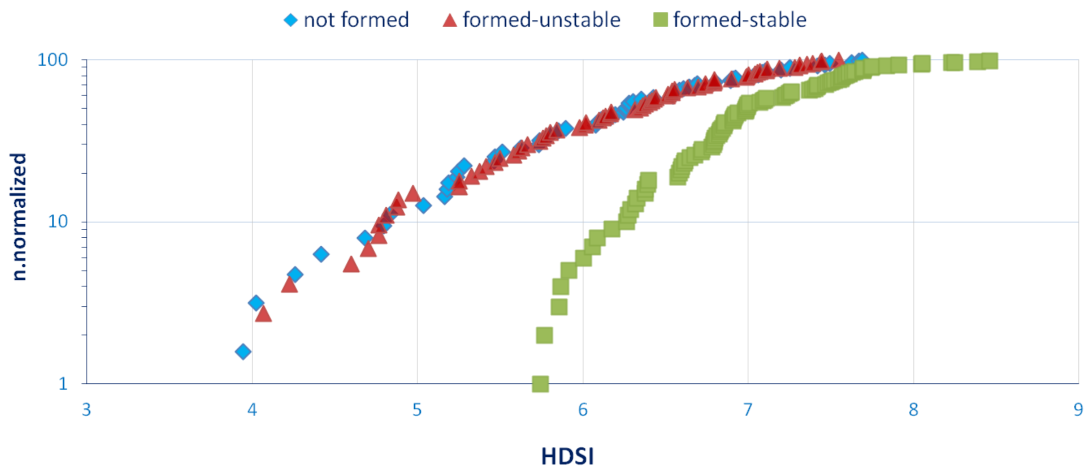

Figure 53 - Hydromorphological Dam Stability Index values distribution of the inventoried landslide dams according to the three evolution classes.

In the diagram it is not possible to clearly distinguish not formed and formed-unstable dams, so it can not be effectively used in this sense as an instrument to predict whether or not the complete occlusion of a stream.

It is possible instead to well distinguish the formed-stable dams from other and so use the diagram as a tool to forecast the stability of the dams.

Also the t-test results, shown in Table 4, confirm the graphically observations. The data sets concerning not formed dams and formed-unstable are statistically too similar (*P(t)* > 0.1), whereas the formed-stable dams the results stated that that these are clearly different from the other two data sets.

T-test result (HDSI) Alpha = 0.05		
Not formed - Unstable	Not formed - Stable	Unstable - Stable
t = 0.5535 P(t) = 0.2903	t = -4.304 P(t) = 1.4327 E-05	t = -2.4559 P(t) = 1.1120 E-06

Table 4 - T-test result of the Hydromorphological Dam Stability Index between the three classes of dam evolution.

Even if the Uncertain determination domain is rather extended and the Stability domain is quite narrow, as the index value increase also the general stability of the dam increase. The assessment of the formation probability of a stable dam can be also derived through a graphical comparison method, comparing the relative frequencies of the three evolution classes. The Index formulation itself does not allow a direct assignment of an occurrence probability value of a single scenario, however, it is possible, through the knowledge of the values assumed by the index in the past cases (shown in Figure 54 in a clearer way), to quantitatively assess the formation probability of a stable dam *P(FS)*.

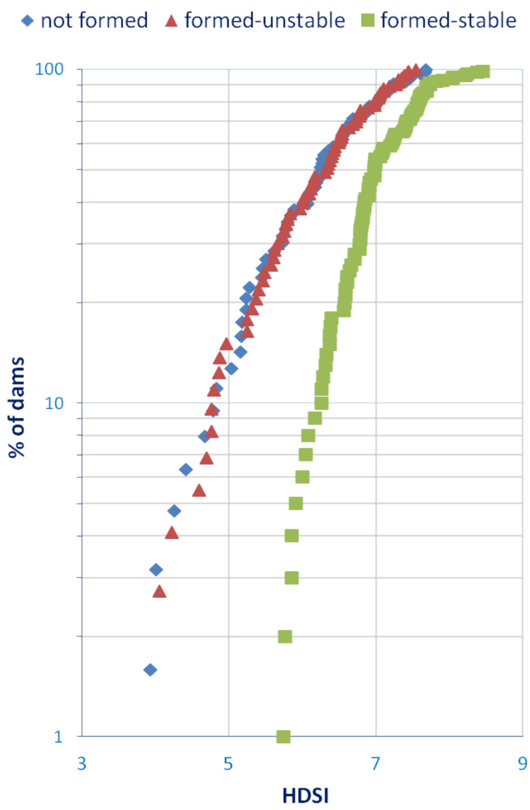

Figure 54 - Percentage distribution of Hydromorphological Dam Stability Index values in the three evolution classes of the censed landslide dams.

Therefore, if the Hydromorphological Dam Stability Index value is assessed, the probability of formation of a stable dam can be expressed as follows:

$$P(FS) = \frac{(100 - FS_y)}{(100 - FS_y) + (100 - FU_y) + (100 - NF_y)} \quad (13)$$

with FS_y, FU_y and NF_y are the ordinate values of Formed-Stable, Formed-Unstable and Not Formed dams for the corresponding HDSI value (Figure 54).

Thus if, for instance, a landslide blocking a river valley results with an HDSI = 7, the formation probability of a stable dam will be:

$$P(FS) = \frac{(100 - 50)}{(100 - 50) + (100 - 80) + (100 - 80)} = 0{,}55 = 55\% \qquad (14)$$

so, in this example, the chance to obtain a stable dam is about 55%.
In conclusion the Hydromorphological Dam Stability Index can be considered a easy and fast tool to carry out preliminary assessment on the stability of landslide dams.

4.4 NEW INDEXES VALIDATION WITH PERUVIAN CASES

In Paragraph 3.3 the studies carried out along the Cordillera Blanca mountain range in Ancash Province, Peru, was mentioned. The morphometric analysis performed on Italian landslide dams was repeated with the Peruvian collected cases. In order to better evaluate the quality of the suggested morphometric indexes and discuss their effectiveness in different geographical areas, particular attention will be paid to the differences between the results about the application of the same analysis conducted on the Italian territory.
About the Peruvian landslide dams, it was possible to collect information and data almost only for cases which were stable for a considerable period of time in order to leave clear and tangible tracks on the terrain morphology. Therefore, processing carried out were performed using only Peruvians cases belonging to the evolution class of formed-stable dams. These represent almost all of the inventoried cases, except for the Jrcacocha lake, whose catastrophic empting caused the destruction of the Yungay town (see Paragraph 3.3).
In Figure 55-a) the result of the geomorphological classification proposed by Swanson et al. (1986) and modified by Costa & Schuster (1988) of inventoried landslide dams is shown. The type II is the most common dam type in this part of the Andes, as in the rest of the world (Costa & Schuster, 1988) and in the Italian database collected for this thesis. According to the frequency it is followed by type III and IV, and there is also one single type V case. There are no cases of type VI and also no cases of type I, because the lack of morphological evidence and documented information.
A classification of the landslides based on the six kinds of landslide movement, proposed by Cruden & Varnes (1996), that originated the dams is reported in the histogram of Figure 55-b). The most common landslides are classified as complex. The term “complex” is referred to the style of a landslide characterized by two or more main movements combined in time or in

space and usually are the result of a first movement consisting of a fall of rock and/or debris, that evolve in a second movement classified as flow of debris and/or rock. Very common throughout the Peruvian territory are also individual fall and flow movement. The first kind of movement is related to the morphology of the very steep slopes of the Andean mountains and their granitoid geology, while the latest is closely connected with the drainage channels of the glacial suspended valleys. The channels download in the main downstream valleys a large amounts of moraine material and tumbled coarser boulders from surrounding peaks, accumulating huge volumes in large debris cones.

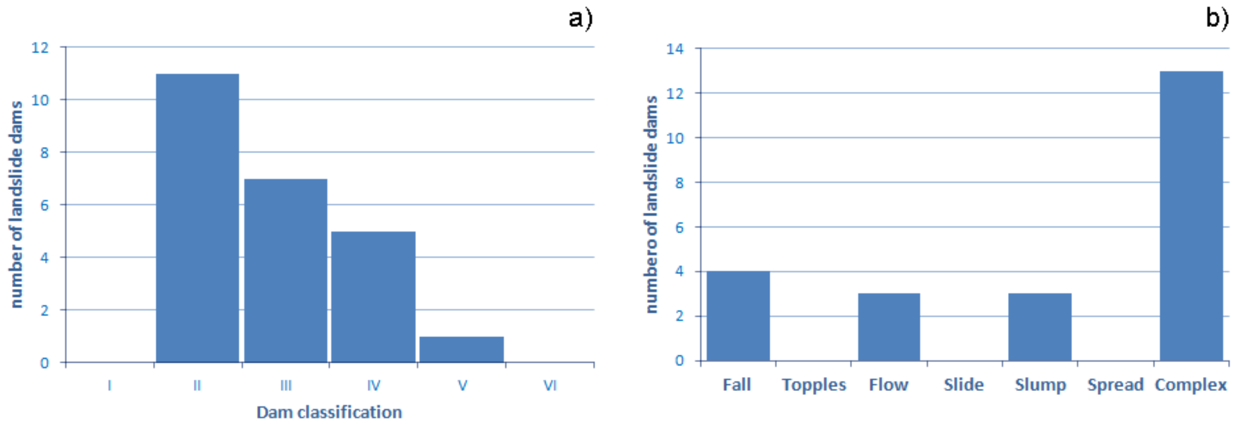

Figure 55 - Classification of landslide dams of Cordillera Blanca, Peru, a) landslide dams types, according to Costa & Schuster (1988) and b) the triggers of landslide movement, according to Cruden & Varnes (1996).

The Figure 56 shows the resulting diagram of the Morphological Obstruction Index, MOI, application on Peruvian landslide dams. The behavior of the cases collected along the Cordillera Blanca shown in the figure is very close to the trend followed by those studied in Italy. The lower value of the Peruvian stable cases, in fact, is with MOI > 3,79, slightly lower than the value of MOI > 3,83 obtained from the Italian cases analysis.

The differences in the trend of the data, compared to the behavior of the Italian dams, has no real importance and is likely due to climatic-geography differences and local morphology-geology of the Peruvian mountains, more locally uniform compared to the Italian variability.

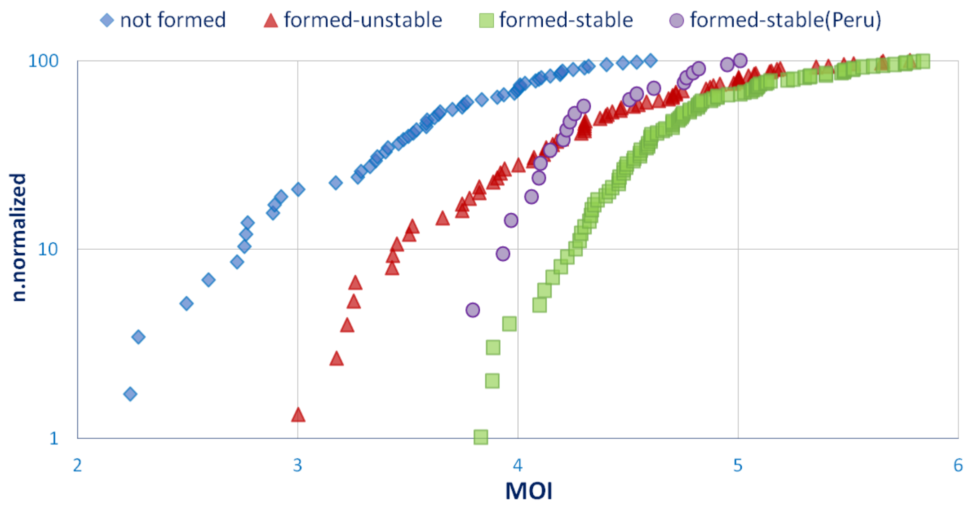

Figure 56 - Morphological Obstruction Index (MOI) values distribution of the inventoried formed-stable Peruvian landslide dams compared with the Italian cases.

Figure 57 shows the same South Americans dams in the bilogarithmic diagram with the volume of landslides, V_l, as ordinates and the width of the valley, W_v, as abscissa. Even here is possible to see how all the reported cases are correctly above the Non-formation red straight line, identified with the Italian cases in Paragraph 4.3.1, and 32% of them are in the Formation domain bounded by the blue Formation Straight Line.

So high similarity between the two groups of data related to dams coming from so different geographical contexts is an encouraging result. Bodes well on the quality of the information obtained from this morphometric index on the formation of stable dams and also on the realistic possibility to apply it to other environments or different geographical areas. It should therefore be interpreted as a tool for carrying out preliminary forecasting on formation of landslide dams for planning purpose along river routes.

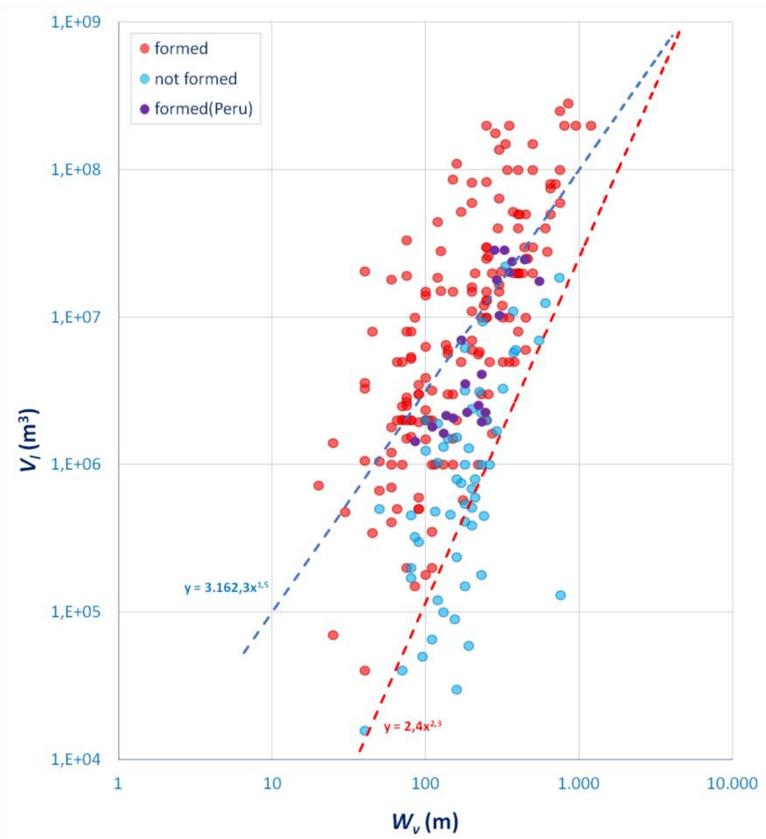

Figure 57 - Ratio between landslide dam volume and width of the dammed valley for Peruvian landslide dams, distinguished in formed and not formed, compared with the Italian cases.

The results obtained by the application of the Hydromorphological Dam Stability Index, HDSI, to the Cordillera Blanca dams shown almost the same behavior as proved in Figure 58. From the diagram, the lower bound to have a stable dam in Peru is with HDSI > 3,54, a very similar value to that obtained with the Italian cases, equal to HDSI > 3.56.

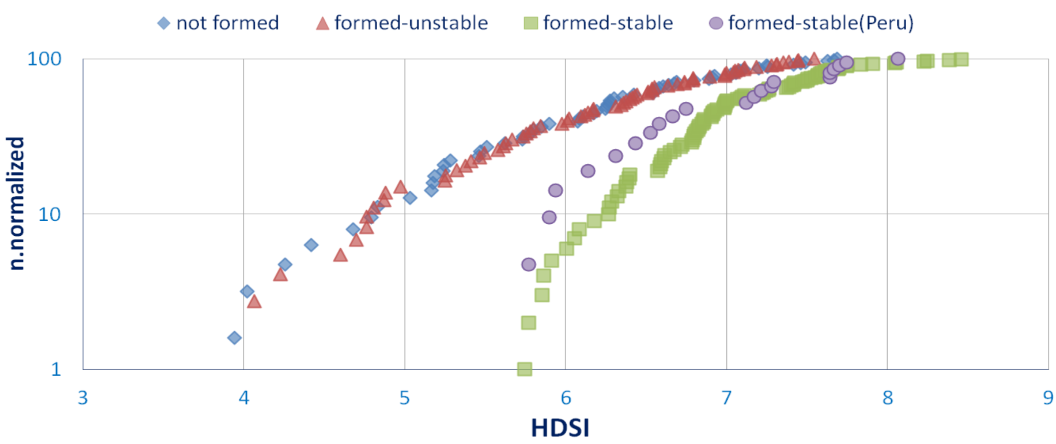

Figure 58 - Hydromorphological Dam Stability Index (HDSI) values distribution of the inventoried formed-stable Peruvian landslide dams compared with the Italian cases.

Also in this case, the small differences between the processing results obtained from the two groups of data can be attributed to the local homogeneity of the environment in Peru against a greater difference in Italy.
On the Cordillera Blanca mountain range there are, indeed, glacial valleys characterized by a recent retreat of glaciers (Lliboutry et al. 1977; Vilìmek et al., 2005) and very steep slopes, with peaks that reach more than 6˙000 meters of altitude. Instead in Italy there are different types of environments and orogenic belts presents a wide variability in both the geology in the morphology of the landforms.
The good results with the Hydromorphological Dam Stability Index lead to suggest also the use of the proposed graphical method as a useful broad assessment tool of landslide dam evolution.

5 DAMMING SUSCEPTIBILITY MAPPING

The collapse of river blockage is the cause of major catastrophic flood events ever recorded. These phenomena can have such proportions to leave indelible traces in the landscape and in the memory of men. In 1841 a huge landslide (Mason, 1929; Hewitt, 2009) broke away from the slopes of Mount Nanga Parbat (in the current Pakistan) and, after about 6˙000 meters of altitude, it had crashed in the Indus valley, causing the formation of a dam over 300 meters high. An entire Sikh army placed in Attock town, 400 km downstream, was swept away in June of the same year by an unexpected flood wave 30m high, caused by the breach of the dam.

Such cases of this magnitude can hardly be countered. Fortunately the events occurring in the world every year or multi-year are generally much smaller. In many cases also the damages could be prevented or produce lower consequences if prevention measures were realized in identified areas with higher risk.

According to Sharpe (1938) and De Graff (1978), in the assessment of single landslide risk, defined as the probability that a potentially destructive phenomenon of certain intensity to occur in a given period of time and in a given area (Varnes & IAEG, 1984), is paramount to identify "structural or predisposing" and "occasional or determinants" causes.

Structural or predisposing causes are represented by geological, structural-geological, geomorphological and hydrogeological factors. The structural causes are "quasi-static" variables, that is affected by very small temporal variations, and affect mainly on the landslides spatial distribution and susceptibility to slopes instability (Wu & Sidle, 1995).

Occasional or determinants causes, instead, result in the alteration of the natural balance at a certain “t” time, as a result of a combination of several environmental components, adverse to the stability. These could be seismic, or volcanic, or climatic events or man-made interference. The variables which express them are called "dynamic", as subject to even fast change in terms of time and space, and control the triggering of landslides in slopes characterized by susceptibility to instability (Wu & Sidle, 1995).

The preparatory factors analysis, therefore, allows the spatial prediction about risk or "susceptibility", while the triggering factors analysis about the prediction time.

In Chapter 4 the results of calculations, about already known indexes in the literature and of new formulation, are presented, performed on the inventoried landslide dams. From time to time, particular attention was payed to emphasize the reliability of these schematizations from the point of view of their forecast application purposes related to the formation or the stability of a dam.

The simplified flow diagram in Figure 59 shows briefly the main evolutionary lines that may be generated in consequence of a dam phenomenon. The different moments are organized according to three different Stages:

Stage1: the activation of a landslide movement threatens to block a watercourse (a);

Stage2: the moving landslide can form (b) a partial damming (not formed dam) or (c) a complete damming;

Stage3: the complete damming can be (d) stable or (e) unstable.

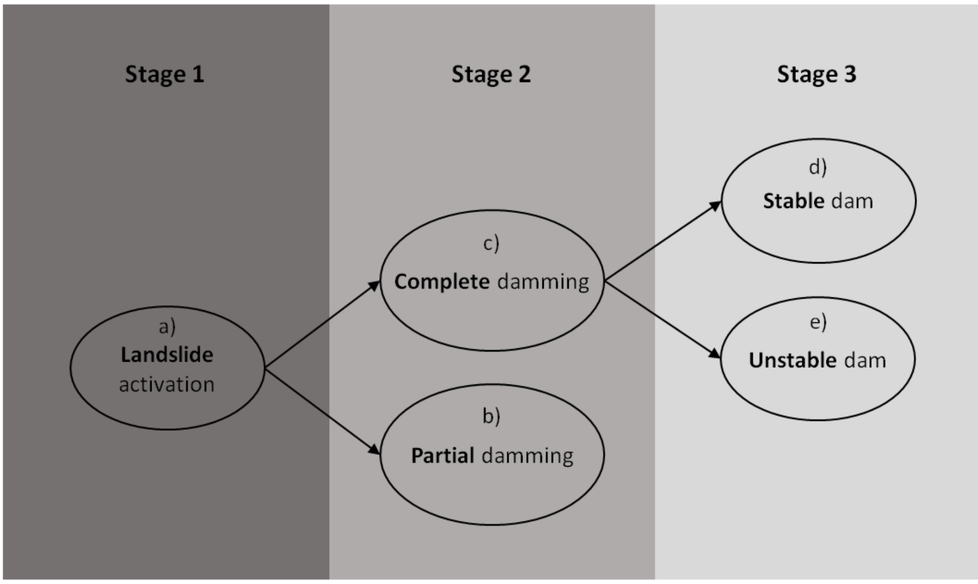

Figure 59 - Schematization of possible steps of a dam evolution.

In the academic world many studies have been aimed at establishing the landslide susceptibility of an area (Wu & Sidle, 1995; Aleotti & Chowdhury, 1999; Ayalew & Yamagishi, 2005), Stage 1 of Figure 59. Also many are the attempts to evaluate the stability of a dam already formed (Ermini & Casagli, 2003; Dong et al., 2009; Dal Sasso et al., 2014), Stage 3, and also this thesis tried to add a contribution with the proposed Hydromorphological Dam Stability Index. Different popularity in the literature have had instead the attempt to predict how much a stretch of river, potentially subject to landslide, may be at damming risk, Stage 2.

The formation of a natural dam by a landslide, as emphasized several times, depends on two contributions, one related to the landslide and one to the river. The proposed morphometric indexes allow to simplify these contributions into simple factors of a ratio.

Aim of this chapter is to show how the application of the Morphological Obstruction Index allow to develop of a simple and effective methodology, completely developed with the aid of a GIS software (Geographic Information System), that can be used as a forecasting and planning tool. This methodology is able to assess, quickly and with few data, the damming predisposition, connected to existing landslides, and the probability of obstruction by new landslides along a river network. This results in a mapping at basin scale (about 1:500.000) about the spatial distribution of predisposition and probability, or susceptibility, to obstruction along the river courses, which can also be extended to mapping even in smaller scale (regional or national).

The application of this method is shown on a test area. The selected area is represented by the Arno River basin. The choice of this study area was driven mainly by practical reasons, related to geographical and morphological characteristics of the basin. The Arno River is the major peninsular river after Tiber River, and anyway one of the largest in Italy, and its considerable surface and the different gradients makes it an ideal test area. Other reason with not negligible weight was, as further shown, the data availability for this area.

5.1 STUDY AREA: THE ARNO RIVER BASIN

The Arno River basin (Figure 60), placed in Central Italy, affects territory of the Tuscany Region (98.4%) and the Region of Umbria (1.6%) with the Provinces of Arezzo, Firenze, Pistoia, Prato, Pisa and partially Siena, Lucca, Livorno and Perugia. The number of municipalities that fall within the administrative limits of the basin is 166. The Arno river basin has an area of 9˙116 km^2 as the fifth largest basin after Italian river Po, Tiber, Adige and Tanaro.

Regarding the altitudes of the basin, 55,3% is lower than 300 meters a.s.l., 30,4% at altitudes between 300 and 600 meters a.s.l., 9,8% at altitudes between 600 and 900 meters a.s.l. and 4,5% higher than 900 meters a.s.l.. The higher elevations are found in the mountainous group of the Falterona and the Pratomagno respectively with the peaks of Monte Falco (1˙657 meters a.s.l.) and the Poggio di Sasso (1˙537 meters a.s.l.).

The whole basin is usually divided in six sub-basins: the Casentino, the Val di Chiana, the Upper Valdarno, the Sieve, the Middle Valdarno, the Lower Valdarno. Casentino, which has an area of 895 km^2, is made by the high Arno basin from its origins to the confluence with the Chiana river. It is bordered by the foothills of the Apennines and the Pratomagno and there are many tributaries, all with torrential behavior, such as the Solano and the Capraia in the right, the Archiano, the Corsalone and the Chiassa in the left.

The Val di Chiana, with an area of 1˙362 km^2, includes a wide area almost completely flat; in ancient times it was a marshy area, but in recent times has been drained and divided between the basins of the Arno and the Tiber.

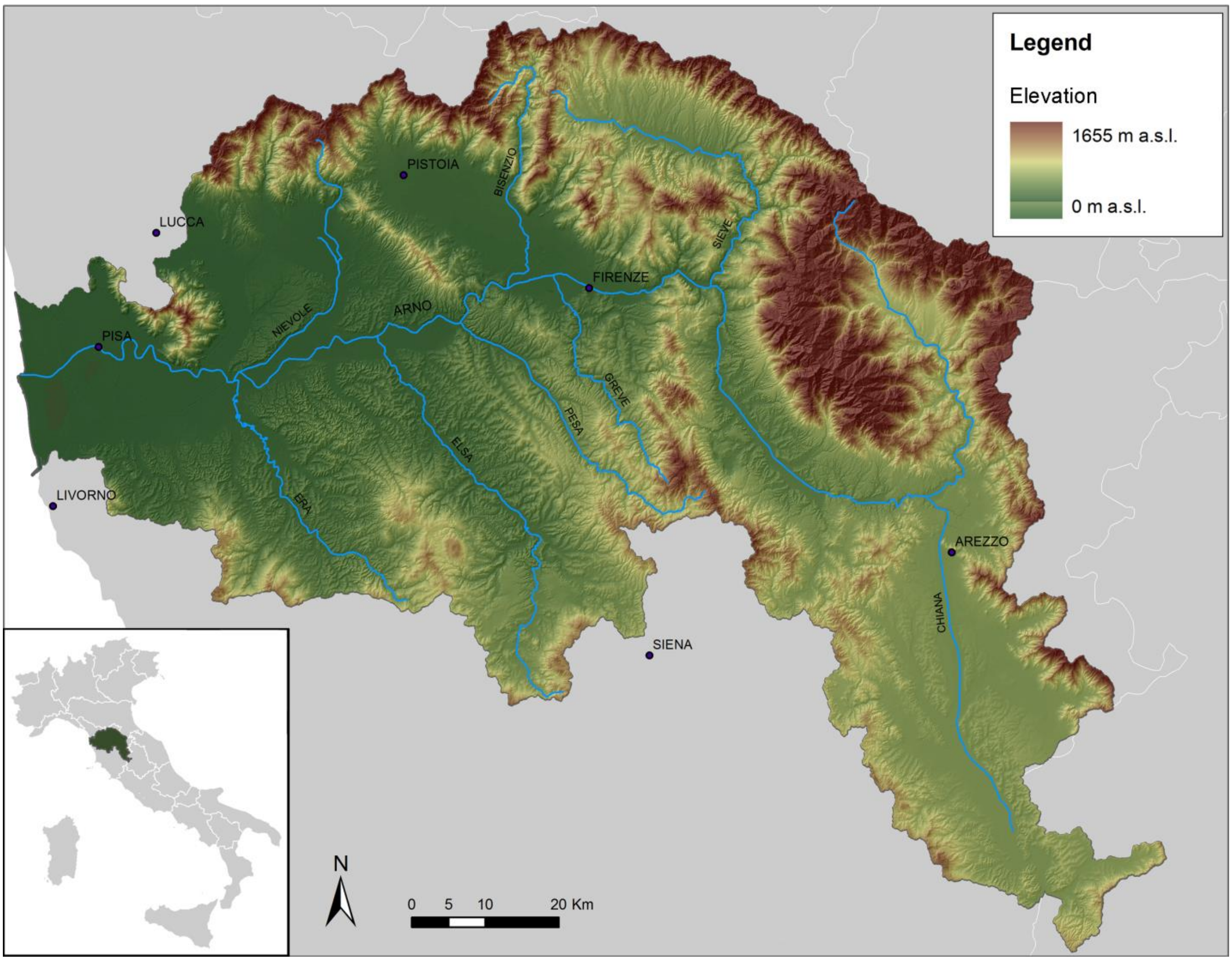

Figure 60 - Location, elevations, main cities and main river network of the Arno River basin.

The Upper Valdarno (997 km2) is formed by a long plain, closed on right by the Pratomagno and on left by small mountains of Siena Province, from which originates the Ambra stream, only one tributary of relevance in the whole sub-basin.

The sub-basin of Sieve, as the Casentino, is a basin between the Apennines and the foothills of the Mugello. Many tributaries flow into the Sieve and it merge with the Arno just upstream of Firenze, delimiting downstream the Upper Valdarno, as well as the Chiana delimits upstream.

The Middle Valdarno (1˙375 km^2) originates downstream of Pontassieve and includes sub-basins of the Bisenzio and the Ombrone on the right and Greve-Ema on the left.

The Lower Valdarno (3˙641 km^2) is characterized by a wide reclaimed plain, with sub-basins Valdinievole and Padule di Fucecchio, in the right and by long valleys flowing with major tributaries such as the Pesa, the Elsa and the Era in the left.

In the distal part next to the sea the floodplain is smoothly joined with a wide coastal plain. Flat surfaces of different extension are found extensively on morphological high, in addition to large areas of flood and coastal plains. It is possible to find large summit fitting areas or real highlands. The areas with steep slopes are extended, in particular, in correspondence of scarps or steep embankments tied to particular situations geomorphological (for example the Monti Pisani and the travertine plateaus of the Upper Val d'Elsa). Anyway, the hilly areas predominate in percentage within the basin (Regione Toscana & Arpat, 2001; Autorità di Bacino del Fiume Arno 2002).

5.1.1 GEOLOGICAL OVERVIEW OF THE BASIN

The Arno River basin is placed in the Northern Apennines chain. The latter is a fold and thrust belt system made up by the juxtaposition of several tectonic units (Boccaletti et al., 1980; Boccaletti & Sani, 1998), because the oceanic Ligurian units were placed over the Tuscan and Umbrian foreland units in a thrust system shifted toward E-NE. The orogenic phase was characterized by a compressive regime until the Middle-Upper Miocene, while the compressional front has migrated progressively towards NE from the Tortonian.

Since Upper Tortonian, the internal side of the northern Apennines was characterized by tectonic regime change from compression to extension that has broken the Apennines chain in a system of structural highs (horst) and tectonic pits (graben), stretched with alignment NW-SE. The latter phase resulted in the emplacement of Neogene sedimentary basins, mainly of marine (to the West) and fluvio-lacustrine (to the East) origin (Martini & Vai, 2001). While the former experienced several episodes of marine regression and transgression during the Miocene and Pliocene, the latter were characterized by a fluvio-lacustrine depositional environment during the Upper Pliocene and Pleistocene and gave rise to the present typical Tuscan smooth landscape (Martini & Sagri, 1993).

The current morphology is laid down by the presence of NW-SE trending ridges, where Mesozoic and Tertiary flysch and calcareous units outcrop, separated by Pliocene-Quaternary basins. The drainage of the Arno River is strongly conditioned by this structures and results in a prevalence of NW-SE trending streams (Figure 61).

Four main ridges can be distinguished (Canuti et al., 1994):

1. **Mt. Pisano - Montagnola Senese**, made up of clastic and carbonate rocks from the Tuscan units of Mesozoic and Paleozoic age;
2. **Mt. Albano - Chianti**, prevalently composed by flysch units of the Tuscan Series emplaced during the Tertiary and the Mesozoic;
3. **Calvana - Mt. Morello - Pratomagno**, made up of calcareous and arenaceous flysch of respectively the Ligurian and the Tuscan Series;
4. **Mt. Falterona - Mandrioli - Alpe di Catenaia**, constituted by arenaceous and marly flysch formations of the Ligurian Series.

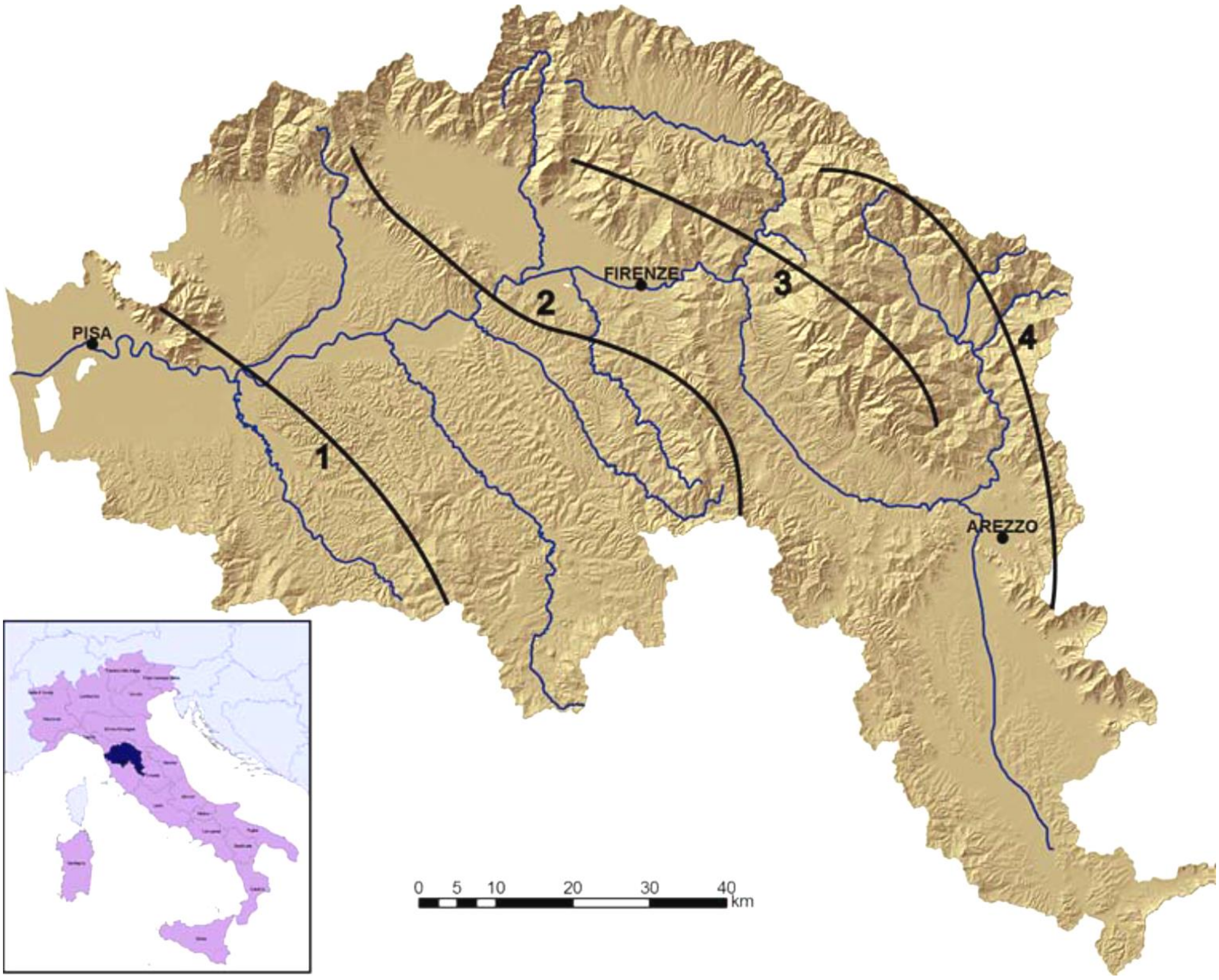

Figure 61 - Location, relief and main drainage of the Arno river basin (from Catani et al, 2005). Major mountain ridges are depicted with black lines: (1) Mt. Pisano-Montagnola Senese; (2) Mt. Albano-Chianti; (3) Calvana-Mt. Morello, Pratomagno; (4) Mt. Falterona-Mandrioli-Alpe di Catenaia.

The Arno River basin consists mainly by flysch and rocks with prevailing pelitic component along the reliefs, and cohesive and granular soils in the hilly basins. Igneous, metamorphic and calcareous rocks outcrop in limited areas of the basin.

These geological settings clearly affect the typology and occurrence of surface processes, primarily through the differences in the mechanical properties linked to the various prevalent lithology of the bedrock and the coverages.

In the Arno River basin can be distinguished six main lithotechnical classes (Canuti et al., 1994) based on the mechanical properties of soils and rocks in the basin, as follows:

1. Cohesive soils;
2. Granular soils;
3. Hard rock;

4. Weak rocks;
5. Hard rocks with pelitic layers;
6. Complex mainly pelitic layers.

5.2 MATERIALS

The proposed methodology has been developed entirely with GIS software (Geografic Infomation System) and each input data was added as a single layer. Two of the best and most popular GIS software were employed, ArcMap (ESRI) and the open source SAGA GIS (System for Automated Geoscientific Analyses).

The Arno River basin was selected as the test area for the presented method because, in addition to its size and favorable morphological characteristics, a set of core data were available for this area.

The different data exploited as a basis in this work are (Figure 62):

1. An updated landslide database;
2. A river network;
3. A Digital Terrain Model;
4. A map of local alpha distribution (Catani et al, in review).

In 2012 the Department of Earth Science of Florence realized a new regional landslide database with the DIANA Project (Interferometric Data for Environmental Analysis: landslides and subsidence) thanks to the partnership of the Tuscany regional authority. The new database was created starting from a previous version, performing an updating and an integration of ground displacement measurements provided by ERS (1992-2000) and ENVISAT (2002-2010) PSI satellite data. About 30˙000 of the 91˙730 landslide polygons in the new database, belong to the basin and have been selected as an updated archive of landslides. Most of the mass movements (about 98%) are connected to rotational or translational slides.

Two other data sets for the Arno River basin were also used: a vector layer of about 74˙000 polylines for the real river network and a DTM (Digital Terrain Model) with 10 meters of resolution. A reconstructed river network, using hydrological models from a DTM, was discarded in order to assess the risk of the real hydrology system. In different points the rivers have suffered anthropogenic changes, requiring to channels very different paths from the directions of the natural hydraulic flow which would be achieved with automated processing.

At last, for the final result of the method, a map of local alpha distribution (Catani et al, in review) has been used, as shown below.

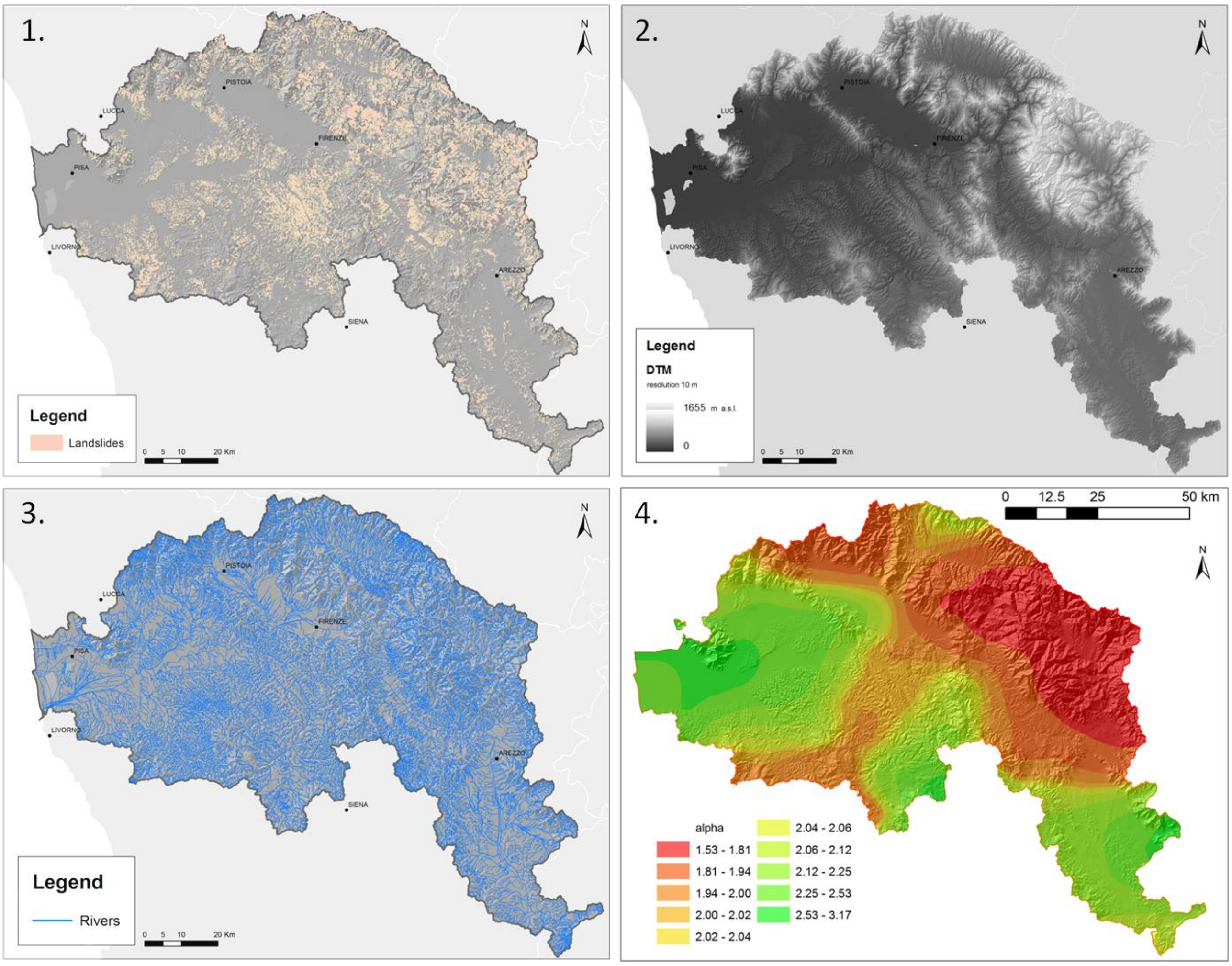

Figure 62 - Data set used in the method. 1.: Landslide database; 2.: DTM (10 m resolution); 3.: Real river network; 4.: Alpha value distribution (from Catani et al., in review).

5.3 MAPPING METHODOLOGY

From the observation of the results obtained and its formulation, the Morphological Obstruction Index, MOI, has allowed to identify in the ratio between the volume of the landslide, V_l, and the valley width, W_v, threshold values of non-formation and formation of landslide dams.

The valley width can be seen as a static variable in the index equation. This morphometric parameter indeed does not change substantially over decades within the landscape. In order to use the Morphological Obstruction Index for forecasting purposes to assess the natural dam formation probability, a minimum volume of a landslide able to block a river has to be stated. This volume has to satisfy the equation of the "Non-formation Straight line" and the "Formation Straight line".

Therefore, a method showing how to automatically measure the valley width, W_v, for each river stretch potentially affected by a landslide dam, is proposed, even before the landslide triggers the movement.

With this information, using the "Non-formation Straight line" (Equation (7)) and "Formation Straight line" (Equation (8)) equations, from the MOI formulation (Paragraph 4.3.1), two boundary values, V_l' and V_l'' are thus obtained. The former (V_l') is the Non-formation volume and is the minimum volume of formation, less than a landslide definitely does not produces complete river obstruction, and the latter (V_l'') is the Formation volume that is the boundary volume above which the river valley is certainly dammed.

Landslides dam, but in general all current landslides, are often reactivations of ancient movements started in the past, as pointed out in Chapter 2. Thanks an updated database of documented mass movements, it is possible, through a number of assumptions and simplifications, to estimate landslides volumes. Landslides potentially more prone to block river stretches are detected comparing their values with the values V_l' and V_l'' identified along each stretch of the river network. Therefore, a "**Map of the Damming Predisposition**" for existing landslides is achieved.

To complete the work, the evaluation of the probability of new landslides, having greater volume than the boundary values, V_l' and V_l'', is suggested.

The magnitude and the volume of new mass movements is difficult to compute. In such cases, as proposed by Catani et al (in review), it is possible to use the statistical properties of landslides volumes distribution in a given area to understand and predict the probability of magnitude for new landslides. In this paper, in particular, the Authors study the spatial properties of volume frequency distributions in the Arno River basin and show how the landslide volumes are distributed according to a power-law scaling, for values greater than a cutoff value of about 10^4 m^3, as shown in Figure 63.

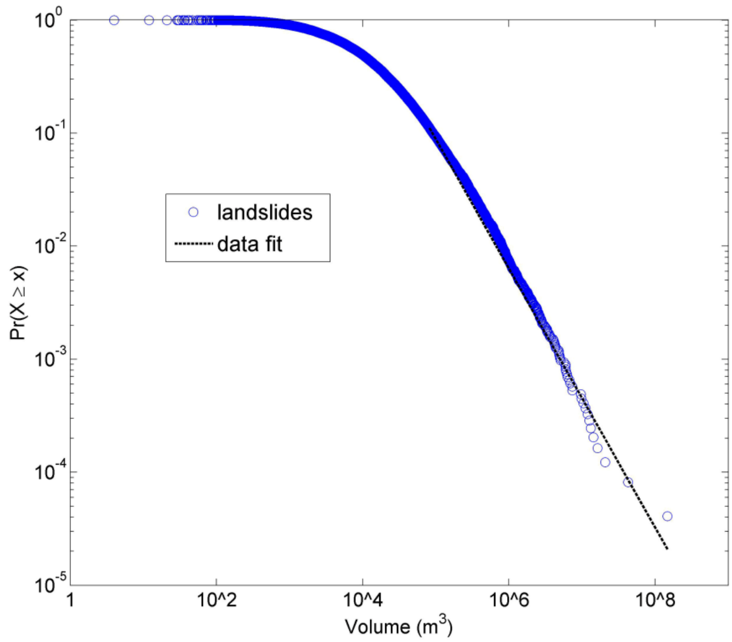

Figure 63 - Frequency-volume plot for the database of Arno river basin landslides (from Catani et al., in review).

The local subsets of the database, based on neighborhoods with different dimension, are set up and the variability of the power-law exponent α, *alpha*, in the geographic space examined by the Authors. The power-law exponent varies according to geographic position and the exponent itself can be treated as a random space function with autocorrelation properties, both at local and regional scale. It is locally stationary only for areas with very homogeneous environmental characteristics (as geology, geomorphology, hydrology, local climate, vegetation, geomorphometry and land use). Based on this finding Catani et al (in review) realized a simple method to map the power-law exponent distribution in space (Figure 64), in order to create maps of exceeding probability of landslide volume to be used in risk analysis.

The latter method is based on the application of the following equation:

$$P(\geq v) = \frac{\alpha - 1}{v_{min}^{(\alpha-1)}} \int_V^{\infty} v^{-\alpha} dv = \left(\frac{v}{v_{min}}\right)^{(-\alpha+1)} \quad (15)$$

where $P(\geq v)$ is the occurrence probability of a landslide with volume equal or greater than v, α the power-law exponent of volume frequency distribution for landslides and v_{min} is the lower cutoff volume for which the volume frequency distribution follows the power-law. For the Arno River basin this value is equal to 10^4 m^3 (Catani et al, in review), that can be considered also the landslide minimum volume to produce some evident effect on the river dynamics, as proposed in Paragraph 3.2 (Figure 26).
Replacing v with the boundary volumes V_l' and V_l'' in the equation, a simple methodology to get the landslide occurrence probability, with greater volume than the Non-formation value V_l' and the Formation value V_l'', is optained. Thus two "**Maps of Damming Probability**" for each stretch of river network is finally proposed.

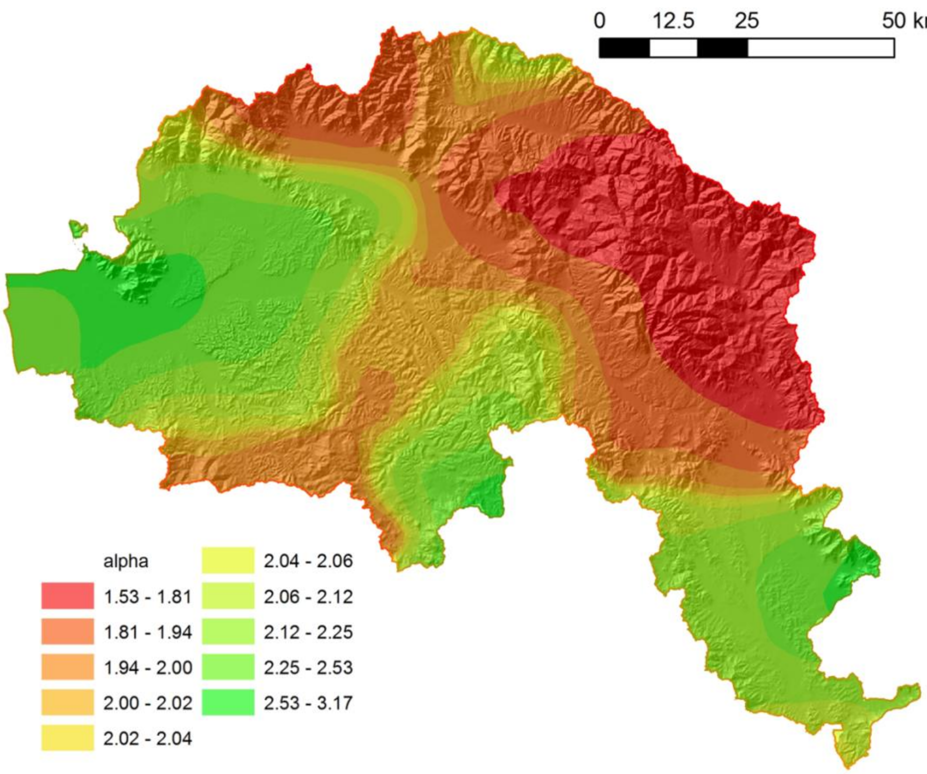

Figure 64 - Maps of local power-law exponent α distribution (from Catani et al., in review).

The methodologies adopted to obtain the two different types of maps are summarized in the flow diagram of Figure 65 and can be briefly summarized in four main steps, as follows:

I. Preliminary Operations:

- Plains and river stretches < 20 m removal;
- Division of the river network in stretches of 300 m long.

II. Calculation *of* W_v, V_l' and V_l'':

- Creation of transects perpendicular to the river stretches;
- Subdivision of the landscape in geomorphological units (Morphometric Feature);
- Conferring of W_v to the river stretches;
- V_l' and V_l'' calculation for each river stretch.

III. Damming Predisposition Mapping:

- Reconstruction of drainage network (DTM reconditioning);
- Watershed basins creation;
- Landslides selection;
- Landslide volume calculation, V_l;
- Volumes comparison between V_l with V_l' and V_l''.

IV. Damming Probability Mapping:

- Alpha max assignment to river stretches;
- Probability calculation $P(\geq V_l', V_l'')$.

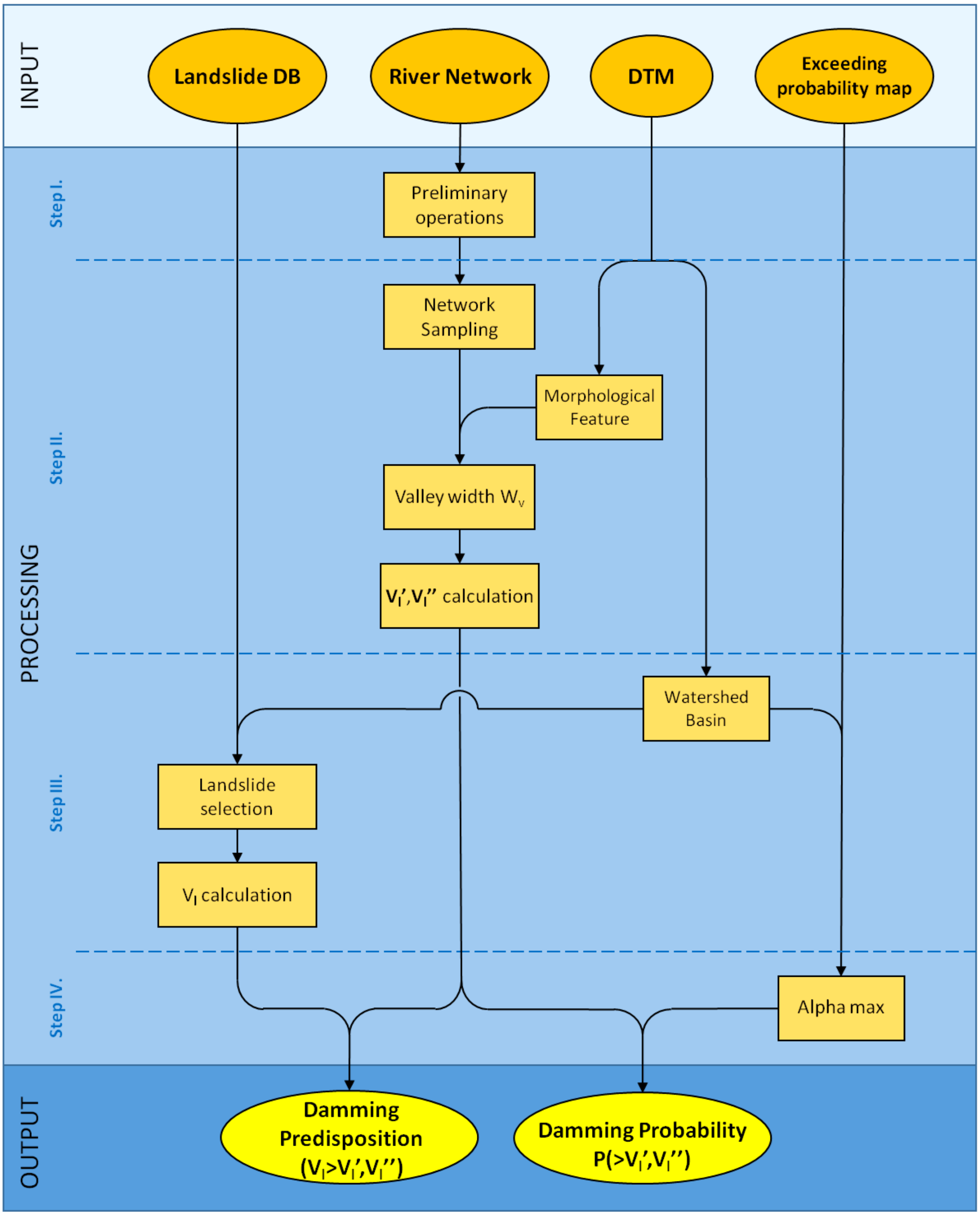

Figure 65 - Flow diagram showing the mapping methodology structure and the main steps.

5.3.1 STEP I. PRELIMINARY OPERETIONS

- Plains and river stretches < 20 m removal:

  In order to reduce the volume of data to analyze, thereby to reduce the processing time and simplify the visualization, it was necessary to remove a series of unnecessary data relating to the river network before going on with any operation.

As shown in Figure 42 of Chapter 4 and as logic suggests, the river blockage take place almost exclusively in hilly or mountainous areas and preferentially along steep slopes. For this reason, sections that run in flat areas have been eliminated from the river network. This was achieved by loading the polylines layer related to river network with ArcMap GIS software and using the simple command "*Clip*" with polygons related to the flat areas. This command allows to subtract from a layer, in this case the polylines of rivers, the parts overlapping the clipping layer, polygons of flat areas.

The remaining river stretches with length less than 20 m were deleted, still to eliminate unnecessary data. According to the small upstream watershed basin and also to the possible reservoir dimension, the consequences that occur with a blockage for so short channels would be indeed really poor.

- Division of the river network in stretches of 300 m long:

  In order to have maps easy to display and understand, the river network has been divided in river stretches 300 meters long. The distributed results, computed for every point in the network, are averaged in these “river stretches unit” to provide a graphically representative unique value.

  This was obtained through two steps. First, using the “*Cross Profiles*” command, in SAGA GIS software, lines perpendicular to the river network polylines were created equally spaced 300 meters apart. Furthermore with the “*Split lines with lines*” command, in SAGA GIS software, polylines of the river network has been broken using created perpendicular lines and subdivided in river stretches 300 meters long. In the attribute table of so gained river network polylines layer there is a single field, “*FIDLINE*”, with the unique identification number for each river stretch unit.

5.3.2 STEP II. CALCULATION OF W_V, V_L' AND V_L''

- Subdivision of the landscape in geomorphological units (Morphometric Feature):

  In order to automatically classify the landforms of the terrain and define the boundaries of the river valleys, the “*Morphometric Features*” module, in SAGA

GIS software, was exploited. Created to study the landscape and classify the surface forms (Wood, 1996; 2009), this tool starts from digital elevation model and uses a multi-scale approach by fitting quadratic parameters to any size window (via least squares) to derive slope, aspect and curvatures for subsequent classification of morphometric features units (peaks, ridges, passes, channels, pits and planes) (Figure 66). This terrain analysis follows a common concept in DEM-based landform mapping that each discrete landform type has a characteristic combination of elevation derivatives, like a geometric or "morphometric signature".

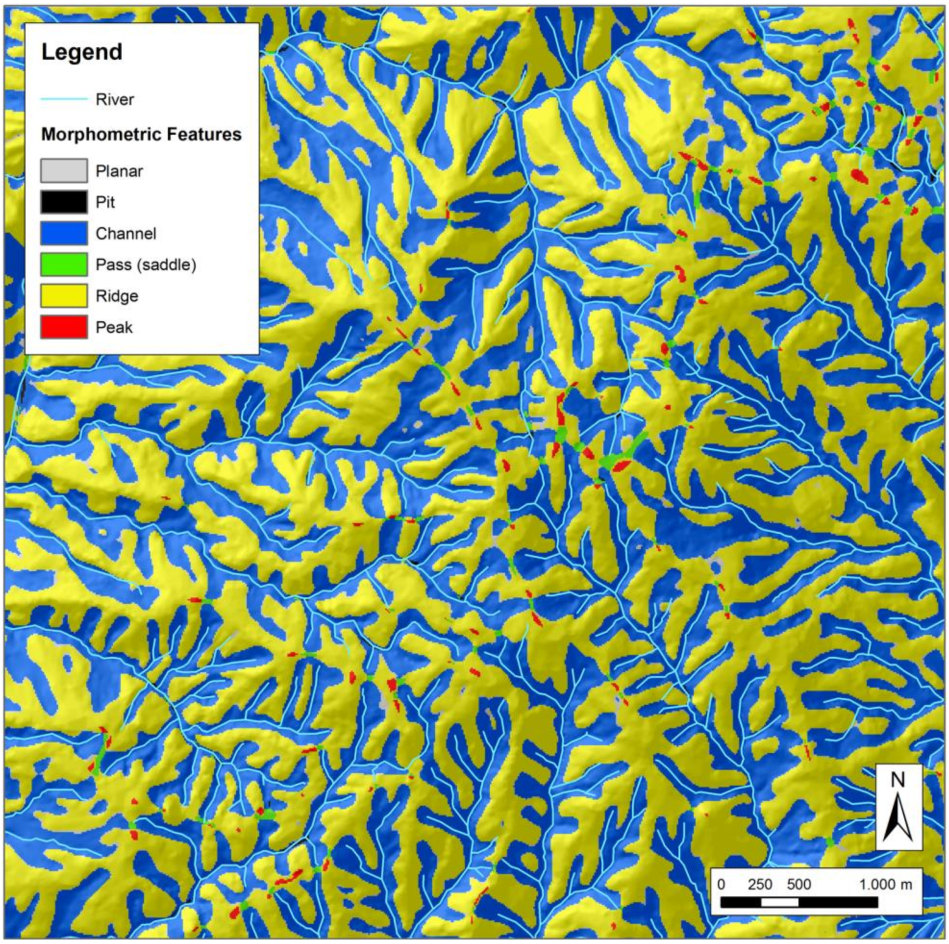

Figure 66 - Subdivision of the landscape in geomorphological units: creation of the Morphometric features.

The ability to distinguish the different geomorphologic land forms of this tool is very effective in mountainous areas with strong relief energy, while it loses precision in very flat areas, where the differences between different land forms are less clear. This loss of quality and precision does not affect significantly this study because, as already stated, the landslide dams occur almost exclusively in hilly and mountainous areas and therefore the flat areas were excluded from this analysis. Polygons of the Morphometric Features classes peaks and ridges were then removed. Then through the "*Merge*" command, in ArcMap software, remaining polygons, belonging to passes, channels, pits and planes classes, were combined together, resulting in the delineation of the areas of the valley floor (Figure 67).

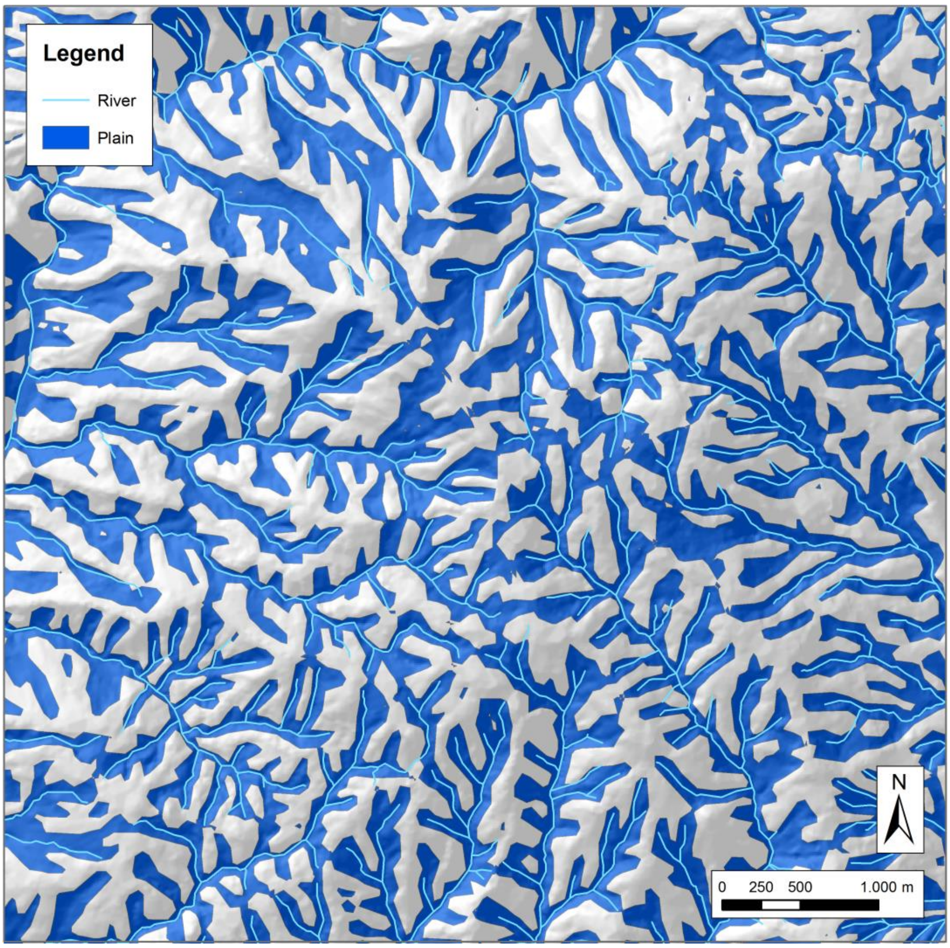

Figure 67 - Subdivision of the landscape in geomorphological units: valley floor polygons extraction.

- Creation of transects perpendicular to the river stretches:

The further step was to associate a valley width value, W_v, to each 300 meters long stretch. The distance of the river valley boundaries was sampled every 20 meters along each river stretches. This was obtained using again the "*Cross*

Profiles" command, imposing a length of 500 m to the perpendicular lines, henceforth "transects", and a distance of 20 m from each other (Figure 68). In the attribute table of perpendicular transects layer there is a single field, "*LINE*", with an unique identification number for each single transects.

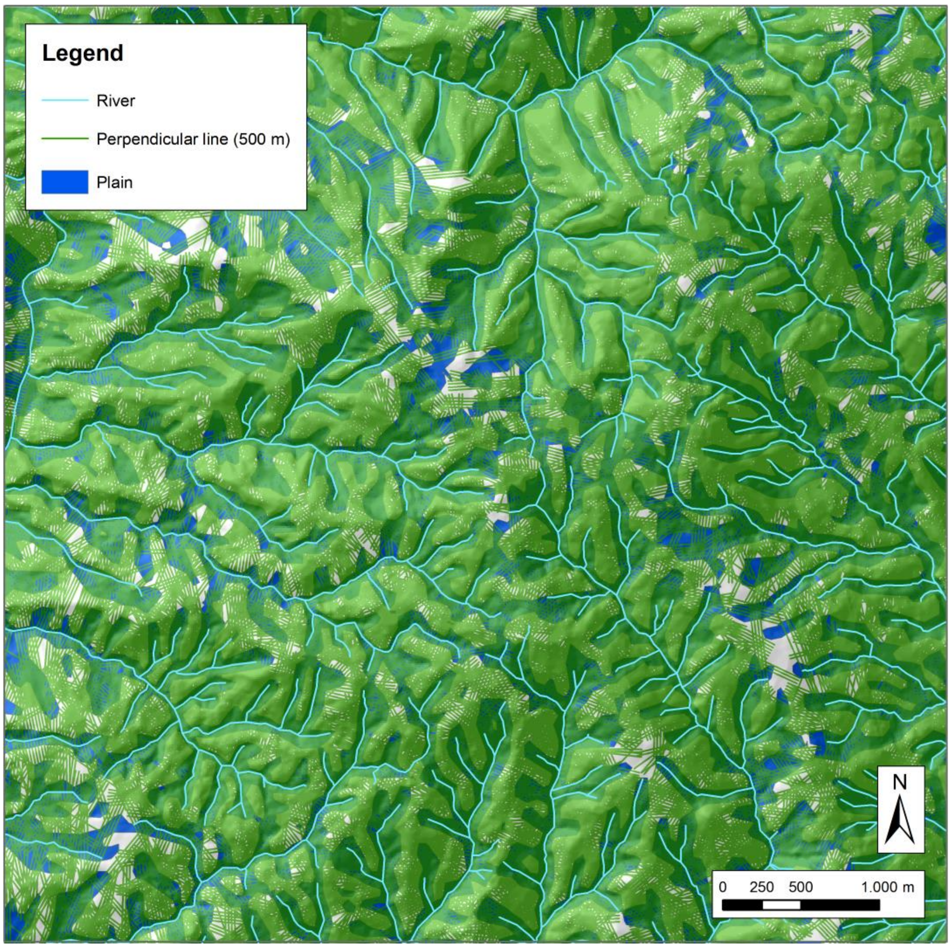

Figure 68 - Creation of lines, transects, 500 m long perpendicular to the river stretches.

- Conferring of W_v to the river stretches:

  In order to obtain the valleys width, or rather the distance between the lateral borders of the created valley floor polygons, the subsequent steps were followed. First the "*Clip*" instrument, in ArcMap software, has been applied on perpendicular transects 500 meters long, using the valley floor polygons as crop area. This way, however, some pieces of cut line remain in neighboring valleys while not intersecting perpendicularly any river, because of the initial length of the transepts. To solve this, the "*Multipart to Singleparts*" tool, in ArcMap software, has been applied on the resulting layer, whereby transects broken into sections were divided into separate parts. Then the "*Spatial Join*" command, in ArcMap software, has been launched between the river stretches and cut transects layers. This command merges the attribute table contents of the first layer to the second one, whenever their elements spatially intersect. Through the "*Select by Attribute*" tool in the attribute table, transects whose identification number "*LINE*" was different from the field "*FIDLINE*", acquired by the river stretches layer, were automatically selected and then deleted (Figure 69). With this simple step in the transects layer there are only the lines cropped on the valley floor polygons that perpendicularly intersect also the river network.

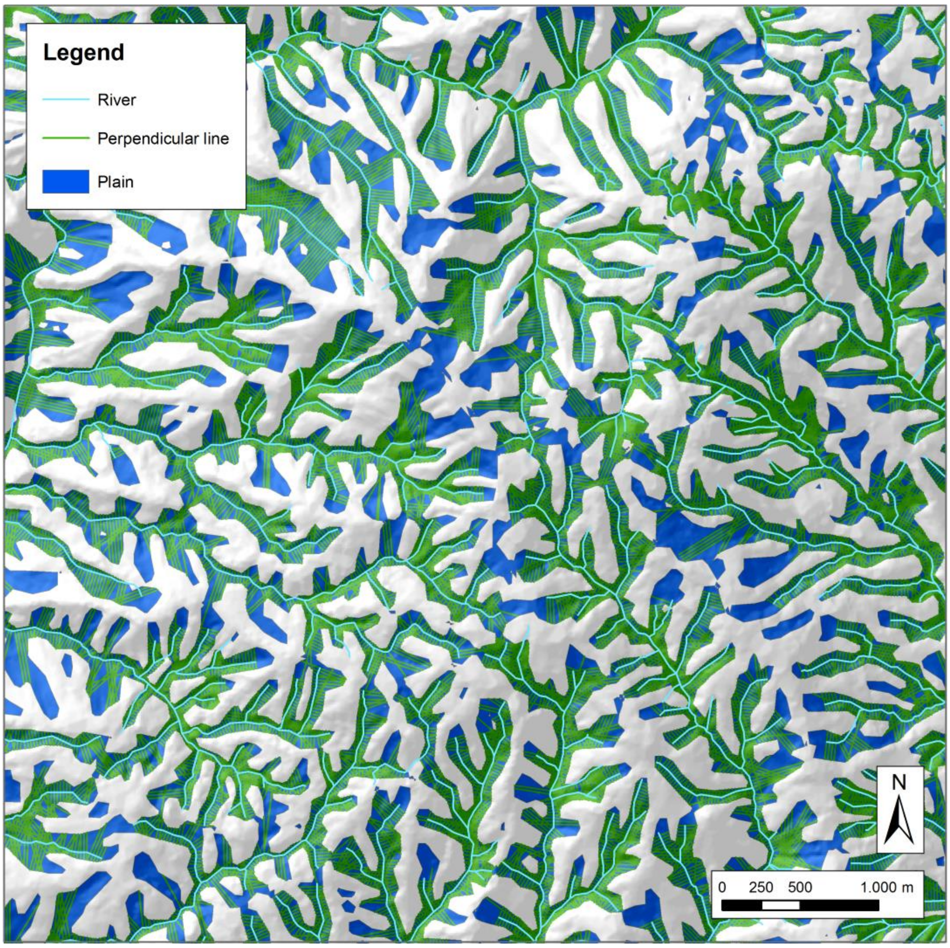

Figure 69 - Clip of transects on valley floor polylines.

Then, a new field "*Length*" was created in the transects layer attribute table and the length of each transect was automatically measured thanks the "*Calculate Geometry*" tool. The achieved values was rounded to the nearest ten lower, in order to follow a prudential principles, applying the function "*Int ([Length] /10) * 10*" to the "*Field Calculator*" tool. A new field "*WMedian*" was created in the river stretches layer attribute table and the "*Length*" median values of the perpendicular transects to each stretches was inserted. The median values was considered more significant rather than an averaged value, because the latter would have suffered most of abnormal values due to the valley geometry, occasionally irregular.

These values were take into account as the valley widths, W_v, for each river stretches.

- V_l', V_l'' calculation for each river stretch:

  Therefore, with a value of width W_v of the valleys, two boundary values, V_l' and V_l'', were calculated for each river stretches applying the equations of "Non-formation" (Equation (7)) and "Formation straight line" (Equation (8)). The two new values were placed in two equivalent new fields, "V_l' " and "V_l'' ", of the river stretches layer attribute table.

5.3.3 STEP III. DAMMING PREDISPOSITION MAPPING

- Reconstruction of drainage network (DTM reconditioning):

  With the boundary volumes V_l' (less than a landslide definitely does not produces complete river blockages) and V_l'' (above which the river valley is certainly dammed), and an updated landslide polygons archive, is possible to assess which landslide, if reactivated, has sufficient volume to obstruct a river valley realizing a complete damming.

  It is possible to approximate that a reactivated landslide will move downstream by gravity, following a path partly similar to the surface water flow. Drained surfaces along the slopes were automatically rebuilt along the river network to simulate this behavior. Many GIS softwares allow to automatically outline watersheds and drained areas from a Digital Terrain Model. The most common use an algorithm of flow direction with eight allowed directions and, for every pixel of the DTM, the flow follows the greater gradient of the eight surrounding possible pixels. Often, however, as in this case, the main water flow resulted by the algorithm does not match the real one, both for a problem of DTM resolution and for the intense human activity on the unnatural channels. This problem can be overtaken, having a real river network, forcing the pixels of the DTM to agree with the river network reducing their elevation along the rivers paths and a buffer zone. This result was obtained applying the "*DTM Reconditioning*" command, in the ArcHydro extention for ArcMap software. In this way, the DTM has been modified, incorporating the river network.

- Watershed basins creation:

  With the "*Watershed Basin (Extended)*" module, in SAGA GIS software, the watershed surfaces on the lateral slopes were automatically reconstructed for all the river network creating a new polygons layer. With this tool the watershed sub-surfaces for each point along the river stretches were created, as shown in Figure 70.

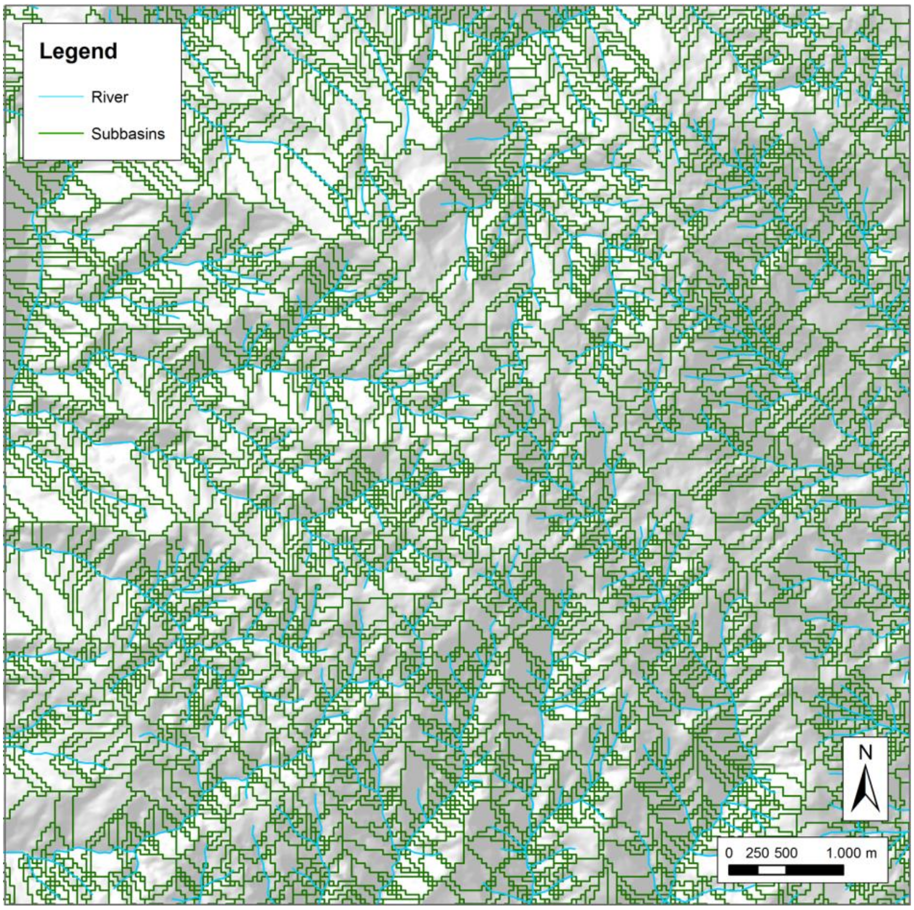

Figure 70 - Watershed sub-surface of single river stretches reconstruction.

- Landslides selection:

  In the next step, each landslide was associated to the river stretch that it should reach if reactivated, according to the realized watershed surfaces. This was possible using two consecutive time the “*Spatial Join*” tool in ArcMap software; the first time between the river layer and the watershed surfaces layer, than between the latter and the landslide layer. In this way the fields “*FIDLINE*”, “V_l'” and “V_l'' “ of the river stretch that could be potentially blocked were copied in the attribute table of each landslide.

- Landslide volume calculation, V_l:

  To calculate the volume of landslides two different procedures were followed, depending on the type of movement; one for rotational slides and another for the rest of the movements (Cruden & Varnes, 1996; Tofani, 2007). As stated in

Chapter 5.2, more than 98% of the mass movements are connected to rotational or translational slides.

The volumes drawn with these two procedures can not be considered exact values, because made through geometric simplifications, but realistically reflect the real magnitude and therefore useful for the purposes of this study.

Volumes of rotational slides, according to a geometrical model assuming a semi ellipsoidal shape, were appraised, using the equation proposed by WP/WLI (1990), as follows:

$$V_l = \frac{1}{6} \cdot \pi \cdot D_r \cdot L_r \cdot W_r \tag{16}$$

where

V_l = landslide volume (m^3);

D_r = depth of the sliding surface (m);

L_r = maximum distance between the foot of the sliding surface and the crown of the landslide (m);

W_r = maximum distance between the sides of the landslide perpendicular to L_r (m).

This dimensions can be better understood in Figure 71 and Figure 72.

It is important to notice that dimensions in the above mentioned equation are referred to pre-rupture conditions, while those that can be directly measured on mapped landslide refer to post-rupture conditions. Generally the movement increases the volume of the material because the move causes a dilation. In fact, while there is a substantial difference between the length of the landslide in pre-rupture conditions and post-rupture, with L_d greater than L_r, it can be reasonably assumed that the width remains more or less the same in conditions of pre- and post-rupture (Figure 72).

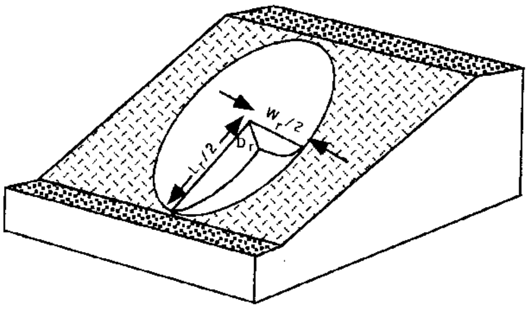

Figure 71 - Geometrical model for rotational slide, assuming a semi ellipsoidal shape (from Cruden & Varnes, 1996).

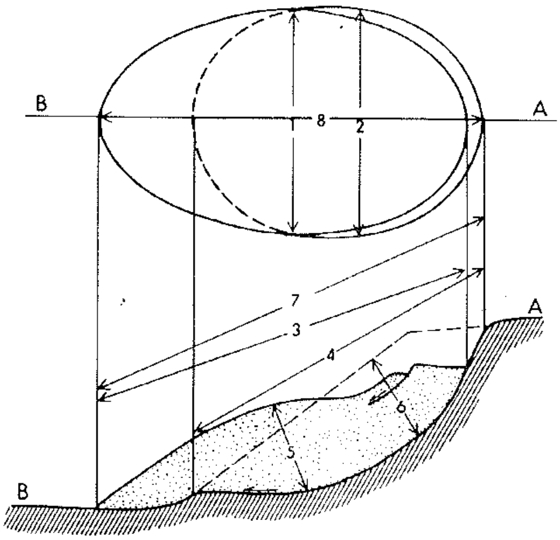

Figure 72 - Geometrical dimensions of a rotational slide (IAEG Commission on Landslides, 1990):
1: W_d = Width of the landslide in post-rupture conditions.
2: W_r = Width of the landslide in pre-rupture conditions.
3: L_d = Length of the landslide in post-rupture conditions.
4: L_r = Length of the landslide in pre-rupture conditions.
5: D_d = Depth of displaced mass.
6: D_r = depth of the sliding surface.
7: L = Total length.
8: L_{cl} = Length of the central line.

The procedure to calculate the volume of rotational slide can be summarized in the following steps:

a) The first step is to obtain minimum and maximum elevation within each landslide. This was possible using the "*Zonal Statistics*" tool, in ArcMap software. The command allows to perform the statistics of the elevations within the perimeter of each mapped landslide, and it calculates the minimum value, maximum value, the mode and the average of the elevation. The height difference between the minimum and the maximum altitude is the *rise*, shown in Figure 73.

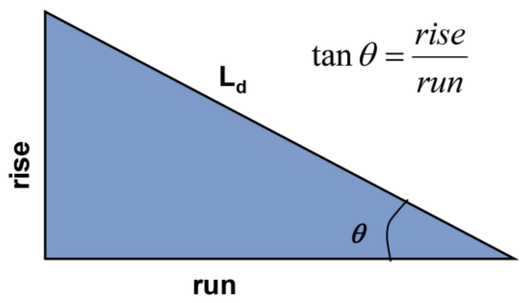

Figure 73 - Trigonometry and relations for the volume calculation.

b) The next step is to create a map of slope, using the "*Slope*" command in ArcMap software, from the DTM of the basin. In Figure 74 is shown the obtained map.

c) Than the "*Zonal Statistics*" tool was performed between landslides and the map of slope, to obtain the average slope within each landslide (ϑ). With a simple trigonometric relation can be determined the horizontal distance between the higher point and the lower point within the landslide (the *run* in Figure 73). Thereafter L_d can be calculated, once again with a simple trigonometric relation.

d) The fourth step is to find the width of the landslide W_d. To get this, the spatial extension of each landslide have to be calculated thanks to the "*Calculate Geometry*" tool in the table of attribute of landslide layer.

Still assuming an ellipse shape, the surface area A (m^2) is equal to:

$$A = \pi \cdot \mathrm{L_d} \cdot \mathrm{W_d} \tag{17}$$

The width (W_d) is therefore given by:

$$W_d = \frac{A}{\pi \cdot \mathrm{L_d}} \tag{18}$$

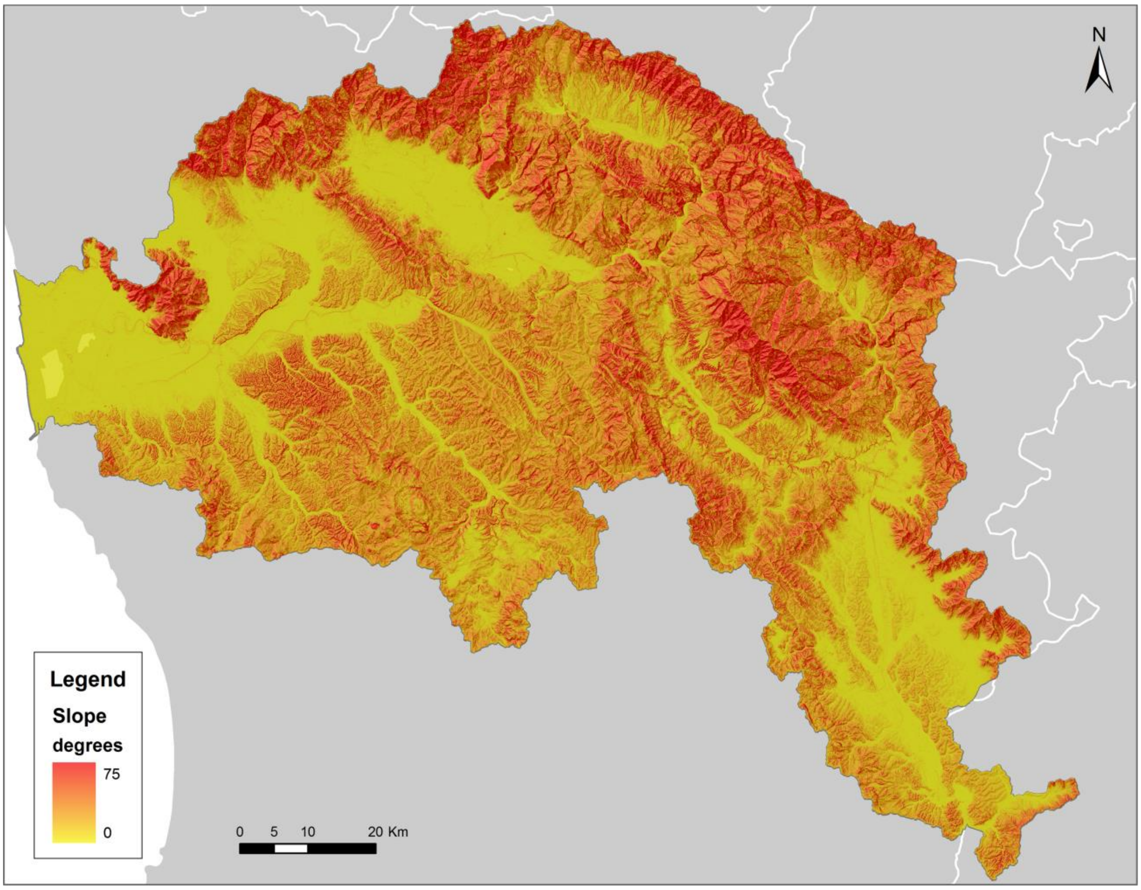

Figure 74 - Slope distribution in the Arno River basin.

e) In the next phase, the length of the landslide value, L_r (Figure 72), was determined starting from L_d. To do this some considerations about the rotational slide were carried out, assuming that in plant, with pre-rupture conditions, such movements take a not very stretched form, next to the circular one, and so that the ratio between the length L_r and width W_r is very close to unit.

The ratio between W_d and L_d was evaluated and two cases were distinguished:

If $\frac{W_d}{L_d} > 0,6$ than $L_d = L_r$;

If $\frac{W_d}{L_d} < 0,6$ than $L_r = L_d * a$

where *a* is a coefficient that $\frac{W_r}{L_r} = 0{,}6$.

The 0,6 value was suggested in previous study (Turner & Schuster, 1996) to describe landslide with rotational sliding movement.

f) Then, the depth of the landslide, D_r, was found. The slide movements usually have a ratio D_r/L_r between 0,15 and 0,33 (Skempton & Hutchinson, 1969).

The 0,33 value was chosen to have the most precautionary condition.

g) The last step was to calculate the volumes of landslides V_l using the Equation (16), previously shown, having all the values of the required elements.

For the other type of landslide different from rotational slide, a planar sliding surface with a constant depth of the landslide was assumed (Cruden & Varnes, 1996). The volume of the landslides was obtained with a simple equation, as follows:

$$V_l = A \cdot D_r \tag{19}$$

The landslide surfaces *A* was automatically computed exploiting the "*Calculate Geometry*" tool of ArcMap software in the attribute table of the landslide layer. A constant average depth of 1 meter was assumed for landslide depth D_r, compatible with the average hillslope soil thickness in the study areas as reported by Catani et al. (2010).

- Volumes comparison between V_l with V_l' and V_l'':

Finally the calculated volume of each landslide, V_l, was compared with the boundary values, V_l', volume of Non-formation, and V_l'', volume of Formation of a dam, about each river stretch that can involve.

Because the computed landslide volumes V_l was based on some approximations, in order to be more precautionary, the comparison was done also with the V_l values increased by 20% ($V_l \cdot 1{,}2$). This was done, according to a prudence principle, because a possible increase of landslide body size to its reactivation or an inaccuracy in the calculation of volume compared to the real value.

A dimensionless value of comparison between both V_l and (V_l ∗ *1,2)* landslide volumes and both V_l' and V_l'' boundary values was assigned to each mapped landslide. The comparison dimensionless value (2, 1 and 0) was derived using the simple scheme in Table 5, as follows:

	$V_l > V_l'$ (V_l'')	$V_l < V_l'$ (V_l'') $< V_l$ ∗ 1,2	$V_l < V_l'$ (V_l'')
Value	**2**	**1**	**0**

Table 5 - Comparison table used to compare landslide calculated volumes, V_l, with the boundary volume of Non-formation and Formation, V_l' and V_l''.

Throw the combination of the two gained comparison dimensionless value in the intensity matrix in Figure 75, an **intensity classification of Damming Predisposition**, for every mapped landslides, was measured. The damming predisposition intensity matrix divides the severity of the damming risk, or susceptibility, associated to each different mapped landslide in the study area, in five classes of a qualitative scale, i.e. Very Low, Low, Moderate, High and Very High, colored dark green, light green, yellow, orange and red respectively. The gray squares, corresponding with high V_l'' values (1 or 2) and lower V_l' value (0 or 1), are not possible combination, because V_l'' is always bigger than V_l' according to their formulation.

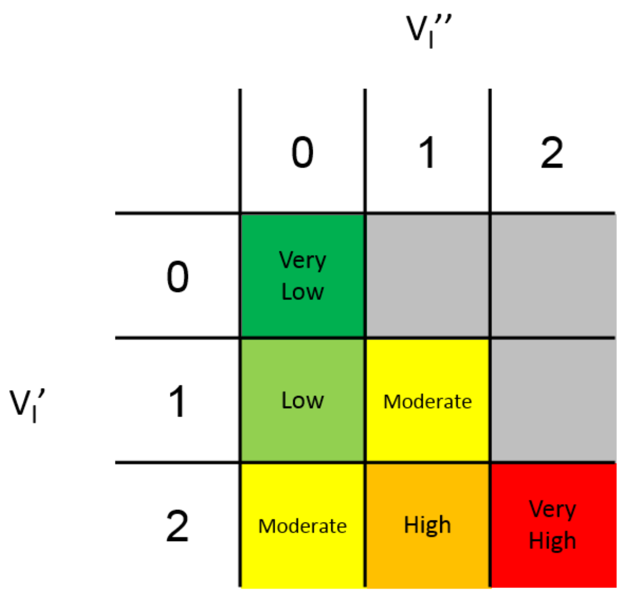

Figure 75 - Predisposition matrix used to the assignment of the damming predisposition intensity to the mapped landslides.

5.3.4 STEP IV. DAMMING PROBABILITY MAPPING

- Alpha max assignment to river stretches:

Although the reactivation of mass movements represent the greatest and more concrete risk for the damming of a river valley, the study concerning the forecasting of new landslides was not left out.

Therefore, a simple method to get a Map of Damming Probability is proposed in this paragraph, starting from the previously shown occurrence probability equation (Equation (15)) of a landslide with volume equal or greater than V proposed by Catani et al (in review). Thence, two maps of occurrence probability for a landslide with volume equal or greater than the boundary values V_l' and V_l'' have been realized.

So, in order to solve the probability Equation (15), three values are needed for each section of the river network. Two boundary volumes V_l' and V_l'', computed in Paragraph 5.3.2, and the alpha value, α, for each river stretches.

In order to achieve the most precautionary forecasting, the maximum alpha value, α_{max}, was selected for each river stretches.

In the same way for a potentially reactivated landslide, can be approximated that also a new landslide will move downstream by gravity, following the main flow directions. For this reason, each river stretches were associated to the maximum alpha value (linked to the maximum probability of landslide occurrence) available within its watershed sub-surfaces polygon (created in Paragraph 5.3.3). This was possible thanks to the "*Grid Statistics for Polygons*" module, in SAGA GIS software, used with the watershed sub-surfaces layer and the alpha spatial distribution map (Catani et al, in review). The tool returns statistics of alpha values within the perimeter of each drained area, providing each polygon the value of alpha minimum, maximum, mean, variance and standard deviation. The maximum alpha value, α_{max}, has been associated to each river stretch using the field "*FIDLINE*" in common in the attributes table of both the river stretches layer and the watershed sub-surfaces layer.

- Probability calculation $P(\geq V_l', V_l'')$:

Starting from the Equation (15) of occurrence probability, previously shown, and by replacing α with α_{max} and V first with V_l', than with V_l'', a new formulation of the occurrence probability equation was proposed, as follows:

$$P(\geq V_l^{\prime,\prime\prime}) = \frac{\alpha_{\max} - 1}{v_{min}^{(\alpha_{\max}-1)}} \int_V^{\infty} v^{-\alpha_{\max}}\, dv = \left(\frac{V_l^{\prime,\prime\prime}}{v_{min}}\right)^{(-\alpha_{\max}+1)} \quad (20)$$

With this equation, the occurrence probability of a landslide, with greater volume than the boundary values V_l' and V_l'', was computed for each river stretches in the Arno River basin.

The two resulting classification of Non-formation and Formation, divide the occurrence probability, or susceptibility, of the river stretches in five classes: Very Low, Low, Moderate, High and Very High, colored dark green, light green, yellow, orange and red respectively. The classes value range are reported in Table 6 for both classifications.

	Susceptibility	Probability of Non-formation $P (\geq V_i')$	Probability of Formation $P (\geq V_i'')$
	Very Low	0 – 1 %	0 – 0,5 %
	Low	1 – 5 %	0,5 – 1 %
	Moderate	5 – 15 %	1 – 2,5 %
	High	15 – 35 %	2,5 – 7,5 %
	Very High	> 35 %	> 7,5 %

Table 6 - River stretches susceptibility classification and related probability of Non-formation and Formation of a dam.

5.4 MAPPING RESULTS

The high costs of reconstruction and losses on both economic and human lives, due to the obstruction effects of a river by a landslide, may be considerably reduced by proper planning and maintenance of the levees and river valleys. This proposed mapping methodology of damming susceptibility could be used to direct planning and maintenance works where the river stretches have high risk and thus further drastically reduce future costs.

The results from the application of the landslide classification of **Damming Predisposition**, proposed in Paragraph 5.3.3, on the Arno River basin landslide database, are shown in Figure 78. The most frequent Predisposition class visibly resulted, hopefully, the Very Low class, with 94,40% of the whole database (Figure 76), followed by the Moderate class with 4,34% and the remaining percentage divided by Low (0,78%), Very High (0,47%) and High (0,02%) classes.

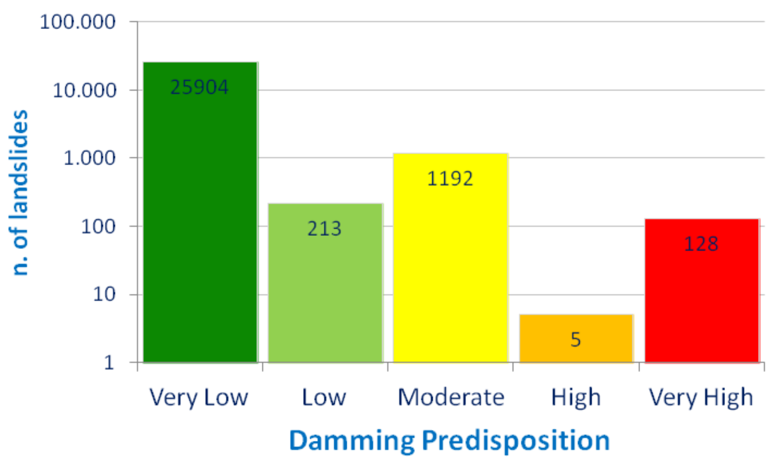

Figure 76 - Distribution of the Damming Predisposition intensity in the Arno River basin landslide by reactivation.

According to the intensity distribution, can be generally observed that areas most exposed to damming phenomena, related to landslide reactivation, are Mt. Morello - Pratomagno and Mandrioli - Alpe di Catenaia mountain ridges described in Figure 61.

The two maps in Figure 79 and Figure 80, resulting from the Damming Probability Mapping, instead, are very different from each other and the percentage distribution of the classes are reported in Figure 77.

In the **Damming Probability Map of Non-formation**, in Figure 79, Low, Moderate and Very Low classes are very frequent, with 36,19%, 28,95% and 23,57% of the river stretches respectively, but also High, with 9,54%, and Very High, with 1,74%, classes are quite widespread. It means that about 10% of all the river stretches have more than 15% chance (see Table 6) that a new landslide has a volume bigger than the boundary value V_l', the landslide minimum volume to have the opportunity to obstruct the river stretch. The possible dam could be not formed, formed-unstable or formed-stable.

This values are widespread in all the basin with a higher concentration barely visible around Mt. Morello - Pratomagno and Mandrioli - Alpe di Catenaia mountain ridges.

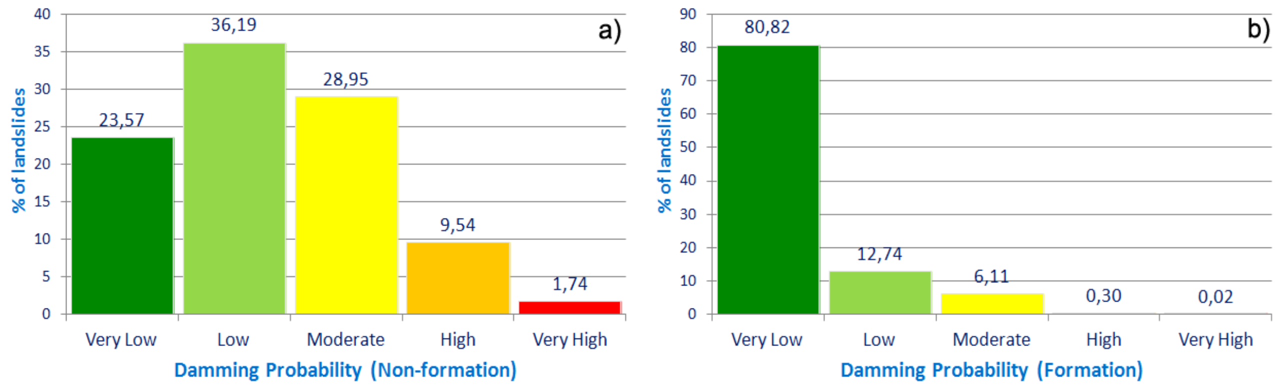

Figure 77 - Distribution of the Damming Probability in the Arno River basin related to a) Non-formation, and b) Formation by new landslide formation.

The **Damming Probability Map of Formation**, in Figure 80, displays a classes division and a spatial distribution much clearer. Almost all (80,82%) the river stretches have a Very Low probability, with a probability lower than 0,5% (see Table 6), that a new landslide has a volume bigger than the second boundary value V_l'', the landslide minimum volume to completely obstruct the river stretch. The remaining 19,18% of river stretches are divided in Low (12,74%), Moderate (6,11%), High (0,30%) and Very High (0,02%) probability and are clearly focused around Pratomagno and, again, Mandrioli - Alpe di Catenaia mountain ridges.

Thanks to the results from these two different mapping methods (Predisposition and Probability), the areas between Firenze and Arezzo Provinces close to Mt. Morello - Pratomagno and Mandrioli - Alpe di Catenaia mountain ridges, in the Eastern part of the basin, can be pointed out as the most susceptible areas to damming events in whole Arno River basin. These are the highest (about 1˙600 meters a.s.l.) mountain ridge in the basin, characterized by calcareous, arenaceous and marly lithology.

In Figure 81, the comparison between the results of the mapping methods and censed landslide dams confirm the validity of the tool. The area highlighted by proposed mapping methods is, indeed, the most subject to damming phenomena in the past.

In these zones work and the deeds of planning should be concentrated to prevent the dam risk.

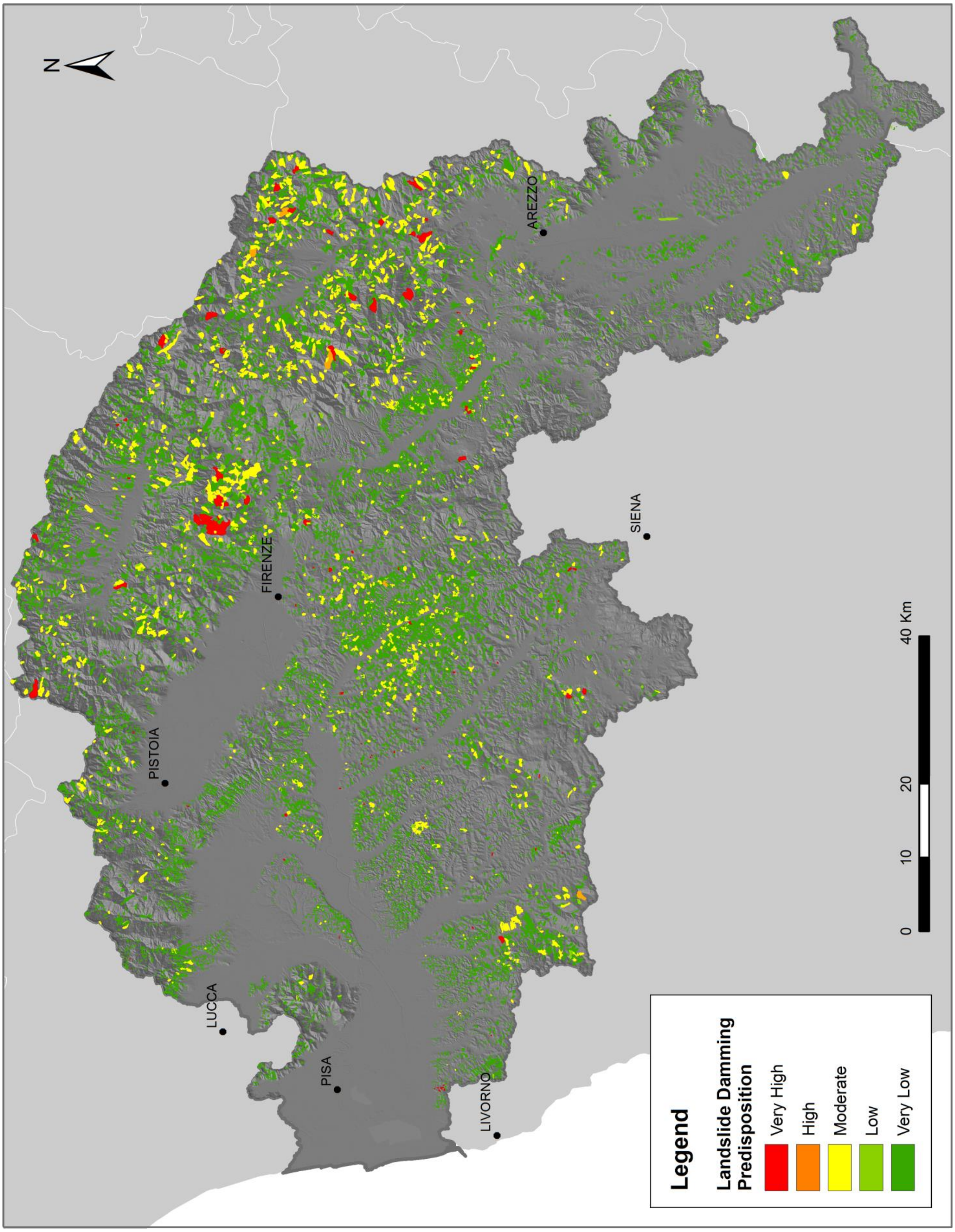

Figure 78 - Damming Predisposition of landslide in the Arno River basin by reactivation.

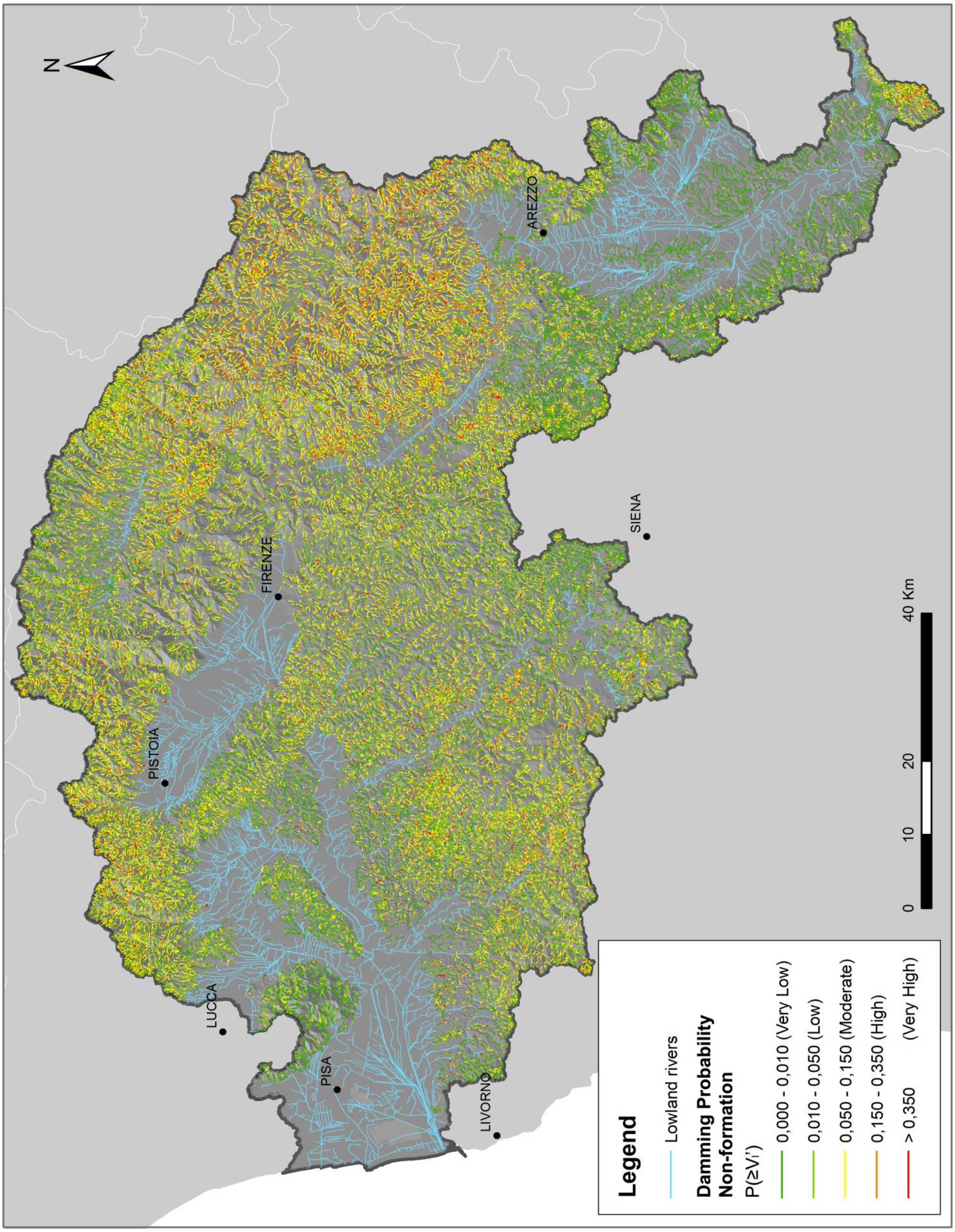

Figure 79 - Damming Probability Map of Non-formation of river stretches in the Arno River basin by new landslides.

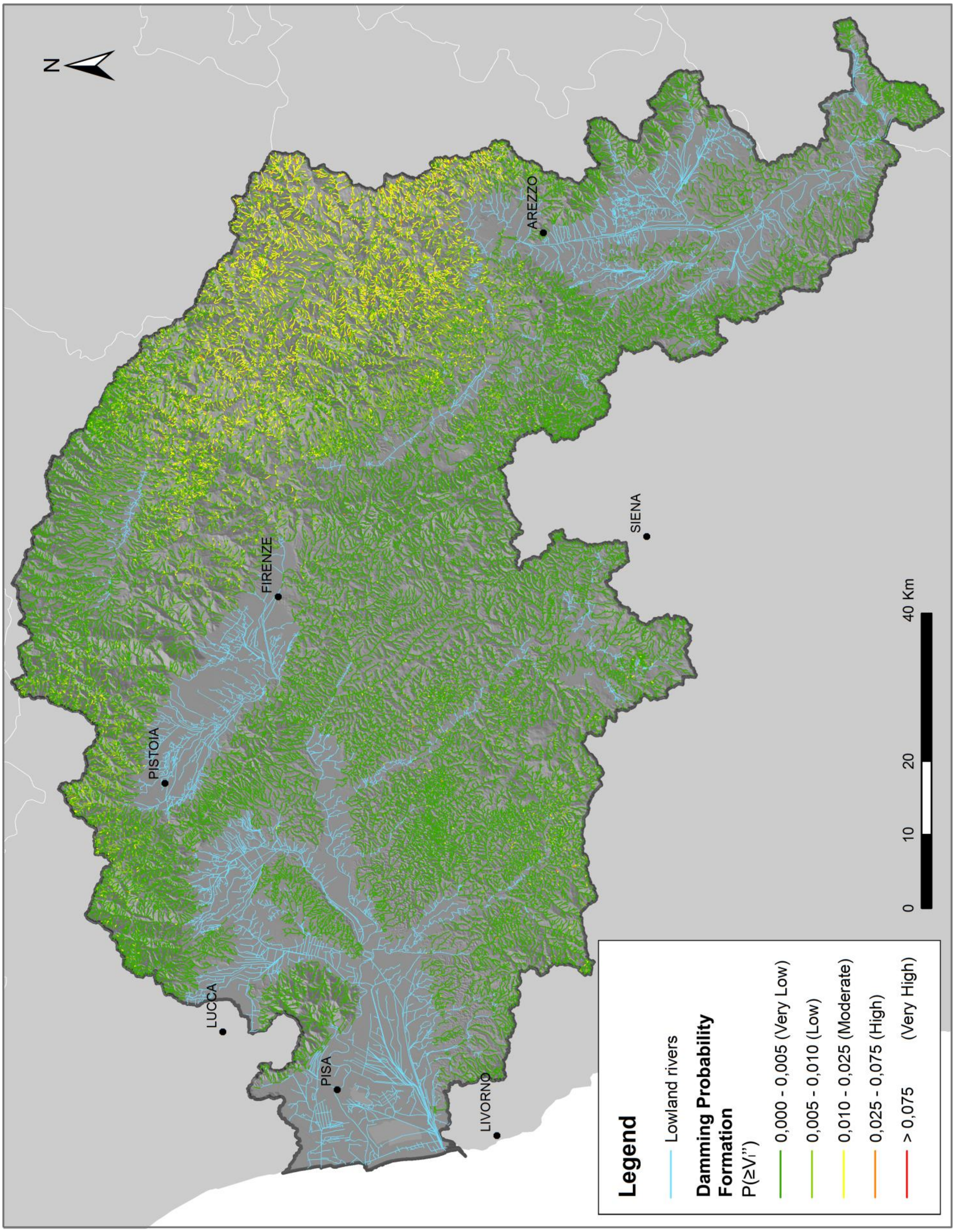

Figure 80 - Damming Probability Map of Formation of river stretches in the Arno River basin by new landslides.

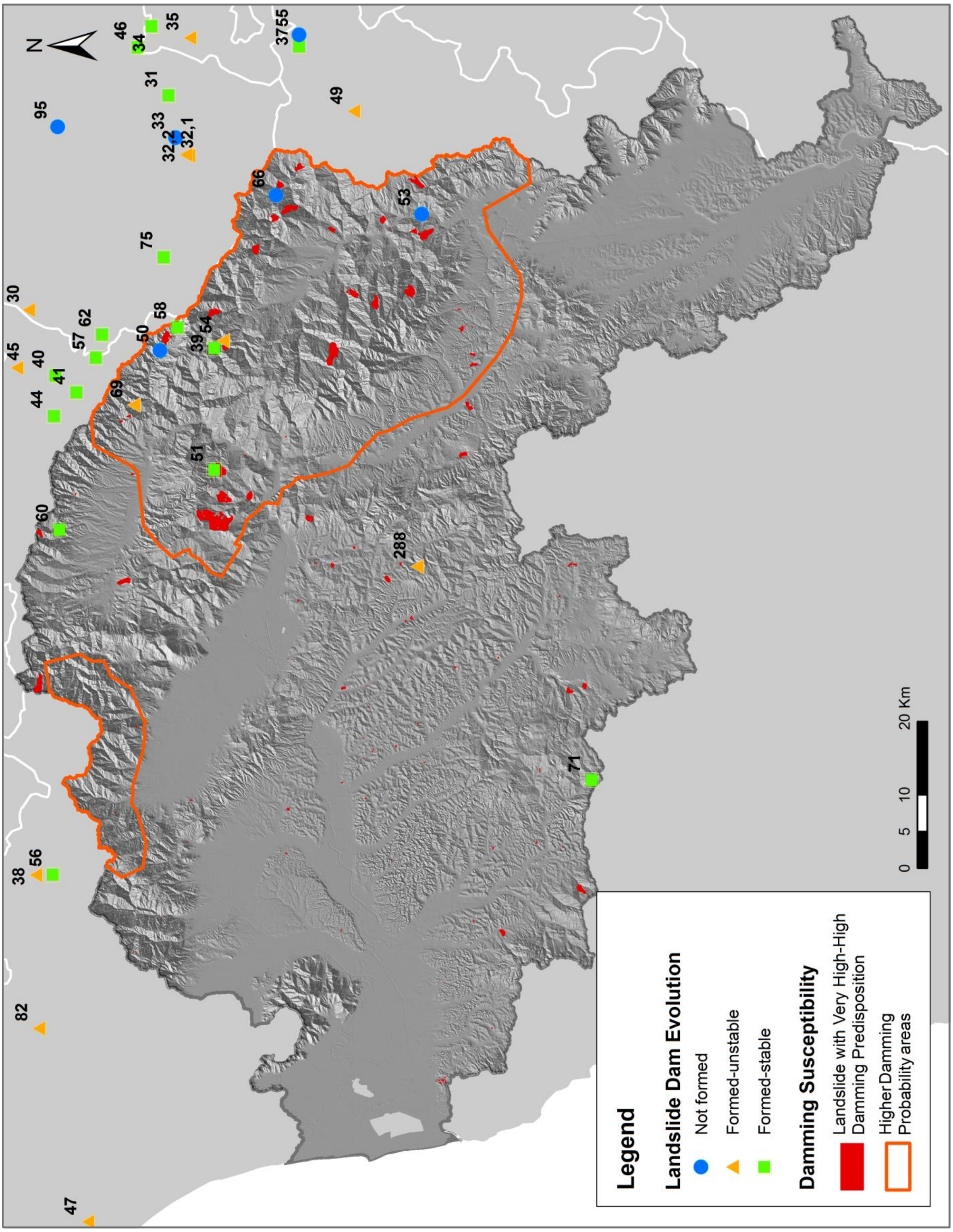

Figure 81 - Comparison between landslides classified as Very High-High Damming Predisposition, higher Damming Probability areas and censed landslide dams (the black bold numbers are the ID number of the dams).

6 CONCLUSIONS

Landslide dams are the result of the complex interaction between river and slope dynamics, not yet fully understood. The main aim of this research was to study landslide dam events and to design a useful and easy tool to assess the damming risk with spatial planning purpose. We tried to resolve two main issues concerning this phenomenon: the likelihood of a landslide forming a dam and its evolution.

The research started by setting up an archive of Italian landslide dams, updating previous studies on the same topic in smaller areas (Pirocchi, 1991; Ermini, 2000; Pacino, 2002), and integrating it through a careful literature review and cartographic and aerial photos interpretation. This data set represents the first systematic national inventory of these events in Italy. The data were gathered in a database, comprising of 291 records, with a friendly format to privilege usability and future implementation. It is composed of 57 easy-to-collect-and-measure information fields.

Many of the cases are from prehistoric events, often linked to big seismic events (mainly in Southern Italy) or deglaciation phenomena (mostly in Northern Italy). In some cases, the lack of historic documents and direct information made it difficult to reconstruct the events, especially where the morphological evidence of the dam were not clear. Ancient documents provide direct information for historic events, often describing catastrophic events as they really happened, but with fictional elements.

The research includes also landslide dam events occurred along the Cordillera Blanca mountain range, in Peru. This has allowed us to study the same event in a very different geographical, climatic and tectonic setting from Italy and to compare the differences between two different data setting.

In the second part of this thesis, a morphological analysis of the collected data was performed to identify morphometric parameters, in order to best define the formation process of a blockage and to acquire more reliable geomorphological indexes, useful for forecasting and planning purposes. This analysis was inspired by past studies, in different geographical and geological regions, by Swanson et al. (1986), Canuti et al. (1998) and Ermini & Casagli (2003) and confirmed the validity of schematizations already developed by these authors.

The new morphometric indexes were obtained by systematically comparing parameters describing both the river and the landslide, using a wider data availability granted by said database. These indexes were designed to meet the basic principle of an easy and fast data collection, crucial during emergencies.

Encouraging results came from the formulation of the *Morphological Obstruction Index*, MOI, that allows to perform a reliable analysis of dam formation and provides a good estimate to forecast a landslide blocking a river, from a geomorphic analysis.

Good results came also from the *Hydromorphological Dam Stability Index*, HDSI. It can distinguish well enough formed-stable dams from other ones; this suggested the use of the proposed graphical method as a useful, easy and fast assessment tool, to carry out preliminary assessment on the stability of landslide dams.

The Peruvian experience made it possible to test, in a very different environment, the validity and the effectiveness of the new indexes.

The ultimate goal of this research was to propose a useful and practical tool to predict which areas have a higher damming susceptibility, and where preventive measures should be focused; so as to avoid damages and suffer less consequences related to landslide dam events. For this reason, a simple GIS methodology was developed, by applying the *Morphological Obstruction Index*, resulting in a useful forecasting and planning tool. This methodology can assess, quickly and with few data, the damming predisposition, connected to existing landslides, and the probability of obstruction by new landslides along a river network.

The proposed methodology was used on a test area, the Arno River basin, and resulted in practical and realistic maps of the spatial distribution of the Predisposition and the Probability, or susceptibility, to obstruction along the river course.

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8 APPENDICES

8.1 APPENDIX 1: THE ITALIAN DATABASE TABLE

8.2 APPENDIX 2: THE PERUVIAN DATABASE TABLE

8.3 APPENDIX 3: DOCUMENTATION OF THE ITALIAN LANDSLIDE DAMS

8 APPENDICES

8.1 APPENDIX 1: THE ITALIAN DATABASE TABLE

Localization	**ID**	[ ]	1	2	3
	Locality	text	Comineto	Groppallo	Lago Nero
	Municipality	text	Farini	Farini	Ferriere
	Province	text	Piacenza	Piacenza	Piacenza
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	549454, 4946810	550187, 4951425	540250, 4934400
	UTM E, N dam	[ ]	549215, 4947647	550087, 4948738	540025, 4934750
News	**L.-damages**	text	Comineto village damaged	Destruction of a cottage	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Almagià (1907), Ermini (2000)	Trabucco (1889), Almagià (1907), Ermini (2000)	Trabucco (1891), Almagià (1907), Ermini (2000)
	Note	text	Man-made emptying lake and fluvial works		
Landslide	**Movement**	text	slump	flow	fall
	Velocity	text		moderate	very fast
	v	[m/s]		5,00E-05	5,00E-01
	Material	text	debris	debris	rock stone
	Lithology	text	clay, sandstone	clay and altered sandstone, limestone	ophiolite
	Water c.	text	wet	wet	
	H L.	[m]	177	618	275
	α	[°]	11	11	19
	β	[°]	12	11	15,9
	L L.tot.	[m]	820	3.680	1.161
	L L.body	[m]	540	1.700	750
	Wmax	[m]	450	725	375
	Wmin	[m]	250	250	200
	D_{rf}	[m]	22,5	25	
	S L.	[m^2]	550.000	1.700.000	
	V L.	[m^3]	2.861.325	22.241.667	
	Trigger	text	fluvial erosion	heavy rainfall	
	Prev. activations	dd/mm/yyyy	1887		
Dam	**Date of damming**	dd/mm/yyyy	1980	30/6/1888	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III b	II	II
	L d	[m]	180	30	250
	W d	[m]	450	150	350
	H d	[m]	15	10	15
	S d	[m^2]			
	V d	[m^3]	500.000	45.000	1.300.000
	Q d	[m] a.s.l.	573	622	1465
	d condition	text	artificially stabilized	toe erosion	slightly cut
	Evolution	text	man-made	not formed	existing lake
	Type of Failure	text		-	
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	T. Lavaiana	T. Lavaiana	R. Grugola
	Wvalley	[m]	75	330	150
	Subt. S	[km^2]	17,59	21,34	0,51
	S	[°]	3,36	8,5	9
Lake	**Lake name**	text	no name		Lago Nero
	L lake	[m]		-	200
	W lake	[m]			100
	D lake	[m]			
	S lake	[m^2]			15.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			1540
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	-	centuries
	Lake Condition	text	extinguished for man-made influence	not formed	existing

Localization	**ID**	[ ]	4	5	6
	Locality	text	Bettola	Illica	Corniglio
	Municipality	text	Bettola	Accumoli	Corniglio
	Province	text	Piacenza	Parma	Parma
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	546125, 4958500	548925, 4936162	585725, 4923687
	UTM E, N dam	[ ]	547825, 4957325	549114, 4935442	585625, 4926200
News	**L.-damages**	text	In 1736 and 1851 distruction of 30 and 20 cottages	Destruction of the Mezzane convent; trasferred to Compiano	Destruction of the aqueduct, 1 cottage, a bridge over Parma; damaged 2 houses
	u-damages	text			Flooding
	d-damages	text			
	Bibliography	text	Trabucco (1891), Almagià (1907), Ermini (2000)	Boccia (1804), Almagià (1907), Ermini (2000)	Boccia(1804), Almagià (1907), Martelli (1916), Ermini (2000)
	Note	text	Not formed lake (slow movement, width of valley)		Damming not complete (Martelli, 1914). Upstream was an ancient lake named as big
Landslide	**Movement**	text	complex		slump
	Velocity	text	moderate	moderate	moderate
	v	[m/s]	5,00E-05	1,39E-04	5,00E-04
	Material	text	debris		debris
	Lithology	text	marly limestone, altered sandstone with clay	clay, sandstone and limestone	sandstone and mudstones
	Water c.	text			
	H L.	[m]	325	475	465
	α	[°]	10	13	13
	β	[°]	11	21,2	10
	L L.tot.	[m]	1.850	1.450	2.940
	L L.body	[m]			
	Wmax	[m]	250	700	1.000
	Wmin	[m]	125	425	
	D_{rf}	[m]	12,5	35	100
	S L.	[m^2]			2.750.000
	V L.	[m^3]	5.781.250	18.591.417	200.000.000
	Trigger	text			heavy rainfall
	Prev. activations	dd/mm/yyyy	1736, 1802, 1851		1612, 1740
Dam	**Date of damming**	dd/mm/yyyy	06/1889	12/11/1725	1770
	Date of failure	dd/mm/yyyy		20/11/1725	
	d type	[ ]	I	IIIa	VI
	L d	[m]	50	150	250
	W d	[m]	425	400	500
	H d	[m]	10	40	25
	S d	[m^2]			
	V d	[m^3]	210.000	1.500.000	3.125.000
	Q d	[m] a.s.l.	335	690	585
	d condition	text	toe erosion	strongly cut	moderatly cut
	Evolution	text	not formed	breached days	breached days
	Type of Failure	text	-	overtopping	-
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	T. Nure	T. Ceno	F. Parma
	Wvalley	[m]	375	120	250
	Subt. S	[km^2]	256,39	64,33	76,94
	S	[°]	1	0,6	1,4
Lake	**Lake name**	text		L. di Illica	no name
	L lake	[m]		2.000	900 ?
	W lake	[m]		300	200 ?
	D lake	[m]		39	
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.		715	585
	h of Lac.dep.	[m]		4,5	
	Lake life time	[dd]	-	days	days
	Lake Condition	text	not formed for erosion	extinguished for dam collapse	extinguished

Localization	**ID**	[ ]	7	8	9
	Locality	text	Signatico	Cerredolo	Ciano
	Municipality	text	Corniglio	Toano	Canossa
	Province	text	Parma	R.Emilia	R.Emilia
	Region	text	Em.Rom.	Em.Rom	Em.Rom.
	UTM E, N crown	[ ]	589500, 4932500	627525, 4917375	612500, 4937800
	UTM E, N dam	[ ]	591192, 4931140	627331, 4918518	611400, 4937675
News	**L.-damages**	text	Provincial street n.13 and 15 buildings damaged		
	u-damages	text	Flooding for 2 km	Flooding	Flooding
	d-damages	text		breakage of an embankment of the Secchia already damaged from a previous flooding	
	Bibliography	text	Almagià (1907), Ermini (2000)	Colombetti et al. (1989),Ermini (2000)	Almagià (1907), Boccia (1804), Ermini (2000)
	Note	text	Landslide was breached to drain the water, in spite of this lake survived for few years	Gradual overflow through a deep men-made channel. Lake survived some time (lacustrine deposits)	
Landslide	**Movement**	text	flow	slump	slump
	Velocity	text	moderate	moderate	
	v	[m/s]	5,00E-04	5,00E-03	5,00E-05
	Material	text	debris	rock and debris	debris
	Lithology	text	marl and limestone	marl and limestone	clay
	Water c.	text	wet		wet
	H L.	[m]	363	305	245
	α	[°]	11	10	13
	β	[°]	9,55	13,6	10
	L L.tot.	[m]	2.427	1.400	1.640
	L L.body	[m]			1.050
	Wmax	[m]	725	500	750
	Wmin	[m]	200	200	300
	D_{rf}	[m]	36,25	33,33333333	37,5
	S L.	[m^2]	1.750.000	600.000	
	V L.	[m^3]	63.784.594	13.000.000	18.545.625
	Trigger	text	rocks orientation-features, river keep materials wet	heavy rainfall	heavy rainfall
	Prev. activations	dd/mm/yyyy	1836, 1879	1939	
Dam	**Date of damming**	dd/mm/yyyy	1896, 1947	05/1725	05/1725
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IIIa	IIIa	I
	L d	[m]	450	250	200
	W d	[m]	620	500	300
	H d	[m]	30	35	15
	S d	[m^2]	100.000	125.000	350.000
	V d	[m^3]	8.370.000	4.375.000	1.400.000
	Q d	[m] a.s.l.	467	330	195
	d condition	text	artificially cut	artificially cut	toe erosion
	Evolution	text	filled lake	man-made	not formed
	Type of Failure	text			-
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	F. Parma	F. Secchia	F. Enza
	Wvalley	[m]	300	250	660
	Subt. S	[km^2]	151,46	341	464,24
	S	[°]	0,65	0,4	0,2
Lake	**Lake name**	text	L. di Curatico - L.di Vestola	L.di Cerredolo	no name
	L lake	[m]	2.000	4.000	
	W lake	[m]	300	300	
	D lake	[m]	30	28	15
	S lake	[m^2]	550.000	942.000	
	V lake	[m^3]	8.000.000	13.188.000	
	Q lake	[m] a.s.l.	475	324,75	205
	h of Lac.dep.	[m]	5,0		
	Lake life time	[dd]	years	months	-
	Lake Condition	text	extinguished for filling and man-made influence	extinguished for man-made influence	not formed

Localization	ID	[ ]	10	11	12
	Locality	text	Cervarezza	Fontanaluccia	Boccassuolo
	Municipality	text	Busana	Frassinoro	Palagano
	Province	text	R.Emilia	Modena	Modena
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	606450, 4914550	621175, 4902250	629900, 4903675
	UTM E, N dam	[ ]	607531, 4914126	620104, 4903043	627050, 4904425
News	L.-damages	text	14 buildings destroyed and 24 damaged	A church and bell tower damaged, 7 barns, 1 cottage	
	u-damages	text		_	Flooding of Cargedolo
	d-damages	text			
	Bibliography	text	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)
	Note	text			
Landslide	Movement	text	complex	complex	complex
	Velocity	text	moderate		
	v	[m/s]	5,00E-05	5,00E-05	5,00E-05
	Material	text			rock and debris
	Lithology	text	clay, sandstone	clay, sandstone	clay, sandstone and ophiole
	Water c.	text			
	H L.	[m]	760	270	680
	α	[°]	27	14	14
	β	[°]	13	12,3	14
	L L.tot.	[m]	3.300	1.500	3.000
	L L.body	[m]	1.500		
	Wmax	[m]	1.200	500	750
	Wmin	[m]	300	350	300
	D_{rf}	[m]	78	25	37,5
	S L.	[m^2]	1.030.000	500.000	
	V L.	[m^3]	50.544.000	9.812.500	44.156.250
	Trigger	text			
	Prev. activations	dd/mm/yyyy	1472,1560,1697,1715		
Dam	Date of damming	dd/mm/yyyy	15/2/1832	15/2/1832	05/1598
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	IIIa
	L d	[m]	70	75	175
	W d	[m]	400	500	700
	H d	[m]	12	30	30
	S d	[m^2]		62.000	
	V d	[m^3]	170.000	1.000.000	3.600.000
	Q d	[m] a.s.l.	502	760	750
	d condition	text	partial blockage	partial blockage	slightly cut
	Evolution	text	not formed	not formed	gradual erosion
	Type of Failure	text	-	-	
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	F. Secchia	T. Dolo	T. Dragone
	Wvalley	[m]	440	100	120
	Subt. S	[km^2]	156,66	34,7	60,81
	S	[°]	1,3	2	1,7
Lake	Lake name	text			no name
	L lake	[m]			1.000
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	-	-	years
	Lake Condition	text	not formed for deviation	not formed	extinguished for filling and man-made influence

Localization	ID	[ ]	13	14	15
	Locality	text	Frassinoro	Tollara	Lama Mocogno
	Municipality	text	Frassinoro	Montefiorino	Lama Mocogno
	Province	text	Modena	Modena	Modena
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	625500, 4908450	626875, 4908800	637200, 4907000
	UTM E, N dam	[ ]	628435, 4906317	628950, 4907375	639050, 4905792
News	L.-damages	text	Distriction in 30 years of Sassatella village, 47 houses, about 1134 hectares of fields; this led many inhabitants to emigrate	Destruction of Casa Tollara (1886)	Destruction of a stretch of Giardini road and many houses
	u-damages	text			Flooding for 4 km
	d-damages	text			
	Bibliography	text	Almagià (1907), Soldati & Tosatti (1993), Ermini (2000)	Almagià (1907), Soldati & Tosatti (1993), Ermini (2000)	Almagià (1907), Ermini (2000)
	Note	text	Lake extension reducted by deposits (map from Soldati & Tosatti, 1993)		
Landslide	Movement	text	complex	complex	complex
	Velocity	text			
	v	[m/s]	5,00E-04	5,00E-04	5,00E-04
	Material	text	debris and earth	earth	
	Lithology	text	clay, sandstone and ophiolite	clay, sandstone and ophiolite	marl, limestone marly and mudstones
	Water c.	text		wet	
	H L.	[m]	640	505	430
	α	[°]	11	28	8
	β	[°]	11	12,44	10,33
	L L.tot.	[m]	3.805	2.550	2.660
	L L.body	[m]			
	Wmax	[m]	1.050	475	1.600
	Wmin	[m]	200	275	270
	D_{rf}	[m]	52,5	23,75	80
	S L.	[m^2]		800.000	1.500.000
	V L.	[m^3]	109.769.494	15.054.828	178.184.533
	Trigger	text	heavy rainfall		
	Prev. activations	dd/mm/yyyy		31/12/1886	1400,1574,1575,1689,1835,1864
Dam	Date of damming	dd/mm/yyyy	05/1598	31/12/1886	06/1879
	Date of failure	dd/mm/yyyy		31/12/1886	
	d type	[ ]	III b	II	IIIa
	L d	[m]	250	200	300
	W d	[m]	1.000	800	800
	H d	[m]	25	25	30
	S d	[m^2]			
	V d	[m^3]	6.250.000	7.000.000	8.000.000
	Q d	[m] a.s.l.	675	595	505
	d condition	text		slightly cut	moderatly cut
	Evolution	text	filled lake	filled lake	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Dragone	T. Dragone	T. Scoltenna
	Wvalley	[m]	125	125	125
	Subt. S	[km^2]	75,17	90,75	218,74
	S	[°]	1,7	4	1,14
Lake	Lake name	text	L. Casoni	L. di Toggiano	L. di Lama Mocogno
	L lake	[m]	1.000	600	1.375
	W lake	[m]	300	250	200
	D lake	[m]	20	15	20
	S lake	[m^2]			
	V lake	[m^3]			750.000
	Q lake	[m] a.s.l.			484
	h of Lac.dep.	[m]			
	Lake life time	[dd]		years	years
	Lake Condition	text	extinguished for filling	extinguished for filling and man-made influence	extinguished for spillway erosion and partly filled

Localization	**ID**	[ ]	16	17	18
	Locality	text	Caselle	Groppo	S.Anna Pelago
	Municipality	text	Fanano	Riolunato	Pievepelago
	Province	text	Modena	Modena	Modena
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	643930, 4894141	629450, 4899875	622501, 4893236
	UTM E, N dam	[ ]	643473, 4894056	631441, 4898654	624235, 4894599
News	**L.-damages**	text	Destruction of 2 buildings and 1 house and a chestnut	47 houses, 1 bridge and Giardini street destroyed	182 buildings, streets, bridges and crops destroyed
	u-damages	text	Flooding for 500 m of Fanano-Ospitale street	Flooding of Riolunato village	
	d-damages	text			
	Bibliography	text	Pellegrini & Tosatti (1982), Ermini (2000)	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)
	Note	text	Man-made emptying lake. Mines detonated on lake side to fill the depression	1 fatality; artificial excavation of a channel	
Landslide	**Movement**	text	slump	slump	complex
	Velocity	text		fast	fast
	v	[m/s]	1,39E-04	5,00E-03	5,00E-03
	Material	text	debris	rock and debris	
	Lithology	text	sandstone, marl and mudstones	sandstone, marl and mudstones	
	Water c.	text			
	H L.	[m]	200	560	556
	α	[°]	31	12	11
	β	[°]	25	14,5	10
	L L.tot.	[m]	500	2.400	3.540
	L L.body	[m]	380		2.000
	Wmax	[m]	500	400	2.500
	Wmin	[m]	150	200	
	D_{rf}	[m]	15	20	60
	S L.	[m^2]	14.000	600.000	7.000.000
	V L.	[m^3]	1.491.500	19.200.000	157.000.000
	Trigger	text	seismic event		
	Prev. activations	dd/mm/yyyy		1636	1590
Dam	**Date of damming**	dd/mm/yyyy	05/03/1952	09/12/1786	21/12/1896
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	III	VI
	L d	[m]	110	150	200
	W d	[m]	320	875	370
	H d	[m]	8	80	40
	S d	[m^2]			
	V d	[m^3]	200.000	10.500.000	1.500.000
	Q d	[m] a.s.l.	628	745	1034
	d condition	text	breached	artificially cut	slightly cut
	Evolution	text	breached days	man-made	breached days
	Type of Failure	text	overtopping		overtopping
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	T. Ospitale	T. Scoltenna	T. Perticara
	Wvalley	[m]	100	75	100
	Subt. S	[km^2]	23,3	147,3	7,88
	S	[°]	0,59	1,2	4,3
Lake	**Lake name**	text	no name	L. di Groppo	no name
	L lake	[m]	500	1.400	Lago vastissimo
	W lake	[m]	50	250	
	D lake	[m]	8	50	
	S lake	[m^2]		230.000	
	V lake	[m^3]		5.300.000	
	Q lake	[m] a.s.l.	628	740	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	months	days
	Lake Condition	text	extinguished for dam collapse	extinguished for man-made influence	extinguished

Localization	**ID**	[ ]	19	20	21
	Locality	text	Silvelle	Lotta	Arsicciola
	Municipality	text	Riolunato	Fanano	Fanano
	Province	text	Modena	Modena	Modena
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	631125, 4902125	641812, 4898725	640615, 4894350
	UTM E, N dam	[ ]	632125, 4900100	644597, 4897552	640537, 4894924
News	**L.-damages**	text		Destruction of Lotta village	15 houses and a church destroyed
	u-damages	text	Flooding	Flooding	Flooding
	d-damages	text			
	Bibliography	text	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)
	Note	text			3 fatalities (1677)
Landslide	**Movement**	text	flow	slump	slump
	Velocity	text			fast
	v	[m/s]		5,00E-04	5,00E-03
	Material	text			rock and debris
	Lithology	text	sandstone, marl and mudstones	sandstone, marl and mudstones	clay
	Water c.	text			
	H L.	[m]	496	510	285
	α	[°]	32	9	29
	β	[°]	13	9	17:06
	L L.tot.	[m]	2.300	3.290	1.000
	L L.body	[m]	1.700		
	Wmax	[m]	1.250	1.000	300
	Wmin	[m]	200	250	125
	D_{rf}	[m]	30	50	15
	S L.	[m^2]		1.900.000	
	V L.	[m^3]	33.362.500	86.088.333	2.355.000
	Trigger	text			heavy rainfall
	Prev. activations	dd/mm/yyyy			20/01/1677
Dam	**Date of damming**	dd/mm/yyyy	21/12/1619	12/4/1590	09/12/1728
	Date of failure	dd/mm/yyyy			10/12/1728
	d type	[ ]	III b	IIIa	II
	L d	[m]	175	300	175
	W d	[m]	250	1.050	250
	H d	[m]	20	40	20
	S d	[m^2]			
	V d	[m^3]	500.000	12.600.000	300.000
	Q d	[m] a.s.l.	640	480	760
	d condition	text	breached	moderatly cut	breached
	Evolution	text	breached hours	filled lake	breached hours
	Type of Failure	text	overtopping		overtopping
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	T. Scoltenna	T. Leo	T. Fellicaloro
	Wvalley	[m]	75	150	100
	Subt. S	[km^2]	151,6	76,65	17,28
	S	[°]	1,3	2	3,1
Lake	**Lake name**	text	no name	L.di Lotta	no name
	L lake	[m]	1.000	1.000	
	W lake	[m]		250	
	D lake	[m]		20	
	S lake	[m^2]		20.000	
	V lake	[m^3]		2.000.000	
	Q lake	[m] a.s.l.		475	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	years	hours
	Lake Condition	text	extinguished for dam collapse	extinguished for filling	extinguished for dam collapse

Localization	**ID**	[ ]	22	23,1	23,2
	Locality	text	Pozzadello	Bombiana	Pian di Casale
	Municipality	text	M.S.Pietro	Gaggio Montano	Gaggio Montano
	Province	text	Bologna	Bologna	Bologna
	Region	text	Em.Rom.	Em.Rom.	Em.Rom
	UTM E, N crown	[ ]	,	658500, 4898100	661800, 4895800
	UTM E, N dam	[ ]	,	660625, 4895900	661000, 4896175
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000)	Calindri (1781), Ermini (2000)	Ermini (2000)
	Note	text			
Landslide	**Movement**	text		complex	slide
	Velocity	text		moderate	moderate
	v	[m/s]		5,00E-05	5,00E-05
	Material	text		debris and earth	
	Lithology	text		clay	clay
	Water c.	text		wet	wet
	H L.	[m]		495	155
	α	[°]		9	10
	β	[°]		9,3	10,96
	L L.tot.	[m]		3.040	815
	L L.body	[m]			
	Wmax	[m]		600	375
	Wmin	[m]		80	200
	D_{rf}	[m]	0	30	18,75
	S L.	[m^2]	35.000		
	V L.	[m^3]		12.420.000	2.998.945
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy	03/1907		
	Date of failure	dd/mm/yyyy	02/03/1907		
	d type	[ ]	II	IV	IV
	L d	[m]	100	250	50
	W d	[m]	250	700	350
	H d	[m]	15	25	18,75
	S d	[m^2]	25.000		
	V d	[m^3]	370.000	4.375.000	315.000
	Q d	[m] a.s.l.		310	303,75
	d condition	text	breached	breached	breached
	Evolution	text	breached hours	breached months	breached months
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	**Main Basin**	text	Reno	Reno	Reno
	Dammed R.	text	T.Tradi'	F. Reno	F. Reno
	Wvalley	[m]	75	90	90
	Subt. S	[km^2]	1,5	260	260
	S	[°]		0,4	0,4
Lake	**Lake name**	text	no name	no name	no name
	L lake	[m]		1.560	1.560
	W lake	[m]		300	300
	D lake	[m]		25	25
	S lake	[m^2]		234.000	
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	months	months
	Lake Condition	text	extinguished for dam collapse	extinguished for dam collapse	extinguished for dam collapse

Localization	**ID**	[ ]	24	25	26
	Locality	text	Cinghiarello	Gardelletta	Maranina
	Municipality	text	Gaggio Montano	Marzabotto	Gaggio Montano
	Province	text	Bologna	Bologna	Bologna
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	658925, 4895875	678125, 4906600	661620, 4898620
	UTM E, N dam	[ ]	659550, 4894525	678325, 4907475	662280, 4898495
News	**L.-damages**	text		4 building and municipal road involved	5 buildings and astretch of Porrettana road destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000)	Catenacci (1992), Ermini (2000)	Calindri (1781), Ermini (2000), Carboni et al. (2001)
	Note	text	Narrowing of the river without lake formation	Formation of a meander in the river path	
Landslide	**Movement**	text	slump	complex	slump
	Velocity	text	moderate	moderate	moderate
	v	[m/s]	5,00E-05	5,00E-05	5,00E-05
	Material	text			earth
	Lithology	text	clay	clay	clay
	Water c.	text			wet
	H L.	[m]	255	180	137
	α	[°]	10	26	11
	β	[°]	10,06	11	11
	L L.tot.	[m]	1.500	1.000	700
	L L.body	[m]			
	Wmax	[m]	500	200	100
	Wmin	[m]	100	100	
	D_{rf}	[m]	25	10	10
	S L.	[m^2]		180.000	70.000
	V L.	[m^3]	9.375.000	2.000.000	700.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy	1901		1100
Dam	**Date of damming**	dd/mm/yyyy	16/02/1906	04/1989	05/02/1996
	Date of failure	dd/mm/yyyy	16/02/1906	02/04/1989	
	d type	[ ]	I	I	I
	L d	[m]	75	50	25
	W d	[m]	550	140	150
	H d	[m]	10	12	7
	S d	[m^2]		5.800	525
	V d	[m^3]	200.000	70.000	20.000
	Q d	[m] a.s.l.	330	197	266
	d condition	text	partial blockage	partial blockage	artificially stabilized
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text	-	-	-
Stream	**Main Basin**	text	Reno	Reno	Reno
	Dammed R.	text	F. Reno	T. Setta	F. Reno
	Wvalley	[m]	235	250	310
	Subt. S	[km^2]	256	275,25	281,34
	S	[°]	0,25	0,35	0,25
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	-	-	hours
	Lake Condition	text	not formed for erosion	not formed for erosion	not formed for erosion

Localization	ID	[ ]	27	28	29
	Locality	text	Serrazanetti	Castel dell'Alpi	Ca' Lamone
	Municipality	text	Gaggio montano	S.Benedetto val di Sambro	Brisighella
	Province	text	Bologna	Bologna	Ravenna
	Region	text	Em.Rom.	Em.Rom.	Em. Rom.
	UTM E, N crown	[ ]	658900, 4895800	681150, 4895550	721075, 4899225
	UTM E, N dam	[ ]	659586, 4894345	681800, 4895525	721087, 4899625
News	L.-damages	text	-	32 buildings involved	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000)	Elmi (1988), Elmi (1993), Ermini (2000)	Ermini (2000)
	Note	text	-	Building of a weir to preserve the dam and decrease erosion	The lake has not formed, just a still existing meander
Landslide	Movement	text		slump	
	Velocity	text	moderate	moderate	
	v	[m/s]	5,00E-05	5,00E-03	
	Material	text	debris		
	Lithology	text	clay	sandstone, marly limestone and mudstones	
	Water c.	text	wet		
	H L.	[m]	220	245	57
	α	[°]	7	9	9
	β	[°]	9	17	7
	L L.tot.	[m]	1.450	820	500
	L L.body	[m]			
	Wmax	[m]	500	500	100
	Wmin	[m]	220	190	75
	D_{rf}	[m]	25	25	5
	S L.	[m^2]	430.000	240.000	50.000
	V L.	[m^3]	18.125.000	5.364.167	130.833
	Trigger	text	heavy rainfall	heavy rainfall	
	Prev. activations	dd/mm/yyyy	1925	(1799;1870),1895,1909	
Dam	Date of damming	dd/mm/yyyy	17/02/1960	02/1955	1855
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	IIIa	I
	L d	[m]	50	200	200
	W d	[m]	220	460	75
	H d	[m]	10	45	5
	S d	[m^2]		80.000	
	V d	[m^3]	110.000	4.000.000	75.000
	Q d	[m] a.s.l.	290	675	
	d condition	text	partial blockage	artificially stabilized	partial blockage
	Evolution	text	not formed	existing lake/man-made	not formed
	Type of Failure	text	-		-
Stream	Main Basin	text	Reno	Reno	Lamone
	Dammed R.	text	F. Reno	T. Savena	T. Lamone
	Wvalley	[m]	100	80	760
	Subt. S	[km^2]	263,34	21,75	375,48
	S	[°]	0,25	1,4	0,8
Lake	Lake name	text		L.di Castel del'Alpi	
	L lake	[m]	-	900	-
	W lake	[m]	-	200	-
	D lake	[m]	-	40	-
	S lake	[m^2]	-		-
	V lake	[m^3]	-	1.500.000	-
	Q lake	[m] a.s.l.	-	695	-
	h of Lac.dep.	[m]	-	25,0	-
	Lake life time	[dd]	hours	years	-
	Lake Condition	text	not formed for erosion	existing partly filled	not formed

Localization	ID	[ ]	30	31	32,1
	Locality	text	Monteforca	Quarto di Savio	S.Piero in Bagno
	Municipality	text	Tredozio	Sarsina	Bagno di R.
	Province	text	Forli'	Forli'	Forli'
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	719412, 4882775	746825, 4866075	742600, 4858500
	UTM E, N dam	[ ]	718600, 4883425	747864, 4864320	739625, 4861500
News	L.-damages	text	4 farms with cottages destroyed	4 cottages and a church destroyed	Baroncini village and a church destroyed
	u-damages	text	Flooding	Flooding of the countrysides	Flooding to the outskirts of S.Piero in Bagno
	d-damages	text			
	Bibliography	text	Almagià (1907), Veggiani (1981), Ermini (2000)	Bertoni (1843), Gambi (1948), Ermini (2000)	Almagià (1907), Pesendorfer (1987), Ermini (2000)
	Note	text	11 fatalities; artificial excavation of a channel in the body of the landslide to prevent its failure	18 fatalities; the dam was lowered in 1828 with mines. Currently there is an artificial reservoir for hydroelectric purposes	
Landslide	Movement	text	slump	slump	slump
	Velocity	text	very fast	very fast	moderate
	v	[m/s]	5,00E-01	5,00E-01	5,00E-04
	Material	text	rock-(debris)		
	Lithology	text	sandstone, marl, mudstones	sandstone, marl, mudstones	clay, sandstone
	Water c.	text	wet		
	H L.	[m]	150	500	420
	α	[°]	12	18	13
	β	[°]	12,5	13	5
	L L.tot.	[m]	1.150	2.259	4.500
	L L.body	[m]			2.900
	Wmax	[m]	1.000	700	1.800
	Wmin	[m]	125	675	600
	D_{rf}	[m]	30	100	50
	S L.	[m^2]	1.000.000	2.000.000	5.000.000
	V L.	[m^3]	18.055.000	82.754.700	136.590.000
	Trigger	text	snow melting, heavy rainfall		
	Prev. activations	dd/mm/yyyy		1400,1584	1400,1584,1827
Dam	Date of damming	dd/mm/yyyy	28/03/1895	21/03/1812	22/02/1855
	Date of failure	dd/mm/yyyy			25/2/1855
	d type	[ ]	IIIa	IIIa	IV
	L d	[m]	200	400	280
	W d	[m]	1.000	600	800
	H d	[m]	15	70	15
	S d	[m^2]			
	V d	[m^3]	3.000.000	16.000.000	1.000.000
	Q d	[m] a.s.l.	390	315	445
	d condition	text	artificially cut	artificially cut	breached
	Evolution	text	man-made	filled lake/antrop.	breached days
	Type of Failure	text			overtopping
Stream	Main Basin	text	Lamone	Savio	Savio
	Dammed R.	text	T. Tramazzo	F. Savio-Para	F. Savio
	Wvalley	[m]	60	250	300
	Subt. S	[km^2]	33,6	214,8	81,55
	S	[°]	2	0,7	1,2
Lake	Lake name	text	no name	L. di Quarto	no name - just a flood
	L lake	[m]	600	1.550	500
	W lake	[m]	60	500	
	D lake	[m]	10	60	
	S lake	[m^2]		900.000	
	V lake	[m^3]		24.335.000	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days		days
	Lake Condition	text	extinguished for man-made influence	extinguished for man-made influence and partly filled	extinguished for dam collapse

Localization	ID	[ ]	32,2	33	34
	Locality	text	S.Piero in Bagno	Tozzi	Tajolo
	Municipality	text	Bagno di R.	Bagno di R.	S.Agata F.
	Province	text	Forli'	Forli'	Pesaro
	Region	text	Em.Rom.	Em.Rom	Marche
	UTM E, N crown	[ ]	738275, 4863700	741925, 4864650	757075, 4866250
	UTM E, N dam	[ ]	739750, 4861913	742100, 4863350	757310, 4866669
News	L.-damages	text		11 buildings destroyed	
	u-damages	text	Flooding to the outskirts of S.Piero in Bagno		Flooding
	d-damages	text			
	Bibliography	text	Almagià (1907), Pesendorfer (1987), Ermini (2000)	Almagià (1907), Ermini (2000)	Almagià (1907), Gambi (1948), Ermini (2000)
	Note	text			
Landslide	Movement	text		slump	complex
	Velocity	text	moderate	fast	fast
	v	[m/s]	5,00E-04	5,00E-04	5,00E-03
	Material	text			debris
	Lithology	text	clay, sandstone	sandstone, marl	chalks and clay
	Water c.	text			wet
	H L.	[m]	325	335	175
	α	[°]	13	22	12
	β	[°]	9	16,6	16,7
	L L.tot.	[m]	2.420	1.370	670
	L L.body	[m]	2.000	900	
	Wmax	[m]	300	400	675
	Wmin	[m]	200	200	100
	D_{rf}	[m]	15	20	33,75
	S L.	[m^2]			220.000
	V L.	[m^3]	4.710.000	3.140.000	7.987.866
	Trigger	text			
	Prev. activations	dd/mm/yyyy	1400,1584,1827		
Dam	Date of damming	dd/mm/yyyy	22/02/1856	1147	1855
	Date of failure	dd/mm/yyyy	25/2/1855		
	d type	[ ]	IV	I	IIIa
	L d	[m]	50	150	100
	W d	[m]	350	325	900
	H d	[m]	20	10	20
	S d	[m^2]			
	V d	[m^3]	262.500	300.000	2.500.000
	Q d	[m] a.s.l.	470	375	320
	d condition	text	breached	partial blockage	slightly cut
	Evolution	text	breached days	not formed	gradual erosion
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Savio	Savio	Savio
	Dammed R.	text	F. Savio	F. Savio	T. Fanante
	Wvalley	[m]	300	225	75
	Subt. S	[km^2]	81,55	110	13,17
	S	[°]	1,2	0,47	3,5
Lake	Lake name	text	no name - just a flood	no name	no name
	L lake	[m]	500		500
	W lake	[m]			70
	D lake	[m]			
	S lake	[m^2]			35.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			-
	Lake life time	[dd]	days	hours	years
	Lake Condition	text	extinguished for dam collapse	not formed-extinguished for dam collapse	extinguished for filling

Localization	ID	[ ]	35	36	37
	Locality	text	S.Agata Feltria	Caitasso	Tramarecchia
	Municipality	text	S.Agata F.	S.Marino	Badia Tedalda
	Province	text	Pesaro		Arezzo
	Region	text	Marche	Rep.S.Mar.	Toscana
	UTM E, N crown	[ ]	759725, 4862000	774800, 4871500	754750, 4845325
	UTM E, N dam	[ ]	755725, 4861400	774400, 4870550	754534, 4846472
News	L.-damages	text	64 buildings destroyed	Houses and fields destroyed	
	u-damages	text	Flooding		
	d-damages	text			
	Bibliography	text	Ermini (2000)	Ermini (2000)	Gambi (1948), Ermini (2000)
	Note	text			In March of 1948: Depth max 5 m. Surf. 50000 m2
Landslide	Movement	text	slump		complex
	Velocity	text	moderate		moderate
	v	[m/s]	5,00E-05		5,00E-04
	Material	text			rock-(debris)
	Lithology	text	clay		limestone, marl, mudstones
	Water c.	text			wet-(molto wet)
	H L.	[m]	593	195	200
	α	[°]	11	10	19
	β	[°]	8,2	11	9,4
	L L.tot.	[m]	4.530	1.020	1.200
	L L.body	[m]	3.000		
	Wmax	[m]	1.375	250	250
	Wmin	[m]	300	125	50
	D_{rf}	[m]	30	15	16,66666667
	S L.	[m^2]		1.200.000	160.000
	V L.	[m^3]	64.762.500	2.001.750	2.666.667
	Trigger	text			Fluvial erosion, dip slope
	Prev. activations	dd/mm/yyyy	1462	1855	
Dam	Date of damming	dd/mm/yyyy	03/1561	03/1854	15/12/1945
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IIIa	II	III
	L d	[m]	200	80	200
	W d	[m]	1.300	250	450
	H d	[m]		10	20
	S d	[m^2]			50.000
	V d	[m^3]	2.000.000	200.000	1.500.000
	Q d	[m] a.s.l.		190	590
	d condition	text	breached	partial blockage	moderatly cut
	Evolution	text	breached days	not formed	filled lake
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Savio	Marecchia	Marecchia
	Dammed R.	text	T. Marecchiola	T. S.Marino	Marecchia
	Wvalley	[m]	75	100	75
	Subt. S	[km^2]	10,79	27,03	40,8
	S	[°]	4,39	1,2	2
Lake	Lake name	text	no name		no name
	L lake	[m]			1.000
	W lake	[m]			200
	D lake	[m]			10
	S lake	[m^2]			98.000
	V lake	[m^3]			580.000
	Q lake	[m] a.s.l.			570
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	-	years
	Lake Condition	text	extinguished	not formed	extinguished for filling

Localization	ID	[ ]	38	39	40
	Locality	text	Lizzano	Campogalli	Gamberara
	Municipality	text	Lizzano	Pratovecchio	Marradi
	Province	text	Pistoia	Arezzo	Firenze
	Region	text	Toscana	Toscana	Toscana
	UTM E, N crown	[ ]	642737, 4882319	712400, 4858850	701175, 4878950
	UTM E, N dam	[ ]	641512, 4882419	713375, 4858075	709650, 4879775
News	L.-damages	text	Destruction of Lizzano and of a bridge over Lima River		
	u-damages	text	Flooding of Modenese road		Flooding
	d-damages	text			
	Bibliography	text	Almagià (1907), Ermini (2000)	Mori (1898), Almagià (1907), Ermini (2000)	Veggiani (1981), Ermini (2000)
	Note	text	In 1815 dam was breached by mines. Currently there is an artificial reservoir for hydroelectric purposes. The landslide is no more visible	A miller realized that something was wrong because water did not reach to his mill despite heavy rain	3 fatalities
Landslide	Movement	text	slide	slide	slide
	Velocity	text	fast	fast	fast
	v	[m/s]	5,00E-03	5,00E-02	5,00E-02
	Material	text	rock	rock	rock
	Lithology	text	sandstone	sandstone, mudstones	sandstone, marl, mudstones
	Water c.	text			
	H L.	[m]	400	369	200
	α	[°]	33	23	
	β	[°]	13	15	21
	L L.tot.	[m]	1.800	1.400	540
	L L.body	[m]			
	Wmax	[m]	750	300	250
	Wmin	[m]	500	175	300
	D_{rf}	[m]	40	15	15
	S L.	[m^2]			60.000
	V L.	[m^3]	28.260.000	6.300.000	2.025.000
	Trigger	text		heavy rainfall 56 mm. in 13 h	heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	31/01/1814	7-8/05/1898	15/04/1899
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	IIIa	IIIa
	L d	[m]	225	150	150
	W d	[m]	500	200	312
	H d	[m]	15	15	15
	S d	[m^2]	112.500	20.000	46.000
	V d	[m^3]	2.000.000	400.000	930.000
	Q d	[m] a.s.l.	555	646	465
	d condition	text	artificially cut	moderatly cut	moderatly cut
	Evolution	text	man-made	filled lake	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Serchio	Arno	Lamone
	Dammed R.	text	Lima	F. Arno	F. Campigno
	Wvalley	[m]	125	100	70
	Subt. S	[km^2]	83	15,32	22,1
	S	[°]	1,5	3,5	2,2
Lake	Lake name	text	L. di Lizzano	L. Virginia	L. di Gamberara
	L lake	[m]	1.125	140	300
	W lake	[m]	250	70	100
	D lake	[m]	14	12	15
	S lake	[m^2]	140.000	6.000	25.000
	V lake	[m^3]	8.400.000		
	Q lake	[m] a.s.l.	550	665	465
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	years	years
	Lake Condition	text	extinguished for man-made influence	extinguished for filling	extinguished for filling

Localization	ID	[ ]	41	42	43
	Locality	text	Farfareta	Boesimo	Boesimo2
	Municipality	text	Marradi	Brisighella	Brisighella
	Province	text	Firenze	Forlì	Forlì
	Region	text	Toscana	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	707975, 4876625	715575, 4891650	715575, 4891650
	UTM E, N dam	[ ]	707343, 4876925	714550, 4891400	715375, 4891240
News	L.-damages	text		4 cottages destroyed	
	u-damages	text		Flooding	
	d-damages	text			
	Bibliography	text	Veggiani (1981), Ermini (2000)	Ermini (2000)	Ermini (2000)
	Note	text	Not sure if it formed the lake or a simple waterlogging	10 fatalities; emptied by Ing. Pier Maria Gravina	
Landslide	Movement	text	slide	slump	slump
	Velocity	text	fast	fast	fast
	v	[m/s]	5,00E-02	5,00E-03	5,00E-03
	Material	text	rock	rock	rock
	Lithology	text	sandstone, marl, mudstones	sandstone, marl, mudstones	sandstone, marl, mudstones
	Water c.	text			
	H L.	[m]	215	165	165
	α	[°]	18	20	12
	β	[°]	16	7	7
	L L.tot.	[m]	800	1.500	1.500
	L L.body	[m]			
	Wmax	[m]	300	625	625
	Wmin	[m]	160	200	200
	D_{rf}	[m]	15	41,66666667	41,66666667
	S L.	[m²]	165.000	450.000	450.000
	V L.	[m³]	3.600.000	20.442.708	20.442.708
	Trigger	text		seismic event of 1688	seismic event of 1688
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy		11/04/1690	11/04/1690
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IIIa	IIIa	IIIa
	L d	[m]	70	150	150
	W d	[m]	200	250	300
	H d	[m]	15	20	40
	S d	[m²]	14.000	106.000	17.500
	V d	[m³]	280.000	500.000	1.500.000
	Q d	[m] a.s.l.	575	230	250
	d condition	text	moderatly cut	artificially cut	strongly cut
	Evolution	text	filled lake	man-made	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Lamone	Lamone	Lamone
	Dammed R.	text	F. Campigno	T. Lamone	R. Boesimo
	Wvalley	[m]	40	313	40
	Subt. S	[km²]	14,75	158,23	4,74
	S	[°]	2,7	0,2	3,6
Lake	Lake name	text	no name	no name	L.di Boesimo
	L lake	[m]	450	812	430
	W lake	[m]	100	250	150
	D lake	[m]		33	
	S lake	[m²]			
	V lake	[m³]			
	Q lake	[m] a.s.l.	575	235	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	months	years
	Lake Condition	text	extinguished for filling	extinguished for man-made influence	extinguished for filling

Localization	ID	[ ]	44	45	46
	Locality	text	Crespino	Sazzi	Sorbano
	Municipality	text	Marradi	Marradi	Sarsina
	Province	text	Firenze	Firenze	Forlì
	Region	text	Toscana	Toscana	Em.Rom.
	UTM E, N crown	[ ]	704650, 4880300	711525, 4884675	753500, 4869850
	UTM E, N dam	[ ]	704120, 4880006	710693, 4885018	754400, 4868550
News	L.-damages	text			Roman necropolis of Pian di Bezzo flooded
	u-damages	text			
	d-damages	text			
	Bibliography	text	Veggiani (1981), Ermini (2000)	Ermini (2000)	Veggiani (1951), Ermini (2000)
	Note	text			
Landslide	Movement	text	slide	slide	slide
	Velocity	text	fast	fast	fast
	v	[m/s]	5,00E-03	5,00E-03	5,00E-03
	Material	text	rock	rock	rock
	Lithology	text	sandstone, marl, mudstones	sandstone, marl, mudstones	sandstone, marl, mudstones
	Water c.	text			
	H L.	[m]		225	231
	α	[°]	20	15	17
	β	[°]		18	9,3
	L L.tot.	[m]	630	770	1.640
	L L.body	[m]			950
	Wmax	[m]	265	350	350
	Wmin	[m]			75
	D_{rf}	[m]	17,66666667	17,5	35
	S L.	[m^2]			360.000
	V L.	[m^3]	1.543.546	2.468.171	5.818.750
	Trigger	text	10°-15° dip slope of layers		
	Prev. activations	dd/mm/yyyy		1854	
Dam	Date of damming	dd/mm/yyyy	?	1895	Roman age
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	200		250
	W d	[m]	350		410
	H d	[m]	15		20
	S d	[m^2]			87.500
	V d	[m^3]	1.000.000		2.600.000
	Q d	[m] a.s.l.	517	300	189
	d condition	text	moderatly cut	breached	moderatly cut
	Evolution	text	filled lake	breached hours	filled lake
	Type of Failure	text		overtopping	
Stream	Main Basin	text	Lamone	Lamone	Savio
	Dammed R.	text	T. Lamone	T. Lamone	Savio
	Wvalley	[m]	80		225
	Subt. S	[km^2]	22	114,96	309,6
	S	[°]	1,0	1,3	1,1
Lake	Lake name	text	no name	no name	no name
	L lake	[m]	900	-	1.500
	W lake	[m]	150	-	500
	D lake	[m]		-	
	S lake	[m^2]		-	
	V lake	[m^3]		-	
	Q lake	[m] a.s.l.		-	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	hours	years
	Lake Condition	text	extinguished for filling	extinguished for filling	extinguished for filling and spillway erosion

Localization	**ID**	[ ]	47	48	49
	Locality	text	Montignoso	Cà di Sotto / S.Benedetto V.S.	P.ve S.Stefano
	Municipality	text	Montignoso	S.Benedetto V.S.	Pieve S.Stefano
	Province	text	Massa	Bologna	Arezzo
	Region	text	Toscana	Em.Rom.	Toscana
	UTM E, N crown	[ ]	594000, 4876000	679250, 4899750	746389, 4839616
	UTM E, N dam	[ ]	594214, 4875338	677517, 4899634	745669, 4838974
News	**L.-damages**	text			
	u-damages	text			Flooding of P.ve S.Stefano
	d-damages	text	Capanne village destroyed		
	Bibliography	text	Sforza (1867), Ermini (2000)	Casagli et al. (1995), Ermini (2000)	Mercanti (1859), Pesendorfer (1987), Cencetti, Viglione (1995), Ermini (2000)
	Note	text		Excavation of a channel to prevent the overtopping	4 fatalities
Landslide	**Movement**	text		complex	slump
	Velocity	text		fast	moderate
	v	[m/s]		5,00E-03	5,00E-04
	Material	text			rock and debris
	Lithology	text	micaschists	marl, limestone marly and mudstones	marly limestone
	Water c.	text		wet	
	H L.	[m]		350	450
	α	[°]	29	9	23
	β	[°]		11,1	14,4
	L L.tot.	[m]		1.133	1.300
	L L.body	[m]			
	Wmax	[m]		352	700
	Wmin	[m]		147	
	D_{rf}	[m]	0	25	35
	S L.	[m^2]		407.000	
	V L.	[m^3]		5.217.843	16.668.167
	Trigger	text	seismic events and heavy rainfall	heavy rainfall	seismic event, heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy	16/05/1771	26/06/1998	16/02/1855
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	III	IIIa
	L d	[m]		200	400
	W d	[m]		450	450
	H d	[m]		25	25
	S d	[m^2]			
	V d	[m^3]		1.125.000	4.500.000
	Q d	[m] a.s.l.		495	
	d condition	text	breached	strongly cut	artificially cut
	Evolution	text	breached hours	existing lake-man-made	man-made
	Type of Failure	text	overtopping		
Stream	**Main Basin**	text		Reno	Tevere
	Dammed R.	text		Sambro	F. Tevere
	Wvalley	[m]		80	300
	Subt. S	[km^2]		15,49	106,9
	S	[°]	15,2	1,2	0,9
Lake	**Lake name**	text	no name	L. di S.Benedetto V.d.S.	no name
	L lake	[m]		250	1.250
	W lake	[m]		40	450
	D lake	[m]			
	S lake	[m^2]		10.000	441.563
	V lake	[m^3]		330.000	3.000.000
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	years	months
	Lake Condition	text	extinguished for dam collapse	existing	extinguished for man-made influence

Localization	**ID**	[ ]	50	51	52
	Locality	text	Castagno d'Andrea	Sturaia di Galiga	Tollara
	Municipality	text	S.Godenzo	Pontassieve	Bettola
	Province	text	Firenze	Firenze	Piacenza
	Region	text	Toscana	Toscana	Em.Rom.
	UTM E, N crown	[ ]	716425, 4861650	697000, 4859825	546375, 4955350
	UTM E, N dam	[ ]	713076, 4865487	696803, 4858063	546568, 4955877
News	**L.-damages**	text			Some cottages Bettola a Farini road destroyed
	u-damages	text		Flooding of a farm	
	d-damages	text			
	Bibliography	text	Ermini (2000)	Almagià (1907), Ermini (2000)	Almagià (1907), Ermini (2000)
	Note	text			
Landslide	**Movement**	text	flow	complex	complex
	Velocity	text		moderate	
	v	[m/s]		2,30E-05	
	Material	text	debris	debris	debris
	Lithology	text	sandstone, mudstones	sandstone, limestone and mudstones	marly limestone, sandstone, mudstones
	Water c.	text		wet	wet
	H L.	[m]	1038	364	186
	α	[°]		23	11
	β	[°]	14,4	15,15	11,7
	L L.tot.	[m]	4.500	1.540	1.020
	L L.body	[m]			
	Wmax	[m]	550	250	200
	Wmin	[m]	250	100	150
	D_{rf}	[m]	27,5	12,5	10
	S L.	[m^2]		450.000	
	V L.	[m^3]	68.062.500	2.518.542	1.067.600
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy		01/05/1898	03/1895
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	340	150	75
	W d	[m]	460	160	250
	H d	[m]	30	15	15
	S d	[m^2]			
	V d	[m^3]	2.000.000	360.000	180.000
	Q d	[m] a.s.l.	487	226	366
	d condition	text		moderatly cut	strongly cut
	Evolution	text		filled lake	breached hours
	Type of Failure	text			overtopping?
Stream	**Main Basin**	text	Arno	Arno	Po
	Dammed R.	text	F.sso Falterona	T. Argomenna	R. Camia
	Wvalley	[m]	240	75	40
	Subt. S	[km^2]	11,66	8,48	9,82
	S	[°]	3,1	2,5	4,7
Lake	**Lake name**	text		no name	?
	L lake	[m]		300	
	W lake	[m]		120	
	D lake	[m]		13	
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]		years	hours
	Lake Condition	text		extinguished for filling	extinguished for dam collapse

Localization	ID	[ ]	53	54	55
	Locality	text	Le Mottacce	Serelli	S.Patrignano
	Municipality	text	Subbiano	Stia	Badia Tedalda
	Province	text	Arezzo	Arezzo	Arezzo
	Region	text	Toscana	Toscana	Toscana
	UTM E, N crown	[ ]	731397, 4829898	714170, 4857180	,
	UTM E, N dam	[ ]	731665, 4829707	714373, 4856868	756100, 4846450
News	L.-damages	text		12 houses of Serelli village and Stia-Londa road destroyed	Weir damaged
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000), Cencetti et al. (2011)	Ermini (2000)	Ermini (2000)
	Note	text		Seepage under the dam	
Landslide	Movement	text	slump	complex	slide
	Velocity	text	moderate	moderate	very fast
	v	[m/s]	5,00E-05	5,00E-04	5,00E-03
	Material	text	debris	rock stone	rock stone
	Lithology	text	silt sandy clay	sandstone and silty shale	marly limestone, mudstones
	Water c.	text		damp	
	H L.	[m]	140	150	60
	α	[°]	10	20	20
	β	[°]	16	20	15,5
	L L.tot.	[m]	420	400	50
	L L.body	[m]			
	Wmax	[m]	250	500	180
	Wmin	[m]			
	D_{rf}	[m]	12,5	25	10
	S L.	[m^2]		150.000	
	V L.	[m^3]	686.875	5.000.000	90.000
	Trigger	text		heavy rainfall, dip slope layers	Fluvial erosion
	Prev. activations	dd/mm/yyyy		1966	
Dam	Date of damming	dd/mm/yyyy	27/11/1987	12/12/1992	
	Date of failure	dd/mm/yyyy		13/12/1992	
	d type	[ ]	I	II	I
	L d	[m]	50	80	
	W d	[m]	150	50	
	H d	[m]	10	12	
	S d	[m^2]			
	V d	[m^3]	50.000	50.000	60.000
	Q d	[m] a.s.l.	260	642	520
	d condition	text	partial blockage	moderatly cut	partial blockage
	Evolution	text	not formed	breached hours	not formed
	Type of Failure	text	-	eros. int. e trac.	-
Stream	Main Basin	text	Arno	Arno	Marecchia
	Dammed R.	text	F. Arno	T. Vallucciole	Marecchia
	Wvalley	[m]	150	70	155
	Subt. S	[km^2]	738	2,8	41,38
	S	[°]	0,2	5	2
Lake	Lake name	text		no name	
	L lake	[m]		40	
	W lake	[m]		25	
	D lake	[m]		12	
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	-	hours	-
	Lake Condition	text	not formed for deviation	extinguished	not formed for deviation

	ID	[ ]	56	57	58
Localization	Locality	text	Popiglio (La Lima)	Pian de' Romiti	F.sso Falterona
	Municipality	text	S. Marcello Pistoiese	Portico e S.Benedetto	S. Godenzo
	Province	text	Pistoia	Forlì	Firenze
	Region	text	Toscana	Em.Rom.	Toscana
	UTM E, N crown	[ ]	640688, 4879175	712290, 4874100	716771, 4863152
	UTM E, N dam	[ ]	641575, 4880150	712080, 4874270	716223, 4863118
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000)	Ermini (2000)	Ermini (2000)
	Note	text	Excavation of a channel to help the flow of water		A debris flow on the dam itself
Landslide	Movement	text		slide	slump
	Velocity	text	moderate	fast	
	v	[m/s]	5,00E-04	5,00E-02	5,00E-03
	Material	text	debris	bedrock	debris
	Lithology	text	sandstone and limestone marly	sandstone, marl, mudstones	sandstone and siltstones
	Water c.	text			wet
	H L.	[m]	360	25	350
	α	[°]	25	15	17
	β	[°]	22	5	30
	L L.tot.	[m]	325	300	700
	L L.body	[m]		160	530
	Wmax	[m]	400	120	200
	Wmin	[m]	300	50	
	D_{rf}	[m]	30	20	10
	S L.	[m^2]	300.000		120.000
	V L.	[m^3]	3.900.000	720.000	1.400.000
	Trigger	text		water infiltration, decrease of shear strength	Fluvial erosion
	Prev. activations	dd/mm/yyyy	1579, 1280		1335, 1641, 1827
Dam	Date of damming	dd/mm/yyyy			26/02/1960
	Date of failure	dd/mm/yyyy			26/02/1960
	d type	[ ]	IIIa	II	II
	L d	[m]	200	160	100
	W d	[m]	275	150	200
	H d	[m]	30	20	20
	S d	[m^2]			
	V d	[m^3]	1.800.000	600.000	400.000
	Q d	[m] a.s.l.	470	720	1020
	d condition	text	strongly cut	slightly cut	moderatly cut
	Evolution	text	gradual erosion	filled lake	gradual erosion
	Type of Failure	text			
Stream	Main Basin	text	Serchio	Montone	Arno
	Dammed R.	text	Lima	T. Acquacheta	F.sso Falterona
	Wvalley	[m]	100	20	25
	Subt. S	[km^2]	107,8	13,17	2,07
	S	[°]	1,1	0,5	10
Lake	Lake name	text	no name	no name (Pian de' Romiti)	
	L lake	[m]	900	700	
	W lake	[m]	125	120	
	D lake	[m]	15	10	
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	years	days
	Lake Condition	text	extinguished for spillway erosion	extinguished for filling	extinguished for dam collapse

Localization	ID	[ ]	59	60	61
	Locality	text	Terrarossa	Cavallico	Campiano
	Municipality	text	Marzabotto	Scarperia	S.Benedetto V.S.
	Province	text	Bologna	Firenze	Bologna
	Region	text	Em.Rom.	Toscana	Em.Rom.
	UTM E, N crown	[ ]	671717, 4910736	,	676460, 4900500
	UTM E, N dam	[ ]	671871, 4911561	688615, 4879265	677723, 4900045
News	L.-damages	text	Crops destroyed		
	u-damages	text	Flooding		
	d-damages	text			
	Bibliography	text	Ermini (2000)	Ermini (2000)	Calindri (1781), Elmi (1988), Ermini (2000)
	Note	text	Landslide caused a river deviation but a channel was excavated to help the flow of water	Lake extension are deducted by lacustrine deposits (Ermini, 2000)	
Landslide	Movement	text	flow	complex	complex
	Velocity	text	moderate		very fast
	v	[m/s]	5,00E-04	5,00E-05	5,00E-03
	Material	text	earth	debris	debris
	Lithology	text	clay	clay, sandstone	marl, marly limestone and mudstones
	Water c.	text	wet	wet	wet
	H L.	[m]	136	469	315
	α	[°]	8	10	18
	β	[°]	9,1	14	12,46
	L L.tot.	[m]	950	2.150	1.460
	L L.body	[m]			
	Wmax	[m]	100	960	1.225
	Wmin	[m]	40	600	925
	D_{rf}	[m]	5	48	61,25
	S L.	[m²]	100.000	2.000.000	
	V L.	[m³]	475.000	51.847.680	57.328.877
	Trigger	text	heavy rainfall		
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			04/02/1772
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IIIa	III	III
	L d	[m]	30	150	150
	W d	[m]	120	850	750
	H d	[m]	15	20	35
	S d	[m²]			
	V d	[m³]	120.000	2.500.000	3.500.000
	Q d	[m] a.s.l.	251	471	435
	d condition	text	partial blockage	strongly cut	strongly cut
	Evolution	text	man-made	filled lake	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Reno	Arno	Reno
	Dammed R.	text	T. Venola	T. Levisone	Sambro
	Wvalley	[m]	30	170	80
	Subt. S	[km²]	17,55	2,71	15,49
	S	[°]	1,24	6,4	1,2
Lake	Lake name	text	no name		L. di Campiano
	L lake	[m]		350	1.000
	W lake	[m]		150	170
	D lake	[m]			
	S lake	[m²]			
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	years	years
	Lake Condition	text	not formed	extinguished for filling	extinguished for filling

Localization	ID	[ ]	62	63	64
	Locality	text	S.Benedetto in Alpe	Roncovetro	Gallare
	Municipality	text	Portico e S.Benedetto	Ciano D'Enza	Farini
	Province	text	Forlì	R.Emilia	Piacenza
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	715300, 4873730	610500, 4931100	546000, 4951500
	UTM E, N dam	[ ]	715220, 4873420	610058, 4928817	545379, 4951699
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ermini (2000)	Ermini (2000)	Ermini (2000)
	Note	text	Over the river a wire was built upstream of the collapsed section	Materials were initially removed, then let them down as fast as possible to avoid overtopping risk	
Landslide	Movement	text	slide	complex	slump
	Velocity	text	fast	moderate	moderate
	v	[m/s]	5,00E-04		2,30E-05
	Material	text	bedrock	debris	
	Lithology	text	sandstone, marl, mudstones	clay, marl	marl, marly limestone and mudstones
	Water c.	text		wet	wet
	H L.	[m]	125	335	90
	α	[°]	19	14	15
	β	[°]	20	7,8	11,53
	L L.tot.	[m]	350	2.500	590
	L L.body	[m]		1.500	400
	Wmax	[m]	200	280	110
	Wmin	[m]	80	60	80
	D_{rf}	[m]	15	15	25
	S L.	[m^2]			140.000
	V L.	[m^3]	1.050.000	3.297.000	575.667
	Trigger	text		heavy rainfall	Fluvial erosion
	Prev. activations	dd/mm/yyyy		06\02\1899	
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	I
	L d	[m]	100	140	70
	W d	[m]	200	180	150
	H d	[m]	15	10	20
	S d	[m^2]			
	V d	[m^3]	400.000	150.000	112.500
	Q d	[m] a.s.l.	515	325	421
	d condition	text	strongly cut	artificially stabilized	artificially stabilized
	Evolution	text	filled lake	man-made	not formed
	Type of Failure	text			
Stream	Main Basin	text	Montone	Po	Po
	Dammed R.	text	T. Acquacheta	Tassobbio	T. Nure
	Wvalley	[m]	50	40	175
	Subt. S	[km^2]	32,4	87,39	109
	S	[°]	1,6	3,4	0,6
Lake	Lake name	text	no name	no name	
	L lake	[m]		200	
	W lake	[m]		35	
	D lake	[m]		3	
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	months	-
	Lake Condition	text	extinguished for filling	extinguished for man-made influence	not formed for deviation

Localization	**ID**	[ ]	65	66	67
	Locality	text	Scapriano	Frassineta	Reggello
	Municipality	text	Teramo	Chiusi della Verna	Reggello
	Province	text	Teramo	Arezzo	Firenze
	Region	text	Abruzzo	Toscana	Toscana
	UTM E, N crown	[ ]	883860, 4735903	733607, 4849805	701455, 4845241
	UTM E, N dam	[ ]	883075, 4735809	734223, 4849622	,
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Provasi (1929), Il Centrale, Il Corriere abruzzese 14-15 Luglio 1900, Catalogo AVI		Ermini (2000)
	Note	text			
Landslide	**Movement**	text	complex	complex	slide
	Velocity	text		fast	very slow
	v	[m/s]	5,00E-04	5,00E-05	5,00E-10
	Material	text		debris	
	Lithology	text	clay	sandstone and siltstones	
	Water c.	text		wet	
	H L.	[m]	135	183	45
	α	[°]	13	14	
	β	[°]	10,9	18	30
	L L.tot.	[m]	700	630	170
	L L.body	[m]			
	Wmax	[m]	200	170	90
	Wmin	[m]			
	D_{rf}	[m]		12	
	S L.	[m^2]		36.000	7.000
	V L.	[m^3]	2.000.000	453.600	40.000
	Trigger	text		Fluvial erosion, heavy rainfall	
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	I	I
	L d	[m]	120	15	15
	W d	[m]	350	150	75
	H d	[m]	15	5	5
	S d	[m^2]			
	V d	[m^3]	650.000	5.625	2.813
	Q d	[m] a.s.l.	325	667	
	d condition	text	moderatly cut	partial blockage	partial blockage
	Evolution	text	gradual erosion	not formed	not formed
	Type of Failure	text			
Stream	**Main Basin**	text	Tordino	Arno	Arno
	Dammed R.	text	T. Aprutina	T. Rimaggio	T. Vicano
	Wvalley	[m]	105	80	70
	Subt. S	[km^2]	11,23	1,22	25,09
	S	[°]	6,8	10,5	5,0
Lake	**Lake name**	text	L. Scapriano		
	L lake	[m]	700		
	W lake	[m]	10		
	D lake	[m]	5		
	S lake	[m^2]	5.495		
	V lake	[m^3]	27.475		
	Q lake	[m] a.s.l.	325		
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	-	-
	Lake Condition	text	extinguished	not formed	not formed

Localization	**ID**	[ ]	68	69	70
	Locality	text	Scanno	Corella	Prato Casarile, Cartagenova
	Municipality	text	Scanno	Dicomano	Genova
	Province	text	L'Aquila	Firenze	Genova
	Region	text	Abruzzo	Toscana	Liguria
	UTM E, N crown	[ ]	904478, 4654578	706003,5, 4868970	500215, 4924309
	UTM E, N dam	[ ]	901762, 4653192	705636, 4869012	499588, 4924640
News	**L.-damages**	text		1 house destroyed	
	u-damages	text			
	d-damages	text			bridge and house (1953), street (1970) destroyed
	Bibliography	text	Nicoletti et al. (1993), Scarascia Mugnozza et al. (2006)	Ermini (2000)	Ermini (2000)
	Note	text		Excavation of a channel to help the flow of water	Ephemeral lake
Landslide	**Movement**	text	complex	complex	slump
	Velocity	text	very fast	fast	
	v	[m/s]	5,00E-02	5,00E-03	
	Material	text	bedrock	debris	debris
	Lithology	text	limestone	marly sandstone	marl, marly limestone and mudstones
	Water c.	text			
	H L.	[m]	495	85	120
	α	[°]	28	6	18
	β	[°]	11,7	12,6	40-20
	L L.tot.	[m]	3.200	389	700
	L L.body	[m]	2.400		
	Wmax	[m]	2.000	260	600
	Wmin	[m]			
	D_{rf}	[m]	50	12,6	
	S L.	[m^2]	2.600.000	55.500	260.000
	V L.	[m^3]	82.000.000	666.917	11.000.000
	Trigger	text		heavy rainfall	
	Prev. activations	dd/mm/yyyy			1970, 1992
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	III
	L d	[m]	500	50	200
	W d	[m]	2.000	200	450
	H d	[m]	33,1	6	40
	S d	[m^2]			
	V d	[m^3]	17.000.000	60.000	1.750.000
	Q d	[m] a.s.l.	935	426	265
	d condition	text	not cut	artificially cut	slightly cut/artificially stabilized
	Evolution	text	existing lake	man-made	filled lake
	Type of Failure	text			-
Stream	**Main Basin**	text	Pescara	Arno	Bisagno
	Dammed R.	text	T. Tasso	F.sso Corella	T. Molassana
	Wvalley	[m]	200	50	200
	Subt. S	[km^2]	95	4,83	1,5
	S	[°]	0,6	3,5	21,8
Lake	**Lake name**	text	L. di Scanno	?	L. di Prato Casarile
	L lake	[m]	1.600		250
	W lake	[m]	690		150
	D lake	[m]	21		30
	S lake	[m^2]	866.640		
	V lake	[m^3]	26.000.000		300.000
	Q lake	[m] a.s.l.	928		260
	h of Lac.dep.	[m]			
	Lake life time	[dd]	millennia		
	Lake Condition	text	existing	existing	extinguished for filling

Localization	ID	[ ]	71	72	73
	Locality	text	Palagione	Scascoli	Succisa
	Municipality	text	Volearth	Loiano	Pontremoli
	Province	text	Pisa	Bologna	Massa
	Region	text	Toscana	Em.Rom.	Toscana
	UTM E, N crown	[ ]	654526, 4805597	683050, 4909448	,
	UTM E, N dam	[ ]	654504, 4806475	683110, 4909430	570235, 4918105
News	L.-damages	text		complete obstruction of the main Fondovalle Savena road	Provincial Road n.38 damaged
	u-damages	text			
	d-damages	text			
	Bibliography	text		Bertolini & Pizziolo (2006)	
	Note	text			
Landslide	Movement	text	slide	topple	complex
	Velocity	text		very fast	fast?
	v	[m/s]		5,00E-03	5,00E-04
	Material	text	earth	bedrock	rock and debris
	Lithology	text	flysch sandy-marly	marl and marl limestonee	sandstone, siltstones and marl
	Water c.	text			wet
	H L.	[m]	115	15	200
	α	[°]	12	20	15
	β	[°]	7,3	10,6	39
	L L.tot.	[m]	900	80	320
	L L.body	[m]		50	
	Wmax	[m]	280	85	160
	Wmin	[m]			
	D_{rf}	[m]			7
	S L.	[m^2]			
	V L.	[m^3]	2.000.000	70.000	200.000
	Trigger	text		Fluvial erosion, discontinuities	heavy rainfall, dip slope layers
	Prev. activations	dd/mm/yyyy		1992	2003
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	II
	L d	[m]	100	30	75
	W d	[m]	270	70	120
	H d	[m]	10	5	5
	S d	[m^2]			
	V d	[m^3]	150.000	10.000	25.000
	Q d	[m] a.s.l.	248	300	383
	d condition	text	slightly cut/artificially stabilized	artificially cut	partial blockage
	Evolution	text	existing lake-man-made	man-made	breached hours
	Type of Failure	text			
Stream	Main Basin	text	Arno	Reno	Magra Lugure
	Dammed R.	text	T. Era Morta	T. Savena	T. Magriola
	Wvalley	[m]	80	25	75
	Subt. S	[km^2]	11	91	19,3
	S	[°]	1,2	0,8	1,9
Lake	Lake name	text	L. del Palagione	no name	-
	L lake	[m]	650	200	-
	W lake	[m]	75	50	-
	D lake	[m]		5	-
	S lake	[m^2]	25.000	7.850	-
	V lake	[m^3]		39.250	-
	Q lake	[m] a.s.l.	245		-
	h of Lac.dep.	[m]		-	
	Lake life time	[dd]	years	days	hours
	Lake Condition	text	existing	extinguished for man-made influence	not formed for deviation

Localization	ID	[ ]	74	75	76
	Locality	text	Schiazzano	Corniolo	Valderchia
	Municipality	text	Pellegrino Parmense	Santa Sofia	Gubbio
	Province	text	Parma	Forlì Cesena	Perugia
	Region	text	Em.Rom.	Em.Rom.	Umbria
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	576524, 4951227	725797, 4864982	788670, 4809475
News	L.-damages	text		2 houses, 300 m of Provincial Road n.4 destroyed	2 houses destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text			Cencetti et al. (2006)
	Note	text			
Landslide	Movement	text	flow	slide	complex
	Velocity	text	very fast	fast	fast
	v	[m/s]	5,00E-02	5,00E-04	2,00E-03
	Material	text	debris and earth	rock	debris
	Lithology	text	mudstones and sandstone	mudstones and sandstone	marly limestone
	Water c.	text	wet	wet	
	H L.	[m]	75	325	110
	α	[°]	12	22	25
	β	[°]	51,3	18,0	14,3
	L L.tot.	[m]	225	1.000	430
	L L.body	[m]	60	530	400
	Wmax	[m]	70	420	170
	Wmin	[m]		200	
	D_{rf}	[m]	15	15	15
	S L.	[m^2]			
	V L.	[m^3]	40.000	3.000.000	500.000
	Trigger	text	heavy rainfall	heavy rainfall	snowfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			06/01/1997
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	II
	L d	[m]	40	180	110
	W d	[m]	65	350	160
	H d	[m]	15	15	9
	S d	[m^2]			
	V d	[m^3]	20.000	500.000	100.000
	Q d	[m] a.s.l.	288	498	605
	d condition	text	artificially cut	artificially stabilized	artificially cut
	Evolution	text	man-made	existing lake	man-made
	Type of Failure	text			
Stream	Main Basin	text	Po	Ronco	Tevere
	Dammed R.	text	T. Dordia	F.sso Bidente di Corniolo	T. S. Donato
	Wvalley	[m]	40	140	90
	Subt. S	[km^2]	5,6	47,8	4,5
	S	[°]	1,9	0,9	3,1
Lake	Lake name	text		L. di Poggio Baldi	-
	L lake	[m]	300	1.000	90
	W lake	[m]	15	100	42
	D lake	[m]	2,5	17	2
	S lake	[m^2]	3.533		2.967
	V lake	[m^3]	8.831	400.000	5.935
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	years	days
	Lake Condition	text	extinguished for man-made influence	existing	extinguished for man-made influence

Localization	ID	[ ]	77	78	79
	Locality	text	Castello di Serravalle	Pasconi	Boschi di Valoria
	Municipality	text	Serravalle di Chienti	San Giorgio la Molara	Frassinoro
	Province	text	Macerata	Benevento	Modena
	Region	text	Marche	Campania	Em.Rom.
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	821352, 4775908	994626, 4582015	621507, 4909242
News	L.-damages	text	distruction of a Romans castle		
	u-damages	text			
	d-damages	text			
	Bibliography	text	Valensise & Guidoboni (2000)		Leuratti et al. (2007), Ronchetti et al. (2007)
	Note	text	500 fatalities		
Landslide	Movement	text	complex	slide	complex
	Velocity	text	extremely fast		fast
	v	[m/s]	5		1,50E-04
	Material	text	debris		earth
	Lithology	text	marly limestone	clay	clay
	Water c.	text			wet
	H L.	[m]	390	0	810
	α	[°]	22		11
	β	[°]	24,9		13,0
	L L.tot.	[m]	1.030	600	3.500
	L L.body	[m]	840		2.000
	Wmax	[m]	280	300	620
	Wmin	[m]			
	D_{rf}	[m]	10		10
	S L.	[m^2]			1.300.000
	V L.	[m^3]	1.000.000	1.500.000	13.000.000
	Trigger	text	seismic event	seismic event	heavy rainfall
	Prev. activations	dd/mm/yyyy		1805, 1930, 1962	1951, 1956, 1972, 1978, 1981, 1984, 2000, 2001
Dam	Date of damming	dd/mm/yyyy	30/04/1279		2001
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	VI	II
	L d	[m]	180		190
	W d	[m]	230		340
	H d	[m]	10		4
	S d	[m^2]			
	V d	[m^3]	200.000		150.000
	Q d	[m] a.s.l.	672	228	530
	d condition	text	strongly cut	toe erosion	moderatly cut
	Evolution	text	breached hours	not formed	breached hours
	Type of Failure	text		-	overtopping
Stream	Main Basin	text	Chienti	Volturno	Po
	Dammed R.	text	F. Chienti di Gelagna	F. Tammaro	T. Dolo
	Wvalley	[m]	130	140	250
	Subt. S	[km^2]	54	578	77,6
	S	[°]	2,6	1,0	1,7
Lake	Lake name	text		-	
	L lake	[m]		-	
	W lake	[m]		-	
	D lake	[m]		-	
	S lake	[m^2]		-	
	V lake	[m^3]		-	
	Q lake	[m] a.s.l.		-	
	h of Lac.dep.	[m]		-	-
	Lake life time	[dd]	hours	-	hours
	Lake Condition	text	extinguished for dam collapse	not formed x deviazione	extinguished for spillway erosion

Localization	ID	[ ]	80	81	82
	Locality	text	Rosola	Roccalbegna	Piaggiagrande-Renaio
	Municipality	text	Zocca	Roccalbegna	Barga
	Province	text	Modena	Grosseto	Lucca
	Region	text	Em.Rom.	Toscana	Toscana
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	654358, 4908857	704576, 4740321	620607, 4882043
News	L.-damages	text			2 houses destrpyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Brunamonte (1998)		
	Note	text			
Landslide	Movement	text	flow	complex	slump
	Velocity	text	moderate	moderate	fast
	v	[m/s]	5,00E-06	5,00E-05	5,00E-04
	Material	text	debris	earth	rock and debris
	Lithology	text	clay	clay	sandstone and mudstones
	Water c.	text		wet	wet
	H L.	[m]	90	234	83
	α	[°]	11	9	20
	β	[°]	4,3	10,2	18,7
	L L.tot.	[m]	1.200	1.300	245
	L L.body	[m]	620	1.300	215
	Wmax	[m]	350	400	130
	Wmin	[m]	60		
	D_{rf}	[m]	12	20	30
	S L.	[m^2]		400.000	
	V L.	[m^3]	1.000.000	8.000.000	700.000
	Trigger	text		heavy rainfall, lithology, quiescent landslide	
	Prev. activations	dd/mm/yyyy			2010
Dam	Date of damming	dd/mm/yyyy			19/01/2014
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	II
	L d	[m]	150	170	90
	W d	[m]	330	110	100
	H d	[m]	6	10	15
	S d	[m^2]			
	V d	[m^3]	250.000	75.000	100.000
	Q d	[m] a.s.l.	290	545	560
	d condition	text	moderatly cut	artificially cut	not cut
	Evolution	text	not formed	man-made	man-made
	Type of Failure	text			
Stream	Main Basin	text	Po	Albegna	Serchio
	Dammed R.	text	Rio Rivella	T. Armancione	Rio Loppora
	Wvalley	[m]	180	80	60
	Subt. S	[km^2]	39,45	9	1,3
	S	[°]	3,5	10,2	9,5
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			2.000
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	-	-	months
	Lake Condition	text	not formed for deviation	not formed	existing

Localization	ID	[ ]	83	84	85,1
	Locality	text	Salto	Camporella	Ossola
	Municipality	text	Montese	Ramiseto	Valmozzola
	Province	text	Modena	R.Emilia	Parma
	Region	text	Em.Rom.	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	655542, 4905377	597875, 4919846	573748, 4937059
News	L.-damages	text			Provincial Road n.42 damaged
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	complex	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	rock and debris	debris	debris
	Lithology	text	limestone and sandstone	marly limestone and sandstone	clay
	Water c.	text			
	H L.	[m]	151	260	170
	α	[°]	13	11	14
	β	[°]	20,7	13,3	7,7
	L L.tot.	[m]	400	1.100	1.250
	L L.body	[m]	300	1.000	950
	Wmax	[m]	250	300	270
	Wmin	[m]		180	75
	D_{rf}	[m]	15	50	15
	S L.	[m^2]			
	V L.	[m^3]	1.000.000	5.000.000	3.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy		27/11/1908	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	IV
	L d	[m]	240	350	180
	W d	[m]	200	250	210
	H d	[m]	10	20	15
	S d	[m^2]			
	V d	[m^3]	240.000	900.000	300.000
	Q d	[m] a.s.l.	695	489	290
	d condition	text	slightly cut	strongly cut	breached
	Evolution	text	filled lake	gradual erosion	breached days
	Type of Failure	text	-	overtopping	overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	Rio Acqua Salata	T. Era	T. Mozzola
	Wvalley	[m]	110	320	110
	Subt. S	[km^2]	1,3	79	42
	S	[°]	3,6	1,9	1,1
Lake	Lake name	text	L. Bracciano (omonimo)		
	L lake	[m]		400	
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			-
	Lake life time	[dd]	millennia	years	days
	Lake Condition	text	extinguished for filling	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	85,2	86	87
	Locality	text	Ossola	Montelago	Settefrati
	Municipality	text	Valmozzola	Sassoferrato	Casapalombo
	Province	text	Parma	Ancona	Macerata
	Region	text	Em.Rom.	Marche	Marche
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	573748, 4937059	805689, 4816184	845134, 4775406
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text		Savelli et al. (2013, 2012)	
	Note	text			
Landslide	Movement	text	flow	slump	complex
	Velocity	text			fast
	v	[m/s]			5,00E-04
	Material	text	debris	rock and debris	rock and debris
	Lithology	text	clay	marly limestone	marly limestone
	Water c.	text			
	H L.	[m]	255	305	63
	α	[°]		25	26
	β	[°]	13,1	31,4	18,8
	L L.tot.	[m]	1.100		185
	L L.body	[m]	140	500	135
	Wmax	[m]	130	420	180
	Wmin	[m]			
	D_{rf}	[m]	15	30	27
	S L.	[m^2]			
	V L.	[m^3]	150.000	6.000.000	343.359
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IV	VI	II
	L d	[m]	85	280	75
	W d	[m]	115	310	150
	H d	[m]	10	15	8
	S d	[m^2]			
	V d	[m^3]	90.000	700.000	60.000
	Q d	[m] a.s.l.		739	682
	d condition	text	breached	slightly cut	not cut
	Evolution	text	breached days	filled lake	existing lake-effimero
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Po	Esino	Chienti
	Dammed R.	text	T. Mozzola	F.sso del Lago	Rio del Monte
	Wvalley	[m]	111	140	45
	Subt. S	[km^2]	42	2	2
	S	[°]	1,1	6,5	17,2
Lake	Lake name	text		no name	no name
	L lake	[m]		200	110
	W lake	[m]		85	30
	D lake	[m]			
	S lake	[m^2]		13.345	2.591
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]	-	13,0	
	Lake life time	[dd]	days	millennia	years
	Lake Condition	text	extinguished for spillway erosion	extinguished for filling	existing-ephemeral

Localization	ID	[ ]	88	89	90
	Locality	text	Benedello	Tassinaro	Draga
	Municipality	text	Marano sul Panaro	Gissi	Maierato
	Province	text	Modena	Chieti	Vibo Valentia
	Region	text	Em.Rom.	Abruzzo	Calabria
	UTM E, N crown	[ ]	651656, 4917859	,	,
	UTM E, N dam	[ ]	651463, 4916515	958761, 4669141	1124904, 4308370
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	flow	flow	complex
	Velocity	text	fast		very fast
	v	[m/s]	5,00E-04		5,00E-01
	Material	text	rock and debris	debris	earth
	Lithology	text	clay	clay and clay marly	sands, clay and limestone
	Water c.	text			wet
	H L.	[m]	246	74	240
	α	[°]	12	14	12
	β	[°]	10,0	10,7	9,7
	L L.tot.	[m]	1.400	390	1.400
	L L.body	[m]	830	275	1.200
	Wmax	[m]	480	170	500
	Wmin	[m]			
	D_{rf}	[m]	20	5	20
	S L.	[m^2]			300.000
	V L.	[m^3]	3.500.000	100.000	6.500.000
	Trigger	text			heavy rainfall
	Prev. activations	dd/mm/yyyy			1932
Dam	Date of damming	dd/mm/yyyy	21/02/1979		15/02/2010
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	III
	L d	[m]	420	100	550
	W d	[m]	340	170	350
	H d	[m]	10	4	10
	S d	[m^2]			
	V d	[m^3]	500.000	20.000	1.000.000
	Q d	[m] a.s.l.	311	197	240
	d condition	text	toe erosion	partial blockage	artificially cut
	Evolution	text	gradual erosion	not formed	man-made
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Panaro	Sinello	Angitola
	Dammed R.	text	Rio Benedello	F.sso Tassinaro	F.sso Scuotrapiti
	Wvalley	[m]	90	130	135
	Subt. S	[km^2]	18	4	4
	S	[°]	1,7	2,3	3,8
Lake	Lake name	text	-		Maretto (1932)
	L lake	[m]	600		250
	W lake	[m]			40
	D lake	[m]			1
	S lake	[m^2]			7.850
	V lake	[m^3]			7.850
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]	-	-	-
	Lake life time	[dd]	days	-	months
	Lake Condition	text	extinguished for spillway erosion	not formed for deviation	extinguished for man-made influence

Localization	**ID**	[ ]	91	92	93
	Locality	text	Acquaviva	Laurenzana	Bardea
	Municipality	text	Montazzoli	Laurenzana	Palanzano
	Province	text	Chieti	Potenza	Parma
	Region	text	Abruzzo	Basilicata	Em.Rom.
	UTM E, N crown	[ ]	,	,	601834, 4924202
	UTM E, N dam	[ ]	950643, 4655811	1092348, 4501796	601651, 4924065
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	**Movement**	text		flow	flow
	Velocity	text		very fast	moderate
	v	[m/s]		5,00E-02	5,00E-06
	Material	text	debris	debris	debris
	Lithology	text	sandstone, marly limestone	sandstone limestonee	sandstone, mudstone
	Water c.	text		wet	
	H L.	[m]	485	103	49
	α	[°]	14	14	21
	β	[°]	13,6	9,9	12,0
	L L.tot.	[m]	2.000	590	230
	L L.body	[m]	1.100	360	130
	Wmax	[m]	350	90	140
	Wmin	[m]			
	D_{rf}	[m]			10
	S L.	[m^2]			
	V L.	[m^3]	600.000	300.000	200.000
	Trigger	text		heavy rainfall	
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy		01/03/2005	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	III	II
	L d	[m]	160	90	100
	W d	[m]	180	360	130
	H d	[m]	12	8	5
	S d	[m^2]			
	V d	[m^3]	150.000	135.000	35.000
	Q d	[m] a.s.l.	671	1225	
	d condition	text	artificially cut	partial blockage	toe erosion
	Evolution	text	man-made	not formed	not formed
	Type of Failure	text		-	-
Stream	**Main Basin**	text	Sinello	Basento	Po
	Dammed R.	text	F. Sinello	F.sso Scarrantone	T. Bardea
	Wvalley	[m]	90	90	80
	Subt. S	[km^2]	19	4	25
	S	[°]	1,2	6,0	2,4
Lake	**Lake name**	text	L. di Acquaviva	-	-
	L lake	[m]		-	-
	W lake	[m]		-	-
	D lake	[m]		-	-
	S lake	[m^2]		-	-
	V lake	[m^3]		-	-
	Q lake	[m] a.s.l.		-	-
	h of Lac.dep.	[m]			-
	Lake life time	[dd]	days	-	-
	Lake Condition	text	extinguished for spillway erosion	not formed	not formed for deviation

Localization	**ID**	[ ]	94	95	96
	Locality	text	Zillona	Voltre	Cà di Rico
	Municipality	text	Trecchina	Civitella di Romagna	Dovadola
	Province	text	Potenza	Forlì Cesena	Forlì Cesena
	Region	text	Basilicata	Em.Rom.	Em.Rom.
	UTM E, N crown	[ ]	567327, 4430053	,	,
	UTM E, N dam	[ ]	1080228, 4451778	743572, 4879449	733219, 4889230
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Dal Sasso (2014)		
	Note	text			
Landslide	**Movement**	text	complex	slide	slide
	Velocity	text		moderate	fast
	v	[m/s]		5,00E-05	5,00E-04
	Material	text	rock and debris	debris and earth	earth
	Lithology	text	limestone, marl and clay	mudstones and sandstone	mudstones and sandstone
	Water c.	text	wet	wet	
	H L.	[m]	145	115	65
	α	[°]	14	7	9
	β	[°]	12,6	9,1	9,0
	L L.tot.	[m]	650	719	410
	L L.body	[m]	375	690	380
	Wmax	[m]	160	150	170
	Wmin	[m]	130	100	
	D_{rf}	[m]	10	10	10
	S L.	[m^2]			
	V L.	[m^3]	350.000	1.000.000	500.000
	Trigger	text	heavy rainfall	heavy rainfall	
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			12/04/2005
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	II
	L d	[m]	110	65	95
	W d	[m]	130	110	100
	H d	[m]	10	4	5
	S d	[m^2]			
	V d	[m^3]	100.000	20.000	25.000
	Q d	[m] a.s.l.	198	221	181
	d condition	text	toe erosion	sbarram. parziale	not cut-artificially stabilized
	Evolution	text	breached days	not formed	existing lake
	Type of Failure	text	overtopping		
Stream	**Main Basin**	text	Noce	Ronco	Montone
	Dammed R.	text	F. Noce	T. Voltre	Rio Pezzolo
	Wvalley	[m]	110	260	65
	Subt. S	[km^2]	240	25	2,8
	S	[°]	1,1	0,9	2,7
Lake	**Lake name**	text	no name	-	no name
	L lake	[m]		-	150
	W lake	[m]		-	20
	D lake	[m]		-	
	S lake	[m^2]		-	2.355
	V lake	[m^3]		-	
	Q lake	[m] a.s.l.		-	
	h of Lac.dep.	[m]	-		
	Lake life time	[dd]	days	-	years
	Lake Condition	text	extinguished for dam collapse	not formed	existing

Localization	ID	[ ]	97	98	99
	Locality	text	Lago Costantino	Ronchi	Covatta
	Municipality	text	San Luca	Varsi	Ripalimosani
	Province	text	R.Calabria	Parma	Campobasso
	Region	text	Calabria	Em.Rom.	Molise
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1114653, 4246003	572345, 4942675	968163, 4625514
News	L.-damages	text			SS 647 street damaged
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			15 fatalities
Landslide	Movement	text	flow	slump	complex
	Velocity	text	very fast	fast	fast
	v	[m/s]	5,00E-02	5,00E-04	5,00E-05
	Material	text	debris and earth	debris	earth
	Lithology	text	silt, sandstone, conglomerate and clay	sandy limestoneo	mudstones (weakly sandy)
	Water c.	text	wet	wet	wet
	H L.	[m]	320	115	280
	α	[°]	25	9	7
	β	[°]	28,1	14,0	11,1
	L L.tot.	[m]	600	460	1.430
	L L.body	[m]	360	410	700
	Wmax	[m]	750	365	500
	Wmin	[m]			
	D_{rf}	[m]	130	20	10
	S L.	[m²]			
	V L.	[m³]	16.000.000	2.000.000	2.000.000
	Trigger	text	heavy rainfall	heavy rainfall	Fluvial erosion at the base of the slope
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	31/12/1972		12/04/1996
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	III
	L d	[m]	220	160	200
	W d	[m]	530	190	400
	H d	[m]	100	20	5
	S d	[m²]			
	V d	[m³]	6.000.000	300.000	200.000
	Q d	[m] a.s.l.	602		327
	d condition	text	strongly cut	slightly cut	artificially cut
	Evolution	text	existing lake-interrito-breached years	existing lake	man-made
	Type of Failure	text			
Stream	Main Basin	text	Bonamico	Po	Biferno
	Dammed R.	text	Fiumara Bonamico	T. Pessola	F. Biferno
	Wvalley	[m]	200	110	250
	Subt. S	[km²]	41	24,5	606
	S	[°]	3,4	1,9	0,3
Lake	Lake name	text	L. Costantino	no name	no name
	L lake	[m]	2400	400	850
	W lake	[m]		100	45
	D lake	[m]	18	15	
	S lake	[m²]		31.400	
	V lake	[m³]	7.000.000	471.000	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	months	days
	Lake Condition	text	existing partly filled	existing	extinguished for man-made influence

Localization	ID	[ ]	100	101	102
	Locality	text	Caridi	Pantana	S. Cristina
	Municipality	text	Soriano	Polistena	Santa Cristina D'Aspromonte
	Province	text	Vibo Valentia	R.Calabria	R.Calabria
	Region	text	Calabria	Calabria	Calabria
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1130074, 4297580	1118863, 4273738	1108958, 4257488
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			Ruberti (1787)
	Note	text			
Landslide	Movement	text	slump	complex	complex
	Velocity	text	very fast	very fast	very fast
	v	[m/s]	5,00E-02	5,00E-02	5,00E-02
	Material	text	debris and earth	debris	debris
	Lithology	text	complex mudstone sandy	sands, sandstone (?)	pelitic sandy complex
	Water c.	text		dry	dry
	H L.	[m]	0	0	101
	α	[°]	17		13
	β	[°]			7,2
	L L.tot.	[m]			800
	L L.body	[m]			750
	Wmax	[m]			1.200
	Wmin	[m]			
	D_{rf}	[m]			70
	S L.	[m^2]			
	V L.	[m^3]	3.000.000		25.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	05/02/1783	05/02/1783	05/02/1783
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	IV-VI?	VI
	L d	[m]			450
	W d	[m]			850
	H d	[m]			50
	S d	[m^2]			
	V d	[m^3]	1.000.000		10.000.000
	Q d	[m] a.s.l.	245	265	340
	d condition	text	strongly cut	artificially cut	artificially cut
	Evolution	text	breached days	man-made	filled lake-man-made
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Mesima	Mesima	Petrace
	Dammed R.	text	T. Calitri	T. Jerapotamo	T. Calabretto
	Wvalley	[m]	150		250
	Subt. S	[km^2]	10	12	21
	S	[°]	6,3	4,5	3,0
Lake	Lake name	text	no name	Pantana	L. di S. Cristina ?
	L lake	[m]		600	1270
	W lake	[m]		500	450
	D lake	[m]			50
	S lake	[m^2]			448.628
	V lake	[m^3]			22.431.375
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	months	years
	Lake Condition	text	extinguished for spillway erosion	extinguished for man-made influence	extinguished for filling

Localization	ID	[ ]	103	104	105
	Locality	text	Marro	Birbo	De' Preti
	Municipality	text	Molochio	Oppido Mamertina	Oppido Mamertina
	Province	text	R.Calabria	R.Calabria	R.Calabria
	Region	text	Calabria	Calabria	Calabria
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1114359, 4265480	1111969, 4260305	1108778, 4264906
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ruberti (1787)	Ruberti (1787)	Ruberti (1787)
	Note	text			
Landslide	Movement	text	complex	slump	complex
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	debris	debris and earth	debris and earth
	Lithology	text	sands, sandstone, gravels	sands, sandstone, gravels	sandy gravels
	Water c.	text	dry	dry	dry
	H L.	[m]	58	0	0
	α	[°]	8	16	12
	β	[°]	4,4		
	L L.tot.	[m]	750		
	L L.body	[m]	650		
	Wmax	[m]	700		
	Wmin	[m]			
	D_{rf}	[m]	50		
	S L.	[m²]			
	V L.	[m³]	15.000.000	2.000.000	
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	05/02/1783	05/02/1783	05/02/1783
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	190	150	
	W d	[m]	470	350	
	H d	[m]	25	30	
	S d	[m²]			
	V d	[m³]	1.200.000	750.000	
	Q d	[m] a.s.l.	186	330	125
	d condition	text	breached	artificially cut	artificially cut
	Evolution	text	breached days	man-made	man-made
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Petrace	Petrace	Petrace
	Dammed R.	text	T. Marro		T. Porcello
	Wvalley	[m]	150	100	310
	Subt. S	[km²]	38	5	17
	S	[°]	1,9	6,6	1,9
Lake	Lake name	text	L. Marro	L. Birbo	L. De' Preti
	L lake	[m]	1000	830	750
	W lake	[m]	400	290	140
	D lake	[m]	30	30	10
	S lake	[m²]	314.000	188.950	82.425
	V lake	[m³]	9.420.000	5.668.485	824.250
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	months	months
	Lake Condition	text	extinguished for spillway erosion	extinguished for man-made influence	extinguished for man-made influence

Localization	**ID**	[ ]	106	107	108
	Locality	text	Cumi	Tricuccio	Cucco
	Municipality	text	Oppido Mamertina	Oppido Mamertina	Cosoleto
	Province	text	R.Calabria	R.Calabria	R.Calabria
	Region	text	Calabria	Calabria	Calabria
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1108721, 4262667	1109550, 4262670	1106525, 4260436
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ruberti (1787)	Ruberti (1787)	Ruberti (1787)
	Note	text			
Landslide	**Movement**	text	slump	complex	slump
	Velocity	text			
	v	[m/s]			
	Material	text	debris and earth	debris and earth	debris and earth
	Lithology	text	marl and clay sands	pelitic sandy complex	marl and claystones
	Water c.	text	dry	dry	dry
	H L.	[m]	61	0	19
	α	[°]	11	16	23
	β	[°]	4,4		2,2
	L L.tot.	[m]	800		500
	L L.body	[m]	710		360
	Wmax	[m]	900		270
	Wmin	[m]			
	D_{rf}	[m]	60		20
	S L.	[m^2]			
	V L.	[m^3]	20.000.000		1.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy	05/02/1783	05/02/1783	05/02/1783
	Date of failure	dd/mm/yyyy			
	d type	[ ]	VI	II	II
	L d	[m]	560		200
	W d	[m]	750		270
	H d	[m]	40		12
	S d	[m^2]			
	V d	[m^3]	8.000.000		300.000
	Q d	[m] a.s.l.	140	205	245
	d condition	text	artificially cut	moderatly cut	artificially cut
	Evolution	text	filled lake-man-made	filled lake	man-made
	Type of Failure	text			
Stream	**Main Basin**	text	Petrace	Petrace	Petrace
	Dammed R.	text	T. Calabretto	T. Riganti	T. Duverso (affluente)
	Wvalley	[m]	210	200	115
	Subt. S	[km^2]	44	3	7
	S	[°]	2,0	3,4	7,8
Lake	**Lake name**	text	L. Cumi	L. Tricuccio	L. Cucco
	L lake	[m]	1300	1100	550
	W lake	[m]	700	120	250
	D lake	[m]	40	20	17
	S lake	[m^2]	714.350	103.620	107.938
	V lake	[m^3]	28.574.000	2.072.400	1.834.938
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	months	years
	Lake Condition	text	extinguished for filling	extinguished for filling	extinguished for man-made influence

Localization	ID	[ ]	109	110	111
	Locality	text	Speziale	Coluce	S. Bruno
	Municipality	text	Cosoleto	Oppido Mamertina	Sinopoli
	Province	text	R.Calabria	R.Calabria	R.Calabria
	Region	text	Calabria	Calabria	Calabria
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1107304, 4260964	1106004, 4262800	1105566, 4260963
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Ruberti (1787)	Ruberti (1787)	Ruberti (1787)
	Note	text			
Landslide	Movement	text		complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debris and earth	debris and earth	debris and earth
	Lithology	text	marl and claystones	marl and claystones	marl and claystones
	Water c.	text	dry	dry	dry
	H L.	[m]	0	0	0
	α	[°]	8		12
	β	[°]			
	L L.tot.	[m]			
	L L.body	[m]			850
	Wmax	[m]			1.100
	Wmin	[m]			
	D_{rf}	[m]			35
	S L.	[m^2]			
	V L.	[m^3]			20.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	05/02/1783	05/02/1783	05/02/1783
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	IV-VI?
	L d	[m]			
	W d	[m]			
	H d	[m]			
	S d	[m^2]			
	V d	[m^3]			10.000.000
	Q d	[m] a.s.l.	180	130	220
	d condition	text	artificially cut	artificially cut	artificially cut
	Evolution	text	man-made	filled lake-man-made	man-made
	Type of Failure	text			
Stream	Main Basin	text	Petrace	Petrace	Petrace
	Dammed R.	text	T. Duverso	T. Duverso	T. Duverso (affluente)
	Wvalley	[m]	170	260	400
	Subt. S	[km^2]	41	62	4,5
	S	[°]	3,3	2,3	4,1
Lake	Lake name	text	L. Speziale		L. di S. Bruno (o Voragine)
	L lake	[m]	480	850	1400
	W lake	[m]	350	170	730
	D lake	[m]	12	27	35
	S lake	[m^2]	131.880	113.433	802.270
	V lake	[m^3]	1.582.560	3.062.678	28.079.450
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	years	years
	Lake Condition	text	extinguished for man-made influence	extinguished for filling	extinguished for man-made influence

Localization	ID	[ ]	112	113	114
	Locality	text	Tofilo	Antrona	Sernio
	Municipality	text	Seminara	Antrona Schieranco	Sernio
	Province	text	R.Calabria	Novara	Sondrio
	Region	text	Calabria	Piemonte	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	1103668, 4268255	430085, 5100679	592475, 5120021
News	L.-damages	text			
	u-damages	text			Flooding of Lovero and crops
	d-damages	text			Tirano partly destroyed
	Bibliography	text	Ruberti (1787)	Montandon (1933), Pirocchi (1991)	Montandon (1933), Eisbacher & Clague (1984), Pirocchi (1991)
	Note	text		93 fatalities; Partly filled	3 fatalities
Landslide	Movement	text	slump	fall	complex
	Velocity	text		very fast	extremely fast
	v	[m/s]		0,05	7
	Material	text		debris and rock	debris
	Lithology	text	marl and claystones	gneiss and micascist	gneiss, micaschists, filladi, gabbri and dioriti
	Water c.	text	dry	dry	wet
	H L.	[m]	0	1500	570
	α	[°]	9	35	30
	β	[°]		45	31
	L L.tot.	[m]		2.900	
	L L.body	[m]		1.200	
	Wmax	[m]		1.700	
	Wmin	[m]		200	
	D_{rf}	[m]		80	43
	S L.	[m^2]		1.970.000	?
	V L.	[m^3]		28.000.000	2.500.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy		1965, 1973	
Dam	Date of damming	dd/mm/yyyy	05/02/1783	27/07/1642	07/12/1807
	Date of failure	dd/mm/yyyy		/	16/05/1808
	d type	[ ]	II / VI	III	III
	L d	[m]		900	300
	W d	[m]		1.800	930
	H d	[m]		50	43
	S d	[m^2]		1.350.000	100.000
	V d	[m^3]		20.000.000	2.000.000
	Q d	[m] a.s.l.		1073	520
	d condition	text	artificially cut	slightly cut	strongly cut
	Evolution	text	man-made	existing lake	breached months
	Type of Failure	text		-	overtopping
Stream	Main Basin	text	Petrace	Po	Po
	Dammed R.	text	F.so Carrà	T. Troncone	F. Adda
	Wvalley	[m]		620	300
	Subt. S	[km^2]	13	40,8	891
	S	[°]	1,6	6,4	0,9
Lake	Lake name	text	L. Tofilo	Lago di Antrona	
	L lake	[m]	630	820	2.580
	W lake	[m]	330	630	830
	D lake	[m]	19	49	40
	S lake	[m^2]	163.202	300.000	1.440.000
	V lake	[m^3]	3.100.829	6.700.000	22.000.000
	Q lake	[m] a.s.l.		1.074	540
	h of Lac.dep.	[m]		1,0	
	Lake life time	[dd]	years	centuries	months
	Lake Condition	text	extinguished for man-made influence	existing	extinguished for spillway erosion

Localization	ID	[ ]	115	116	117
	Locality	text	Val Pola	Alleghe	Val Vanoi
	Municipality	text	Valdisotto	Alleche	Canal San Bovo
	Province	text	Sondrio	Belluno	Trento
	Region	text	Lombardia	Veneto	Trentino
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	604095, 5138265	731503, 5142402	709036, 5116378
News	L.-damages	text	Santonio Morignone, Morignone, Poz, Tirindè, S.Martino and part of Aquilone destroyed		
	u-damages	text		Flooding up to Caprile	Flooding of 36 house in Ponte
	d-damages	text			Remesori destroyed
	Bibliography	text	Lunardi (1988), Pirocchi (1991), Govi et al. (2002), Crosta et al. (2004)	Montandon (1933), Eisbacher & Clague (1984), Pirocchi (1991)	Zaniboni (1877), Montandon (1933), Eisbacher & Clague (1984), Pirocchi (1991)
	Note	text	29 fatalities; two by-pass galleries, excavation of an overflow channel, downstream construction of weirs	49 (1807) + 3 (1808) fatalities; high rate of filling	52 fatalities
Landslide	Movement	text	fall	slump	complex
	Velocity	text	very fast	very fast	moderate
	v	[m/s]	5,00E-02	5,00E-02	5,00E-05
	Material	text		debrisbedrock	debris
	Lithology	text	dioriti, gabbri, gneiss and micaschists	limestone and dolomite	gneiss, filladi and quarziti
	Water c.	text			
	H L.	[m]	1340	900	820
	α	[°]	19		
	β	[°]	32	30	25
	L L.tot.	[m]	2.035	2.000	2.428
	L L.body	[m]	900	750	600
	Wmax	[m]	1.700	1.400	1.200
	Wmin	[m]			
	D_{rf}	[m]	90	70	100
	S L.	[m^2]	3.110.000	1.350.000	1.330.000
	V L.	[m^3]	40.000.000	20.000.000	15.000.000
	Trigger	text	Fluvial erosion, heavy rainfall		
	Prev. activations	dd/mm/yyyy	previous events		1793, 1823
Dam	Date of damming	dd/mm/yyyy		11/01/1771	12/1825
	Date of failure	dd/mm/yyyy	30/08/1987	/	25/02/1909
	d type	[ ]	III	III	III
	L d	[m]	860	550	500
	W d	[m]	1.700	1.375	1.000
	H d	[m]	50	16	40
	S d	[m^2]	1.710.000	550.000	490.000
	V d	[m^3]	35.000.000	5.500.000	10.000.000
	Q d	[m] a.s.l.	1107	966	760
	d condition	text	artificially cut	moderatly cut	breached
	Evolution	text	man-made	existing lake	breached years
	Type of Failure	text	svuotamento	-	overtopping
Stream	Main Basin	text	Po	Piave	Brenta
	Dammed R.	text	F. Adda	F. Cordevole	T. Vanoi
	Wvalley	[m]	400	400	300
	Subt. S	[km^2]	540	248	167
	S	[°]	1,2	0,8	1,6
Lake	Lake name	text		Lago di Alleghe	Lago Nuovo
	L lake	[m]	3.100	4.500	2.000
	W lake	[m]	450	550	950
	D lake	[m]	60	50	40
	S lake	[m^2]	920.000	1.040.000	570.000
	V lake	[m^3]	20.000.000	15.000.000	18.200.000
	Q lake	[m] a.s.l.	1.100	967	
	h of Lac.dep.	[m]		15,0	0,5-0,8
	Lake life time	[dd]	months	centuries	years
	Lake Condition	text	extinguished for man-made influence	existing	extinguished

Localization	ID	[ ]	118	119	120
	Locality	text	Kummersee	Borta	Rovina
	Municipality	text	Mosso in Passiria	Socchieve	Entracque
	Province	text	Bolzano	Udine	Cuneo
	Region	text	Trentino	Friuli	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	664618, 5190779	791720, 5143547	367787, 4893646
News	L.-damages	text		Town of Barga destroyed	
	u-damages	text			
	d-damages	text	1419 villages destroyed, 1503, 1512, 1572 Merano damaged, 1721, 1772, 1774 buildings of Merano destroyed		
	Bibliography	text	Eisbacher & Clague (1984), Pirocchi (1991)	Montandon (1933), Cavallin & Martinis (1974), Pirocchi (1991), Porton & Podda (1995), Podda (2000), Ponton et al. (2002)	Sacco (1927), Pirocchi (1991)
	Note	text	400 fatalities	53 fatalities (166 in a '700 narrative)	Purely filled, currently there is an artificial reservoir for hydroelectric purposes (ENEL)
Landslide	Movement	text	complex	slump	fall
	Velocity	text			very fast
	v	[m/s]			5,00E-02
	Material	text	rock and debris	debrisbedrock e debris	debrisbedrock e debris
	Litholgy	text	micaschists, gneiss, quarziti, limestone	limestone and dolomite	gneiss
	Water c.	text			
	H L.	[m]	250	925	150
	α	[°]			
	β	[°]	30	30	12,1
	L L.tot.	[m]		2.200	600
	L L.body	[m]		950	700
	Wmax	[m]		1.150	980
	Wmin	[m]		150	
	D_{rf}	[m]	100	100	50
	S L.	[m^2]	580.000	1.090.000	
	V L.	[m^3]	7.000.000	30.000.000	8.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	1401	15/08/1692	Prehistoric
	Date of failure	dd/mm/yyyy	1419, 1503, 1512, 1572, 1721, 1772, 1774		
	d type	[ ]	III	III	III
	L d	[m]	300	600	400
	W d	[m]	600	1.150	900
	H d	[m]	50	70	15
	S d	[m^2]	170.000	600.000	
	V d	[m^3]	6.000.000	23.000.000	2.000.000
	Q d	[m] a.s.l.	1.325	580	1.540
	d condition	text	breached	breached	slightly cut
	Evolution	text	breached years	breached years	existing lake
	Type of Failure	text	overtopping	overtopping	-
Stream	Main Basin	text	Adige	Tagliamento	Po
	Dammed R.	text	F. Passirio	F. Tagliamento	T. Bucera
	Wvalley	[m]	200	250	350
	Subt. S	[km^2]	85	190	17,2
	S	[°]	1,1	0,5	20,9
Lake	Lake name	text	Kummersee (Lago della Disgrazia)	Lago di Caprizzi	Lago della Rovina
	L lake	[m]	1.250	7.000	600
	W lake	[m]	250	300	300
	D lake	[m]	50	80	10
	S lake	[m^2]	78.125	1.820.000	140.000
	V lake	[m^3]	5.750.000	91.000.000	1.200.000
	Q lake	[m] a.s.l.			1.535
	h of Lac.dep.	[m]	?	15,0	?
	Lake life time	[dd]	centuries	centuries	millennia
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	existing partly filled

Localization	ID	[ ]	121	122	123
	Locality	text	Chiotti Sant'Anna	Ussolo	Villar
	Municipality	text	Castelmagno	Prazzo	Sampeyre
	Province	text	Cuneo	Cuneo	Cuneo
	Region	text	Piemonte	Piemonte	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	355237, 4917352	344292, 4926626	351970, 4938143
News	L.-damages	text	Some buildings destroyed		
	u-damages	text			
	d-damages	text			
	Bibliography	text	Merlo (1969), Pirocchi (1991)	Pirocchi (1991)	Govi et al. (1984), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	slump	complex	fall
	Velocity	text			
	v	[m/s]			
	Material	text	debrisbedrock e debris	rock and debris	rock
	Lithology	text	calceschists and schists quartzy	calceschists	serpentinites
	Water c.	text	wet		
	H L.	[m]	330\660	500	780
	α	[°]			
	β	[°]	25	19,7	18,7
	L L.tot.	[m]	630\1500	1.700	2.800
	L L.body	[m]	450\1200	1.400	2.300
	Wmax	[m]		1.300	1.500
	Wmin	[m]			800
	D_{rf}	[m]		100	120
	S L.	[m^2]	500000?		1.350.000
	V L.	[m^3]	20.000.000	25.000.000	150.000.000
	Trigger	text	snow melting		
	Prev. activations	dd/mm/yyyy	Prehistoric		
Dam	Date of damming	dd/mm/yyyy	04/1966	Prehistoric	Prehistoric
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IV	III	II
	L d	[m]	650	600	400
	W d	[m]	850	1.250	1.200
	H d	[m]	20	40	30
	S d	[m^2]			
	V d	[m^3]	5.000.000	13.500.000	6.480.000
	Q d	[m] a.s.l.	1.580	1.090	1.100
	d condition	text	moderatly cut	moderatly cut	moderatly cut
	Evolution	text	gradual erosion	filled lake	filled lake
	Type of Failure	text	overtopping	-	-
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Grana	T. Maira	T. Varaita
	Wvalley	[m]	400	460	330
	Subt. S	[km^2]	14,63	159,52	203,9
	S	[°]	9,5	1,3	1,3
Lake	Lake name	text			
	L lake	[m]	850		2.000
	W lake	[m]	200		370
	D lake	[m]			
	S lake	[m^2]	90.000	180.000	690.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.	1.600		
	h of Lac.dep.	[m]		?	?
	Lake life time	[dd]	?	?	?
	Lake Condition	text	extinguished for spillway erosion	extinguished for filling	extinguished for filling

Localization	ID	[ ]	124	125	126
	Locality	text	Villaretto	Prà	Prali
	Municipality	text	Pontechianale	Bobbio Pellice	Prali
	Province	text	Cuneo	Torino	Torino
	Region	text	Piemonte	Piemonte	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	346313, 4940777	345125, 4959706	346158, 4973193
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Govi et al. (1984), Pirocchi (1991)	Pirocchi (1991)	Pirocchi (1991)
	Note	text			
Landslide	Movement	text	complex	complex	slump
	Velocity	text			
	v	[m/s]			
	Material	text	rock and debris	rock and debris	debris
	Lithology	text	calceschists	calceschists and serpentinites	calceschists
	Water c.	text			
	H L.	[m]	425	450	270
	α	[°]			
	β	[°]	28,9	22,2	25,0
	L L.tot.	[m]	900	1.600	840
	L L.body	[m]	770	1.100	580
	Wmax	[m]	1.200	850	800
	Wmin	[m]		250	
	D_{rf}	[m]	80		
	S L.	[m²]	462.000	467.500	
	V L.	[m³]	60.000.000		10.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy		Prehistoric	Prehistoric
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	300	550	400
	W d	[m]	1.300	850	700
	H d	[m]	30	20	30
	S d	[m²]			
	V d	[m³]	5.000.000	4.000.000	7.000.000
	Q d	[m] a.s.l.	1.490	1.700	1.450
	d condition	text	moderatly cut	moderatly cut	slightly cut
	Evolution	text	filled lake	filled lake	filled lake
	Type of Failure	text	-	-	-
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Varaita di Vhianale	T. Pellice	T. Germanasca
	Wvalley	[m]	200	200	250
	Subt. S	[km²]	94,52	17,7	47,7
	S	[°]	2,8	1,2	1,2
Lake	Lake name	text			
	L lake	[m]	900	1.000	1.000
	W lake	[m]	200	550	600
	D lake	[m]			
	S lake	[m²]	180.000	530.000	500.000
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]	?	?	
	Lake life time	[dd]	?	?	?
	Lake Condition	text	extinguished for filling	extinguished for filling	extinguished for filling

			127	128	129
Localization	ID	[ ]	127	128	129
	Locality	text	Ghigo	Fenestrelle	Serre la Voute
	Municipality	text	Prali	Fenestrelle	Salbertrand
	Province	text	Torino	Torino	Torino
	Region	text	Piemonte	Piemonte	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	345686, 4972041	343318, 4989940	335145, 4993836
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pirocchi (1991)	Carraro & Forno (1981), Pirocchi (1991)	Govi et al. (1984), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	slump	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debris	rock and debris	rock and debris
	Lithology	text	calceschists	calceschists and serpentinites	calceschists
	Water c.	text			
	H L.	[m]	310	300	590
	α	[°]			
	β	[°]	29,4	14,0	18,1
	L L.tot.	[m]	770	1.600	1.900
	L L.body	[m]	550	1.200	1.800
	Wmax	[m]	600	1.100	1.350
	Wmin	[m]		600	500
	D_{rf}	[m]		100	140
	S L.	[m^2]		700.000	1.200.000
	V L.	[m^3]	10.000.000	100.000.000	150.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	Prehistoric	Prehistoric	-9500 years BP
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	III	III
	L d	[m]	700	700	600
	W d	[m]	400	1.200	1.000
	H d	[m]	30	40	45
	S d	[m^2]			
	V d	[m^3]	6.000.000	30.000.000	20.000.000
	Q d	[m] a.s.l.	1.470	1.390	1.010
	d condition	text	slightly cut	strongly cut	strongly cut
	Evolution	text	filled lake	filled lake	gradual erosion
	Type of Failure	text	-	-	
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Germanasca	T. Chisone	F. Dora Riparia
	Wvalley	[m]	320	500	500
	Subt. S	[km^2]	36,9	124	559,38
	S	[°]	1,2	1,1	0,9
Lake	Lake name	text			
	L lake	[m]	1.000	4.200	5.000
	W lake	[m]	380	500	550
	D lake	[m]			
	S lake	[m^2]	350.000	2.000.000	2.730.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]		?	10,0
	Lake life time	[dd]	?	?	years/centuries
	Lake Condition	text	extinguished for filling	extinguished for filling	extinguished for spillway erosion

Localization	ID	[ ]	130	131	132
	Locality	text	Piazzette-Usseglio	Rocca Tavo	Noasca
	Municipality	text	Usseglio	Balme	Noasca
	Province	text	Torino	Torino	Torino
	Region	text	Piemonte	Piemonte	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	362604, 5009361	358285, 5018182	367517, 5034658
News	L.-damages	text			
	u-damages	text			
	d-damages	text	Lemie destroyed		
	Bibliography	text	Audisio (1975), Monticelli (1998), Pirocchi (1991)	Montandon (1933), Pirocchi (1991)	Pirocchi (1991)
	Note	text	Some (?) fatalities		
Landslide	Movement	text	complex	fall	fall
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	calceschists and serpentinites	serpentinites	gneiss
	Water c.	text			
	H L.	[m]	430	0	240
	α	[°]			
	β	[°]	15,0		20,3
	L L.tot.	[m]	2.300		1.400
	L L.body	[m]	1.600		650
	Wmax	[m]	1.450		700
	Wmin	[m]			
	D_{rf}	[m]			80
	S L.	[m^2]			250.000
	V L.	[m^3]	50.000.000	30.000.000	10.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	Prehistoric	Prehistoric	Prehistoric
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	II
	L d	[m]	1.000		350
	W d	[m]	1.100		800
	H d	[m]	40		40
	S d	[m^2]			
	V d	[m^3]	18.000.000		5.000.000
	Q d	[m] a.s.l.	1.250	1.754	1.130
	d condition	text	strongly cut	moderatly cut	moderatly cut
	Evolution	text	filled lake	filled lake	gradual erosion
	Type of Failure	text	-	-	
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	F. Stura di Viù	F. Stura d'Ala	T. Orco
	Wvalley	[m]	650	440	250
	Subt. S	[km^2]	93,25	31,35	116,8
	S	[°]	1,0	2,1	6,8
Lake	Lake name	text	Lago del Vallone		
	L lake	[m]	3.000		
	W lake	[m]	500		
	D lake	[m]			
	S lake	[m^2]	1.490.000	390.000	210.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years/centuries	?	?
	Lake Condition	text	extinguished for filling	extinguished for filling	extinguished for spillway erosion

Localization	ID	[ ]	133	134	135
	Locality	text	Campiglia	Miage	Val Veni
	Municipality	text	Valprato Soana	Courmayeur	Courmayeur
	Province	text	Torino	Aosta	Aosta
	Region	text	Piemonte	Valle d'Aosta	Valle d'Aosta
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	384989, 5044547	334572, 5071392	340110, 5075263
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pirocchi (1991)	Mortara & Scorzana (1987), Pirocchi (1991)	Pirocchi (1991)
	Note	text			
Landslide	Movement	text	complex	fall	fall
	Velocity	text			
	v	[m/s]			
	Material	text	rock and debris	rock	rock
	Lithology	text	calceschists and serpentinites	dolomite and chalks	granite
	Water c.	text			
	H L.	[m]	280		
	α	[°]			
	β	[°]			
	L L.tot.	[m]			
	L L.body	[m]			
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]			
	S L.	[m^2]			
	V L.	[m^3]	15.000.000	300.000	4.500.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	Prehistoric		
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	III	II
	L d	[m]			
	W d	[m]			
	H d	[m]			
	S d	[m^2]			
	V d	[m^3]			
	Q d	[m] a.s.l.	1.412	1.965	1.469
	d condition	text	strongly cut	strongly cut	strongly cut
	Evolution	text	filled lake	gradual erosion	gradual erosion
	Type of Failure	text	-	overtopping	overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Soana	F. Dora di Veni	F. Dora di Veni
	Wvalley	[m]	250		
	Subt. S	[km^2]	31	24,96	73,9
	S	[°]	2,9	0,9	1,4
Lake	Lake name	text		Lago Miage	
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	140.000	30.000	50.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]		hours	days
	Lake Condition	text	extinguished for filling	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	136	137	138
	Locality	text	Val Ferret	Becca de Luseney	Ussin
	Municipality	text	Courmayeur	Bionaz	Valtournenche
	Province	text	Aosta	Aosta	Aosta
	Region	text	Valle d'Aosta	Valle d'Aosta	Valle d'Aosta
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	348135, 5080930	380193, 5082480	391839, 5078728
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Orombelli & Porter (1981), Pirocchi (1991)	Stragiotti & Peretti (1953), Dutto & Montara (1992), Pirocchi (1991)	Pirocchi (1991)
	Note	text	7 fatalities	4 fatalities	
Landslide	Movement	text	fall	fall	
	Velocity	text			
	v	[m/s]			
	Material	text	debris	debris	debris
	Lithology	text	granite	kinzigite	serpentinites
	Water c.	text			
	H L.	[m]	1250	340	400
	α	[°]			
	β	[°]		25,9	22,8
	L L.tot.	[m]	7.000		
	L L.body	[m]		700	950
	Wmax	[m]	500	400	900
	Wmin	[m]			
	D_{rf}	[m]	15		30
	S L.	[m^2]			
	V L.	[m^3]	20.000.000	1.000.000	
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy		08/06/1952	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	II
	L d	[m]		300	550
	W d	[m]		300	550
	H d	[m]		10	
	S d	[m^2]			
	V d	[m^3]	500.000	405.000	
	Q d	[m] a.s.l.	1.750	1.650	1.300
	d condition	text	moderatly cut	strongly cut	strongly cut
	Evolution	text	gradual erosion	breached days	breached days
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	F. Dora di Ferret	T. Buthier	T. Marmore
	Wvalley	[m]	400	150	450
	Subt. S	[km^2]	39,51	84	110,32
	S	[°]	4,0	16,7	4,1
Lake	Lake name	text			
	L lake	[m]		600	
	W lake	[m]		400	
	D lake	[m]			
	S lake	[m^2]	30.000	40.000	33.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	days	days
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	139	140	141
	Locality	text	Monte Avi	Zerbion	S. Giovanni
	Municipality	text	Montjovet	Ayas	Crevoladossola
	Province	text	Aosta	Aosta	Verbano-Cusio-Ossola
	Region	text	Valle d'Aosta	Valle d'Aosta	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	395839, 5065397	398900, 5074235	444783, 5112251
News	L.-damages	text			
	u-damages	text			
	d-damages	text			Some houses of S. Giovanni destroyed, interruption of the railway and the highway
	Bibliography	text	Grasso (1967), Grasso (1968), Pirocchi (1991)	Pirocchi (1991)	Zoppetti (1952), Zoppetti (1959), Eisbacher & Clague (1984), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	complex	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	rock and debris	rock and debris	debrisbedrock e debris
	Lithology	text	serpentinites	calceschists and serpentinites	gneiss
	Water c.	text			wet
	H L.	[m]	370	0	0
	α	[°]			
	β	[°]	18,6		
	L L.tot.	[m]	1.600		
	L L.body	[m]	1.100		
	Wmax	[m]	900		
	Wmin	[m]			
	D_{rf}	[m]	70		
	S L.	[m^2]			
	V L.	[m^3]	8.000.000	200.000.000	2.000.000
	Trigger	text			heavy rainfall
	Prev. activations	dd/mm/yyyy			12/11/1951
Dam	Date of damming	dd/mm/yyyy			19/08/1958
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	IIIa+II
	L d	[m]	650		150
	W d	[m]	700		600
	H d	[m]	20		10
	S d	[m^2]			
	V d	[m^3]	4.000.000		400.000
	Q d	[m] a.s.l.	440	1.523	358
	d condition	text	strongly cut	strongly cut	breached
	Evolution	text	gradual erosion	gradual erosion	breached days
	Type of Failure	text	overtopping		overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	F. Dora Baltea	T. Evancon	Rio di Burra/T. Diveria
	Wvalley	[m]	400	350	100
	Subt. S	[km^2]	2435,07	132,5	314,69
	S	[°]	0,3	1,7	1,4
Lake	Lake name	text			
	L lake	[m]	4.500		
	W lake	[m]	650		
	D lake	[m]			
	S lake	[m^2]	3.010.000	560.000	15.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]	?		
	Lake life time	[dd]	years		days
	Lake Condition	text	extinguished for spillway erosion-filling	extinguished for spillway erosion-filling	extinguished for spillway erosion

Localization	ID	[ ]	142	143	144
	Locality	text	Crodo	Le Casse	Piuro
	Municipality	text	Crodo	Formazza	Piuro
	Province	text	Verbano-Cusio-Ossola	Verbano-Cusio-Ossola	Sondrio
	Region	text	Piemonte	Piemonte	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	445419, 5120626	455668, 5132040	533887, 5130695
News	L.-damages	text			Town of Piuro (Plurs) buried
	u-damages	text			
	d-damages	text	46 houses of Crodo destroyed		
	Bibliography	text	Montandon (1933), Eisbacher & Clague (1984), Govi et al. (1984), Pirocchi (1991)	Pirocchi (1991)	Heim (1932), Pirocchi (1991)
	Note	text			1200 fatalities
Landslide	Movement	text	complex	fall	complex
	Velocity	text		very fast	very fast
	v	[m/s]		5,00E-02	5,00E-02
	Material	text	debrisbedrock e debris	rock	debrisbedrock e debris
	Lithology	text	gneiss	gneiss	gneiss
	Water c.	text	wet		wet
	H L.	[m]	0	0	1250
	α	[°]			
	β	[°]		0,0	55
	L L.tot.	[m]		2.000	3.000
	L L.body	[m]		1.400	1.000
	Wmax	[m]		450	900
	Wmin	[m]			
	D_{rf}	[m]		140	10
	S L.	[m²]			700.000
	V L.	[m³]		20.000.000	6.000.000
	Trigger	text	heavy rainfall		mining activities, heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	27/08/1834		04/09/1618
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]		480	520
	W d	[m]		500	800
	H d	[m]		30	7
	S d	[m²]			
	V d	[m³]		3.000.000	1.500.000
	Q d	[m] a.s.l.	1.197	1.219	425
	d condition	text	breached	strongly cut	breached
	Evolution	text	breached hours	filled lake	breached days
	Type of Failure	text	overtopping	-	overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Alfenza	F. Toce	F. Mera
	Wvalley	[m]	220	375	450
	Subt. S	[km²]	3,78	120,32	222,82
	S	[°]	16,0	1,2	3,6
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]	5.000	1.680.000	40.000
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	?	days
	Lake Condition	text	extinguished for dam collapse		extinguished for spillway erosion

Localization	ID	[ ]	145	146	147
	Locality	text	Monte Gruf	Torre di Santa Maria	Gerna
	Municipality	text	Novate Mezzola	Torre di Santa Maria	Fusine
	Province	text	Sondrio	Sondrio	Sondrio
	Region	text	Lombardia	Lombardia	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	540370, 5123411	564927, 5120624	558041, 5107572
News	L.-damages	text			
	u-damages	text			
	d-damages	text		Some houses destroyed by a debris flow	
	Bibliography	text	Montandon (1933), Eisbacher & Clague (1984), Pirocchi (1991)	Ceriani et al. (1991), Pirocchi (1991)	Pirocchi (1991)
	Note	text			
Landslide	Movement	text	fall	slump	slump
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	rock and debris	debris	debris
	Lithology	text	gneiss	gneiss	gneiss
	Water c.	text		wet	wet
	H L.	[m]	0	600	0
	α	[°]			
	β	[°]		38,7	
	L L.tot.	[m]		1.450	
	L L.body	[m]		750	
	Wmax	[m]		200	
	Wmin	[m]			
	D_{rf}	[m]		27	
	S L.	[m²]			
	V L.	[m³]	200.000	1.500.000	1.500.000
	Trigger	text		heavy rainfall, foot's undermining	heavy rainfall
	Prev. activations	dd/mm/yyyy			1911
Dam	Date of damming	dd/mm/yyyy	15/07/1988	19/07/1987	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	IV	II
	L d	[m]		230	
	W d	[m]		480	
	H d	[m]		5	
	S d	[m²]			
	V d	[m³]		200.000	
	Q d	[m] a.s.l.	1.270	1.050	994
	d condition	text	strongly cut	breached	breached
	Evolution	text	breached hours	breached hours	breached hours
	Type of Failure	text		overtopping	overtopping
Stream	Main Basin	text	Po	Po	Po
	Dammed R.	text	T. Codera	T. Torreggio	T. Madrasco
	Wvalley	[m]	110	150	75
	Subt. S	[km²]	26,17	26,24	23,12
	S	[°]	5,7	13,5	8,0
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]	63.000	?	?
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	hours	hours
	Lake Condition	text	extinguished for dam collapse	extinguished for dam collapse	extinguished for dam collapse

Localization	**ID**	[ ]	148	149	150
	Locality	text	Baita Caprile	Sulini	Bracca
	Municipality	text	Fusine	Caiolo	Bracca
	Province	text	Sondrio	Sondrio	Bergamo
	Region	text	Lombardia	Lombardia	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	558153, 5106398	564026, 5109664	555925, 5074678
News	**L.-damages**	text			Truchel and Bruga hamlets destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pirocchi (1991)	Pirocchi (1991)	Montandon (1933), Pirocchi (1991)
	Note	text			
Landslide	**Movement**	text	fall	slump	complex
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	debris	debris	debris
	Lithology	text	gneiss	micaschists	schists and limestone marly
	Water c.	text	wet		wet
	H L.	[m]	0	0	
	α	[°]			
	β	[°]		0,0	0,0
	L L.tot.	[m]			
	L L.body	[m]		250	550
	Wmax	[m]		450	480
	Wmin	[m]			
	D_{rf}	[m]		20	4
	S L.	[m^2]			
	V L.	[m^3]	150.000	1.000.000	3.000.000
	Trigger	text	heavy rainfall		
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy	1947		13/09/1888
	Date of failure	dd/mm/yyyy	07/1987		01/1989
	d type	[ ]	II	II	II
	L d	[m]			530
	W d	[m]			350
	H d	[m]			4
	S d	[m^2]			
	V d	[m^3]			400.000
	Q d	[m] a.s.l.	1.173	738	608
	d condition	text	breached	breached	moderatly cut
	Evolution	text	breached years	breached hours	man-made
	Type of Failure	text	overtopping	overtopping	
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	T. Madrasco	T. Livrio	T. Ambra
	Wvalley	[m]	85	70	230
	Subt. S	[km^2]	21,92	31,06	29,6
	S	[°]	6,1	6,3	2,2
Lake	**Lake name**	text			
	L lake	[m]			400
	W lake	[m]			60
	D lake	[m]			15
	S lake	[m^2]	11.000	7.000	20.000
	V lake	[m^3]			200.000
	Q lake	[m] a.s.l.			475
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	hours	months
	Lake Condition	text	extinguished for dam collapse	extinguished for dam collapse	extinguished for man-made influence

Localization	**ID**	[ ]	151	152	153
	Locality	text	Cima Dosdé	Bormio	Idro-Cima d'Antegolo
	Municipality	text	Valdidentro	Valdidentro	Idro
	Province	text	Sondrio	Sondrio	Brescia
	Region	text	Lombardia	Lombardia	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	590528, 5141872	603373, 5148766	613197, 5065469
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Heim (1932), Pirocchi (1991)	Heim (1932), Pozzi & Sfondrini (1972), Pirocchi (1991)	Agnetti (1988), Pirocchi (1991)
	Note	text			
Landslide	**Movement**	text	complex	complex	slump
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	debris
	Lithology	text	gneiss graniteide	dolomite	sandstone
	Water c.	text			
	H L.	[m]	0	0	250
	α	[°]			
	β	[°]	0,0	0,0	11,8
	L L.tot.	[m]			
	L L.body	[m]	600	1.200	1.200
	Wmax	[m]	1.500	1.300	550
	Wmin	[m]			
	D_{rf}	[m]	40	150	40
	S L.	[m^2]			500.000
	V L.	[m^3]	20.000.000	75.000.000	6.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	525	1.100	450
	W d	[m]	1.100	1.170	510
	H d	[m]	30	40	25
	S d	[m^2]			
	V d	[m^3]	7.000.000	20.000.000	2.500.000
	Q d	[m] a.s.l.	2.285	1.262	370
	d condition	text	slightly cut	strongly cut	moderatly cut
	Evolution	text	existing lake	filled lake	existing lake
	Type of Failure	text	-		-
Stream	**Main Basin**	text	Po	Po	Po
	Dammed R.	text	F. Viola Bormina	F. Viola Bormina	F. Chiese
	Wvalley	[m]	430	650	200
	Subt. S	[km^2]	8,5	136,9	615,22
	S	[°]	3,3	1,0	0,1
Lake	**Lake name**	text	Lago di Val Viola		Lago di Idro
	L lake	[m]	600		9.000
	W lake	[m]	170		1.000
	D lake	[m]			120
	S lake	[m^2]	90.000	950.000	11.400.000
	V lake	[m^3]			33.500.000
	Q lake	[m] a.s.l.	2.267		368
	h of Lac.dep.	[m]			
	Lake life time	[dd]	centuries	?	centuries?
	Lake Condition	text	existing partly filled	extinguished for filling	existing partly filled

Localization	ID	[ ]	154	155	156
	Locality	text	Tenno	Loppio	Laghi
	Municipality	text	Tenno	Nago-Torbole	Laghi
	Province	text	Trento	Trento	Vicenza
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Venato
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	640892, 5087670	647919, 5081865	676918, 5076797
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Venzo (1935), Vaia (1981), Pirocchi (1991)	Venzo (1938), Pirocchi (1991)	De Vecchi et al. (1986), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	slump	slump	slump
	Velocity	text			
	v	[m/s]			
	Material	text	debris	debris	debris
	Lithology	text	limestone	limestone	dolomite
	Water c.	text			
	H L.	[m]	130	15	0
	α	[°]			
	β	[°]	6,7	0,7	0,0
	L L.tot.	[m]			
	L L.body	[m]	1.100	1.200	800
	Wmax	[m]	1.400	700	450
	Wmin	[m]			
	D_{rf}	[m]	80	40	40
	S L.	[m^2]			
	V L.	[m^3]	60.000.000	10.000.000	5.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	III	II
	L d	[m]	900	800	620
	W d	[m]	650	450	450
	H d	[m]	50	40	10
	S d	[m^2]			
	V d	[m^3]	10.000.000	4.000.000	1.000.000
	Q d	[m] a.s.l.	490	270	517
	d condition	text	slightly cut	slightly cut	slightly cut
	Evolution	text	existing lake	existing lake-man-made	existing lake
	Type of Failure	text	-	-	-
Stream	Main Basin	text	Po	Adige	Brenta
	Dammed R.	text	T. Magnone	Rio Cameras	T. la Zara
	Wvalley	[m]	750	450	380
	Subt. S	[km^2]	19,26	14	20,55
	S	[°]	3,2		1,9
Lake	Lake name	text	Lago di Tenno	Lago di Loppio	?
	L lake	[m]	720		
	W lake	[m]	270		
	D lake	[m]	50	0	
	S lake	[m^2]	200.000	600.000	210.000
	V lake	[m^3]	5.000.000		
	Q lake	[m] a.s.l.	571	225	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	centuries	centuries?	centuries?
	Lake Condition	text	existing partly filled	existing-extinguished for man-made influence	existing partly filled

Localization	**ID**	[ ]	157	158	159
	Locality	text	La Marogna	Cei	Ponte Pia
	Municipality	text	Pedemonte	Villa Lagarina	Stenico
	Province	text	Vicenza	Trento	Trento
	Region	text	Venato	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	681647, 5085013	657731, 5091352	641958, 5101725
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Dal Pozzo (1910), Pirocchi (1991), Carotta (1997)	Pirocchi (1991)	Pirocchi (1991)
	Note	text			
Landslide	**Movement**	text	complex	slump	fall
	Velocity	text			very fast
	v	[m/s]			5,00E-02
	Material	text	rock	debrisbedrock e debris	rock and debris
	Lithology	text	limestone and dolomite	limestone	limestone
	Water c.	text			
	H L.	[m]	400		90
	α	[°]			
	β	[°]	18,4		14,4
	L L.tot.	[m]	1.300		
	L L.body	[m]	1.200		350
	Wmax	[m]	850		500
	Wmin	[m]			
	D_{rf}	[m]	50		30
	S L.	[m^2]			
	V L.	[m^3]	12.000.000		2.000.000
	Trigger	text	seismic event		
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy	03/01/1117		
	Date of failure	dd/mm/yyyy	1278		
	d type	[ ]	II	III	II
	L d	[m]	550		200
	W d	[m]	650		480
	H d	[m]	20		20
	S d	[m^2]			
	V d	[m^3]	7.000.000		850.000
	Q d	[m] a.s.l.	400	926	480
	d condition	text	strongly cut		strongly cut
	Evolution	text	gradual erosion	existing lake	gradual erosion
	Type of Failure	text	overtopping	-	overtopping
Stream	**Main Basin**	text	Brenta	Adige	Po
	Dammed R.	text	T. Astico	Rio Arione	F. Sarca
	Wvalley	[m]	315	700	160
	Subt. S	[km^2]	91	1,63	582,7
	S	[°]	0,6		1,0
Lake	**Lake name**	text		Lago di Cei (derivazione latina, Cellius, Ceius)	Lago di Ponte Pià
	L lake	[m]		350	
	W lake	[m]		95	
	D lake	[m]		13	
	S lake	[m^2]	230.000	43.000	880.000
	V lake	[m^3]		300.000	3.760.000
	Q lake	[m] a.s.l.		918	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	centuries	centuries	?
	Lake Condition	text	extinguished for spillway erosion	lago existing	extinguished for spillway erosion

Localization	ID	[ ]	160	161	162
	Locality	text	Molveno	Tovel	Magrè
	Municipality	text	San Lorenzo in Banale	Tuenno	Magre' sulla strada del vino
	Province	text	Trento	Trento	Bolzano
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	649303, 5106451	650739, 5125421	669341, 5128374
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Marchesoni (1954), Marchesoni (1959), Pirocchi (1991)	Biondi et al. (1981), Pirocchi (1991)	Pirocchi (1991)
	Note	text			
Landslide	Movement	text	complex	complex	slump
	Velocity	text			very fast
	v	[m/s]			5,00E-02
	Material	text	rock	rock	debrisbedrock e debris
	Lithology	text	limestone	limestone	dolomite
	Water c.	text			
	H L.	[m]	80	150	0
	α	[°]			
	β	[°]	2,7	5,7	0,0
	L L.tot.	[m]		2.300	290
	L L.body	[m]	1.700	1.500	190
	Wmax	[m]	4.200	1.750	180
	Wmin	[m]			
	D_{rf}	[m]	80	140	10
	S L.	[m^2]			
	V L.	[m^3]	200.000.000	200.000.000	178.980
	Trigger	text			
	Prev. activations	dd/mm/yyyy			1854
Dam	Date of damming	dd/mm/yyyy			26/10/1952
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	III / IV	II
	L d	[m]	1.300	1.300	180
	W d	[m]	3.200	1.700	150
	H d	[m]	30	45	5
	S d	[m^2]			
	V d	[m^3]	40.000.000	40.000.000	75.000
	Q d	[m] a.s.l.	800	1.185	550
	d condition	text	slightly cut	slightly cut	artificially cut
	Evolution	text	existing lake	existing lake	not formed
	Type of Failure	text	-	-	
Stream	Main Basin	text	Po	Adige	Adige
	Dammed R.	text	Rio di Lambin	T. Tresenica	Rio Favogna
	Wvalley	[m]	1.200	800	100
	Subt. S	[km^2]	73,12	40,4	5,59
	S	[°]	3,5	5,7	18,8
Lake	Lake name	text	Lago di Molveno	Lago di Tovel	
	L lake	[m]	3.800	930	
	W lake	[m]	900	810	
	D lake	[m]	110	39	
	S lake	[m^2]	3.270.000	380.000	
	V lake	[m^3]	161.000.000	7.370.000	
	Q lake	[m] a.s.l.	821	1.178	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	millennia	centuries	days
	Lake Condition	text	lago existing	lago existing	not formed for infiltration

	ID	[ ]	163	164	165
Localization	Locality	text	Rio Brusago	Ridanna	Novale
	Municipality	text	Grumes	Racines	Val di Vizze
	Province	text	Trento	Bolzano	Bolzano
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	677548, 5121163	676669, 5197828	692020, 5199508
News	L.-damages	text	1 house destroyed		
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pirocchi (1991)	Pirocchi (1991)	Castiglioni & Gatto (1969), De Vecchi & Baggio (1982), Pirocchi (1991)
	Note	text	3 fatalities		The lake was very large; currently is an artificial reservoir for hydroelectric purposes partly filled
Landslide	Movement	text	flow	slump	slump
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	debris	debrisbedrock	debrisbedrock
	Lithology	text		micaschists	calceschists
	Water c.	text			
	H L.	[m]	0	170	95
	α	[°]			
	β	[°]	0,0	5,4	4,5
	L L.tot.	[m]			
	L L.body	[m]	5.000	1.800	1.200
	Wmax	[m]	200	2.500	1.200
	Wmin	[m]			750
	D_{rf}	[m]	7	120	130
	S L.	[m²]			
	V L.	[m³]	5.600.000	100.000.000	20.000.000
	Trigger	text	heavy rainfall		
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	09/1882		
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	II
	L d	[m]	270	570	1.100
	W d	[m]	1.500	1.400	800
	H d	[m]	5	35	60
	S d	[m²]			
	V d	[m³]	1.000.000	10.000.000	23.760.000
	Q d	[m] a.s.l.	608	1.310	1.360
	d condition	text	breached	strongly cut	strongly cut
	Evolution	text	breached hours	gradual erosion	existing lake
	Type of Failure	text	overtopping		-
Stream	Main Basin	text	Adige	Adige	Adige
	Dammed R.	text	T. Avisio	Rio Ridanna	T. di Vizze
	Wvalley	[m]	220	400	500
	Subt. S	[km²]	795,94	95,92	113,18
	S	[°]	6,9	1,2	0,6
Lake	Lake name	text			Lago di Novale
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]		1.700.000	2.850.000
	V lake	[m³]			
	Q lake	[m] a.s.l.			1.367
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	?	centuries
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	existing partly filled

Localization	ID	[ ]	166	167	168
	Locality	text	Stilves	Valdurna	S. Giacomo
	Municipality	text	Campo di Trens	Sarentino	Valle Aurina
	Province	text	Bolzano	Bolzano	Bolzano
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	691126, 5192527	686301, 5179016	728100, 5209772
News	L.-damages	text			
	u-damages	text			
	d-damages	text			9 houses destroyed and many damaged
	Bibliography	text	Castiglioni & Gatto (1969), Gatto (1971), Pirocchi (1991)	Pirocchi (1991)	Eisbacher & Clague (1984), Montara et al. (1986), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	slump	slump	flow
	Velocity	text			
	v	[m/s]			
	Material	text	debrisbedrock	debrisbedrock	debris
	Lithology	text	calceschists	filladi	gneiss
	Water c.	text			wet
	H L.	[m]	0	0	0
	α	[°]			
	β	[°]			0,0
	L L.tot.	[m]			
	L L.body	[m]			750
	Wmax	[m]			900
	Wmin	[m]			
	D_{rf}	[m]			15
	S L.	[m^2]			
	V L.	[m^3]	40.000.000		5.000.000
	Trigger	text			heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			10/09/0867
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	III
	L d	[m]			550
	W d	[m]			900
	H d	[m]		30	8
	S d	[m^2]			
	V d	[m^3]	3.000.000		1.500.000
	Q d	[m] a.s.l.	925	1.555	1.105
	d condition	text	strongly cut	slightly cut	breached
	Evolution	text	gradual erosion	existing lake	breached months
	Type of Failure	text	overtopping	-	overtopping
Stream	Main Basin	text	Adige	Adige	Adige
	Dammed R.	text	F. Isarco	Rio Valdurna	T. Aurino
	Wvalley	[m]	1.000	150	260
	Subt. S	[km^2]	511,43	24,38	130,15
	S	[°]	0,9	4,1	2,1
Lake	Lake name	text		Lago di Valdurna (Durnholzer Bee)	
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	7.600.000	90.000	270.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.		1.545	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	centuries	months
	Lake Condition	text	extinguished for spillway erosion	existing partly filled	extinguished for spillway erosion

Localization	ID	[ ]	169	170	171
	Locality	text	S. Martino	Campo Tures	Chiusa
	Municipality	text	Valle Aurina	Campo Tures	Chiusa
	Province	text	Bolzano	Bolzano	Bolzano
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	722680, 5205775	724506, 5197652	696323, 5168068
News	L.-damages	text	Foundry copper mine destroyed		
	u-damages	text	Flooding up to S. Martino	Railway, highway and some houses damaged	Flooding of Chiusa village, railway damaged
	d-damages	text			
	Bibliography	text	Montandon (1933), Eisbacher & Clague (1984), Montara et al. (1986), Pirocchi (1991)	Montara et al. (1986), Pirocchi (1991)	Montara et al. (1986), Pirocchi (1991)
	Note	text		1 fatality	4-20 fatalities
Landslide	Movement	text	flow	flow	flow
	Velocity	text			
	v	[m/s]			
	Material	text	debris	debris	debris
	Lithology	text	gneiss	filladi and micaschists	gneiss, filladi and micaschists
	Water c.	text	wet	wet	wet
	H L.	[m]	0	0	0
	α	[°]			
	β	[°]			
	L L.tot.	[m]			
	L L.body	[m]			
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]			
	S L.	[m^2]			
	V L.	[m^3]	1.000.000	9.000	1.620.000
	Trigger	text	heavy rainfall	heavy rainfall	heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	16-17/08/1878	06-07/08/1931	09/08/1921
	Date of failure	dd/mm/yyyy			01/1922, 03/1923
	d type	[ ]	II	I / II	II
	L d	[m]			
	W d	[m]			
	H d	[m]			10
	S d	[m^2]			
	V d	[m^3]			
	Q d	[m] a.s.l.	1.006	858	518
	d condition	text	breached	breached	artificially cut
	Evolution	text	breached days	breached days	breached months
	Type of Failure	text	overtopping	overtopping	artificiale
Stream	Main Basin	text	Adige	Adige	Adige
	Dammed R.	text	T. Aurino	T. Aurino	F. Isarco
	Wvalley	[m]	370	400	270
	Subt. S	[km^2]	192,46	521,78	3156,01
	S	[°]	0,4	1,1	2,5
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	300.000	700.000	470.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	days	months
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	172	173	174
	Locality	text	Rio Orli	Colma di Barbiano	Rasciesa
	Municipality	text	Villandro	Barbiano	Ortisei
	Province	text	Bolzano	Bolzano	Bolzano
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	694370, 5165406	693520, 5162786	702577, 5161442
News	L.-damages	text		13 houses of Colma village destroyed	
	u-damages	text	Railway damaged		
	d-damages	text			
	Bibliography	text	Montara et al. (1986), Pirocchi (1991)	Montara et al. (1986), Pirocchi (1991)	Fuganti (1969), Pirocchi (1991)
	Note	text		39 fatalities; a landslide causes emptying a lake and abnormal flood wave	
Landslide	Movement	text	flow	flow	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debris	debris	rock and debris
	Lithology	text	filladi and micaschists	filladi and micaschists	volcanics ignimbrite
	Water c.	text	wet	wet	
	H L.	[m]	0	0	140
	α	[°]			
	β	[°]			8,0
	L L.tot.	[m]			
	L L.body	[m]			1.000
	Wmax	[m]			550
	Wmin	[m]			
	D_{rf}	[m]			110
	S L.	[m^2]			
	V L.	[m^3]		1.000.000	50.000.000
	Trigger	text	heavy rainfall	heavy rainfall	
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	27/07/1938	17-18/08/1837	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]			700
	W d	[m]			620
	H d	[m]			100
	S d	[m^2]			
	V d	[m^3]			15.000.000
	Q d	[m] a.s.l.	490	458	1.135
	d condition	text	breached	breached	moderatly cut
	Evolution	text	breached hours	breached hours	filled lake
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	Main Basin	text	Adige	Adige	Adige
	Dammed R.	text	F. Isarco	F. Isarco	Rio Gardena
	Wvalley	[m]	140	220	400
	Subt. S	[km^2]	3386,03	3469,04	156,78
	S	[°]	11,0	1,0	2,3
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	43.000	160.000	110.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	hours	?
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	175	176	177
	Locality	text	Val Badia	Ponsin	Campo di Grevena
	Municipality	text	Badia	Campitello di Fassa	Campitello di Fassa
	Province	text	Bolzano	Trento	Trento
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Trentino Alto Adige
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	721322, 5167257	708053, 5152086	705476, 5152405
News	L.-damages	text			
	u-damages	text			
	d-damages	text	Some vilagges damaged		
	Bibliography	text	Eisbacher & Clague (1984), Pirocchi (1991)	Panizza (1973), Pirocchi (1991)	Pirocchi (1991)
	Note	text	Some (?) fatalities		
Landslide	Movement	text	slump	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debrisbedrock	debrisbedrock	rock
	Lithology	text	sandstone and limestone	volcanics	breccia di pillows
	Water c.	text			
	H L.	[m]	0	0	210
	α	[°]			
	β	[°]	0,0	0,0	13,6
	L L.tot.	[m]			
	L L.body	[m]	2.000	900	870
	Wmax	[m]	1.500	550	740
	Wmin	[m]			
	D_{rf}	[m]		40	100
	S L.	[m^2]			
	V L.	[m^3]	15.000.000	10.000.000	10.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	19/06/1821		
	Date of failure	dd/mm/yyyy	giu. 1827		
	d type	[ ]	II	II	I
	L d	[m]		550	160
	W d	[m]		500	470
	H d	[m]		20	30
	S d	[m^2]			
	V d	[m^3]	3.000.000	2.000.000	1.000.000
	Q d	[m] a.s.l.	1.250	1.840	1.930
	d condition	text	strongly cut	moderatly cut	slightly cut
	Evolution	text	breached years	filled lake	breached days
	Type of Failure	text	overtopping		
Stream	Main Basin	text	Adige	Adige	Adige
	Dammed R.	text	Rio Gader	Rio di Duron	Rio di Duron
	Wvalley	[m]	100	350	230
	Subt. S	[km^2]	129,37	9,6	4,23
	S	[°]	3,0	1,7	3,9
Lake	Lake name	text			
	L lake	[m]	1.000		
	W lake	[m]			
	D lake	[m]	35		
	S lake	[m^2]	300.000	360.000	260.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	?	days
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	not formed for deviation

Localization	ID	[ ]	178	179	180
	Locality	text	Antermoia	S. Martino di Castrozza	Agordo
	Municipality	text	Mazzin	Siror	La Valle Agordina
	Province	text	Trento	Trento	Belluno
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Veneto
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	704354, 5150558	716151, 5125692	734096, 5128239
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pirocchi (1991)	Panizza (1974), Pirocchi (1991)	Decima & Cimpelin (1982), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	fall	complex	
	Velocity	text	extremely fast		
	v	[m/s]	5		
	Material	text	rock	rock	
	Lithology	text	dolomite	dolomite	sandstone
	Water c.	text			
	H L.	[m]	30	250	280
	α	[°]			
	β	[°]	10,0	14,0	4,6
	L L.tot.	[m]			
	L L.body	[m]	170	1.000	3.500
	Wmax	[m]	190	1.400	1.800
	Wmin	[m]			
	D_{rf}	[m]	24	70	60
	S L.	[m^2]			
	V L.	[m^3]	405.688	15.000.000	80.000.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	II	III
	L d	[m]	100	260	1.200
	W d	[m]	190	900	1.800
	H d	[m]	10	30	20
	S d	[m^2]			
	V d	[m^3]	75.000	3.500.000	18.000.000
	Q d	[m] a.s.l.	2.527	1.300	550
	d condition	text	slightly cut	moderatly cut	strongly cut
	Evolution	text	existing lake	gradual erosion	filled lake
	Type of Failure	text	-	overtopping	overtopping
Stream	Main Basin	text	Adige	Brenta	Piave
	Dammed R.	text	Rio Val di Udui	T. Cismon	T. Cordevole
	Wvalley	[m]	60	200	650
	Subt. S	[km^2]	4,23	7,14	580,04
	S	[°]	2,6	6,6	1,5
Lake	Lake name	text	Lago D'Antermoia		
	L lake	[m]			8.500
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	41.000	450.000	1.660.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	centuries	days	centuries
	Lake Condition	text	existing partly filled	extinguished for spillway erosion	extinguished for spillway erosion

Localization	**ID**	[ ]	181	182	183
	Locality	text	Vedana	Lago Morto	Fadalto
	Municipality	text	Sedico	Vittorio Veneto	Farra d'Alpago
	Province	text	Belluno	Treviso	Treviso
	Region	text	Veneto	Veneto	Veneto
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	740842, 5117166	756072, 5104620	757988, 5108311
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Montandon (1933), Panizza (1974), Eisbacher & Clague (1984), Pirocchi (1991)	Pellegrini & Zambrano (1979), Pirocchi (1991)	Montandon (1933), Panizza (1974), Eisbacher & Clague (1984), Pirocchi (1991)
	Note	text			
Landslide	**Movement**	text	complex	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	rock and debris	rock and debris	rock and debris
	Lithology	text	limestone	limestone	limestone
	Water c.	text			
	H L.	[m]	0	0	0
	α	[°]			
	β	[°]		0,0	0,0
	L L.tot.	[m]			
	L L.body	[m]		650	1.500
	Wmax	[m]		2.000	2.300
	Wmin	[m]			
	D_{rf}	[m]		80	130
	S L.	[m^2]			
	V L.	[m^3]	100.000.000	50.000.000	200.000.000
	Trigger	text	seismic event		
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	III	III
	L d	[m]		540	730
	W d	[m]		2.000	2.400
	H d	[m]		40	100
	S d	[m^2]			
	V d	[m^3]	2.500.000	20.000.000	120.000.000
	Q d	[m] a.s.l.	400	295	490
	d condition	text	strongly cut	not cut	not cut
	Evolution	text	gradual erosion	existing lake	existing lake
	Type of Failure	text		-	-
Stream	**Main Basin**	text	Piave	Livenza	Piave
	Dammed R.	text	T. Cordevole	F. Meschio	F. Tesa
	Wvalley	[m]	340	410	950
	Subt. S	[km^2]	683,59	17,2	187,29
	S	[°]	0,5		1,1
Lake	**Lake name**	text		Lago Morto	Lago di Santa Croce
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	?	760.000	13.490.000
	V lake	[m^3]		23.690.000	
	Q lake	[m] a.s.l.		276	
	h of Lac.dep.	[m]			
	Lake life time	[dd]	months	centuries	centuries
	Lake Condition	text	extinguished for spillway erosion	existing partly filled	existing partly filled

Localization	ID	[ ]	184	185	186
	Locality	text	Vajont	Zuel	Antelao
	Municipality	text	Erto e Casso	Cortina d'Ampezzo	Borca di Cadore
	Province	text	Pordenone	Belluno	Belluno
	Region	text	Friuli Venezia Giulia	Veneto	Veneto
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	757250, 5129365	740957, 5155378	746490, 5148360
News	L.-damages	text			Taolen and Mareana villages destroyed
	u-damages	text			
	d-damages	text	Longarone village destroyed		
	Bibliography	text	Semenza (1966), Panizza (1974), Eisbacher & Clague (1984), Hendron & Patton (1985), Pirocchi (1991)	Panizza (1973), Pirocchi (1991)	Montandon (1933), Panizza (1973), Eisbacher & Clague (1984), Pirocchi (1991)
	Note	text	1917 fatalities		250 fatalities
Landslide	Movement	text	slump	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debrisbedrock	rock and debris	rock
	Lithology	text	limestone	dolomite	dolomite
	Water c.	text	wet		
	H L.	[m]	110	0	0
	α	[°]			
	β	[°]	4,5	0,0	0,0
	L L.tot.	[m]			
	L L.body	[m]	1.400	900	1.100
	Wmax	[m]	1.300	1.200	1.000
	Wmin	[m]			
	D_{rf}	[m]	140	50	40
	S L.	[m^2]			
	V L.	[m^3]	250.000.000	30.000.000	5.000.000
	Trigger	text	changes in reservoir level		
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	09/10/1963		21/04/1814
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	1.000	750	350
	W d	[m]	1.200	1.000	550
	H d	[m]	90	30	7
	S d	[m^2]			
	V d	[m^3]	50.000.000	10.000.000	600.000
	Q d	[m] a.s.l.	825	1.155	930
	d condition	text	not cut	strongly cut	moderatly cut
	Evolution	text	existing lake	gradual erosion	gradual erosion
	Type of Failure	text	-	overtopping	overtopping
Stream	Main Basin	text	Piave	Piave	Piave
	Dammed R.	text	T. Vajont	T. Boite	T. Boite
	Wvalley	[m]	750	500	350
	Subt. S	[km^2]	60,31	200,3	294,72
	S	[°]		1,4	1,2
Lake	Lake name	text	Lago di Vajont		
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]	2.110.000	590.000	130.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	years	hours
	Lake Condition	text	existing partly filled	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	187	188	189
	Locality	text	Perarolo	Forni di Sotto	Val Visdende
	Municipality	text	Perarolo di Cadore	Forni di Sotto	San Pietro di Cadore
	Province	text	Belluno	Udine	Belluno
	Region	text	Veneto	Friuli Venezia Giulia	Veneto
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	757132, 5143956	780721, 5143401	777970, 5166990
News	L.-damages	text			
	u-damages	text			
	d-damages	text	Pererolo partly destroyed		
	Bibliography	text	Montandon (1933), Eisbacher & Clague (1984), Pirocchi (1991)	Gortani (1907), Pirocchi (1991)	Colantoni & Cremonini (1971), Pirocchi (1991)
	Note	text			
Landslide	Movement	text		slump	complex
	Velocity	text			
	v	[m/s]			
	Material	text		debrisbedrock	rock
	Lithology	text	chalks	limestone	dolomite and limestone
	Water c.	text			
	H L.	[m]	0	0	0
	α	[°]			
	β	[°]		0,0	0,0
	L L.tot.	[m]			
	L L.body	[m]		800	500
	Wmax	[m]		2.500	650
	Wmin	[m]		600	
	D_{rf}	[m]		150	40
	S L.	[m^2]			
	V L.	[m^3]	500.000	50.000.000	30.000.000
	Trigger	text		snow melting (ice), stratigraphy (seismic event?)	
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy	10/1820		
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]		1.100	350
	W d	[m]		1.000	550
	H d	[m]		80	30
	S d	[m^2]			
	V d	[m^3]		20.000.000	2.500.000
	Q d	[m] a.s.l.	560	725	1.240
	d condition	text	breached	strongly cut	strongly cut
	Evolution	text	breached hours	breached years	filled lake
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	Main Basin	text	Piave	Tagliamento	Piave
	Dammed R.	text	T. Boite	F. Tagliamento	T. Cordevole
	Wvalley	[m]	90	450	250
	Subt. S	[km^2]	389,49	131,76	67,82
	S	[°]	1,5	0,8	1,0
Lake	Lake name	text			
	L lake	[m]		6.500	
	W lake	[m]		1.500	
	D lake	[m]		40	
	S lake	[m^2]	44.000	4.500.000	1.370.000
	V lake	[m^3]		250.000.000	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	centuries	?
	Lake Condition	text	extinguished for spillway erosion	extinguished for spillway erosion	extinguished for spillway erosion

Localization	ID	[ ]	190	191	192
	Locality	text	Moscardo	Sutrio	Val Alba
	Municipality	text	Paluzza	Sutrio	Moggio Udinese
	Province	text	Udine	Udine	Udine
	Region	text	Friuli Venezia Giulia	Friuli Venezia Giulia	Friuli Venezia Giulia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	807071, 5164554	807103, 5156096	823806, 5147405
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Tosolini (1974), Pirocchi (1991)	Gortani (1896), Martinis (1979), Pirocchi (1991)	Marinelli (1909), Pirocchi (1991)
	Note	text			
Landslide	Movement	text	flow	complex	slump
	Velocity	text			
	v	[m/s]			
	Material	text	debris	rock and debris	debris
	Lithology	text	claystones and argilloschists	dolomite	dolomite and limestone
	Water c.	text	wet		
	H L.	[m]	0	190	0
	α	[°]			
	β	[°]	0,0	8,3	
	L L.tot.	[m]			
	L L.body	[m]	1.000	1.300	
	Wmax	[m]	1.200	2.000	
	Wmin	[m]		250	
	D_{rf}	[m]	10	120	
	S L.	[m^2]			
	V L.	[m^3]	5.000.000	100.000.000	2.500.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy	?		
Dam	Date of damming	dd/mm/yyyy			20/10/1896
	Date of failure	dd/mm/yyyy			1905
	d type	[ ]	III	III	II
	L d	[m]	620	1.050	
	W d	[m]	950	1.800	
	H d	[m]	5	50	
	S d	[m^2]			
	V d	[m^3]	2.500.000	40.000.000	
	Q d	[m] a.s.l.	815	480	328
	d condition	text	strongly cut	strongly cut	strongly cut
	Evolution	text	breached years	filled lake	gradual erosion
	Type of Failure	text	overtopping		overtopping
Stream	Main Basin	text	Tagliamento	Tagliamento	Tagliamento
	Dammed R.	text	T. Burt	T. Burt	Rio Alba
	Wvalley	[m]	515	750	70
	Subt. S	[km^2]	57,71	148,99	20,3
	S	[°]	0,2	1,0	3,4
Lake	Lake name	text			
	L lake	[m]			200
	W lake	[m]			
	D lake	[m]		100	
	S lake	[m^2]	?	6.000.000	30.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]		100+	
	Lake life time	[dd]	years	millennia	years
	Lake Condition	text	extinguished for spillway erosion	extinguished for filling	extinguished for spillway erosion

Localization	ID	[ ]	193	194	195
	Locality	text	Pertusio	Camorone	Algua
	Municipality	text	Ala di Stura	Brembilla	Algua
	Province	text	Torino	Bergamo	Bergamo
	Region	text	Piemonte	Lombardia	Lombardia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	367480, 5018982	547605, 5072573	556215, 5075126
News	L.-damages	text		10 houses destroyed	10 houses of Algua destroyed
	u-damages	text			
	d-damages	text	Pertusio destroyed		
	Bibliography	text	Porporato (1962)		
	Note	text	Some (?) fatalities		
Landslide	Movement	text	complex	slump	slump
	Velocity	text		fast	
	v	[m/s]		5,00E-04	
	Material	text	debris	debrisbedrock	debris
	Lithology	text	anfiboliti	claystones	schists and limestone marly
	Water c.	text	wet	wet	
	H L.	[m]	0	0	0
	α	[°]			
	β	[°]		0,0	
	L L.tot.	[m]		700	
	L L.body	[m]		640	
	Wmax	[m]		200	
	Wmin	[m]		60	
	D_{rf}	[m]			
	S L.	[m^2]			
	V L.	[m^3]	2.000.000	2.000.000	
	Trigger	text	heavy rainfall	heavy rainfall	
	Prev. activations	dd/mm/yyyy		1960, 11/2000	
Dam	Date of damming	dd/mm/yyyy	17/09/1665	27/11/2002	24/10/1896
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	400	110	
	W d	[m]	600	230	
	H d	[m]	10	20	
	S d	[m^2]			
	V d	[m^3]	1.000.000	500.000	
	Q d	[m] a.s.l.	1.020	377	476
	d condition	text	breached	breached	slightly cut
	Evolution	text	breached hours	breached days	existing lake
	Type of Failure	text			
Stream	Main Basin	text	Po	Po	Tagliamento
	Dammed R.	text	F. Stura d'Ala	T. Brembilla	Rio Alba
	Wvalley	[m]	255	80	180
	Subt. S	[km^2]	97	32	20
	S	[°]	3,1	1,5	3,4
Lake	Lake name	text			Laghetto di Algua
	L lake	[m]		250	500
	W lake	[m]		20	100
	D lake	[m]			15
	S lake	[m^2]		400	40.000
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	hours	days	years
	Lake Condition	text	extinguished for spillway erosion	extinguished for dam collapse	existing partly filled

Localization	ID	[ ]	196	197	198
	Locality	text	Torre	Anterselva	Trelli
	Municipality	text	Lusevera	Rasun Anterselva	Paularo
	Province	text	Udine	Bolzano	Udine
	Region	text	Friuli Venezia Giulia	Trentino Alto Adige	Friuli Venezia Giulia
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	828806, 5136898	740369, 5197106	814993, 5156968
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Garofalo & Pugliese (1990)		Venturini (2002)
	Note	text			
Landslide	Movement	text	complex	flow	complex
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	rock	rock and debris	rock
	Lithology	text	dolomite and limestone	filladi and micaschists	sandstone and schists
	Water c.	text			
	H L.	[m]	80	155/455	0
	α	[°]			
	β	[°]	5,3	#VALORE!	
	L L.tot.	[m]			
	L L.body	[m]	860	1.100	
	Wmax	[m]	360	2.000	
	Wmin	[m]			
	D_{rf}	[m]	30	150	
	S L.	[m^2]			
	V L.	[m^3]	8.000.000	80.000.000	
	Trigger	text	seismic event, strati franapoggio		
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	IV	II
	L d	[m]	90	960	
	W d	[m]	320	1.000	
	H d	[m]	40	45	
	S d	[m^2]			
	V d	[m^3]	1.500.000	7.000.000	
	Q d	[m] a.s.l.	515	1.645	555
	d condition	text	strongly cut	not cut	strongly cut
	Evolution	text	gradual erosion	existing lake	filled lake
	Type of Failure	text	overtopping	-	-
Stream	Main Basin	text	Isonzo	Adige	Tagliamento
	Dammed R.	text	T. Mea	Rio di Anterselva	T. Chiarso
	Wvalley	[m]	45	700	150
	Subt. S	[km^2]	26	19,5	92
	S	[°]	4,5	6,0	1,6
Lake	Lake name	text		Lago di Anterselva (Antholzer See)	
	L lake	[m]	1.400	950	5.000
	W lake	[m]	400	650	350
	D lake	[m]		37	130
	S lake	[m^2]	500.000	410.000	1.500.000
	V lake	[m^3]		2.700.000	16.000.000
	Q lake	[m] a.s.l.		1642	
	h of Lac.dep.	[m]			11,0
	Lake life time	[dd]	years		millennia
	Lake Condition	text	extinguished for spillway erosion	existing partly filled	extinguished for filling

			199	200	201
Localization	ID	[ ]	199	200	201
	Locality	text	Cimego	Braies	Nibbio
	Municipality	text	Cimego	Braies	Mergozzo
	Province	text	Trento	Bolzano	Verbania
	Region	text	Trentino Alto Adige	Trentino Alto Adige	Piemonte
	UTM E, N crown	[ ]	,	,	,
	UTM E, N dam	[ ]	624900, 5084658	735888, 5176581	453311, 5095276
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text		Irmler et al. (2006)	
	Note	text			
Landslide	Movement	text	slump	complex	topple
	Velocity	text		very fast	extremely fast
	v	[m/s]		5,00E-02	5
	Material	text	debrisbedrock	rock and debris	
	Lithology	text	limestone and dolomite	limestone marly and dolomite	gneiss, dioriti
	Water c.	text			
	H L.	[m]	345	270	320
	α	[°]			32
	β	[°]	13,8	12,7	69,4
	L L.tot.	[m]			450
	L L.body	[m]	1.400	1.200	120
	Wmax	[m]	1.100	1.100	350
	Wmin	[m]			
	D_{rf}	[m]	110	75	
	S L.	[m²]			
	V L.	[m³]	25.000.000	51.810.000	500.000
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			19/04/2005
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	III
	L d	[m]	470	540	100
	W d	[m]	450	900	350
	H d	[m]	60	20	10
	S d	[m²]			
	V d	[m³]	4.000.000	8.000.000	400.000
	Q d	[m] a.s.l.	460	1.500	700
	d condition	text	strongly cut	not cut	not cut
	Evolution	text	gradual erosion	existing lake	not formed
	Type of Failure	text		-	?
Stream	Main Basin	text	Po	Adige	Po
	Dammed R.	text	F. Chiese	Rio Fosco	Rio Nibbio
	Wvalley	[m]	450	370	50
	Subt. S	[km²]	255	29	2
	S	[°]	0,8	4,0	24,9
Lake	Lake name	text		Lago di Breies	-
	L lake	[m]		1.150	-
	W lake	[m]		360	-
	D lake	[m]		17	-
	S lake	[m²]		324.990	-
	V lake	[m³]		5.524.830	-
	Q lake	[m] a.s.l.		1491	-
	h of Lac.dep.	[m]	6+	12,0	-
	Lake life time	[dd]	months	millennia	-
	Lake Condition	text	extinguished for spillway erosion	existing partly filled	not formed x infiltrazione

Localization	**ID**	[ ]	202	203	204
	Locality	text	Contr. Terra di Bove	Contr. La Rocca	Contr. Cugno Giovanni
	Municipality	text	Vizzini	Vizzini	Vizzini
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	485725, 4110200	486975, 4114812	484350, 4115850
	UTM E, N dam	[ ]	1019397, 4126020	1019980, 4130701	1016760, 4131930
News	**L.-damages**	text	State Highway n.124 and some rural settlements damaged/destroyed	State Highway n.124 and some rural settlements damaged/destroyed	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	**Movement**	text	slide	slide	slide
	Velocity	text			fast
	v	[m/s]			5,00E-04
	Material	text	rock	rock	rock
	Lithology	text	marl with limestone-marly layers	volcanoclastites and lava flows	volcanoclastites and lava flows
	Water c.	text	dry	dry	dry
	H L.	[m]	240	150	145
	α	[°]			
	β	[°]	10,1	18,4	19,9
	L L.tot.	[m]	1350	450	400
	L L.body	[m]	1100		230
	Wmax	[m]	900		275
	Wmin	[m]			
	D_{rf}	[m]	50		40
	S L.	[m^2]			
	V L.	[m^3]	25.905.000		1.324.033
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	50	100	75
	W d	[m]	200	125	225
	H d	[m]	9,0	34,6	20,0
	S d	[m^2]			
	V d	[m^3]	44.919	216.408	168.750
	Q d	[m] a.s.l.	670		414
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	**Main Basin**	text	San Leonardo	San Leonardo	San Leonardo
	Dammed R.	text	T. Sughereta	T. La Rocca	tributario s. n. T. Risicone
	Wvalley	[m]	140		130
	Subt. S	[km^2]	6,42	16,02	5,9
	S	[°]	2,9		3,2
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	205	206	207
	Locality	text	Contr. Canseria	Contr. Boschitello	Contr. San Giovanni
	Municipality	text	Vizzini	Vizzini - Licodia Eubea	Licodia Eubea
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	481850, 4115750	475200, 4112000	471675, 4113075
	UTM E, N dam	[ ]	1014379, 4131829	1009599, 4125971	1005130, 4128276
News	L.-damages	text		Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	complex	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	volcanoclastites and lava flows	calcilutites, breccias, limestone and calcirudites	marl with layers limestoneci-marly
	Water c.	text	dry	dry	dry
	H L.	[m]	115	310	130
	α	[°]			
	β	[°]	17,3	8,8	9,5
	L L.tot.	[m]	370	2000	780
	L L.body	[m]	230		700
	Wmax	[m]	320		870
	Wmin	[m]			
	D_{rf}	[m]	40		44
	S L.	[m^2]			
	V L.	[m^3]	1.540.693		14.023.240
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	II
	L d	[m]	75	25	95
	W d	[m]	200	775	140
	H d	[m]	24,1	3,9	16,0
	S d	[m^2]			
	V d	[m^3]	180.687	37.843	106.278
	Q d	[m] a.s.l.	525	381	404
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	San Leonardo	Acate o Dirillo	Acate o Dirillo
	Dammed R.	text	T. te Risicone	F. Vizzini	Vallone Mangalavite
	Wvalley	[m]	160		130
	Subt. S	[km^2]	46,0	57,44	17,97
	S	[°]	3,5	1,8	2,5
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	**ID**	[ ]	208	209	210
	Locality	text	Contr. Casaletto	Poggio Vascello	Rocca
	Municipality	text	Licodia Eubea	Licodia Eubea	Vizzini
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	476100, 4107475	475100, 4109000	485225, 4113625
	UTM E, N dam	[ ]	1009103, 4122698	1008546, 4123944	1018438, 4129246
News	**L.-damages**	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	**Movement**	text	complex	slide	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	succession of biolimestone and limestone and sometime calcirudites	limestone and sub. marly limestone and calcilutites	volcanoclastites and lavas
	Water c.	text	dry	dry	dry
	H L.	[m]	210	205	225
	α	[°]	15	22	
	β	[°]	13,1	14,4	18,4
	L L.tot.	[m]	900	800	675
	L L.body	[m]	600		
	Wmax	[m]	1.100		
	Wmin	[m]			
	D_{rf}	[m]	58		
	S L.	[m^2]			
	V L.	[m^3]	36.000.000		
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II-VI	I	I
	L d	[m]	50	25	50
	W d	[m]	375	125	100
	H d	[m]	11,9	6,6	17,3
	S d	[m^2]			
	V d	[m^3]	111.404	10.235	43.282
	Q d	[m] a.s.l.	410	365	466
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	**Main Basin**	text	Acate o Dirillo	Acate o Dirillo	San Leonardo
	Dammed R.	text	F. Amerillo	F. Vizzini e Dirillo	T. Sughereta
	Wvalley	[m]			
	Subt. S	[km^2]	44,71	60,55	0,02
	S	[°]	1,1	0,3	3,8
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	211	212	213
	Locality	text	M.Piano del Pozzo I	M.Piano del Pozzo II	M.Piano del Pozzo III
	Municipality	text	Vizzini	Vizzini	Vizzini
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	485425, 4114150	486125, 4114300	486225, 4114625
	UTM E, N dam	[ ]	1018790, 4129646	1019193, 4130023	1019592, 4130476
News	L.-damages	text	Some rural settlements damaged/destroyed		
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slide	slump
	Velocity	text		fast	
	v	[m/s]		5,00E-04	
	Material	text	rock	rock	rock
	Lithology	text	volcanoclastites and lavas	volcanoclastites and lavas	volcanoclastites and lavas
	Water c.	text	dry	dry	dry
	H L.	[m]	215	265	205
	α	[°]			
	β	[°]	16,5	19,5	18,9
	L L.tot.	[m]	725	750	600
	L L.body	[m]		550	
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]		50	
	S L.	[m^2]			
	V L.	[m^3]		8.270.000	1.300.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	50	50	100
	W d	[m]	250	175	300
	H d	[m]	15,3	18,4	35,6
	S d	[m^2]			
	V d	[m^3]	95.488	80.677	533.420
	Q d	[m] a.s.l.	437	421	394
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	San Leonardo	San Leonardo	San Leonardo
	Dammed R.	text	T. La Rocca	T. La Rocca	T. La Rocca
	Wvalley	[m]			190
	Subt. S	[km^2]	13,8	14,60	17,09
	S	[°]	3,5	2,8	2,4
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	214	215	216
	Locality	text	Contr. Franca	Contr. S. Nicola	Contr. Nocito
	Municipality	text	Mineo	Caltagirone	Caltagirone
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	476850, 4124200	455200, 4116150	452600, 4113700
	UTM E, N dam	[ ]	1009290, 4139924	988177, 4130139	985803, 4127577
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slump	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	volcanoclastites and lavas	limestone, calcirudites and sands; lacustrine deposits	limestone, calcirudites and sands; lacustrine deposits
	Water c.	text	dry	dry	dry
	H L.	[m]	175	100	130
	α	[°]			
	β	[°]	10,8	18,4	6,9
	L L.tot.	[m]	920	300	1080
	L L.body	[m]			966
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]			50
	S L.	[m^2]			
	V L.	[m^3]			27.800.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	63	?	50
	W d	[m]	150	?	500
	H d	[m]	12,1		6,0
	S d	[m^2]			
	V d	[m^3]	57.316		75.597
	Q d	[m] a.s.l.	321	344	288
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text		Acate o Dirillo	Acate o Dirillo
	Dammed R.	text	T. Catalfaro	F.sso del Naufro	F.sso del Naufro
	Wvalley	[m]			
	Subt. S	[km^2]	11,2	2,82	5,38
	S	[°]		2,0	2,3
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	217	218	219
	Locality	text	Contr. Saracena	Croce del Vicario	Contr. Rocca Fisauli
	Municipality	text	Caltagirone	Caltagirone	Randazzo
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	457750, 4115500	458775, 4118475	480400, 4177875
	UTM E, N dam	[ ]	990995, 4129288	991582, 4132868	1009932, 4193520
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Guzzetti et al. (1994), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slump	flow
	Velocity	text			moderate
	v	[m/s]			5,00E-06
	Material	text	rock	rock	debris e earth
	Lithology	text	limestone, calcirudites and sands; lacustrine deposits	limestone, calcirudites and sands; lacustrine deposits	clay
	Water c.	text	dry	dry	umido?
	H L.	[m]	90	75	230
	α	[°]			
	β	[°]	10,2	15,0	17,0
	L L.tot.	[m]	500	280	750
	L L.body	[m]			670
	Wmax	[m]			370
	Wmin	[m]			
	D_{rf}	[m]			
	S L.	[m^2]			350.000
	V L.	[m^3]	750.000		7.000.000
	Trigger	text	seismic event	seismic event	heavy rainfall
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	25	25	125
	W d	[m]	75	175	500
	H d	[m]	4,5	6,9	39,6
	S d	[m^2]			
	V d	[m^3]	4.265	15.009	1.236.938
	Q d	[m] a.s.l.	295	405	419
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Acate o Dirillo	Acate o Dirillo	Simeto
	Dammed R.	text	V.ne Saracena	V.ne Saracena	F.me Simeto
	Wvalley	[m]	170		550
	Subt. S	[km^2]	14,5	1,88	131,57
	S	[°]	1,3	2,8	0,7
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	220	221	222
	Locality	text	Mineo - SudOvest	Randazzo - Nord	Contr. Ficuzza
	Municipality	text	Mineo	Randazzo	Caltagirone
	Province	text	Catania	Catania	Catania
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	472375, 4124375	495425, 4192700	455650, 4103825
	UTM E, N dam	[ ]	1003639, 4139087	1023282, 4209460	988953, 4118305
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Guzzetti et al. (1994), Pacino (2002)	Guzzetti et al. (1994), Ferrara & Pappalardo (2000,) Pacino (2002)	Guzzetti et al. (1994), Nicoletti et al. (1998), Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	fall	6
	Velocity	text		fast	
	v	[m/s]		5,00E-04	
	Material	text	rock	debrisbedrock e debris	earth
	Lithology	text	silty-marly clay with interbedded sandy-siltose;marl and marly limestone	lavas and clay	limestone, calcirudites and sands; lacustrine deposits and silty-marly clay
	Water c.	text		wet	dry
	H L.	[m]	172	25	140
	α	[°]			
	β	[°]	17,4	18,4	6,4
	L L.tot.	[m]	550	75	1250
	L L.body	[m]	260		
	Wmax	[m]	250	150	3200
	Wmin	[m]			
	D_{rf}	[m]	5- 10	10	35,0
	S L.	[m^2]	130.000		
	V L.	[m^3]	170.000	18.421.333	80.000.000
	Trigger	text	heavy rainfall	heavy rainfall	seismic event
	Prev. activations	dd/mm/yyyy		previous events	
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	II
	L d	[m]	50	20	70
	W d	[m]	125	125	2500
	H d	[m]	16,2	6,9	7,9
	S d	[m^2]			
	V d	[m^3]	50.521	25.000	688.883
	Q d	[m] a.s.l.	234	733	123
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Simeto	Alcantara	Acate o Dirillo
	Dammed R.	text	F. Caldo	F.me Alcantara	T. Ficuzza
	Wvalley	[m]	80	190	
	Subt. S	[km^2]	12	182,6	114,46
	S	[°]	2,5	2,1	0,5
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	223	224	225
	Locality	text	Monte San Marco	Contr. Torazza	Nicosia - NordEst
	Municipality	text	Randazzo	Radazzo	Nicosia
	Province	text	Catania	Catania	Enna
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	495500, 4193425	496475, 4195650	,
	UTM E, N dam	[ ]	1023671, 4209661	1025596, 4210992	,
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Guzzetti et al. (1994), Pacino (2002)	Basile et al (1996), Guzzetti et al. (1994), Pacino (2002)	Guzzetti et al. (1994), Pacino (2002)
	Note	text			2 fatalities
Landslide	Movement	text	complex	complex	slide
	Velocity	text		moderate-fast	moderate
	v	[m/s]		5,00E-05	5,00E-06
	Material	text	debris, earth	earth and debris	debrisbedrock e earth
	Lithology	text	flysch	sandy-clay terrains and detrital coverages	claystones and flysch material
	Water c.	text	wet	wet- molto wet	wet
	H L.	[m]	175	400	60
	α	[°]			
	β	[°]	14,0	10,3	9,1
	L L.tot.	[m]	700	2200	375
	L L.body	[m]			
	Wmax	[m]	110	800	130
	Wmin	[m]	70	200	
	D_{rf}	[m]		?	
	S L.	[m^2]	80.000	1.350.000	50.000
	V L.	[m^3]		20.000.000	
	Trigger	text	heavy rainfall	heavy rainfall, seismic event	heavy rainfall (litologia)
	Prev. activations	dd/mm/yyyy	previous events	1880, 1914, 1920, 1921, 1928, 1933, 1934, 1951, 1952, 1972, 1973, 1973, 1981	previous events
Dam	Date of damming	dd/mm/yyyy		29/03/1996	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	I
	L d	[m]	75	250	
	W d	[m]	225	100	
	H d	[m]	19,2	17,5	
	S d	[m^2]			
	V d	[m^3]	161.584	218.750	
	Q d	[m] a.s.l.		653	
	d condition	text	partial blockage	artificially stabilized	partial blockage
	Evolution	text	not formed	existing lake-man-made	not formed
	Type of Failure	text			
Stream	Main Basin	text	Alcantara	Alcantara	Salso o Imera Meridionale
	Dammed R.	text	F.me Alcantara	F.me Alcantara	F.sso Sant'Onofrio
	Wvalley	[m]		270	
	Subt. S	[km^2]	183,8	207,5	
	S	[°]		4,0	
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]		375.000	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]		months	
	Lake Condition	text	not formed for deviation	existing	not formed for deviation

Localization	**ID**	[ ]	226	227	228
	Locality	text	Piazza Armerina - Nord	Contr. Schiavone	Contr. Vettrana
	Municipality	text	Piazza Armerina	Troina	San Fratello
	Province	text	Enna	Enna	Messina
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	443750, 4138075	462550, 4190000	464850, 4208300
	UTM E, N dam	[ ]	975039, 4151460	992476, 4204822	988029, 4224145
News	**L.-damages**	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements and houses destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Guzzetti et al. (1994), Pacino (2002)	Guzzetti et al. (1994), Pacino (2002)	Crinò (1921), Oginben (1960), Ministero LL. PP. (1963), Catenacci, (1992), Pacino (2002)
	Note	text	4 fatalities		10 fatalities
Landslide	**Movement**	text	complex	flow	complex
	Velocity	text	extremely fast	moderate	very fast
	v	[m/s]	5	5,00E-06	5,00E-03
	Material	text	rock and earth	debrisbedrock e earth	rock and earth
	Lithology	text	quartzy sands and quartzy sandstones	claystones	dolomite and filladi
	Water c.	text	wet	wet	wet
	H L.	[m]	150	209	415
	α	[°]			
	β	[°]	51,3	7,4	7,9
	L L.tot.	[m]	120	1600	3000
	L L.body	[m]	20	1700	2350
	Wmax	[m]		620	720
	Wmin	[m]		200	400
	D_{rf}	[m]	5		12
	S L.	[m^2]		420.000	1.980.000
	V L.	[m^3]	15.700	6.000.000	6.210.920
	Trigger	text	heavy rainfall (litologia e acclività)	Fluvial erosion, heavy rainfall	snowfall, heavy rainfall
	Prev. activations	dd/mm/yyyy		previous events	1745, 1905,
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	10	75	100
	W d	[m]	75	275	900
	H d	[m]	5	9,9	10
	S d	[m^2]			
	V d	[m^3]	1.875	101.609	450.000
	Q d	[m] a.s.l.	644	996	72
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	**Main Basin**	text	di Gela	Simeto	Torrente Furiano
	Dammed R.	text	Tributario no name in sinistra Torrente Nocciara	T. S. Elia	Torrente Furiano
	Wvalley	[m]	40	385	180
	Subt. S	[km^2]	2,8	14,00	140,28
	S	[°]	2,1	0,9	1,6
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	229	230	231
	Locality	text	Chiesa delle Grazie	Roccella Valdemone	Roccella Valdemone-Ovest
	Municipality	text	San Fratello	Roccella Valdemone	Roccella Valdemone
	Province	text	Messina	Messina	Messina
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	464700, 4208750	498625, 4199400	500800, 4198725
	UTM E, N dam	[ ]	993280, 4224937	1027238, 4217106	1027904, 4215741
News	L.-damages	text			Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Pacino (2002)	Pacino (2002)	Guzzetti et al. (1994), Bottari et al. (1998), Pacino (2002)
	Note	text			
Landslide	Movement	text	complex	flow	complex
	Velocity	text	very fast		slow
	v	[m/s]	5,00E-03		5,00E-08
	Material	text	rock and earth	earth	rock and earth
	Lithology	text	limestone and clay	claystones and marl-clay interbedded with limestoneo-marly and sandstone layers	limestone and quartzy sandstones, debris and schists clay
	Water c.	text			wet
	H L.	[m]	450	300	130
	α	[°]			
	β	[°]	11,8	11,3	17,2
	L L.tot.	[m]	2150	1500	420
	L L.body	[m]			410
	Wmax	[m]	600	500	260
	Wmin	[m]	100	450	80
	D_{rf}	[m]			9
	S L.	[m^2]			110.000
	V L.	[m^3]	180.000	150.000	479.700
	Trigger	text	Fluvial erosion at the base of the slope	heavy rainfall	heavy rainfall (litologia ed acclività)
	Prev. activations	dd/mm/yyyy			1880, 1901, 1902, 1905
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	50	25	25
	W d	[m]	200	500	200
	H d	[m]	10,6	5,1	9,0
	S d	[m^2]			
	V d	[m^3]	53.103	31.673	22.500
	Q d	[m] a.s.l.	144	761	778
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Torrente Inganno	Alcantara	Torrente Camaro
	Dammed R.	text	Torrente Inganno	Torrente Roccella	T. te Roccella
	Wvalley	[m]	230	180	115
	Subt. S	[km^2]	54,34	17,02	42,8
	S	[°]	2,8	10,4	3,6
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]		-	-
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

			232	233	234
Localization	ID	[ ]	232	233	234
	Locality	text	Camaro	Cozzo della Difesa	Casa Firrionello
	Municipality	text	Messina	Tusa	Scillato
	Province	text	Messina	Messina	Palermo
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	545650, 4227050	482050, 4204000	405250, 4190500
	UTM E, N dam	[ ]	1071323, 4247272	959587, 4218412	932476, 4200365
News	L.-damages	text	Some houses destroyed		Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Catenacci (1992), Pacino (2002)	Gazzetta del Sud 17/3/1987 pag.6, Catenacci (1992), Pacino (2002)	Albanese & Colosimo (1971), Pacino (2002)
	Note	text			
Landslide	Movement	text			slump
	Velocity	text			
	v	[m/s]			
	Material	text			earth
	Lithology	text	limestone,sands,marl clay		clay sandy clay marly limestone blocks and marl clay
	Water c.	text			wet
	H L.	[m]	80	398	47
	α	[°]			
	β	[°]	28,1	11,3	10,6
	L L.tot.	[m]	150	2000	250
	L L.body	[m]	140		
	Wmax	[m]	175	625	120
	Wmin	[m]		175	
	D_{rf}	[m]	30	5	
	S L.	[m^2]		1.000.000	190.000
	V L.	[m^3]	412.125	3.270.833	30.000
	Trigger	text			Fluvial erosion at the base of the slope
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			23/03/1969
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	10	25	125
	W d	[m]	100	200	175
	H d	[m]	5,9	5,0	23,8
	S d	[m^2]			
	V d	[m^3]	2.952	12.604	260.103
	Q d	[m] a.s.l.	153	352	239
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Vallone Nacchio	Imera Settentrionale	Imera Settentrionale
	Dammed R.	text	T. Camaro	Vallone Nacchio	F. me Imera Sett.
	Wvalley	[m]	180	320	160
	Subt. S	[km^2]	5,15	2,24	91,63
	S	[°]	5,8	6,9	1,8
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	-	-	-
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	**ID**	[ ]	235	236	237
	Locality	text	Vallone della Ginestra	Vallone San Nicola	Portella Colla I
	Municipality	text	Palermo	Palermo	Polizzi Generosa
	Province	text	Palermo	Palermo	Palermo
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	408300, 4186475	409266, 4187845	414625, 4190575
	UTM E, N dam	[ ]	937158, 4198231	936982, 4198621	938689, 4197852
News	**L.-damages**	text			Some rural settlements and cottages damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Albanese & Colosimo (1971), Pacino (2002)	Albanese & Colosimo (1971), Pacino (2002)	Crinò (1921), Oginben (1960), Albanese & Colosimo (1971), Pacino (2002)
	Note	text			
Landslide	**Movement**	text	flow	complex	complex
	Velocity	text			
	v	[m/s]			
	Material	text	earth	debris and earth	debris-earth-rock
	Lithology	text	clay, sandy clay		limestone dolomite blocks, claystonesche debris rocks
	Water c.	text		?	wet
	H L.	[m]	286	176	1290
	α	[°]			
	β	[°]	16,0	12,4	11,7
	L L.tot.	[m]	1000	800	6250
	L L.body	[m]		610	4500
	Wmax	[m]	375	270	3000
	Wmin	[m]			2000
	D_{rf}	[m]		20	40
	S L.	[m^2]			
	V L.	[m^3]		2.260.800	282.600.000
	Trigger	text	Fluvial erosion at the base of the slope		heavy rainfall (tettonica)
	Prev. activations	dd/mm/yyyy			Pliocene
Dam	**Date of damming**	dd/mm/yyyy	04/1969		
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	I
	L d	[m]	100	50	125
	W d	[m]	125	250	725
	H d	[m]	29,4	11,2	26,2
	S d	[m^2]			
	V d	[m^3]	183.789	69.881	1.185.951
	Q d	[m] a.s.l.		384	491
	d condition	text	breached	partial blockage	partial blockage
	Evolution	text	breached days	not formed	not formed
	Type of Failure	text			
Stream	**Main Basin**	text	Imera Settentrionale	Imera Settentrionale	Acate
	Dammed R.	text	F. me Imera Sett.	F. me Imera Sett.	Rio Secco
	Wvalley	[m]		230	
	Subt. S	[km^2]	22,71	23,33	18,87
	S	[°]		1,5	7,0
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	-	-
	Lake Condition	text	extinguished for spillway erosion	not formed for deviation	not formed for deviation

Localization	ID	[ ]	238	239	240
	Locality	text	Portella Colla II	Portella del Lupo I	Portella del Lupo II
	Municipality	text	Polizzi Generosa	Alia	Alia
	Province	text	Palermo	Palermo	Palermo
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	414625, 4190575	387500, 4182575	387175, 4181975
	UTM E, N dam	[ ]	936945, 4198418	914730, 4192921	914669, 4191135
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Crinò (1921), Oginben (1960), Albanese & Colosimo (1971), Pacino (2002)	Guzzetti et al. (1994), Pacino (2002)	Guzzetti et al. (1994), Pacino (2002)
	Note	text			
Landslide	Movement	text	complex	flow	complex
	Velocity	text			
	v	[m/s]			
	Material	text	debris-earth-rock	earth	debrisbedrock debris
	Lithology	text	limestone dolomite blocks, claystonesche debris rocks	quartzy sandstone and sandy marl clay	quartzy sandstone and sandy marl clay
	Water c.	text	wet		
	H L.	[m]	1290	250	273
	α	[°]			
	β	[°]	11,7	10,3	13,6
	L L.tot.	[m]	6250	1375	1125
	L L.body	[m]	4500	460	875
	Wmax	[m]	3000	250	
	Wmin	[m]	2000		
	D_{rf}	[m]	40		
	S L.	[m²]	14.500.000		700.000
	V L.	[m³]	282.600.000	600.000	
	Trigger	text	heavy rainfall	infiltration into the head	infiltration into the head and fluvial erosion
	Prev. activations	dd/mm/yyyy	Pliocene		
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	I
	L d	[m]	150	50	25
	W d	[m]	320	50	100
	H d	[m]	20,0	9,2	6,2
	S d	[m²]			
	V d	[m³]	480.000	11.491	7.736
	Q d	[m] a.s.l.	383	530	
	d condition	text	breached	partial blockage	partial blockage
	Evolution	text	breached days	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Acate	Acate	Irminio
	Dammed R.	text	F. me Imera Sett.	V.ne Rociura	V.ne Zappalanotte
	Wvalley	[m]	850	210	
	Subt. S	[km²]	23,33	4,08	4,88
	S	[°]	3,5	4,4	
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]			
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	days	-	-
	Lake Condition	text	extinguished per erosione della soglia	not formed for deviation	not formed for deviation

Localization	ID	[ ]	241	242	243
	Locality	text	Cimitero di Ragusa I	Cimitero di Ragusa II	Contr. Monte
	Municipality	text	Ragusa	Ragusa	Ragusa
	Province	text	Ragusa	Ragusa	Ragusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	475375, 4087625	476050, 4087275	478587, 4084975
	UTM E, N dam	[ ]	1009909, 4103198	1010845, 4102704	1012448, 4100795
News	L.-damages	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999b), Pacino (2002)	Nicoletti et al. (1999b), Pacino (2002)	Guzzetti et al. (1994), Nicoletti & Terranova (1998), Nicoletti et al. (1999b), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slump	complex
	Velocity	text			extremely fast
	v	[m/s]			5
	Material	text	debrisbedrock	debrisbedrock	debrisbedrock-debris
	Lithology	text	succession of calcilutites and marl	succession of calcilutites and marl	limestone and calcirudites; succession of calcilutites and marl
	Water c.	text	dry	dry	dry
	H L.	[m]	190	170	210
	α	[°]	28	20	20
	β	[°]	23,8	23,0	13,9
	L L.tot.	[m]	430	400	850
	L L.body	[m]	340		550
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]	80		60
	S L.	[m^2]			
	V L.	[m^3]	9.960.000	120.000	12.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	II
	L d	[m]	75	25	375
	W d	[m]	575	125	960
	H d	[m]	35,5	11,3	60
	S d	[m^2]			
	V d	[m^3]	1.725.000	17.679	10.800.000
	Q d	[m] a.s.l.		482	278
	d condition	text	strongly cut	partial blockage	inciso
	Evolution	text	filled lake	not formed	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Cassibile	Cassibile	Cassibile
	Dammed R.	text	F. San Leonardo	F. San Leonardo	F.me Irminio
	Wvalley	[m]		120	240
	Subt. S	[km^2]	17,29	19,39	6,04
	S	[°]	5,3	3,3	0,4
Lake	Lake name	text			
	L lake	[m]			1000
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			2.200.000
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			60,0
	Lake life time	[dd]			millennia
	Lake Condition	text	extinguished for filling	not formed for deviation	extinguished for filling

Localization	**ID**	[ ]	244	245	246
	Locality	text	Contr. Ufra	Contr. Steppenosa	Cozzo Pirato Grande
	Municipality	text	Modica	Scicli	Modica
	Province	text	Ragusa	Ragusa	Ragusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	479325, 4079325	474450, 4077500	476325, 4076000
	UTM E, N dam	[ ]	1013931, 4095056	1009479, 4092490	1011061, 4091711
News	**L.-damages**	text	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999b), Pacino (2002)	Nicoletti et al. (1999b), Pacino (2002)	Nicoletti et al. (1999b), Pacino (2002)
	Note	text			
Landslide	**Movement**	text	slide	slide	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	strati limestoneci with succession of limestoneo-marly layers; limestone and calcirudites ;alternation of calcilutites and marl	limestone with succession of limestoneo-marly layers	limestone with succession of limestoneo-marly layers; limestone and calcirudites
	Water c.	text	dry	dry	dry
	H L.	[m]	130	70	190
	α	[°]	16	12	21
	β	[°]	10,5	22,4	12,2
	L L.tot.	[m]	700	170	880
	L L.body	[m]	640	253	733
	Wmax	[m]	1000		
	Wmin	[m]			
	D_{rf}	[m]	87	60	120
	S L.	[m^2]			
	V L.	[m^3]	40.000.000	459.000	26.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	I	II
	L d	[m]	125	25	175
	W d	[m]	325	275	325
	H d	[m]	28,0	10,9	57
	S d	[m^2]			
	V d	[m^3]	568.750	37.532	1.620.938
	Q d	[m] a.s.l.	333	351	228
	d condition	text	inciso	partial blockage	strongly cut
	Evolution	text	filled lake	not formed	filled lake
	Type of Failure	text			
Stream	**Main Basin**	text	Cassibile	Cassibile	Torrente Pisciarello
	Dammed R.	text	T. Passo Gatta	Cava Manca	Fiumara di Modica
	Wvalley	[m]	295	145	255
	Subt. S	[km^2]	18,22	0,23	43,97
	S	[°]	1,1	2,0	1,4
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	extinguished for filling	not formed for deviation	extinguished for filling

Localization	ID	[ ]	247	248	249
	Locality	text	Fondo Barone	Contr. Billona	Contr. Utra I
	Municipality	text	Vittoria	Vittoria	Monterosso Almo
	Province	text	Ragusa	Ragusa	Ragusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	455750, 4086675	460187, 4090450	477675, 4105000
	UTM E, N dam	[ ]	990050, 4100160	995187, 4104756	1011524, 4121369
News	L.-damages	text		Some rural settlements damaged/destroyed	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999b), Pacino (2002)	Nicoletti et al. (1999b), Pacino (2002)	Nicoletti et al. (1999a), Nicoletti & Parise (2002), Pacino (2002)
	Note	text			
Landslide	Movement	text	flow	slide	slump
	Velocity	text	fast		
	v	[m/s]	5,00E-04		
	Material	text	earth	rock	rock
	Lithology	text	limestones; marl limestone and marly limestone	marly limestones, silts and travertes; limestone	limestones and calcirudites; succession of calcisiltstones, marl and marly limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	40	25	250
	α	[°]	10	12	18
	β	[°]	3,1	5,1	9,8
	L L.tot.	[m]	750	280	1450
	L L.body	[m]	600	253	1250
	Wmax	[m]	300		
	Wmin	[m]			
	D_{rf}	[m]	18	26	83
	S L.	[m^2]			
	V L.	[m^3]	1.695.600	1.940.000	84.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	I
	L d	[m]	50	225	175
	W d	[m]	125	450	275
	H d	[m]	2,7	26	83
	S d	[m^2]			
	V d	[m^3]	8.341	1.316.250	1.997.188
	Q d	[m] a.s.l.	70	156	460
	d condition	text	partial blockage	strongly cut	partial blockage
	Evolution	text	not formed	filled lake	not formed
	Type of Failure	text			
Stream	Main Basin	text	Torrente Pisciarello	Asinaro	Asinaro
	Dammed R.	text	tributario s. n. in dx F.me Ippari	tributario s. n. in dx F.me Ippari	Rio Amerillo
	Wvalley	[m]	290	90	
	Subt. S	[km^2]	3,14	53	31,16
	S	[°]	2,4	0,3	2,6
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	extinguished for filling	not formed for deviation

Localization	ID	[ ]	250	251	252
	Locality	text	Contr. Utra II	Piano degli Angeli I	Piano degli Angeli II
	Municipality	text	Monterosso Almo	Monterosso Almo	Monterosso Almo
	Province	text	Ragusa	Ragusa	Ragusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	477200, 4104000	476850, 4101325	476875, 4100550
	UTM E, N dam	[ ]	1011850, 4119404	1011052, 4116916	1010764, 4117099
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1998), Nicoletti et al. (2000), Nicoletti & Parise (2002), Pacino (2002)	Nicoletti et al. (1998), Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	complex	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	limestones and calcirudites; succession of calcsiltstones, marl and marly limestone	limestones and calcirudites; succession of calcsiltstones, marl and marly limestone	limestone and calcirudites; succession of calcsiltstones, marl and marly limestone
	Water c.	text	dry	dry	
	H L.	[m]	230	160	110
	α	[°]	26	34	34
	β	[°]	10,9	7,9	8,9
	L L.tot.	[m]	1200	1150	700
	L L.body	[m]	1000	800	500
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]	75	80	
	S L.	[m^2]			
	V L.	[m^3]	50.000.000	50.000.000	
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	VI	I
	L d	[m]	150	225	20
	W d	[m]	450	675	250
	H d	[m]	75	80	3,2
	S d	[m^2]			
	V d	[m^3]	2.531.250	6.075.000	7.922
	Q d	[m] a.s.l.	520	621	608
	d condition	text	strongly cut	not cut	partial blockage
	Evolution	text	filled lake	filled lake	not formed
	Type of Failure	text			
Stream	Main Basin	text	Asinaro	Asinaro	Asinaro
	Dammed R.	text	Rio Amerillo	Rio Amerillo	Rio Amerillo
	Wvalley	[m]			
	Subt. S	[km^2]	12,10	9,15	6,25
	S	[°]	1,0	2,8	2,8
Lake	Lake name	text			
	L lake	[m]	1400		
	W lake	[m]	150		
	D lake	[m]	30		
	S lake	[m^2]	164850		
	V lake	[m^3]	2.472.750		
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]	40,0		
	Lake life time	[dd]	millennia		
	Lake Condition	text	extinguished for filling	extinguished for filling	not formed for deviation

Localization	ID	[ ]	253	254	255
	Locality	text	Contr. Barone	Contr. Bregoliti	Cugni Fassio I
	Municipality	text	Giarratana	Ragusa	Avola
	Province	text	Ragusa	Ragusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	482650, 4103075	476100, 4095150	512950, 4090400
	UTM E, N dam	[ ]	1016395, 4118662	1010214, 4110706	1047905, 4108539
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slide	slump
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	marl and clay	limestone and calcirudites	limestone and marly limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	110	70	360
	α	[°]	22	14	
	β	[°]	14,3	19,3	27,2
	L L.tot.	[m]	430	200	700
	L L.body	[m]		130	540
	Wmax	[m]		320	
	Wmin	[m]			
	D_{rf}	[m]		40	100,0
	S L.	[m^2]			
	V L.	[m^3]		1.339.733	42.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	I
	L d	[m]	50	65	50
	W d	[m]	175	180	700
	H d	[m]	13,1	20,0	28,2
	S d	[m^2]			
	V d	[m^3]	57.213	117.000	494.374
	Q d	[m] a.s.l.	602	730	86
	d condition	text	partial blockage		partial blockage
	Evolution	text	not formed		not formed
	Type of Failure	text			
Stream	Main Basin	text	Asinaro	Asinaro	Asinaro
	Dammed R.	text	F.me Irminio	tributario in dx Cava Canseria	F.me Cassibile
	Wvalley	[m]		140	
	Subt. S	[km^2]	6,34	4,19	82,34
	S	[°]	4,1	4,9	0,9
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation		not formed for deviation

Localization	ID	[ ]	256	257	258
	Locality	text	Giserotta	Contr. Salmicella	Cugni di Cassero
	Municipality	text	Noto	Noto	Cassibile
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	512000, 4091500	510575, 4091750	514787, 4091625
	UTM E, N dam	[ ]	1046605, 4109211	1044943, 4108855	1049069, 4109216
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slump	slump
	Velocity	text	very fast	fast	very fast
	v	[m/s]	5,00E-03	5,00E-04	5,00E-02
	Material	text	rock	rock	rock
	Lithology	text	calcirudites and limestones	limestone and marly limestone	calcirudites and limestone
	Water c.	text	dry	dry	
	H L.	[m]	150	240	140
	α	[°]			
	β	[°]	31,0	28,1	29,2
	L L.tot.	[m]	250	450	250
	L L.body	[m]		185	
	Wmax	[m]		280	
	Wmin	[m]			
	D_{rf}	[m]		20	
	S L.	[m^2]			
	V L.	[m^3]	50.000	542.173	
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	25	25	
	W d	[m]	150	175	
	H d	[m]	17,1	14,8	0,0
	S d	[m^2]			
	V d	[m^3]	32.069	32.288	
	Q d	[m] a.s.l.		166	174
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text	Tellaro	Tellaro	Tellaro
	Dammed R.	text	Cava Passetti	F.me Cassibile	Cava Fontanelle
	Wvalley	[m]	95	180	
	Subt. S	[km^2]	1,19	89,63	1,9
	S	[°]	2,0	2,0	5,4
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	259	260	261
	Locality	text	Cugni Fassio II	Contr. Bellicci I	Contr. Bellicci II
	Municipality	text	Avola	Avola	Avola
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	513075, 4089925	508250, 4088150	508950, 4087950
	UTM E, N dam	[ ]	1047583, 4107262	1042743, 4105875	1043360, 4105260
News	L.-damages	text		Several fatalities; Three mills destroyed	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Campisi (1961), Guzzetti et al. (1994), Nicoletti et al. (1999b), Nicoletti & Terranova (1998), Pacino (2002)	Nicoletti et al. (1999a), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slide	slide
	Velocity	text	very fast	very fast	
	v	[m/s]	5,00E-03	5,00E-02	
	Material	text	rock	rock	rock
	Lithology	text	limestone, marly limestone and limestone	thick limestone; succession of limestone and marly limestone	thick limestone; succession of limestone and marly limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	130	180	50
	α	[°]			
	β	[°]	27,5	27,2	15,5
	L L.tot.	[m]	250	350	180
	L L.body	[m]	220	350	90
	Wmax	[m]			230
	Wmin	[m]			
	D_{rf}	[m]	20,0	75	15
	S L.	[m^2]			
	V L.	[m^3]	1.030.000	3.000.000	324.990
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	I
	L d	[m]	25	175	25
	W d	[m]	25	370	220
	H d	[m]	14,3	75	7,1
	S d	[m^2]			
	V d	[m^3]	4.473	2.428.125	19.604
	Q d	[m] a.s.l.	232	292	215
	d condition	text	partial blockage	moderatly cut	partial blockage
	Evolution	text	not formed	filled lake	not formed
	Type of Failure	text			
Stream	Main Basin	text	Anapo	Anapo	Fiumara Grande
	Dammed R.	text	Cava Tangi	T. Pisciarello	T. Pisciarello
	Wvalley	[m]	110	70	
	Subt. S	[km^2]	0,18	6,3	5,6
	S	[°]	11,1	3,3	11,1
Lake	Lake name	text			
	L lake	[m]		500	
	W lake	[m]		80	
	D lake	[m]		22,5	
	S lake	[m^2]			
	V lake	[m^3]		180.000	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]		20- 25	
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	extinguished for filling	not formed for deviation

Localization	ID	[ ]	262	263	264
	Locality	text	Timpa Sole	Contr. Lenzevacche	Cozzo del Ferraro I
	Municipality	text	Noto	Noto	Noto
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	503275, 4085950	504425, 4086825	504425, 4084825
	UTM E, N dam	[ ]	1037782, 4102821	1039263, 4104046	1039294, 4101961
News	L.-damages	text	Some rural settlements damaged/destroyed		Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999a), Pacino (2002)	Guzzetti et al. (1994), Nicoletti et al. (1999a), Pacino (2002)	Nicoletti et al. (1999a), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slump	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	limestone, marly limestone and limestone	limestone, marly limestone and limestone	marl with limestoneci-marly layers
	Water c.	text	dry	dry	dry
	H L.	[m]	190	150	180
	α	[°]		17	
	β	[°]	15,2	34,3	24,2
	L L.tot.	[m]	700	220	400
	L L.body	[m]		220	400
	Wmax	[m]			
	Wmin	[m]			
	D_{rf}	[m]		55	40,0
	S L.	[m^2]			
	V L.	[m^3]	65.000	2.000.000	3.180.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	I
	L d	[m]	50	150	25
	W d	[m]	125	350	225
	H d	[m]	13,9	55	12,1
	S d	[m^2]			
	V d	[m^3]	43.484	1.443.750	33.965
	Q d	[m] a.s.l.	230	257	
	d condition	text	partial blockage	strongly cut	partial blockage
	Evolution	text	not formed	filled lake	not formed
	Type of Failure	text			
Stream	Main Basin	text	Fiumara Grande	Fiumara Grande	Cava San Cusimano
	Dammed R.	text	Cava Ferraro	Cava Santa Chiara	Cava Tortorone
	Wvalley	[m]	110	75	180
	Subt. S	[km^2]	14,45	13,75	13,16
	S	[°]	1,8	0,8	2,2
Lake	Lake name	text			
	L lake	[m]		1000	
	W lake	[m]		70	
	D lake	[m]		55	
	S lake	[m^2]			
	V lake	[m^3]		1.283.333	
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	extinguished for filling	not formed for deviation

Localization	ID	[ ]	265	266	267
	Locality	text	Cozzo del Ferraro II	Contr. Oliva	Cava S. Giuseppe Nord
	Municipality	text	Noto	Noto	Noto
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	504450, 4085525	501225, 4087350	501211, 4086949
	UTM E, N dam	[ ]	1039526, 4102680	1035962, 4104404	1035843, 4103627
News	L.-damages	text	Some rural settlements damaged/destroyed		
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999a), Pacino (2002)	Guzzetti et al. (1994), Nicoletti et al. (1999a), Nicoletti et al. (1998), Pacino (2002)	Guzzetti et al. (1994), Nicoletti et al. (1999a), Nicoletti et al. (1998), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slide	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	marl with limestoneci-marly layers	limestone, marly limestone and limestone	limestone, marly limestone and limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	160	160	120
	α	[°]		23	15
	β	[°]	21,8	19,6	20,0
	L L.tot.	[m]	400	450	330
	L L.body	[m]	220	260	300
	Wmax	[m]	280		400
	Wmin	[m]			
	D_{rf}	[m]	12		30
	S L.	[m^2]			
	V L.	[m^3]	386.848	3.000.000	1.000.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	II	IV
	L d	[m]	37	150	100
	W d	[m]	250	575	375
	H d	[m]	15,6	40	30
	S d	[m^2]			
	V d	[m^3]	72.350	1.725.000	562.500
	Q d	[m] a.s.l.		273	279
	d condition	text	partial blockage	strongly cut	strongly cut
	Evolution	text	not formed	filled lake	filled lake
	Type of Failure	text			
Stream	Main Basin	text	Anapo	Tellaro	Tellaro
	Dammed R.	text	Cava Tortorone	Cava San Calogero- Cava Carosello e F. s. n.	Cava San Giuseppe e tributario s. n.
	Wvalley	[m]	200	90	
	Subt. S	[km^2]	13,47	5	2,8
	S	[°]	2,7	3,5	5,0
Lake	Lake name	text			
	L lake	[m]		300- 400	200
	W lake	[m]		40- 50	50
	D lake	[m]		40	30
	S lake	[m^2]			
	V lake	[m^3]		160000-260000	100.000
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	extinguished for filling	extinguished for filling

Localization	ID	[ ]	268	269	270
	Locality	text	Cava S. Giuseppe Sud	Noto Antica	Contr. Renna Alta
	Municipality	text	Noto	Noto	Noto
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	501383, 4086481	502375, 4087675	497175, 4083875
	UTM E, N dam	[ ]	1035843, 4103627	1037182, 4104367	1032417, 4100195
News	L.-damages	text			Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999a), Nicoletti et al. (1998), Pacino (2002)	Bottone (1718), Nicoletti et al. (1999a), Nicoletti et al. (1998), Pacino (2002)	Nicoletti et al. (1999a), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slump	slump
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	limestone, marly limestone and limestone	limestone, marly limestone and limestone	marly limestone and marl and succession of limestone-marl
	Water c.	text	dry	dry	dry
	H L.	[m]	120	180	70
	α	[°]	18	30	
	β	[°]	21,8	23,2	15,6
	L L.tot.	[m]	300	420	250
	L L.body	[m]	260		220
	Wmax	[m]	500		260
	Wmin	[m]			
	D_{rf}	[m]	30		15
	S L.	[m^2]			
	V L.	[m^3]	1.800.000	2.000.000	449.020
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IV	II	I
	L d	[m]	100	125	50
	W d	[m]	550	475	425
	H d	[m]	30	60	14,4
	S d	[m^2]			
	V d	[m^3]	825.000	1.781.250	152.763
	Q d	[m] a.s.l.		280	225
	d condition	text	strongly cut	not cut	partial blockage
	Evolution	text	filled lake	filled lake	not formed
	Type of Failure	text			
Stream	Main Basin	text	Anapo	Anapo	San Leonardo
	Dammed R.	text	Cava San Giuseppe e tributario s. n.	Vallone Pisciatura	Valle Battali
	Wvalley	[m]		65	240
	Subt. S	[km^2]	0,6	0,72	3,17
	S	[°]		4,3	5,4
Lake	Lake name	text			
	L lake	[m]	300		
	W lake	[m]	50		
	D lake	[m]	20		
	S lake	[m^2]			
	V lake	[m^3]	100.000		
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	extinguished for filling	extinguished for filling	not formed for deviation

	ID	[ ]	271	272	273
Localization	Locality	text	Contr. La Sarculla	Contr. Mezzo Gregorio	Costa San Nicola
	Municipality	text	Noto	Noto	Cassaro
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	496450, 4089000	496050, 4090075	496800, 4107100
	UTM E, N dam	[ ]	1031035, 4105361	1030820, 4106378	1030236, 4123560
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (1999a), Pacino (2002)	Nicoletti et al. (1999a), Pacino (2002)	Nicoletti & Catalano (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slump	fall
	Velocity	text	very fast	fast	very fast
	v	[m/s]	5,00E-03	5,00E-04	5,00E-02
	Material	text	rock	rock	rock
	Lithology	text	marly limestone and marl and succession of limestone-marl	marly limestone and marl and succession of limestone-marl	limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	200	180	140
	α	[°]			
	β	[°]	27,8	25,9	25,0
	L L.tot.	[m]	380	370	300
	L L.body	[m]	220	440	
	Wmax	[m]	800		
	Wmin	[m]			
	D_{rf}	[m]	15	50	
	S L.	[m^2]			
	V L.	[m^3]	1.000.000	58.000.000	
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	II
	L d	[m]	25	25	125
	W d	[m]	800	225	125
	H d	[m]	14,5	13,2	50
	S d	[m^2]			
	V d	[m^3]	145.245	37.187	390.625
	Q d	[m] a.s.l.	355	473	357
	d condition	text	partial blockage	partial blockage	breached
	Evolution	text	not formed	not formed	sfondato
	Type of Failure	text			
Stream	Main Basin	text	San Leonardo	San Leonardo	
	Dammed R.	text	Cava dell'Urva	Cava d'Angelo	F. Anapo
	Wvalley	[m]	230		
	Subt. S	[km^2]	1,3	1,99	89,9
	S	[°]	8,9	6,6	1,2
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			years
	Lake Condition	text	not formed for deviation	not formed for deviation	extinguished for spillway erosion

Localization	ID	[ ]	274	275	276
	Locality	text	Contr. Scala Vecchia	Contr. Malfitano	Contr. Civanna
	Municipality	text	Cassaro	Melilli	Melilli
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	495750, 4105550	505225, 4117600	504375, 4118050
	UTM E, N dam	[ ]	1029026, 4122026	1038484, 4134994	1037539, 4135236
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti & Catalano (2000), Pacino (2002)	Nicoletti & Catalano (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	fall	slump	slump
	Velocity	text	extremely fast		
	v	[m/s]	5		
	Material	text	rock	rock	rock
	Lithology	text	sequences of limestones and marly limestone subordinatedd	volcanoclastites and lava flows slightly altered	volcanoclastites and lava flows slightly altered
	Water c.	text	dry	dry	dry
	H L.	[m]	150	80	100
	α	[°]			
	β	[°]	31,0	9,5	9,5
	L L.tot.	[m]	250	480	600
	L L.body	[m]	230	314	500
	Wmax	[m]	400		
	Wmin	[m]			
	D_{rf}	[m]	30	35,0	28,0
	S L.	[m^2]			
	V L.	[m^3]	800.000	11.000.000	12.500.000
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	25	50	100
	W d	[m]	75	200	225
	H d	[m]	17,1	8,4	16,8
	S d	[m^2]			
	V d	[m^3]	16.034	42.057	189.256
	Q d	[m] a.s.l.	381		304
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text			
	Dammed R.	text	F. Anapo	tributario s. n. in dx Fiumara Grande	tributario s. n. in dx Fiumara Grande
	Wvalley	[m]	210	370	600
	Subt. S	[km^2]	63,49	7,81	7,85
	S	[°]	0,4	1,7	1,9
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Section	Parameter	Unit			
Localization	ID	[ ]	277	278	279
	Locality	text	Case Santuccio	Contr. Parisa	Madredonne
	Municipality	text	Melilli	Augusta	Palazzolo Acreide
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	509025, 4118950	512675, 4116837	503400, 4106500
	UTM E, N dam	[ ]	1041480, 4136517	1045301, 4134547	1036903, 4123857
News	L.-damages	text		Some rural settlements damaged/destroyed	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti & Catalano (2000), Pacino (2002)	Nicoletti & Catalano (2000), Pacino (2002)	Nicoletti & Catalano (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slump	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	calcilutites, limestone, calcirudites	limestone and marly limestone	limestone and calcirudites
	Water c.	text	dry	dry	dry
	H L.	[m]	35	20	90
	α	[°]			
	β	[°]	14,0	6,3	10,4
	L L.tot.	[m]	140	180	490
	L L.body	[m]	100	140	
	Wmax	[m]		270	
	Wmin	[m]			
	D_{rf}	[m]	14,0	12	
	S L.	[m^2]			
	V L.	[m^3]	510.000	237.384	
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	25	45	75
	W d	[m]	75	180	275
	H d	[m]	6,4	5,0	13,9
	S d	[m^2]			
	V d	[m^3]	5.985	20.334	143.679
	Q d	[m] a.s.l.	150	77	436
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text			
	Dammed R.	text	tributario s. n. in dx Cava Belluzza	Cava S. Cusimano	Cava Monasterello
	Wvalley	[m]	200	160	
	Subt. S	[km^2]	4,38	5,62	3,23
	S	[°]	3,5	1,3	2,2
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	280	281	282
	Locality	text	Contr. Banco I	Contr. Banco II	Contr. Calanca
	Municipality	text	Palazzolo Acreide	Palazzolo Acreide	Ferla
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	485525, 4100050	488300, 4099775	493825, 4109625
	UTM E, N dam	[ ]	1019329, 4115982	1022395, 4115598	1027072, 4125873
News	L.-damages	text		Some rural settlements damaged/destroyed	Some rural settlements damaged/destroyed
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slump	slump	slide
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	marl with layers limestone-marl	marl with layers limestone-marl	carbonates sequences with limestone and subordinated marly limestone
	Water c.	text	dry	dry	dry
	H L.	[m]	130	110	90
	α	[°]			
	β	[°]	8,2	12,4	12,7
	L L.tot.	[m]	900	500	400
	L L.body	[m]			260
	Wmax	[m]			320
	Wmin	[m]			
	D_{rf}	[m]			45
	S L.	[m²]			
	V L.	[m³]			1.959.360
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]			50
	W d	[m]			175
	H d	[m]			11,4
	S d	[m²]			
	V d	[m³]			50.066
	Q d	[m] a.s.l.	538	426	577
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text			
	Dammed R.	text	F.sso Mastica	F.sso Mastica	Cava Calcinaro
	Wvalley	[m]			120
	Subt. S	[km²]	1,14	5,53	3,53
	S	[°]	3,9	2,9	4,0
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]			
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	ID	[ ]	283	284	285
	Locality	text	Ceusa	Contr. Madonna delle Grazie	Contr. S. Maria
	Municipality	text	Carlentini	Buccheri	Buccheri
	Province	text	Siracusa	Siracusa	Siracusa
	Region	text	Sicilia	Sicilia	Sicilia
	UTM E, N crown	[ ]	494100, 4113700	485925, 4108775	484875, 4108212
	UTM E, N dam	[ ]	1026733, 4130426	1018762, 4124944	1018353, 4124642
News	L.-damages	text		Some rural settlements damaged/destroyed	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)	Nicoletti et al. (2000), Pacino (2002)
	Note	text			
Landslide	Movement	text	slide	slump	slump
	Velocity	text			
	v	[m/s]			
	Material	text	rock	rock	rock
	Lithology	text	volcanoclastites and lava flows	volcanoclastites and lava flows	volcanoclastites and lava flows
	Water c.	text	dry	dry	dry
	H L.	[m]	70	180	150
	α	[°]	16		
	β	[°]	11,0	14,4	14,5
	L L.tot.	[m]	360	700	580
	L L.body	[m]	250		340
	Wmax	[m]	380		550
	Wmin	[m]			
	D_{rf}	[m]	25		30
	S L.	[m^2]			
	V L.	[m^3]	1.242.917	800.000	2.402.100
	Trigger	text	seismic event	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	I	I
	L d	[m]	50	50	90
	W d	[m]	200	175	200
	H d	[m]	9,8	13,1	15,0
	S d	[m^2]			
	V d	[m^3]	49.233	57.523	150.000
	Q d	[m] a.s.l.	596	734	815
	d condition	text	partial blockage	partial blockage	partial blockage
	Evolution	text	not formed	not formed	not formed
	Type of Failure	text			
Stream	Main Basin	text			
	Dammed R.	text	T. Gelso	T. Sughereta	T. Sughereta
	Wvalley	[m]		160	200
	Subt. S	[km^2]	1,93	2,09	4,76
	S	[°]	3,4	5,7	6,1
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	not formed for deviation	not formed for deviation	not formed for deviation

Localization	**ID**	[ ]	286	287	288
	Locality	text	Contr. Bosco Pisano	Cavallerizzo	Testi
	Municipality	text	Buccheri	Cerzeto	San Casciano in Val di Pesa
	Province	text	Siracusa	Cosenza	Firenze
	Region	text	Sicilia	Calabria	Toscana
	UTM E, N crown	[ ]	487075, 4114275	595537, 4374417	,
	UTM E, N dam	[ ]	1019606, 4130653	1112141, 4398036	683603, 4830333
News	**L.-damages**	text	Some rural settlements damaged/destroyed	10 houses and 400 m of the road	
	u-damages	text			
	d-damages	text			
	Bibliography	text	Nicoletti et al. (2000), Pacino (2002)		
	Note	text			
Landslide	**Movement**	text	slump	complex	slump
	Velocity	text	fast		
	v	[m/s]	5,00E-04		
	Material	text	rock	rock and debris	debris
	Lithology	text	volcanoclastites and lava flows	schists and argilel marly	marls
	Water c.	text	dry	wet	wet
	H L.	[m]	185	143	48
	α	[°]		12	11
	β	[°]	23,8	9,0	9,4
	L L.tot.	[m]	420	1.100	340
	L L.body	[m]		900	290
	Wmax	[m]		200	400
	Wmin	[m]		50	
	D_{rf}	[m]		40	20
	S L.	[m^2]		350.000	
	V L.	[m^3]		5.000.000	1.214.133
	Trigger	text	seismic event	heavy rainfall and tettonic	heavy rainfall and materials properties
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy		07/03/2005	
	Date of failure	dd/mm/yyyy			
	d type	[ ]	I	III	II
	L d	[m]	50	70	90
	W d	[m]	275	600	260
	H d	[m]	23,0	9,2	12,8
	S d	[m^2]			
	V d	[m^3]	158.125	192.184	149.654
	Q d	[m] a.s.l.	383	337	281
	d condition	text	partial blockage	breached	artificially cut
	Evolution	text	not formed	breached days	man-made
	Type of Failure	text			
Stream	**Main Basin**	text		Crati	Arno
	Dammed R.	text	T. La Rocca		Fosso di Storno
	Wvalley	[m]		65	60
	Subt. S	[km^2]	15,4	3	0,7
	S	[°]	2,3	8,4	9,8
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]		days	
	Lake Condition	text	not formed for deviation	extinguished for spillway erosion	extinguished for man-made influence

Localization	ID	[ ]	289	290	291
	Locality	text	Daglio	Budrialto	Calitri
	Municipality	text	Carrega Ligure	Marradi	Calitri
	Province	text	Alessandria	Firenze	Avellino
	Region	text	Piemonte	Toscana	Campania
	UTM E, N crown	[ ]	511853, 4943814	717810, 4888706	,
	UTM E, N dam	[ ]	510661, 4944764	718821, 4888501	1042374, 4546415
News	L.-damages	text			Roards and some civil and industrial buildings damaged
	u-damages	text			
	d-damages	text			
	Bibliography	text		Valensise & Guidoboni (2000)	Esposito et al., 1998; Parise & Wasowski (1998)
	Note	text			
Landslide	Movement	text	complex		complex
	Velocity	text	very fast		
	v	[m/s]	5,00E-02		
	Material	text	debris		
	Lithology	text	marly limestones		sands and conglomerates
	Water c.	text	wet		
	H L.	[m]	346	220	172
	α	[°]	24		
	β	[°]	13,9	20,1	15
	L L.tot.	[m]	1700	1100	850
	L L.body	[m]	1400	600	500
	Wmax	[m]	200	600	600
	Wmin	[m]			400
	D_{rf}	[m]		30	15
	S L.	[m²]			300.000
	V L.	[m³]	10.000.000	5.652.000	2.300.000
	Trigger	text	heavy rainfall	seismic event	seismic event
	Prev. activations	dd/mm/yyyy			1456?
Dam	Date of damming	dd/mm/yyyy	12/10/1872		
	Date of failure	dd/mm/yyyy	29/10/1889		
	d type	[ ]	II	II	I/II
	L d	[m]		389	
	W d	[m]		600	
	H d	[m]		20,0	
	S d	[m²]			
	V d	[m³]	2.000.000	2.334.000	#RIF!
	Q d	[m] a.s.l.	583	303	
	d condition	text	breached	slightly cut	artificially cut
	Evolution	text	breached years	filled lake	man-made
	Type of Failure	text			
Stream	Main Basin	text	Po	Lamone	Ofanto
	Dammed R.	text	T. Agnellasca	T. Acerrata	F. Ofanto
	Wvalley	[m]	85	140	650
	Subt. S	[km²]	52,8	40	
	S	[°]	1,4	0,8	
Lake	Lake name	text	L. di Daglio		
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m²]			
	V lake	[m³]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]	years	centuries	
	Lake Condition	text	extinguished for dam collapse	extinguished for filling	not formed

8.2 APPENDIX 2: THE PERUVIAN DATABASE TABLE

Localization	ID	[ ]	P1	P2	P3
	Locality	text	Llanganuco Alta-187	Llanganuco Baja-190	343
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	209923, 8996637	208467, 8995382	209298, 9007307
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	fall - flow	fall - flow	flow
	Velocity	text	slow to rapid	slow to rapid	slow to rapid
	v	[m/s]			
	Material	text	rock, debris	rock, debris	debris, earth
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	234	210	130
	α	[°]	30	42	32
	β	[°]	14,89088537	14,88626685	28,44292862
	L L.tot.	[m]	880	790	240
	L L.body	[m]	880	790	240
	Wmax	[m]	1.100	1.500	70
	Wmin	[m]	500	1.100	
	D_{rf}	[m]	40	40	
	S L.	$[m^2]$	484.000	434.500	8.400
	V L.	$[m^3]$	20.273.745	24.818.582	
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IV	III	I / II
	L d	[m]	570	430	95
	W d	[m]	920	900	100
	H d	[m]	10	15	x
	S d	$[m^2]$			
	V d	$[m^3]$	874.000	967.500	
	Q d	[m] a.s.l.	3853	3839	4386
	d condition	text	poorly cut	poorly cut	poorly cut
	Evolution	text	existing lake	existing lake	existing lake
	Type of Failure	text			
Stream	Main Basin	text	Rio Santa	Rio Santa	Rio Santa
	Dammed R.	text			Q. Paròn
	Wvalley	[m]	350	440	
	Subt. S	$[km^2]$	28,5	32,6	
	S	[°]	0,808827861	0,37366283	33,17851166
Lake	Lake name	text	Llanganuco Lake	Llanganuco Lake	Artesoncocha Lake
	L lake	[m]	1.420	1.320	60
	W lake	[m]	430	600	30
	D lake	[m]			
	S lake	$[m^2]$	1.917.284	2.486.880	5.652
	V lake	$[m^3]$			
	Q lake	[m] a.s.l.	3834	3821	4400
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	existing	existing	existing

Localization	ID	[ ]	P4	P5	P6
	Locality	text	412	490	1014
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	206804, 9011708	201094, 9023151	206506, 9028439
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	fall	fall	slide - flow
	Velocity	text	slow to rapid	slow to rapid	
	v	[m/s]			
	Material	text	rock, debris	debris, earth	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	195	160	15
	α	[°]	39	25	
	β	[°]	14,76261697	15,67952412	14,03624347
	L L.tot.	[m]	740	570	60
	L L.body	[m]	740	570	60
	Wmax	[m]	1.240	510	35
	Wmin	[m]			
	D_{rf}	[m]	60	15	
	S L.	[m^2]	458.800	145.350	1.050
	V L.	[m^3]	28.827.254	2.283.152	
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	IV	IV	II
	L d	[m]	460	320	45
	W d	[m]	780	230	20
	H d	[m]	25	10	
	S d	[m^2]			
	V d	[m^3]	1.495.000	122.667	
	Q d	[m] a.s.l.	3902	4086	4138
	d condition	text	poorly cut	moderatly cut	
	Evolution	text	existing lake	existing lakefilled lake	existing lake
	Type of Failure	text			
Stream	Main Basin	text	Rio Santa	Rio Santa	Rio Santa
	Dammed R.	text			
	Wvalley	[m]	325	185	45
	Subt. S	[km^2]	27,8	18,8	
	S	[°]	1,271478054	1,513681296	21,21796958
Lake	Lake name	text	Lag. Jatuncocha	490	1014
	L lake	[m]	1.250	40	12
	W lake	[m]	510	36	9
	D lake	[m]			
	S lake	[m^2]	2.001.750	4.522	339
	V lake	[m^3]			
	Q lake	[m] a.s.l.	3886	4102	
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	existing	existing partialy filled	existing

Localization	**ID**	[ ]	P7	P8	P9
	Locality	text	1015	1858	1916
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	206439, 9028622	262326, 8911760	259920, 8893846
	UTM E, N dam	[ ]			
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	**Movement**	text	slide - flow	fall - flow	slump - flow
	Velocity	text		slow to rapid	
	v	[m/s]			
	Material	text	debris	rock, debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	5	151	26
	α	[°]			11
	β	[°]	9,462322208	19,34937702	5,937416099
	L L.tot.	[m]		540	280
	L L.body	[m]	30	430	250
	Wmax	[m]	12	480	190
	Wmin	[m]			
	D_{rf}	[m]		65	20
	S L.	[m^2]	180	103.200	23.750
	V L.	[m^3]		7.024.601	497.419
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	V	II
	L d	[m]	12	440	85
	W d	[m]	28	180	210
	H d	[m]		126,3474841	7,915620911
	S d	[m^2]			
	V d	[m^3]		1.667.787	23.549
	Q d	[m] a.s.l.	4096	4735	4440
	d condition	text		poorly cut	poorly cut
	Evolution	text	existing lake	existing lake	existing lake
	Type of Failure	text			
Stream	**Main Basin**	text	Rio Santa	Rio Pativilca	Rio Santa
	Dammed R.	text			
	Wvalley	[m]	12	170	80
	Subt. S	[km^2]		0,2	1,55
	S	[°]	12,63906244	32,21092772	5,426812499
Lake	**Lake name**	text	1015	1858	1916
	L lake	[m]	16	130	30
	W lake	[m]	9	60	35
	D lake	[m]			
	S lake	[m^2]	452	24.492	3.297
	V lake	[m^3]			
	Q lake	[m] a.s.l.		4740	4438
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	existing	existing	existing

Localization	ID	[ ]	P10	P11	P12
	Locality	text	2009	2197	c1
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	256966, 8913998	244096, 8923964	239215, 8953308
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	fall	slide - flow	slump - flow
	Velocity	text	slow to rapid	slow	slow to rapid
	v	[m/s]			
	Material	text	rock, debris	debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	115	125	141
	α	[°]		23	28
	β	[°]	19,76716868	10,12467166	14,8977692
	L L.tot.	[m]	320	700	530
	L L.body	[m]	320	700	530
	Wmax	[m]	430	960	410
	Wmin	[m]			
	D_{rf}	[m]	30	50	20
	S L.	[m^2]	68.800	336.000	108.650
	V L.	[m^3]	2.161.416	17.592.919	2.275.560
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	IV	II
	L d	[m]	270	720	360
	W d	[m]	390	403	270
	H d	[m]	10	30	5
	S d	[m^2]			
	V d	[m^3]	175.500	1.450.800	81.000
	Q d	[m] a.s.l.	4660	4006	3965
	d condition	text	poorly cut	poorly cut	strongly cut
	Evolution	text	existing lake	existing lake	gradual spillway erosion
	Type of Failure	text			overtopping
Stream	Main Basin	text		Rio Santa	Rio Santa
	Dammed R.	text			Q Quilcahyuanca
	Wvalley	[m]	135	550	245
	Subt. S	[km^2]	0,6	23,3	60,6
	S	[°]	10,7288593	2,9288582	1,562224917
Lake	Lake name	text	2009	Lag. Querococha	
	L lake	[m]	75	2.300	
	W lake	[m]	65	700	
	D lake	[m]			
	S lake	[m^2]	15.308	5.055.400	
	V lake	[m^3]			
	Q lake	[m] a.s.l.	4669	4002	
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	existing	existing partialy filled	extinct by spillway erosion

Section	Parameter	Unit			
Localization	ID	[ ]	P13	P14	P15
	Locality	text	c2	c3	c4
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	242996, 8922604	247384, 8920415	259542, 8922153
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	flow	slide - flow	slump
	Velocity	text	slow	slow	slow
	v	[m/s]			
	Material	text	debris	debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	84	80	178
	α	[°]	24	20	26
	β	[°]	7,363566664	10,91112838	16,78829573
	L L.tot.	[m]	650	570	590
	L L.body	[m]	650	415	590
	Wmax	[m]	1.220	450	410
	Wmin	[m]			
	D_{rf}	[m]	25	20	20
	S L.	[m^2]	396.500	93.375	120.950
	V L.	[m^3]	10.380.346	1.955.641	2.533.171
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	III	II
	L d	[m]	470	290	260
	W d	[m]	700	400	310
	H d	[m]			10
	S d	[m^2]			
	V d	[m^3]			134.333
	Q d	[m] a.s.l.	3959	4134	4020
	d condition	text	strongly cut	strongly cut	strongly cut
	Evolution	text	gradual spillway erosion	gradual spillway erosion	gradual spillway erosion
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	Main Basin	text	Rio Santa	Rio Santa	
	Dammed R.	text			
	Wvalley	[m]	300	230	220
	Subt. S	[km^2]	25,1	7,5	21,6
	S	[°]	1,447164504	1,122853508	1,762391024
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	extinct by spillway erosion	extinct by spillway erosion	extinct by spillway erosion

		ID	[ ]	P16	P17	P18
Localization	Locality	text	c5	c6	Jrcacocha-c7
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	260720, 8923822	232341, 8952325	233458, 8953427
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			15.000 people died (Yungay destroyed)
	Bibliography	text			
	Note	text			
Landslide	Movement	text	slump	fall - flow	fall - flow
	Velocity	text	slow to rapid	slow to rapid	slow to rapid
	v	[m/s]			
	Material	text	rock, debris	debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	100	203	93
	α	[°]	23	38	49
	β	[°]	13,39249775	27,08225079	12,20390909
	L L.tot.	[m]	420	397	530
	L L.body	[m]	420	397	430
	Wmax	[m]	440	438	635
	Wmin	[m]			
	D_{rf}	[m]	15	20	25
	S L.	[m^2]	92.400	86.943	136.525
	V L.	[m^3]	1.451.416	1.820.930	3.574.216
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	II	II
	L d	[m]	200	200	384
	W d	[m]	450	345	468
	H d	[m]	10		15
	S d	[m^2]			
	V d	[m^3]	150.000		449.280
	Q d	[m] a.s.l.	3956	3990	4095
	d condition	text	strongly cut	strongly cut	strongly cut
	Evolution	text	gradual spillway erosion	gradual spillway erosion	breached years
	Type of Failure	text	overtopping	overtopping	
Stream	Main Basin	text		Rio Santa	Rio Santa
	Dammed R.	text			
	Wvalley	[m]	85	110	180
	Subt. S	[km^2]	29,9	45,7	39,9
	S	[°]	1,357622718	3,851355734	1,886708146
Lake	Lake name	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	extinct by spillway erosion	extinct by spillway erosion	extinct by spillway erosion

Localization	**ID**	[ ]	P19	P20	P21
	Locality	text	c8	c9	c10
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	230713, 8962433	230251, 8967176	217106, 8986285
	UTM E, N dam	[ ]			
News	**L.-damages**	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	**Movement**	text	flow	slump-flow	topple-fall-flow
	Velocity	text	slow to rapid	slow to rapid	slow to rapid
	v	[m/s]			
	Material	text	debris	debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	111	66	203
	α	[°]	30	30	40
	β	[°]	15,50933452	10,98549778	16,71479472
	L L.tot.	[m]	400	340	676
	L L.body	[m]	400	340	676
	Wmax	[m]	500	615	1.135
	Wmin	[m]			
	D_{rf}	[m]	20	15	60
	S L.	[m^2]	100.000	104.550	383.630
	V L.	[m^3]	2.094.395	1.642.268	24.104.184
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	**Date of damming**	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	II	III	III
	L d	[m]	250	230	390
	W d	[m]	350	544	667
	H d	[m]			
	S d	[m^2]			
	V d	[m^3]			
	Q d	[m] a.s.l.	4180	4216	3788
	d condition	text	strongly cut	strongly cut	strongly cut
	Evolution	text	gradual spillway erosion	gradual spillway erosion	gradual spillway erosion
	Type of Failure	text	overtopping	overtopping	overtopping
Stream	**Main Basin**	text		Rio Santa	Rio Santa
	Dammed R.	text			
	Wvalley	[m]	150	130	365
	Subt. S	[km^2]	35	15,6	29,3
	S	[°]	4,332977955	6,891530234	1,074169998
Lake	**Lake name**	text			
	L lake	[m]			
	W lake	[m]			
	D lake	[m]			
	S lake	[m^2]			
	V lake	[m^3]			
	Q lake	[m] a.s.l.			
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	extinct by spillway erosion	extinct by spillway erosion	extinct by spillway erosion

Localization	ID	[ ]	P22	P23	P24
	Locality	text	c11	c12	c13
	Municipality	text			
	Province	text	Huaraz	Huaraz	Huaraz
	Region	text	Ancash	Ancash	Ancash
	UTM E, N crown	[ ]	204482, 9010711	258117, 8921485	260099, 8922605
	UTM E, N dam	[ ]			
News	L.-damages	text			
	u-damages	text			
	d-damages	text			
	Bibliography	text			
	Note	text			
Landslide	Movement	text	fall	slump	slide - flow
	Velocity	text	slow to rapid	slow to rapid	slow
	v	[m/s]			
	Material	text	debris, earth	rock, debris	debris
	Lithology	text	granite	granite	granite
	Water c.	text			
	H L.	[m]	157	339	64
	α	[°]	39	18	29
	β	[°]	14,66362622	21,62789161	7,016501745
	L L.tot.	[m]	700	1.200	550
	L L.body	[m]	600	855	520
	Wmax	[m]	1.150	800	380
	Wmin	[m]			
	D_{rf}	[m]	50	80	40
	S L.	$[m^2]$	345.000	342.000	98.800
	V L.	$[m^3]$	18.064.158	28.651.325	4.138.525
	Trigger	text			
	Prev. activations	dd/mm/yyyy			
Dam	Date of damming	dd/mm/yyyy			
	Date of failure	dd/mm/yyyy			
	d type	[ ]	III	I / II	IV
	L d	[m]	371	240	240
	W d	[m]	340	342	300
	H d	[m]	15		
	S d	$[m^2]$			
	V d	$[m^3]$	315.350		
	Q d	[m] a.s.l.	3853	4078	3986
	d condition	text	poorly cut	strongly cut	strongly cut
	Evolution	text	filled lake	gradual spillway erosion	gradual spillway erosion
	Type of Failure	text		overtopping	overtopping
Stream	Main Basin	text	Rio Santa		
	Dammed R.	text			
	Wvalley	[m]	290	280	230
	Subt. S	$[km^2]$	34,1	17,8	28,1
	S	[°]	1,549978173	2,100564481	1,503668902
Lake	Lake name	text			
	L lake	[m]	350		
	W lake	[m]	330		
	D lake	[m]			
	S lake	$[m^2]$	362.670		
	V lake	$[m^3]$			
	Q lake	[m] a.s.l.	3849		
	h of Lac.dep.	[m]			
	Lake life time	[dd]			
	Lake Condition	text	existing partialy filled	extinct by spillway erosion	extinct by spillway erosion

8.3 APPENDIX 3: DOCUMENTATION OF THE ITALIAN LANDSLIDE DAMS

1 - COMINETO (PZ)

The landslide involves the Lavaiana stream, a right tributary of the Nure River. In the ’80s completely blocks the stream forming a dammed lake. The involved lithology owns to the Arenarie di Scabiazza Formation, consists of thin or very thin turbidites with a sandstone portion represented by gray sandstone, fine-grained, micaceous, followed by a portion of pelitic clays or dark gray shales.

It is the reactivation of a previous landslide of 1887 with a surface of 550.000 m2, censed by Almagià (1907), that involves the Comineto village.

Bibliography:

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2 - GROPPALLO (PZ)

The landslide started on March 27, 1888, and involved a surface of 1.700.000 m^2 of the right slope of the Lavaiana stream, formed by Arenarie di Scabiazza Formation (turbidites thin or very thin with a portion sandstone represented by gray sandstone, fine-grained, micaceous, followed by a portion of pelitic clays or shales dark gray). At the foothill there is the passage to Argille a Palombini Formation, formed by alternating irregular clay with layers of thickness of decimetric resedimented calcilutites.

Both Trabucco (1889) and Almagià (1907) describe the movement as a flow, 4 km long, triggered by heavy rainfall that reach the velocity of 3 m/day.
Throughout lasted 65 days and Trabucco (1889) wrote: "It ran between Case Stromboli and Pennula, destroying the latest, turn around C. Poverella, pass throw Costa and Chiapetti, skirted Tornara and Strario, and, following its downstream movement, reached the Rio Cavalà stream, ran between Canevari and Barche and stopped in the river bed of the Lavaiana stream".
The landslide brought to light some pine logs showing signs of incipient carbonization. Surely it was therefore a reactivation.
There were no reports regarding a lake formation. Most probably a partial blockage of the stream realized, still visible today in the path of the river, which in this section forms a loop.

Bibliography:
Almagia', R. (1907). *Studi Geografici sopra le frane in Italia. .* Mem. Soc. Geogr. It., Vol XIII, p. 76
Ermini, L. (2000). Elaborazione di un modello per la previsione dell'evoluzione di sbarramenti fluviali causati da frane. Unpublished PhD thesis, Firenze, pp. 159.
Trabucco, G. (1889). *Le frane dell'alto Piacentino*. pp. 4-5.

3 - LAGO NERO (PZ)

Lago Nero is a small lake placed at the slopes of Mt. Nero, on the Apennine ridge in the Piacenza province.
According to some authors (Trabucco, 1991; Almagià, 1907) it is a landslide dammed lake, formed by a detachment of ophiolite blocks from the North wall of Mt. Black, occurred in an unknown time.
There are some concerns about the landslide genesis of this lake, because its altitude, 1550 m, suggests that subexcavation glacial processes have also influenced.

Bibliography:
Almagia', R. (1907). *Studi Geografici sopra le frane in Italia.* Mem. Soc. Geogr. It., Vol XIII, p. 76.
Ermini, L. (2000). Elaborazione di un modello per la previsione dell'evoluzione di sbarramenti fluviali causati da frane. Unpublished PhD thesis, Firenze, pp. 159.
Trabucco, G. (1891). *Un'escursione ai laghi dell'alto piacentino*. Estr. da "La Libertà" di Piacenza, n. VII, nn. 1955-57. 6 p.

4 - BETTOLA (PZ)

The landslide occured in May 1889 close to Bettola, Piacenza province, on the left side of the valley of the Nure. Is described in detail by both Almagià (1907) and Trabucco (1889).
The movement, classified as complex, is characterized by multiple sliding in crown evolving in flow at the foot of the slope.
The slope is formed by the alternation of marly limestones and sandstones with interbedded pelitic, belonging to Albirola Formation. Also in this case it wasan activation of a new landslide, as there are news of this landslide since 1730, followed by reactivation in 1800 and in 1851 (Cortesi G., 1819).
The volume of the dam is estimated in 2 x 10^5 m^3 and the river basin covers an area of 256 km^2.

Bibliography:
Almagià, R. (1907). *Studi Geografici sopra le frane in Italia. .* Mem. Soc. Geogr. It., Vol XIII, p. 76.
Cortesi, G. (1819). Saggi storici sugli stati di Parma e Piacenza. Piacenza, pp. 125.
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5 - ILLICA (PR)

The Illica landslide occurred on the slopes of Mt. Bello and is reminded of piecemeal by Almagià (1907), who reported that the event destroyed a convent called of "*Mezzane*".
More detailed information can be found in Boccia (1804), which it provides this description:
"Is tradition that on this mountain there was a convent of nuns who were called to live to Compiano established and built by Polissena Doria, hapless wife of Agostino di Lando.
From this hill, in 1725 November 12, a tremendous landslide broke off that ran in Ceno against Masanti for the length of a mile.
The torrent was closed for eight days and formed a lake along a mile and a half, that rose to Mount Vacaro place among Nociveglia and Tasola."

There is no news about the life of the lake, so can be inferred that it survived shortly. The basin underlying the dam is 64,5 km^2, while the volume of the dam was about 1,5 million m^3. The slope is formed by alternating limestone marl turbidites and mudstones belonging to the Formation of M. Antola.

Bibliography:
Almagià, R. (1907). *Studi Geografici sopra le frane in Italia. .* Mem. Soc. Geogr. It., Vol XIII, p. 86-7.
Boccia, A. (1804*). Viaggio ai monti di Parma*. (1804) Parma.
Ermini, L. (2000). Elaborazione di un modello per la previsione dell'evoluzione di sbarramenti fluviali causati da frane. Unpublished PhD thesis, Firenze, pp. 159.

6 - CORNIGLIO (PR)

The Corniglio landslide is one of the largest phenomena that affected the Northern Apennines. The last reactivation was in 1994 and brought substantial damage to the fraction of Linaro, as well as seriously injured the economy of this part of the Alta Val Parma, based on tourism and business activities related to the production and curing of hams.
It is a complex movement, formed in the crown area by a multiple sliding rotational, passing through the bottom to a sliding translational. Whenever there is detachment of material from the crown, it goes to weigh the impressive accumulation of debris that forms the main part of the landslide body, reactivating it. The slope in landslide consists mainly from Complesso di Canetolo Formation. Below there is the Arenarie di Ponte Bratica Formation, consist of feldspathic turbidites with carbonate cement, passers to top to Arenarie di Petrignacola (coarse turbiditic sandstones with thin argillite layers). Superimposed on these, by tectonic contact, there is the Flysh di M. Caio, mainly constituted by alternating layers of calcareous marly basinal turbidites through the roof to a dark gray shales.
Douring the event a complete damming of the Parma River was formed, that in this point has a subtended hydrological surface of 76.94 km^2. It should be emphasized that this is a base break, that is one of those slides that move along a sliding surface that passes beneath the valley floor, and then up the other side. This determines the elevation of the riverbed of Parma; the phenomenon, quantifiable with a height of 5 meters, has caused the emergence from the bottom of the riverbed of the remains of an old stone bridge destroyed by the landslide of 1902, previously covered by a mattress of floods.
The thickness of the debris affected by the landslide reaches 100 m of thickness at the foot, with a volume of 200 million m^3, making it difficult to design of any intervention.
There are news of this landslide since the year 1612, which it is then reactivated in 1740, 1770 and 1902. The 1770 event is probably the only one that caused the complete damming of the Parma River, as reported by Boccia (1804). Almagià (1907) and Martelli (1916) describe in detail the great event of 1902. The landslide interested in a partial way the riverbed Parma without blocking it completely.
In the 30s were performed both hydraulic refurbishment of Parma, and reforestation, as reported by Bernardini (1957).

Bibliography:
Almagià, R. (1907). *Studi Geografici sopra le frane in Italia.* Mem. Soc. Geogr. It., Vol XIII. p. 95-102.
Bernardini, F. (1957). Contributo alla sistemazione delle frane dell'Appennino Emiliano (zona Corniglio). Monti & Boschi, n.7, 8, pp. 311-321, e pp. 364-374.
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7 - SIGNATICO (PR)

There are reports of landslides that occurred between Signatico and Curiatico starting from 1836, with reactivation in 1879, 1896 and in the 70s. The most important event, reported by Almagià (1907), took place in April 1896, and led to the complete damming of the river Parma, with the formation of a lake that reached the maximum length of 2 km. The landslide is placed in Corniglio Municipality and spreads with a length of about 3.5 km on the left side of the middle Val Parma, reaching the bed of the river with the same name.
The landslide, complex type, evolved through a series of regressive rotational-translational slide movements of the crown area that involved, more than once, even the Signatico village; downstream of the town the landslide developed with a series of flows that, in later times, have overlied the previous ones, forming in this way an extended accumulation in the Parma Torrent riverbed.
The side affected by the landslide is formed by M. Caio Flysh, formed mainly by alternating layers of calcareous marly turbidites passersby to roof to dark gray shales. Sometimes there are also thin layers of quartz mica sandstones,

passing up to dark gray mudstones, and medium to thick layers of whitish limestone fine grain, passing up to marl limestone with laminations.
The lake, having significantly reduced its extension following the opening of an artificial drainage canal, was around 10 years.
The volume of the dam was about 8 x 10^6 m^3, and the surface of the subtended basin was 151 km^2.
Were substantial damage both from the landslide, with the destruction of some houses and a bridge over a tributary of Parma, Rio Venturina, and from flooding upstream of fields and crops.
The Signatico landslide, already mentioned in a document dated 870 A.D., was characterized by an intermittent activity; among the most important reactivations those of 1710, 1836, 1879, 1896 can be mentioned, when a wide dammed lake was formed in the Parma Torrent riverbed (Almagià, 1907).
In 1906 a further reactivation damaged Signatico's houses and Church and in 1945 an huge detritus mass obstructed the Parma Torrent creating a new dammed lake which occupied the valley for a length of over 2 km; the lake persisted for some years and became an attraction for inquiring people and fishing lovers. On this occasion the landslide detachment niche retreated by more than 100 m and the fluidized clay material reached the Parma Torrent riverbed in the form of a long flow. The dammed lake presence is evidenced in 1947 by historical document and also by thin pelitic deposits outcropping along the river scarp and well documented in the 90s; such deposits are now completely reworked or disguised by works for the protection of the banks recently realized in the riverbed.
After a further reactivation in 1957, there was another one in 1977, that is the latest one. The movement began in the first days of the month and was accentuated in the following days; after the main movement, evolved in the crown with regressive movements, induced lateral landslides appeared, especially on the landslide left side. During this reactivation was involved most of the Signatico town, which will be rebuilt in a more stable area. The large accumulation, still present in the Parma Torrent riverbed, significantly restricts the river section, up to a few meters width.
After 1977, there were only landslide reactivations related rainy periods. The final and most recent activation dates back to 2013 and has damaged the Provincial road n° 13.

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8 - CERREDOLO (RE)

The landslide occurred April 23, 1960 on the right bank of the river Secchia, bringing the full blockage of the river forming a dam 30 m thick. The upstream lake reached the length of about 4 km and 26 million m^3 of volume.
The volume of the dam was about 8 x 10^6 m^3, and the surface of the subtended basin was 341 km^2.
The landslide is classifiable as a sliding translational occurred on a slope with dip slope layers formed by alternating marly calcareous turbidites with pelitic turbidite sandstone belonging to Flysh M. Venus (Colombetti et al., 1989). The interventions were geared to the emptying of the lake, in order to decrease the hydraulic risk from a collapse of the dam.
The lake survived around eight months during which lake sediments accumulated to a depth of about 4.5 m, indicative of the high sediment transport which is characterized by the Secchia River.

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9 - CIANO (RE)

There are news about a landslide dam along Enza River in Ciano locality in two old document, Vallisnieri (1726) and Boccia (1804).
The two authors speak of two different events occurred in the same place, M. Casone, 1 km upstream from Ciano, the first occurred in 1710 and the other in 1780, therefore, it should be the same landslide reactivated on subsequent occasions.

Vallisnieri (1726) talks about a complete blockage of the Enza River also cited by Almagià (1907). This has always aroused some doubts because in that point the valley has a width of 500 m. Instead the record of Boccia (1804) tells of a partial blockage.
The landslide can be classified as a rotational sliding, consists of clays belonging to Argille Scagliose Formation. The area of the upstream basin is 464 km^2, while the volume of the dam must be just over one million m^3.

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10 - CERVAREZZA (RE)

The landslide has occurred March 23, 1936. It was the reactivation of a movement already occurred in 1472, 1560, 1697, 1715. The latter is described by Vallisnieri (1726).
During the event in 1936, classified as complex, translational sliding passing to flow at the bottom, there was the partial blockage of the Secchia River, who at this point has an upstream basin of 156 km^2. The side affected by the landslide is mainly composed of two formations: the Arenarie di Petrignacola, turbidite layers of sandstone with thin clay layers, and the Argille Scagliose.
The landslide is really impressive, reaching a volume of about 50 million m^3 of material. Only the outer part of the foot interacts with the Secchia River, and the dam must not have exceeded 1.7×10^5 m^3 of volume.
During the event 14 buildings were destroyed, while 24 were injured.

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11 - FONTANALUCCIA (MO)

The censed landslide, involving Fontanaluccia village, occurred in February 15, 1832, as reported by the local newspaper of Modena *La Voce della Verità*, and later there are news of reactivations during 1930, 1976, 1978.
The landslide affects the right side of the Dolo stream, which in this section is formed at the top by alternating layers of sandstone with marl layers (*Arenarie del Cervarola*), with thickness from a few cm to a few dm, overlapped on a olistostrome body, formed by clays incorporating sandstone boulders.
The movement is classified as complex, at the top we have a rotational sliding passing down to a flow.
In all its activations, it always caused a partial damming.
In 1832, the landslide damaged the church, the bell tower, a shed and 7 huts, before entering the Dolo River with a front of about 500 m. The volume of the dam was about 7.5×10^5 m^3, and subtended a basin of 34 km^2.
Currently the foot of the landslide is reached by an artificial lake built with hydroelectric purposes.

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S:C:A:I: Regione Emilia Romagna , Provincia di Modena, Fontanaluccia, p. 18-9.

12 - BOCCASSUOLO (MO)

Boccassuolo is a town located in the valley of the river Dragone, the northern Apennines. There are news about a landslide from 1707, with reactivations in 1728, 1750, 1939, 1986.
The slope where the landslide occurred is formed in the upper part by alternating marl and sandstone (Mt. Venere Flysh), passing down to tectonized clays (Argille a Palombini) and ophiolite blocks. In the crown there was a rotational sliding evolving at the foot in a flow.
The volume of the dam wandered about 3 million m^3 of material, while the catchment area was 60.81 km^2. The lifetime of the lake is unknown.

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13 - FRASSINORO (MO)

Frassinoro is one of the most famous and extensive landslides of Northern Apennines. The earliest records tell of a downfall occurred in 1598 and then repeated in 1605, 1616, 1717, 1905, 1956, 1984, 1989. The landsliding slope is placed on the left bank of the Dragone River and stretches from the slopes of Mt. Modino to the bed of the stream, for a length of more than 4 km. It is made at the top by an alternation of marl and sandstone (Flysh Mt. Venere), passing down to tectonised clays (Argille a Palombini) and ophiolite blocks. The movement is classified as complex and is characterized in the crown by a rotational slipping movement that evolve to flow in the foot.

The landslide has also been the subject of specific studies (Soldiers & Tosatti, 1993) which showed the different activations. In some events also completely blocked the Dragone and resulted in the formation of lakes, now completely filled, but their tracks are visible to a careful mapping examination.

Considering what remains, the dam is estimated at around 6 million m^3, with an underlying area of 75 km^2.

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14 - TOLLARO (MO)

The landslide affects the left side of the Dragone stream and it is formed at the top by an alternation of marl and sandstone (Flysh Mt. Venere), passing down to tectonized clays (Argille a Palombini) and ophiolite blocks. The movement is classified as complex and is characterized in the crown by a rotational slipping movement that evolve to flow in the foot. The first collected data is from December 12, 1886, but surely it was not the first activation (Almagià, 1907). Later movements have occurred in 1944, 1959, 1973. During the event of 1959, the complete blockage of the Dragone stream took place with the formation of a lake, now completely filled (Soldiers & Tosatti, 1993).

The dam reached a volume estimated at around 7 million m^3, subtending a basin of 90.75 km^2.

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15 - LAMA MOCOGNO (MO)

The landslide of Lama Mocogno falls within the Scoltenna basin a tributary of Panaro River. There are news about it from 1400 and reactivations in 1574-75, 1689, 1835, 1864, 1879, 1920, 1926.

The most significant event and even better documented is certainly that of 1879, which led to the complete obstruction of the river, forming an upstream lake basin. The lake, whose maximum extension reached 4 km long, was alive a few years, then disappeared for silting.

The involved slope was formed by alternating layers of limestone marl, or calcareous marl interspersed with shaly layers, belonging to the Flysch of Mt. Venere.

The movement is classified as complex and is characterized in the crown by a rotational slipping movement that evolve to flow in the foot. The landslide caused extensive damage, in particular the destruction of the Via Giardini and several cottages. The left side of the valley of Scoltenna in this section is full of landslides that forced to build exclusively on the ridge, where there are the villages of Lama Mocogno and Mezzolato.

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16 - CASELLE (MO)

The Caselle landslide occurred in March 4, 1952, coinciding with an earthquake with epicentral area in Prignano sulla Secchia (Pellegrini & Tosatti, 1982), and had a partial reactivation May 30, 1953, following an heavy rain.
The movement caused the partial dam of the Ospitale River, which formed upstream pond about 8 m deep. The next day the water eroded the dam and the lake disappeared in a short time. (LA NAZIONE, 23-30/12/1952). The path of the stream has a loop in this point, only trace left notice of the dam.
The landslide is classified as a sliding of debris and has occurred on a slope formed by regular alternating layers of sandstone and marl, belonging to the *Arenarie del Cervarola*.
Some homes of Caselle were damaged, and upstream of the landslide dam the flooding of Fanano-Ospitale was recorded. Some hydraulic works were realized, to limit the effects of erosion at the foot of the landslide.

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17 - GROPPO, RIOLUNATO, (MO)

The Groppo landslide is one of the best-known, by quality and quantity of information, throughout the Northern Apennines. The most important movement has occurred December 29, 1786 and is subsequently reactivated in 1791, 1800, 1850. There are also reports of a landslide in 1636 that would have destroyed a third of the village of Groppo.
The landslide falls in the catchment area of the Scoltenna River, which was completely blocked during the event of 1786. Chronicles speak of a dam of large proportions, 150 arms in height (about 80 m), with formation of a large lake. The overflowing waters of the river began to erode the opposite slope, threatening the stability of the whole slope where Riolunato was built. It was an open channel in the dam, which allowed the water to flow (Pantanelli & Santi, 1895).
The landslide caused significant damage to Groppo, with the destruction of 47 houses, 1 bridge and a stretch of Via Giardini.
The movement is classified as a rapid translational sliding of debris, which occurred on a side made up mainly of sandstone (*Arenarie di Mt. Modino*) and strongly tectonised clay (*Formation of Pievepelago*).
The dam reached a volume of about 10 x 10^6 m^3 of material and a subtended area of 147 km^2. The lake was alive about a year.

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18 - S.ANNA PELAGO (MO)

The first description of Sant'Anna Pelago landslide came from the work of Almagià (1907), "Studi geografici sulle frane in Italia" (Geographical studies on landslides in Italy), as follows:

"*…Ma tristamente celebre è la valletta del torrente Sant'Anna, contigua a quella delle Tagliole, per la terribile frana che distrusse interamente, il 21 dicembre 1896, il paese di Sant' Anna Pelago. Questo era stato costruito nel secolo XVII sui detriti appartenenti forse a frane antichissime, a circa 1070 m. di altezza, a cavaliere della valle del torrente Sant' Anna.*

La frana si staccò improvvisamente di sotto la cima dei monti Spicchio (1665 m.) e Santa Maria (1226 m.) nella località detta Bonacce (circa m. 1300) e, sommovendo il terreno a onde, a sbalzi, con sollevamenti e sprofondamenti, distensioni e costipamenti della superficie, a seconda delle resistenze incontrate, discese fino al fosso, che ne fu ostruito, e stendendosi per una larghezza di circa 2 km. Sulla via nazionale delle Radici, la asportò e ricoperse interamente, salvo un piccolo tratto; nel suo percorso incontrò l'abitato di Sant'Anna, il cui caseggiato centrale fu ridotto un mucchio di rottami: cento e ottantadue fabbricati andarono distrutti. Tutta la plaga, sconvolta come da un violento terremoto, presentava ondulazioni ed accavallamenti caratteristi; nelle bassure si eran formati laghetti e pozzanghere, un bacino abbastanza esteso era sorto per ostruzione traverso il rio Martino. L'area della regione devastata dalla frana comprende circa 7 kmq.; per la sua estensione e per le rovine arrecate questo può dunque ritenersi come il più ingente scoscendimento avvenuto, almeno in tempi recenti, nell'Appennino settentrionale. La strada delle Radici, che traversa l'intera zona franata, avea già da qualche tempo dato cenno di piccoli movimenti, ma la frana si iniziò solo la sera del 21 dicembre, dapprima con moto assai lento, poi con rovinio sempre più rapido: il giorno seguente era già avvenuta la totale distruzione del paese. La causa immediata del grandioso fenomeno fu ricercata nell'azione erosiva del torrente Sant'Anna, ma è probabile che a provocarlo abbiano contribuito eziandio le acque sotterranee; infatti sopra al ruinato paese esistevano i cosiddetti Lagacci della Porticciola ed altre pozze d'acqua originate forse dal distacco di più antiche frane e non ancora prosciugate…"

According to Almagnà (1907) the landslide, December 21, 1896, destroyed 182 buildings of Sant' Anna Pelago, a long stretch of the main road and reached the Perticara stream, blocking it for 2 km. The landslide had a surface of about 7 km^2 and was probably triggered by the erosive action of the stream at its toe.

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19 - SILVELLE (MO)

The censed event occurred in Dicember 21, 1619, and completely blocked the Scoltenna River, with the formation of a short lived lake. Morphological evidences of the dam are no more visible, so it is probable that it was soon overflowed by impounded water.
The landslide had moved again in November 1st, 1621, but without completely blocking the river.

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20 - LOTTA (MO)

The Lotta landslide, April 12, 1590, brought to the total obstruction of the Leo stream, a tributary of Panaro River. The lake that formed was the source of fevers and miasma. In this point the left slope of the valley, formed by alternating layers of turbidite sandstone and marl of the *Arenarie del Cervarola* Formation, is entirely covered by debris of landslides.
The lake, whose burial is clearly visible even to an mapping examination, reached a maximum size of over 1 km and remained alive for some years.
The landslide stretches along the slope for more than 3 km, occupying the whole slope between Sestola and Leo villages. The movement is classified as complex and is characterized in the crown by a rotational slipping movement that evolve to flow in the foot. According to Almagià (1907), the Lotta village, composed by 104 buildings and a church, was destroyed with a lot of deaths among men and animals.
The dam was composed by 12 x 10^6 m^3 of materials and a subtended area of 76.65 km^2.

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21 - ARSICCIOLA (MO)

The landslide occurred in December 9, 1728, destroying Arsicciola, a town located in the basin of the Fellicaloro River. Now there is a house named Arsicciola on the left side of the stream, while on the right side evidence of landslide are visible. It is probably that on this side there was the former Arsicciola, rebuilt on the opposite safe side after the disaster. Then the landslide had activated again in 1779 and 1788 and a previous time in 1677.
During the event of 1728 the river, flowing in a very narrow stretch, was totally blocked for one day until the impounded water overflow the dam.
The dam was composed by 3 x 10^5 m^3 of materials and a subtended basin of 17,45 km^2.

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23 - BOMBIANA-PIAN DI CASALE (BO)

The exact date of this event is unknown, but is to be placed in the eighteenth century as reported by Calindri (1781). The author talks about two landslides, still visible, occurred simultaneously on opposite sides that came together to block the Reno River in the same point. The first, largest in area Bombiana, on the left bank of the Reno and the other smaller in Pian di Casale in the right bank.
The dam, with a subtended basin of 216 Km^2, was composed by 4,5 x 10^6 m^3 of materials and formed a lake about 1 mile in length. The lake survived a few months until the impounded water overflow the dam. Both sides are composed of clays embedding lithoid blocks of limestone or marl.
The landslides are classified as slides of earth triggered by heavy rainfall. A known reactivation occurred in February 1960.

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24 - CINGHIARELLO (BO)

The Cinghiarello landslide is one of landslides that periodically involved the Reno River in the section between the confluence with the Silla stream and with the Marano stream.
The landslide is classified as a slide of earth and interested the Reno on February 15, 1902, and in February 1996 had a reactivation as a result of heavy rainfall.
The event of 1902 was a partial obstruction, without formation of a lake, that put at serious risk the railway line passing on the opposite side of the landslide, due to the deviation that suffered the Reno River (Almagià, 1907).

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25 - GARDELLETTA (BO)

The event has taken place during the spring of 1985, and in its course interested in the Setta River.
The right side, where the landslide is occurred, consists of marly mudstones and sands with included sandstones. The dam was partial. The section of the river Setta it was halved, putting at risk from flooding the town of Gardelletta, located on the opposite bank.
The movement is classified as complex, characterized by a sliding rotational crown, evolving in translational sliding at the foot. The landslide involved 40 buildings and some roads.

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26 - MARANINA, G. MONTANO (BO)

The landslide started January 31, 1996, in Maranina locality, on the laft bank of the Reno River, upstream of the confluence with the Marano River. The day after the movement reached the river with a front of about 50 m width.
The landslide is classified as one slide of earth and involved clayey materials, destroyed 4 houses and carried off about 100 m to the highway "Porrettana". The river bed was raised by about 1 m during the event.
The operations were directed to maintain the flow section of the Reno free, through the continuous removal of the collapsed materials, in order to prevent its closure. Even a simple deviation would push the water to erode the opposite bank, putting at serious risk of collapse of the railway line that passes over it.
In the past is likely that landslide dam lakes were formed, because in an excavation near the river were found lacustrine clays. Calindri (1781-5) speaks about a landslide dam, occurred at an unknown time, at the confluence between the Reno with the Marano River.

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27 - SERRAZANETTI, GAGGIO MONTANO (BO)

The Serrazanetti landslide is placed on the left bank of the Reno River, just downstream of the confluence with the Silla River.
The census landslide, occurred on February 15, 1960, has affected the slope for a length of 1450 meters and causing the partial damming of the river. The news was widely reported by the newspaper *Il Resto del Carlino* and *La Nazione*.
The movement was classified as slippage into the ground, which occurred within clay materials belonging to the complex chaotic, triggered by heavy rainfall that preceded it. The landslide progressed to more than 20 m in the riverbed of the Rhine, with a front of more than 200 m, and then stop around February 23. The greatest damage was the removal of a stretch of "Porrettana" highway.

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28 - CASTEL DELL'ALPI (BO).

The history of the landslide occurred in Castel dell'Alpi area is quite long.
Both sides that form the bank of the Savena stream are covered with debris produced by landslides that cyclically affected the waterway, leading to the formation of lakes on several occasions. On both sides are highly erodible rock types clay and stone intensely fractured rocks.
Each landslide affecting the stream causes the immediate effect is to divert the river bed, increasing erosion at the foot of the opposite slope, which becomes more unstable. It can trigger a cyclical nature with landslides that follow alternately on the two opposite sides of the same valley.
These events are called with "See-Saw" (Elmi, 1988).
The case of Castel dell'Alpi is among the most famous: the first known landslide occurred in 1799 in the right bank, then reactivated at half of the '800 and later in 1895 and 1909. The last event, in February 1951, on the left bank, is responsible for the formation of the lake basin existing till today; also in this case it was a reactivation of a landslide of 1870.
The movement is classified as a rotational slide, which involved a arenaceous pelitic flysh (*Arenarie di Monghidoro*), strongly tectonized.
The erosion at the foot of the slope can be the predisposing cause, and the strong precipitation that characterized the month of January of the year 1951 the triggering cause. The landslide caused the emplacement of a dam of about 4 x 10^6 m^3 of material, which implies a catchment area of 21.75 km^2.

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30 - MONTEFORCA (FO)

The landslide occurred March 28, 1895 on the right bank of the Tramazzo River just upstream of Tredozio. The movement, a slide of rock, very fast, wet, involved a portion of materials belonging to the formation *Marnoso Arenacea*, for an extension of about 1 km^2.
The landslide caused the damming of the Tramazzo River, which formed a lake about 600 m long. The first works were directed to keep down the lake water level, in order to decrease the risk of flooding for the eventual rupture of the dam, with a drainage channel. The lake was alive a few days.
The dam must have had a maximum volume of about 3 x 10^6 m^3, subtending a catchment area of 33.6 km^2.
The landslide caused the destruction of 4 farms with 4 annex farmhouses; 11 people lost their lives.

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31 - QUARTO DI SAVIO (FO)

The landslide took place March 21, 1812 near Quarto di Savio and evolved in one of the most important damming case in Italy. The event killed 18 people; the damage was huge, 4 houses and the church. The greater knowledge derived from a specific study performed by Eng G. Bertoni (1849).
The movement, classified as translational-rotational slide movement of rock, very quick, involved a large portion of the left side of the valley of Savio, formed by rocks belonging to the formation *Marnoso Arenacea*.
The landslide caused a dam across the Savio, with a volume of about 1.6 x 10^7 m^3.
The catchment area had an extension of 214.8 km^2.
It formed a lake of great proportions; a branch stretched almost to Bagno di Romagna, placed 4 km upstream, and another went up the Para stream. According Bertoni (1849) waters reached a maximum depth of 120 m.
In 1828, owing to a particularly dry summer, the overflow level of the lake was lowered with some explosive charges, in order to powered the mills in the valley.
In 1923 the S.I.D.A.S. (*Hydroelectric Company of Upper Savio*) realized an artificial concrete dam for hydroelectric purposes, by exploiting the barrage of landslides. In 1926 the volume of retained water was 4.5 x 10^6 m^3; currently it is greatly reduced due to siltation and does not exceed 4 x 10^5 m^3.

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32 - S. PIERO IN BAGNO (FO)

The event has taken place February 14, 1855, just below the village of San Piero in Bagno. Two landslides detached from opposite sides went to converge in the river Savio, damming it. Soon there was a lake that reached S. Piero, about 800 m upstream of the dam (Veggiani, 1995). The lake level dropped much in a day's time, probably due to overtopping and erosion of the dam.
The movements, classified as complex, slides evolving in flows, represent the reactivation of dormant landslides occurred within debris coverages. Previous activations of the landslide in the right bank on Mt. Comero are known since 1400, then in 1574, 1827 (Veggiani, 1995). In some event must be also formed a lake basin, whose memory has remained in the place name "*Pian del lago*", that means "*Plain of the lake*".

The reconstruction of the event in 1855 shows that the dam must have reached a volume of 4.5 x 10^6 m^3, subtending a catchment area of 81.55 km^2. Were destroyed the Baroncini village and a church.

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33 - TOZZI (FO)

The event has taken place March 20, 1903, in the Tozzi locality, in the municipality of San Piero in Bagno.
The movement is classified as a fast translational slide that affected the left side of the Savio River, formed by rocks belonging to *Marnoso-Arenacea*. It was preceded by heavy rainfall.
The damming was only partial and caused the deviation of Savio, which at this point forms a loop. The landslide destroyed 11 buildings.

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34 - TAJOLO (PE)

The landslide occurred in 1855 damming the Fanatello creek, a waterway forming part of the basin of the Savio River.
The movement is classified as a rotational slide and involved a slope formed by the alternation of gypsum and clay. It realized the total damming Fanantello, with formation of a lake that was alive 25 years before disappearing for silting.
The dam was 1.3 x 10^6 m^3 of materials, subtending an area of 13.17 km^2.

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37 - TRAMARECCHIA (AR)

The landslide has occurred December 15, 1945 in Tramarecchia location and provoked complete damming of the Marecchia River and the formation of a lake, "*Lago delle Rofelle*".
The waters of the river after about four months opened a gap between materials collapsed, but the dam resisted the overflow. The lake basin, whose maximum depth was 5 m, has been alive for four years before disappearing for silting.
The movement, classified as complex, evolving in slip flow, has taken place along the right side of the Marecchia valley, formed by the alternation of marls and limestones with pelitic levels, belonging to the formation of M. Morello, with dip slope layers. The last activation of the landslide was in 1960.

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38 - LIZZANO (PT)

The Lizzano landslide occurred Genuary 26, 1814, completely destroying the old Lizzano. The event was specifically studied, rare instance for the time, by Cav. Luigi Serristori (1815).
The movement classified as complex, wet, is the result of a rapid rotational slide, which evolves at the foot in a fast translational slide. It involved a large portion of the left side of Lima, in this section consisted of quartz feldspathic sandstones alternating with marls and silty shales belonging to the Formation of Londa.

The landslide was triggered by heavy rains that preceded it, "continuously", according to the Almagià (1907), in the period from May to December 1813.
During the event was recorded the damming of Lima with the flooding of the Modenese road along the river.
The landslide dam had a volume estimated at around 2 x 10^6 m^3, subtending a catchment area of 83 km^2, and it was undamaged for a total of 13 months. Following the normal erosive action of the river, favored by the actions of man through the explosion of some explosive charges within collapsed materials, the dam was dismantled.
Currently there is an artificial dam in the area set on bedrock outcropping about 100 m downstream of the remains of the foot of the landslide.

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39 - CAMPOGALLI, PRATO AI GALLI (AR)

The landslide occurred the night between 7 and May 8, 1898 in Campogalli locations, about 5 km downstream of Capo d'Arno, and has led to the damming of the Arno River with formation of a lake, "*Lago Virginia*". It was actually two elliptical basins, which reached a maximum depth of 10 m (De Gasperi, 1912).
The movement, classified as a translational slide, very fast, in rock, was preceded by heavy rainfall; 56 mm were recorded in 13 hours.
The affected silope was made of layers metric sandstones alternating with thin pelitic levels, belonging to the Formation of *Arenarie del Falterona*.
The miller of Mulin di Bucchio, placed just downstream, realized the event as, getting up early, saw that the waters of the Arno had suddenly stopped to flow (Mori, 1898). In 1912 the lake had already disappeared. As a result of important rainfall events still form of standing water upstream of the dam. The latter consists of large blocks of sandstone and proves to be minimally engraved.

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40 - GAMBERARA (FI)

The April 14, 1899, after two days of heavy rainfall, a landslide occurred in Gamberara, Municipality of Marradi (FI).
This was a translational slide of rock, very fast, detached from Poggio delle Scalelle (650 m a.s.l.). The landslide covered the whole slope and poured into the Campigno stream, causing the formation of a type IIIa landslide dam.
The volume of the landslide was the 2 x 10^6 m^3 and the dam of 9 x 10^5 m^3. The catchment area underlying the dam has an area of 22 km^2. The triggering cause of the landslide is detectable in heavy rains that preceded it. The layers have dip slope arrangement in relation to the valley of Campigno, but anti-dip slope markedly less inclined than the slopes of the valleys of the tributaries courses, those were responsible in this case the instability.
The dam of 1899, quickly led to the formation of a lake upstream, so that three victims were found, trapped in homes by water Gamberara. The lake, with a length of 300 m and a width of 150 m, however, was short-lived, around 5-6 years having been subject to rapid silting (Sestini, 1930). Later, the erosion carried out by the torrent Campigno, caused a lowering of the level of local base of the stream and the resulting terracing upstream of lake deposits.

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41 - FARFARETA (FI)

The landslide is visible C. Ler Pianelle in area, right bank of the Campigno River, south of the town of Farfareta. It is a roto-translational slide, which is the reactivation of a previous landslide occurred within the *Marnoso Arenacea*.

The dates of the movements are unknown, although the inhabitants of the area have been passed on by oral tradition about a giant landslide. According Sestini (1930) the landslide has affected the Campigno stream, causing the upstream damming and silting.

Cartographic analysis shows clearly a vast elliptical plain located upstream of the landslide; it is terraced alluvial deposits consist mainly of coarse gravels. It is fairly unlikely that the Farfareta landslide might have produced major dam episodes.

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42 - BOESIMO (FI)

The landslide occurred the April 11, 1690 on the left side of the Rio Boesimo, a tributary of the Lamone River, in which it meets near S.Cassiano.

The chronology of the event and the size of the landslide are reported in an ancient text of the duct Marco Antonio Melli (Rotten Antonii Mellii, 1693). In the book, is supported the thesis that the triggering cause was the earthquake that affected the Romagna in 1688, unlikely eventuality given the two years that elapsed before the landslide happened, dated 1690.

The movement originated from Mount Budrialto and interested, blocking them, both the Rio Boesimo, the Lamone River, and causing the formation of two lakes: the first large on Lamone, the second smallest of the Rio Boesimo. Ten people died in the event. The dam on the Lamone must have been minor, as was quickly removed on project of the plumber Pier Maria Cavina. The lake on the Rio Boesimo, today completely filled, must be left alive a few years.

It was probably a complex movement characterized by a rotational slide in the crown area passing through the foot to a translational slide.

The dam had an estimated volume of 2 x 10^6 m^3; its major portion blocked the Rio Boesimo (1.5 x 10^6 m^3), while the terminal part of the Lamone (5 x 10^6 m^3). River basins subtended by the Rio Boesimo and Lamone reach an surface of 4.7 km^2 and 158 km^2 respectively.

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44 - CRESPINO DEL LAMONE (FI)

The landslide has occurred in an undefined period along the right side of the Lamone River in Valbura locations, downstream of the Crespino railway station.

Probably it was a translation slide which involved turbidite layers belonging to *Marnoso Arenacea* Formation. The landslide probably occurred along a layer surface and the detachment was certainly helped by erosion at the base operated by a right tributarie of Lamone.

The topography of the area has been significantly changed by the event, as evidenced by the important counterslope which is formed to the east of the Mulino Valbura.

The landslide blocked Lamone and formed a long lake ably until Crespino, then completely filled.

The dam was estimated about 2 x 10^6 m^3, while the river basin has a surface of 22 km^2.

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46 - SORBANO (FO)

The landslide interested in the right side of the Savio River, near Sorbano, locality situated just downstream of Sarsina. It is difficult to estimate the volume of the landslide dam, which still had to be about 2.5 x 10^6 m^3 of material. The catchment area was 309 km^2. The date is unknown, but is placed around the second century AD.

During an campaign of archaeological excavations in 1951 were discovered, at Pian di Bezzo, some funerary artifacts from the Roman era. These were placed in a terrace below 3.3 m of lake deposits. The hypothesis is that a large landslide has blocked the river, to the formation of a lake basin upstream and the subsequent flooding of the Roman necropolis. Later the lake was completely filled and Roman layer was under 3.3 m of deposits.
In this stretch the valley of Savio is cut inside the *Marnoso Arenacea* Formation, on the left side layers are dip slope, preparing the genesis of landslides. The landslide is partially reactivated in 1939.

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47 - MONTIGNOSO DI LUNIGIANA (MS)

In 1717 the landslide occurred due to heavy rains in the Cerreto locality, leading to the damming of the Corsanico Channel.
The slide movement, wet, very quick, occurred along the right side of the valley formed by strongly tectonized mica schist. The chronicles of Bartolomeo Bertocchi (1844) tell that the dam collapsed, bringing destruction across the valley floor.
A similar event occurred in the July 8, 1844, when as a result of a period of heavy rain formed a dam of rocks and trees upstream of Montignoso. The dam collapsed causing the formation of a flood wave that brought further damage to Montignoso despite the levees built as a result of the event of 1717 (Sforza, 1867).

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48 - CÀ DI SOTTO, S.BENEDETTO VAL DI SAMBRO (BO)

The landslide has occurred during June 1994 in Cà dei Rossi and resulted in the complete closure of the Sambro stream and the formation of a lake basin upstream.
The movement is classified as complex, formed by a rotational slide in crown, wet, fast, passing through to a translational slide.
The mobilized materials amount to 5.2 x 10^6 m^3, while the dam is estimated around 1 x 10^6 m^3. The landslide has involved a large portion of the slope formed mainly by alternating layers of marl and limestone with intercalated pelitic levels, strongly tectonized and belonging to the formation of *Mt. Venere*.
The catchment area subtended by the dam is of 15.49 km^2.
With coordination by the Civil Protection of the Region Emilia Romagna, the interventions were aimed at maintaining the dam landslide by the emplacement of two underground pipelines that bypass the dam, limiting the overflow.
On the opposite side of the valley of Sambro, in Campiano locality, there is another landslide that in 1772 caused the damming of the river, with the formation of a lake of over 1 km in length.

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49 - PIEVE S. STEFANO (AR)

The landslide took place February 14, 1855 consequently to a period of heavy rain that caused flooding and landslides, in San Piero in Bagno, in Romagna.
The movement classified as a rotational slide, wet, fast, involved the left side of the Tevere River in Poggio Belmonte, causing the destruction of some buildings.
In this stretch outcrop turbidite layers of limestone marl and calcareous marl belonging to the of *Mt. Morello* Formation.

The Tevere was completely blocked and submerged in a large lake the center of Pieve Santo Stefano. Seven victims were counted.
The dam, with a volume of about 4 x 10^6 m^3, survived about a year; during this time the interventions were targeted to open way for the waters of the Tevere.

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51 - STURAIA DI GALIGA (FI)

The landslide occurred during the Spring of 1898 in the Sturaia Galiga locality and caused the dam of the Argomenna River, a tributary of the Sieve River.
The movement, classified as complex, wet, fast, given by a rotational slide in crown evolving to the foot in a translational slide, is still well identified due to the formation of a counterslope in the crown area. The interested left side of the valley was formed by alternating layers of turbidite sandstones belonging to *Arenarie di M. Senario*.
During the event a mill and a farmhouse were destroyed.
The dam volume was estimated around 3.6 x 10^5 m^3, subtended a catchment area of 8.48 km^2.
It formed a lake about 200 m long, which remained a few years.

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52 - TOLLARA (PZ)

The news of this landslide, which occurred in March 1895, is reported by Almagià (1907).
The landslide destroyed "many houses" and barred the Rio Camia, a Nure left tributary with confluence at Bettola locality.
The dam was short-lived and the river dug a new way through the collapsed materials. The slope is formed by alternation of marly limestones and sandstones with interbedded pelitic, belonging to *Albirola* Formation.
According to an approximate estimate, the dam was about 1.8 x 10^5 m^3 of materials, subtending a catchment area of 9.82 km^2.

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53 - LE MOTTACCE (AR)

The landslide occurred November 27, 1987 at Le Mottacce near Subbiano (AR).
It was the partial reactivation of a dormant landslide, which interested the Arno River with a front of about 100 m. It was partial damming, as the landslide stopped after having penetrated into the river bed to 2/3 of its outflow section.
The movement has affected the right side, formed by a cover formed by silty clayey sands with lithoid elements with diameter less than 10 cm.
The dam was not large, 5 x 10^4 m^3, but its danger remarkable since even a simple deviation of the Arno, 738 km^2 of subtended watershed, would likely have affected the town of Subbiano. The movement is classified as a translational slide, which occurred in the debris resulting from the *Arenarie del Cervarola*.
The landslide caused significant damage as it carried off for a stretch of about 100 m of both the railway line Arezzo-Stia, and the provincial road that runs alongside.

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54 - SERELLI (AR)

The landslide occurred in Serelli locality, Municipality of Stia, December 12, 1992.
The triggering cause of the movement, a planar slide from moderate to fast, was the heavy rains that preceded it: the slope is formed by silty sandstones layers alternating with pelitic levels (*Arenarie del Falterona*), with dip slope trim.
The landslide is still visible on the right bank of the Fosso Vallucciole for a front of 400 m.
The chronicles tell that the Vallucciole river rose its level upstream of the obstacle, forming a pond a few meters deep. The pond greatly diminished its extension in a day, as a result of the overflow of the dam.
The case is of modest size and the volume of the dam estimated around 4.5 x 10^4 m^3, with a subtended catchment area of 2.8 km^2.
The damage was considerable: the landslide completely destroyed the town of Serelli and a stretch of road that connected Stia with Vallucciole. It was the reactivation of a dormant landslide that, in 1966, had already shown signs of activity, without causing damage.

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55 - S.PATRIGNANO (AR)

The landslide occurred during 1990 in the S.Patrignano locality, destroying a stretch of public road and a bridle situated along the Marecchia River.
The movement, classified as a translational slide, fast, was in the right hydrography of Marecchia and determined the partial damming, causing only the narrowing of the river runoff section.
The landslide materials consist of blocks of limestone layers belonging to the *Mt. Morello* Formation, were subsequently removed.

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56 - POPIGLIO (LA LIMA) (PT)

The landslide occurred December 15, 1933 in Ponte Lima (PT), affecting the right slope of the river Lima for an extension of about 3 x 10^5 m^3.
There had been some phenomena in previous years, such as the formation of the cracks on the road Bagni di Lucca-Abetone.
The movement is classified as a sliding translational, fast, occurred inside a debris cover formed from sandstone blocks immersed in finer material.
The landslide caused the complete damming of the Lima River and the subsequent formation of a lake about 900 m long. The lake survived a little over a year, before becoming extinct for gradual erosion of the dam due to the work of the man who dug a channel in order to help the flow of water.
The dam was 1.8 x 10^4 m^3 of volume, subtending a hydrographic surface of 107.8 km^2.
The landslide destroyed a section of a 300 m of the road Bagni di Lucca-Abetone.

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57 - PIAN DÈ ROMITI (FI)

The Pian dei Romiti is a vast area of flat land located at an altitude of 710 m along the Fosso Acquacheta stream, near the Muraglione Pass between the provinces of Firenze and Forlì.
On the North Western margin of the plain is located the famous waterfall of Acquacheta told by Dante which compares it to the Flegetonte jump into the abyss of the Eighth Circle of Hell:

Even as that stream which holdeth its own course	*"Come quel fiume c'ha proprio cammino*
The first from Monte Veso tow'rds the East,	*prima del Monte Veso in ver levante,*
Upon the left-hand slope of Apennine,	*dalla sinistra costa dell'Appennino,*
Which is above called Acquacheta, ere	*che si chiama Acquacheta suso, avante*
It down descendeth into its low bed,	*che si divalli giù nel basso letto,*
And at Forli is vacant of that name,	*e a Forlì quel nome é vacante,*
Reverberates there above San Benedetto	*rimbomba là sovra S. Benedetto*
From Alps, by falling at a single leap,	*dell'Alpe per cadere ad una scesa*
Where for a thousand there were room enough;	*ove dovrìa per mille essere recetto;*
Thus downward from a bank precipitate,	*così giù d'una ripa discoscesa,*
We found resounding that dark-tinted water,	*trovammo risonar quell'acqua tinta,*
So that it soon the ear would have offended.	*sì che 'n poc'ora avrìa l'orecchia offesa.*
(DANTE, Inferno, XVI, 94-105)	*(DANTE, Inferno, XVI, 94-105)*

The genesis of the Plan of Romiti is somewhat unclear; Veggiani (1972) suggests that it is the filling of a landslide dam lake. The hypothesis is that a translational slide movement with Southeast-Northwest of materials belonging to *Marnoso Arenacea* Formation, has crossed in ancient times the Fosso Acquacheta stream, forcing him to form a lake. According to this interpretation, the river flowed originally farther north.
Consequently the landslide formed a spillway where the minimum altitude was place where now stands the Acquacheta waterfall, which is the easternmost part of the dam.

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58 - F.SSO DI FALTERONA (FI)

The landslide took place February 26, 1966 along the northern slope of Mount Falterona.
The movement is classified as a rotational slide, fast, that affected a thickness of 40 m of debris coverage resulting from the tectonic disintegration of layers belonging to *Marnoso Arenacea* Formation.
The landslide liquified once reached the Fosso Falterona resulting in a debris flow channeled along the creek. The volume of material is estimated at around 4×10^5 m^3; however largely remained near the foot of the landslide causing an expansion of the stream bed from 10 m to 50 m (Grazi, 1966).
The slopes of the Falterona were interested in historical times by another major landslide. In May 15, 1335 a landslide about 6 km long, involved the whole slope that descends to Dicomano, destroying the Castagno d'Andrea village.

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59 - TERRAROSSA (BO)

The landslide has started to move during April 1996. It was the reactivation of a dormant landslide with an unknown history; its extension is easily detected on topographical maps before the last event.
The movement is classified as a flow, wet, occurred along the right side of the Venola torrent, a left tributary of the Reno River, formed in this section clays including calcareous with size less than the decimeter belonging to *Complesso Caotico*.
The landslide caused the dam on the Venola torrent and the formation of a small lake basin upstream.

The interventions were designed to keep open a runoff channel for the lake water and prevent the formation of a big reservoir.
The Venola torrent underwent a shift of about 20 m north.
The landslide destroyed a field and flooded a vineyard.

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60 - CAVALLICO (FI)

Near Cavallico (upper basin of Levisone River) there is a debris cover with 2 km^2 of extension, on the edge of the unit *Castel Guerrino*, the *Super Group Umbro* and the *Complesso Caotico*.
In historical time a currently quiescent landslide reactivated part of the debris, blocking the Levisone River and forming a pond.
The movement, classified as a flow, most likely occurred along the waterproof substrate constituted by the *Complesso Caotico*.
The pond was filled as evidenced by lacustrine deposits present in locations Cavallico.
The volume of the dam is very impressive, 1.8 x 10^6 m^3, especially compared with the low extension of the subtended catchment area of 2.71 km^2.

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61 - CAMPIANO (BO)

The landslide has occurred February 4, 1772 in Campiano locality. The chronicles tell of a movement of vast proportions that swept the sanctuary of Campiano, destroying it completely.
The movement, classified as a rotational slide, affected the left side of the Sambro River, characterized by alternating layers of marl and limestone with intercalated limestones and pelitic levels, belonging to the formation of *Mt .Venere* Formation.
Along the Sambro a lake, reaching a maximum length of 1000 m, formed and survived for an unspecified time. Another lake formed in a counterslope upstream of the landslide toe.
The site is currently designated as the "*E pelgh*" in Bolognese dialect which means stagnation, swamp.
The dam reached a volume of 3.5 x 10^6 m^3, subtending a surface of 15.49 km^2. During 1994 it is moved to the opposite side of the landslide S. Benedetto Val di Sambro, which he again crossed the waterway.
The analysis of these movements, which are called "*See-Saw*" (Elmi, 1988), leads to the conclusion that after an event occurs a diversion dam river, with increased erosion at the foot of the opposite side of the landslide and generation of instability conditions.

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Stefanelli, D.E. (1975). *S.Benedetto Val di Sambro.* Crespellano (BO), p.78-96.

62 - S. BENEDETTO IN ALPE (FO)

The landslide has occurred at the end of the last century along the left side of the Fosso Acquacheta ditch, just upstream of the S. Benedetto in Alpe village.
It was a fast translational slide, happened in the rock that led to the damming of the river.
Along the slope, layers of marl and sandstone outcrops interspersed with pelitic levels, belonging to the *Marnoso Arenacea* Formation and dip slope trim.
The landslide formed a lake which remained until the '20s before disappearing for silting.

Bibliography:
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64 - GALLARE, FARINI DELL'OLMO (PZ)

The landslide began January 13, 1996, affecting the location of Gallare, placed just downstream of the Farini dell'Olmo, in the right bank of the Nure River.
The phenomenon has affected the stream Nure causing narrowing of the outflow section, and the raising of the riverbed.
The slope affected by the landslide is composed of calcareous marl and sandstone turbidites pelitic belonging to the Flysch of Farini dell'Olmo.
The movement is classified as a multiple rotational slide, which has reactivated a portion of the slope already meved about 50 years ago, causing a partial obstruction of the watercourse.
The volume of the dam is estimated around 1.1 x 10^5 m^3 and underlies a catchment area of 109 km^2.
The trigger of the landslide is to be attributed to the foot erosion by the Nure and poor water management systems in crowning area.
The first interventions were aimed at maintain free the flow section of the Nure River and to allow a better flow of water in the crown by the emplacement of gutters and drains.

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Ermini, L. (2000). Elaborazione di un modello per la previsione dell'evoluzione di sbarramenti fluviali causati da frane. Unpublished PhD thesis, Firenze, pp. 159.

68 - SCANNO (AQ)

The bibliographical research conducted as part of the study, showed that several authors have studied the formation of the Scanno Lake and the age of the landslide that created the lake, since the second half of 1800 and early 1900. Some studies were often deeply influenced by imaginative local legends appeared without any scientific basis.
The Scanno landslide dammed the Tasso River and caused the impoundment of the Scanno Lake, which is one of the most famous example of naturally dammed lake in Central Apennines; it has an area of approximately 1 km^2, a perimeter of about 5 km and a maximum depth of 33 m.
Far more significant is the presumed age of the lake. In fact, according to reports and documents by Roman historians the event could date back to 217 B.C. (Nicoletti et al., 1993). Further, radiocarbon dating of a paleosoil sample collected in the accumulation area just below the rockslide debris yielded an age of about 12800 years.
The movement is classified as a rockslide-avalanche and the estimated volume of the debris accumulation is about 96 × 10^6 m^3. Late Miocene mudstone and sandstone outcrop along the interested area.

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70 - PRATO CASARILE, CARTAGENOVA (GE)

In Genova Molassana locality, close to Cartagenova in the Geirato River basin, the ephemeral Prato Casarile lake filling occurs during particularly intense rains. It is a lawn, a floodplain lake formed by the dam by a huge landslide. This slump movement has exceptional extension even for a very crumbling area like Liguria is. The area of the landslide is about 2,6 x 10^5 m^3 and knowing its thickness, about 40 metres, we can deduce a volume around 11 x 10^6 m^3, a very big size.
The lake of barrage is about 3 x 10^5 m^3, mainly filled with thin and rough sediments coming from the paleo-landslide or from tributary rivers.
There are no known overflows (water seeps inside the landslide body), at least from 1953, but the erosion of the foot is regressive and, despite the impressive works created after 1970, it is estimated that its withdrawal could trigger rapid emptying of the reservoir of all the fine sediments, endangering the Molassana village. At present, however, there is widespread bank erosion even if the weirs are in good conditions. In the Geirato river basin there was probably another similar phenomenon, smaller in size, in the locality Carpi.

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71 - LAGO PALAGIONE (PI)

The Palagione lake is a small lake at the Terzi Mountain slope (Province of Pisa) and it was formed by the Era Morta Torrent damming around 1887.
The dam has a volume of about 2 x 10^5 m^3 and underlies a 11 km^2 basin.
The landslide is classifiable as a translational slide occurred on a dip slope layers, constituited by sandstone-marl Flysch.
Currently the lake basin, partially filled, has an extension of 25,000 m^2.

72 - SCASCOLI (BO)

The Scascoli gorges are in the Savena Torrent valley, on the Appennines, south from Bologna. They are closed between vertical rock walls, high between 40 and 80 meters.
In 2002, from the left bank of the Scascoli gorges, between Pianoro and Loiano localities, fell down 7 x 10^4 m^3 of rock that, rushing downstream, have created a dammed lake (raising up of 25 cm / h), which was quickly emptied by two water pump of the Fire Department.
In 2005 there was a reactivation of the landslide, with the collapse of about 2,5 x 10^4 m^3 of rock; however it did not involve the river bed.

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73 - SUCCISA (MS)

The landslide occurred on February 7th, 2009, in the Succisa locality, in the Pontremoli Municipality (MS), and it blocked the Magriola Torrent valley. A survey carried out by the authorities few days after the event (Giuntini and Mazzali, 2009) has shown that, despite the small stagnation, the waters of the river were able to infiltrate the landslide material.
The landslide, composed by sandstones, siltstones and marls, has a volume of about 2 x 10^5 m^3. The movement, triggered by heavy rainfall, can be classified as landslide with complex movement; a first planar movement in the most downstream slope, would follow the rotational slide portion of the mountain. The distribution of activity of the landslide is widening.

Bibliography:
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74 - SCHIAZZANO (PA)

On November 19th, 2012, there was a landslide that caused the occlusion of the Dordia Torrent with the formation of a dammed lake between the towns Scarampi and Schiazzano.
The movement has been classified as a flow of earth and debris and, although the volume mobilized was relatively small (approximately 4 x 10^4 m^3), the lake formed, with a volume of approximately 9000 m^3, with a catchment area of 5 km^2, reaches a length of about 300 m in a few hours.
Several works were made, with great urgency between November 27 and December 18, 2012, to ensure conditions for a controlled outflow of the lake.

75 - CORNIOLO (FC)

The Corniolo landslide, in the Municipality of Santa Sofia (Forli Cesena), in March 2010 has affected the left side of the Fosso Bidente, a tributary of the Ronco River, consisting on top of alternating sandstones and mudstones.
The movement, classified as a translational slide of debris, wet, fasts, involved about 3 x 10^6 m^3 of rock and stopped invading the valley floor and creating a dammed lake, which still exists today, of about 4 x 10^5 m^3 of volume and with a catchment area of 47 km^2.
In the Municipality there were several landslides and in the past may have formed another dammed lake, extinguished for a long time, whose memory has remained in the name of the location called "*Lago*" ("Lake" in Italian), less than 2 km from the landslide area.

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76 - VALDERCHIA (PG)

On January 6th, 1997, after a heavy snowfall followed by a sudden total dissolution occurred the reactivation of an ancient landslide located in Valderchia, Gubbio area (PG).
The landslide, because the geometry, the trigger conditions and evolution, is complex, a rotational-translational slide, evolved in a flow. The landslide, with a length of about 450 m and an area of almost 18 x 10^4 m^2, destroyed two homes, blocked the San Donato Torrent creating a dammed lake, involved numerous support poles of power and telephone lines and stopped close the SS 452.
The landslide dammed the S. Donato Torrent for few day and had a volume of approximately 5 x 10^5 m^3, with a catchment area of 4 km^2.
The feed area of the landslide coincides with marly rock types, while the adjacent sectors are characterized by the presence of limestone and sandstone rock types.
Then some interventions have been executed to create a by-pass to the San Donato Torrent and to empty the dammed lake, as well as to guarantee the safety of the landslide itself.

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77 - CASTELLO DI SERRAVALLE (MC)

The Castello di Serravalle landslide is an old event, occurred in the Roman age, but its consequences were reported by many author of that time.
The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a flow, extremely fast, has an uncertain volume of approximately 1 x 10^6 m^3, with a catchment area of 54 km^2.
The event caused the death of about 500 Roman soldiers and the destruction of a castle, as reported by the following document.
From Continuatio Pontificum Italica II (cent. XIII):

"In this time [under Pope Nicholas III, 1277-1280] due to the enormous earthquake many castles in Tuscany and Romagna were destroyed with great fright for men."

"Huius tempore ex terremotu nimio multa castella Tuscie et Romandiole corruerunt cum magno hominum interitu."

From Cronica S. Petri Erfordensis moderna (cent. XIV):

"The miracle of the earthquake.
The fourth Sunaday after Easter, when it was the eve of Philip and James, just after vespers in the town of Camerino and in the town of Nocera, wich are located in the Ancona Marche exactly seven days away from Rome, there was a great earthquake, so strong that in Camerino all the towers and houses collapsed and more than a thousand men died. In the town of Nocera the monastery of the main church collapsed with all the buildings and all the canon's houses, more than half of the sid town; and innumerable people died but the bishop was saved. Nocera was sited on a hill, and it faced another hill, and

"Miracolum de terre motu.
In "Deo catate", quando fuit vigilia Philippi et Iacobi, inmediate post vesperas fuit terre motus maximus in civitate Camerina et in civitate Nuchir, que sunt site in marchia Anchonitana et distant a Roma bene ad VII dietas, ita quod Camerina amnes turres et domus corruerunt, et fuerunt mortui plus quam mille homines. In cicitate Nuchir corruit monasterium maiores ecclesie cum edificiis et omnibus curiis canonicorum, plus quam media pars ipsius civitatis; et mortue fuerunt persone infinite, sed episcopus evasit. Nuchir fuit sita in monte, et fuit alius mons ex opposito, et quoddam castellum

a castle was situated between one hill and other; here there were exactly five hundred guests, and it was called Serravalle. These hills were pitched against each other and they covered that castle which was in the middle, with all people within. And now it is so flattened, as if there had never been any building there. And in the areas surrounding those two towers there are other castles, in which because of the same earthquake many men died. And in those regions it is held to be a great prodigy. In Rome they had felt that earthquake to some extent and the pope was at that hour at dinner and the table at which he was dining, and the whole palace moved miraculously. And believe for certain, this is the hidden judgment of God."

fuit situm inter alios duos montes. Ibi fuerunt bene quingenti hospites. Et habebat nomen Serravallis. Isti montes venurunt unus contra alium et cooperuerunt illud castrum, quod fuiti di medio, cum omnibus personis, que fuerunt intus, et est ita planum, sicud numquam fuerunt ibi aliqua edificial. Et circa illas duas civitates sunt alia castella, in quibus de eodem terre motu perierunt homines multi. Et habetur in partibus illis pro maximo miraculo. In Roma senserant aliqualiter de illo terre motu, et papa fuit illa hora in mensa, et tabula, in qua cenavit, et totum palacium mirabiliter movebatur. Et credatis pro firmo, quod est indicum Dei occultum."

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79 - BOSCHI DI VALORIA (MO)

The landslide developed within the valley of the Rio Rumaggio, a Dolo River tributary, which drains the slope portion called "Boschi di Valoria", situated in Romanoro (city of Frassinoro). The instability has evolved rapidly in April 2001 because the high rainfall period. The crown area has been affected by rotational-translational slide that have evolved in a muddy flow with eterometrics blocks of stone rocks (sandstones and limestones). Despite the drainage activities, the landslide portion in the mountain above "I Boschi" and "La Teggia" areas moved again causing the removal of a section of the road called "S.Scolastica – I Boschi".
The area affected by the landslide is an area of about 1,3 x 10^5 m^2 and a total volume of about 13 x 10^6 m^3 (Lauretti and others, 2007), including a basin of 77.6 km^2.
After another period of very intense rainfall (Ronchetti and others, 2007), between April and December 2005, the landslide underwent a retrogressive reactivation interrupting again the viability of the area. To reactivate the connections, in 2009 was inaugurated a connecting viaduct which passes over the landslide.

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82 - PIAGGIAGRANDE-RENAI (LU)

The Piaggiagrande landslide, which occurred on January 19th, 2014, is the reactivation of a pre-existing movement and it consists of alternating layers of smooth sandstone and pelitic levels.
The landslide seriously damaged a private building, it interrupted the municipal Renaio road and reached the Lopporetta torrent riverbed causing the partial damming. Such occlusion led to the formation of a small pond with a volume of about 2000 m^3.
The movement, classified as a wet rotational slide of debris and rocks, has a volume of approximately 7 x 10^5 m^3, with a catchment area of about 1 km^2.
The debris is composed of coarse sand and has a thickness of several meters.
The dam is currently sliced and overflowed by the torrent stream and this is causing the progressive dismantling.

83 - SALTO (MO)

The activation of a landslide on the northern slopes of Montello, at the head of a watershed afferent to the Rio Rivella, in a prehistoric age, caused the formation of a lake basin.
The movement, classified as complex given by a rotational slide in crown evolving to the foot in a flow, has a volume of approximately 1 x 10^6 m^3, with a catchment area of about 1 km^2.
The stretch of water, progressively turned in a marsh for silting, was finally reclaimed in the mid 70s. At a later stage, the erosion exerted by Rio Rivella determined the disappearance of the areas of stagnant water.
In this locality were found some votive bronze statues; in fact, around the sixth century B.C. probably there was a worship place, frequented also for therapeutic purposes because of the presence of a salt-water spring.

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84 - CAMPORELLA (RE)

The Camporella town is situated on a ridge at about 610 m above sea level. From the nearby NE slope, three landslide bodies radiated with different directions involving some buildings. The landslide also has brushed the Provincial Road 80 from Montedello to Vaestano, which is a very important connection way between the provinces of Reggio Emilia and the Parma; it also dammed the Era Torrent, creating a 400 m basin, persisted for two years.
The movement, classified as complex, composed by a rotational slide in crown evolving to the foot in a flow, has a volume of approximately 5 x 10^6 m^3, with a catchment area of 79 km^2.
The Camporella – Varchero area has been inserted among the area with a very high hydrogeological risk by the Authority of the River Po Basin and in these years have been done several works to fix the landslide.

86 - MONTELAGO (AN)

In the early Holocene a small lake formed by landslide-damming of the Fosso del Lago stream close to Montelago (Sassoferrato, Province of Ancona), a village of the northern Marche sector of the Adriatic side of the Umbria-Marche Apennines (central Italy). The damming landslide is the reactivation of a larger «first time landslide» post-dating the upper Pleistocene coldest stages.
The landslide, classified as a slump, had a volume estimated at around 6 x 10^6 m^3.
Large amounts of calcareous breccia boulders incorporated into the Montelago landslide runout caused an effective stream blockage and the formation of a small lake. The radiocarbon dating of the lacustrine sediment was useful for roughly constraining the landslide blockage at about 8990-8550 years BP (Savelli et al., 2013).
Although the age of the landslide-dammed lake extinction is not strictly constrained, it is yet ascertained that the water pond represented in the 19th century Gregorian cadastral maps a little further upstream the paleolake site, far from being a relic of the landslide-dammed lake, is rather a small man-made reservoir dug long after the former lake dried up.

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90 - DRAGA (VV)

On February the 15th, 2010, in the Municipality of Maierato, in the Province of Vibo Valentia (Calabria), a massive rotational-translational landslide evolved in flow, involved the left side of the Scuotrapiti torrent in the the Draga locality; also it brushed the village itself and interrupted the Provincial Road to Filogaso. Five days after the landslide moved again with the retreat of the crown. The involvement of people was avoided thanks to an evacuation plan and the slowness of the phenomenon deformation phase. The landslide, moved after weeks of apparent deformation, is characterized by an area of about 0.3 km^2 and has traveled a distance of over 1.2 km, for an estimated volume of around 10 x 10^6 m^3. The involved materials are composed by alternating layers of sandy, marl and clay deposits.
The main cause of this landslide is probably the heavy rains of the previous days that have fueled the aquifers in the soils of the slope taking them to overpressure.
In the following years some activities have been done to fix the hydraulic system and to guarantee the safety of the landslide.

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97 - LAGO COSTANTINO (RC)

On January 1973, because a flood, a large landslide, classified as a debris and earth flow, broke away from the top of Constantine Mount, in the locality of Prache di Cucco (City of San Luca) in Calabria region (southern Italy). From about 1300 m a.s.l. 16 x 10^6 m^3 of earth and rocks fell down to 340 m at the Bonamico Torrent riverbed forming a natural dam of about 600 m long and 130 m height, with an average width of the dam of about 100 m. In a few days, a lake of about 7 x 10^6 m^3 have been formed, causing considerable concerns because a possible failure of the dam and the consequent downstream flood. There were various solutions: use of explosives to drain the water gradually, water pump interventions to empty the reservoir, consolidation of the dam, or other solutions. But the nature provided to itself: a fissure opened in the natural dam and the water level decreased. Initially the lake was called "*degli Oleandri*", but later was named Constantino, the name of the area from which the landslide broke away where there were the ruins of a Basilian monastery. This created a lake that for decades has been one of the most unique attractions in Aspromonte.

Year after year, its dimensions have been reduced due to the solid contribution of the stream, until its almost total filling in January 2009, when a great flood smashed through the embankment in the earth dam. Today there is just a small pond.

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99 - COVATTA (CB)

The landslide occurred in the municipality of Ripalimosani (CB), blocked the bed of the Biferno River on April 12th, 1996. Immediately some bulldozers have removed material from the front to try to make the flow of the water easier. The left bank, apparently more stable, was also set back to ensure the maintenance of the outflows. Three steel pipe, with a diameter of 120 cm and a total length of over 500 meters, were positioned to allow the outflow of river water even in case of feed of the landslide body and increases of flow. The landslide underwent other further reactivations during the years, particularly in 1997.

The movement has affected a side made up by mainly fine material, clays with sands, involving a volume of about 1-2 x 10^6 m^3. The complex landslides system included a series of rotational slide and lateral expansions of land in the upper and upper-middle parts of the slope, while below, the movement assumed the character of a flow of earth.

The landslide caused significant damage as in the following years, particularly in 1997, in addition to blocking the Biferno also destroyed a long stretch of the "Bifernina" n°647 highway.

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100 - CARIDI (VV)

On February 5th, 1783 in the south of Italy, particularly in Calabria and Sicily occurred one of the most catastrophic Italian earthquakes. The epicenter of the violent earthquake was located in the area between the cities of Bagnara, S. Cristina, Cinquefrondi (RC) and a stretch of sea near Palmi and Gioia Tauro (RC) (Mercalli, 1897). The first shock, the most terrible, lasted about three minutes and occurred at 12:45 a.m.; the next two days two other shocks of almost the same intensity occurred. These shocks were followed by others of mediocre and light intensity, in a period of about four years, from 1783 to 1786.

The worst damage occurred in the Pleistocene deposits between S. Cristina and S. Giorgio Morgeto and along the Tyrrhenian coast between Palmi and Scilla. On February 6^{th} , 1783 in Sicily there was a tsunami which killed 2475 people, escaped by the main shock of the previous day and sought refuge on the coast.

The earthquake caused more than 31000 victims and real devastation: half of the 384 towns in the "*Calabria Ulteriore*" region completely destroyed, deep gravitational deformations, several large landslides, whole villages swept downstream and destroyed, watercourses diverted or dammed, with the formation of at least 215 lakes (Ruberti, 1787). Of these lakes, after the withering works and more than two centuries of alteration, only for some of the biggest has been possible to determine the precise location and get some information and data on the dam.

"[...] Until now are known two hundred and

"[...] *Sono dunque i noti finora duecentoquindici.*

fifteen of them. But to understand in one shot their extension and the place we will split up all the Plain area, where they are spread, in seven districts, and also the lakes in big, medium and small. We will consider as big those that are 400 meters long; as medium those that are not so long but at least 130 meters long; as small those are less long that 130 meters. [...] Fourteen of first order, thirty-five of second order, and one hundred sixty-six of third order. [...]"(Ruberti 1787).

Ma per comprendere ad un colpo d'occhio la loro estensione, ed il sito, divideremo tutto il suolo della Piana, nel quale essi sono sparsi, in sette ripartimenti; come anche i Laghi stessi in grandi, mezzani e piccioli. Intenderemo per grandi quelli, che saranno nella massima loro lunghezza da sopra i palmi 1˙500; saranno mezzani quelli, che non eccedono questa misura in lunghezza, ma superano quella di palmi 500; si diranno finalmente piccioli quelli, la cui lunghezza non eccede i detti palmi 500. [...] Quattordici di primo ordine, trentacinque di secondo ordine e centosessantasei di terzo ordine. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

As reported by Vivenzio (1788):

"Near Soriano, from east to west, flows a river named Caridi, who is flanked by two high hills, of which the one in the North had a plan interposed between the flaps, and the river, where there were gardens irrigated by the water of the river; and the one in the South was covered with olive trees. This, due to an earthquake, passed to the other side with all the trees [...]. Due to this incident the river was blocked formed a lake. In this upheaval remained killed fifteen people, that unfortunately were there." (Vivenzio, 1788)

"*Presso a Soriano scorre dall' E. all'W. un fiume detto Caridi, che ha a' fianchi due alte colline, delle quali quella al N. aveva un piano frapposto tra le falde, ed il fiume, in cui vi erano degli orti, che venivano irrigati dalle acque del medesimo; e quella al S., che con dolce declivio terminava lungo le ripe, era ricoperta di Olive. Or questa nell'atto della scossa fendendosi in lunghezza di cento palmi, ed in sessanta di profondità, passò sull'istante alla parte opposta con tutti gli alberi, de' quali alcuni rimasero in piedi, ed altri caddero, chi con i rami rivolti al N., e chi al S. Il fiume arrestò il corso per tale avvenimento, e penetrando per altra via formò un Lago, al quale non molto dopo si diede scolo. In tale sconvolgimento restarono oppresse quindici persone, che si trovavano in quel luogo infelice.*" (Vivenzio, 1788). [1 palmo = 26,5 cm. n.d.r.]

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102 - S. CRISTINA (RC)

The S. Cristina landslide consisting of pelitic sandy complex, after the earthquake of 1783 in southern Italy, has affected the Calabretto Torrent, a tributary of the Petrace River,.

The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a translational slide-flow, fast, dry, has an uncertain volume of approximately 25 x 10^6 m^3, with a catchment area of 21 km^2.

As reported by Ruberti (1787), near Santa Cristina (RC) in the beginning there were twelve Lakes: one large, one medium, and ten small. To empty the big one were not made interventions but is expected its natural silting, but it was not complete. Then, in 1823 the dam formed by the landslide has been raised, thus increasing the hydraulic load on the spillway, and artificially triggering the overflow to empty it.

"In the Santa Cristina are, from which we decide to start, there were twelve Lakes:

"*Nel Ripartimento di Santa Cristina, dal quale stimiamo convenevole dar principio, vi* *one large, one medium, and ten small. The big one was 1270 meters long, 450 meters wide and 50 meters deep. For its emptying no costs is required. It would be unnecessary and excessive, because the lake has a big tributary, that has rapid waters with a lot of sediments loaded.”* (Ruberti 1787).

erano dodici Laghi: un grande, un mezzano, e dieci piccoli. Il grande era nella maggior lunghezza palmi 4.800, nella larghezza palmi 1700, e nella profondità palmi 200. Per lo disseccamento di esso non si è stimato sare spesa alcuna. Essa sarebbe stata eccessiva, e sperflua ciocche in detto Lago s'immette un fiume ben grande; che ne tiene sempre in moto le acque, cosicchè esse sono limpide, e non putride. Un tal fiume seco conduce molta terra.” (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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103 - MARRO (RC)

The Marro landslide, occurred in the Molonchio Municipality after the earthquake of 1783 in southern Italy, consisting of sands, sandstone, gravels, has affected the Marro Torrent, a tributary of the Petrace River.

The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a translational slide-flow, fast, dry, has an uncertain volume of approximately 15 x 10^6 m^3, with a catchment area of 38 km^2.

Ruberti (1787) report as follows:

"[...]In the Terranova area, there were thirty-four lakes: three big, ten medium and twenty small. The Marro, the bigger of the largest ones, was 1020 meters long, 400 meters wide and 35 meters deep. Currently it appears dry and to get such a result was enough to divert the water courses of the rivers Marra and Crimi, tributaries of this lake. The lake emptied in few days. [...]” (Ruberti 1787).

“[...]Nel ripartimento di Terranova eranvi trentaquattro laghi: tre grandi, dieci mezzani, e ventuno piccioli. Il Marro, il maggiore de’ grandi, era di palmi 3850 per la sua lunghezza, 1500 per la larghezza, e 130 in profondità. Esso oggigiorno vedesi all’intutto secco: e per ottenersi un tale intento non vi è abbisognato che picciolissima spesa impiegata ad ajutare le molte acque de' fiumi Marra e Crimi che in esso Lago mettevano, a procacciarsi l'esito per mezzo dell'arenose rovine, che loro impedivano il corso quantunqae unite. Appena un filetto di acqua si fé strada in quelle arene, che allargatoti il sentiero in pochi giorni, disparve il vasto Lago. [...]” (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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104 - BIRBO (RC)

The Birbo lake, the bigger one in the Oppido nuovo area, has been formed from a deep landslide, a rotational slide with an approximately volume of 2 x 10^6 m^3 of clay and sandstone.

As described by Ruberti (1787), to secure the waters of this lake, formed by a landslide triggered by the earthquake of February 5th, 1783 in southern Italy, they tried to open a drainage channel. Because of its great depth, about 30 m, and the poor mechanical properties of soils (clays) its walls collapsed constantly endangering workers and pushing up costs. So it was decided to fill it through the use of mines.

Ruberti (1787) report as follows:

"In the Oppido nuovo area, namely the Tuba, there are only ten lakes, two large and eight small. The Birbo lake, the bigger one, required all the resources. This lake was 830 meters long, 290 metrs wide and 30 meters deep. The landslide that formed it was made by mixed clay and sand.

[...] As first, in order to empty the lake, a drainage channel, 400 meter long, 60 meters wide and 30 meters deep, was realized. However, because the hight of the debris would have required excessive costs, it was chosed to fill the lake. Some mines were used in order to obtain it." (Ruberti 1787).

"[...]Passiamo ora al ripartimento di Oppido nuovo, ossia la Tuba. In esso veggonsi solamente dieci Laghi, due grandi, ed otto della terza classe, mancandovene della seconda. Il Lago detto del Birbo, il maggiore de' due grandi, è quello tra tutti i Laghi, nel quale si sono adoperate tutte le forze dell'ingegno, e tutti i mezzi dell'arte. Questo Lago era di lunghezza palmi 3150, di larghezza palmi 1100, e palmi 120 di profondità. Le ruine, che l'hanno formato, sono un miscuglio di creta, e di arena così alla rinfusa, che sovente volte ritrovasi l'una sotto l'altra.

[...] Per lo disseccamento di questo Lago dunque primieramente si è tagliato un canale lungo palmi 1500, largo 230, e profondo 110. Indi perchè l'eccessiva altezza, volendosi tirar avanti il cavamento, avrebbe predetta una necessaria eccedente spesa, si pensò procedere al riempimento. [...]Quindi fi giudicarono opportune le mine reali in questi si fatti luoghi. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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105 - DE' PRETI (RC)

The De' Preti landslide, occurred in the Oppido Mamertina Municipality after the earthquake of 1783 in southern Italy, consisting of sandstone, gravels, has involved a Petrace River tributary, the Porcello Torrent.

The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a translational slide, fast, dry.

Ruberti (1787) report as follows:

"*[...]*The other lake of this area *[Oppido nuovo] is the one called de' Preti. It was 750 meters long, 140 meters wide and 10 meters deep. Now the lake is empty, so that you can walk on its bed. The lake was emptied with several filling material and a drainage channel, 560 meters long, 68 meters wide and 37 meters deep, that allowed the water to flow. [...]"(Ruberti 1787).*

"[...]L'altro Lago grande di questo Ripartimento [Oppido nuovo], è quello detto de' Preti. La sua lunghezza era palmi 2820, la sua larghezza palmi 530 e la sua profondità palmi 37. Questo Lago oggi giorno vedesi all'intutto asciutto; e può liberamente camminarsi per ogni parte del suo letto. Un canale lungo palmi 2112, largo palmi 256, e profondo palmi 140, e non poco riempimento sono fiati i mezzi, co' quali si sono disseccate le acque di quello Lago. Egli è vero però, che le alluvioni, e la gran forza delle acque trattenute artatamente, hanno per la maggior parte contribuito a questa tal opera. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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106 - CUMI (RC)

The landslide that formed the Cumi lake in the town of Oppido Mamertina (RC) in southern Italy, during the earthquake of 1783, was one of the largest and probably was a landslides in which the sliding surface passes below the river bed going then on the opposite side of the valley. In fact, it affected about 20 x 10^6 m^3 and the sliding surface interested the same riverbed.
The lake formed upstream of this landslide had to be large, about 30 x 10^6 m^3. For its reclamation was engraved a small canal just 75 m long, 10 m wide and about 4 m deep. The water from the catchment upstream, covering some 44 km^2, completed the work burying the residual basin.

"*[...]*In the *Oppido diruto district there were nine lake. Two of them were big and seven were small, but there were no medium lakes. The bigger of the big ones was Cumi Lake. It was 1350 meters long, 705 meters wide and 40 meters deep. It was not necessary work hardly to empty this lake because the two tributaries rivers. So that, after a draining channel 75 meters long, 10 meters wide and 4 meters deep so that its water does not grow more, the task of filling it was left to the rivers. [...]"(Ruberti 1787).*

"*[...]Nove, e non più sono i Laghi del distretto di Oppido diruto. Due della prima classe, e sette della terza, mancandovi qui ancora quelli della classe media. Il maggiore de' due grandi è quello di Cumi. Esso era lungo palmi 5000, largo 2650, e profondo palmi 160. Per lo disseccamento di questo Lago non si è stimaro procedere a grande lavoro; perciocchè due fiumi, che vi mettono dentro, sono piucchè sufficienti a colmarlo. Sicchè dopo aver fatto un canale di palmi 280 di lunghezza, 36 palmi largo, e 16 profondo, perchè le sue acque non più crescessero, ed avessero libero l'esito, si è lasciato a carico di essi fiumi la cura di ricolmarlo. [...]*" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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107 - TRICUCCIO (RC)

The Tricuccio lake, as reported by Ruberti in 1787, was one of the greatest lake created by the earthquake of February 5th, 1783 in the municipality of Oppido Mamertina (RC) in southern Italy.
The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a translational slide, fast, dry, consisting of pelitic sandy complex, has involved a Riganti River tributary, the Porcello Torrent.
As many dammed lakes of this area, its filling was pretty fast (2-3 years) and not even required the human intervention.
Ruberti (1787) report as follows:

"[...]Tricuccio is the name of the second big lake of this area [Oppido diruto]. It was 1090 meters long, 120 meters wide and 19 meters deep. Also the filling of this lake was left to the river. And this is it, now all around is dry. [...]"(Ruberti 1787).

"*[...]Tricuccío è il nome del secondo Lago grande di questo Ripartimento [Oppido diruto]. Egli era lungo palmi 4.100, 450 largo, e 72 profondo. Questo Lago ancor esso per lo suo riempimento venne lasciato a cura del fiume, che dentro vi metteva; e puntualmente è avvenuto il desiderato effetto, vedendosi ora all'intutto secco. [...]*" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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108 - CUCCO (RC)

The Cucco landslide, occurred in the Cosoleto Municipality after the earthquake of 1783 in southern Italy, consisting of marl and clay materials, has involved a Duverso River tributary, the Porcello Torrent.
The movement, classified a rotational slide, fast, dry, has an uncertain volume of approximately 1 x 10^6 m^3, with a catchment area of 7 km^2.
Ruberti (1787) report as follows:

"[...]In the Sitizzano area, with the ruins of the territories, were formed fifty-five lakes and ponds, 3 large, 14 medium and 38 small. The Cucco lake, the most famous of the big ones, is 543 meters long, 246 meters wide, 17 meters deep. It lies on a wide concavity and then it was able to grow a lot. The waterways which powered it were small, so it stagnated causing lethal fumes to neighboring countries. Its desiccation has been quite difficult and challenging. [...]" (Ruberti 1787).

"[...]Nel ripartimento di Sitizzano colle rovine de' territorj vennero formati cinquantacinque, tra Laghi e Laghetti, tre della prima classe, 14 della seconda, e 38 della terza. Il Lago detto Cucco, il più famoso di quelli della prima classe, aveva di lunghezza palmi 2050, di larghezza 930, e 64 di profondità. La concavità, ove giaceva, è ben vasta, ond'esso Lago era alla portata di crescere immensamente. Le acque, che lo formavano, erano picciole, ragion per la quale ristagnavano, ed erano di esalazioni letali a' paesi, che presso vi si ritrovano. Il suo disseccamento ha esatto forti, e penosissime fatiche. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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109 - SPEZIALE (RC)

The Speziale landslide, occurred in the CosoletoMunicipality after the earthquake of 1783 in southern Italy, consisting of marl and clay materials, has affected the Duverso Torrent, a tributary of the Petrace River.
Ruberti (1787) report as follows:

"[...]Among the large Lakes of the district called "dello Speziale", there is one 468 m long, 351 m wide and 12 m deep. It is powered by a great river, so it was not considered necessary to work for the its total emptying, but we left to the river to fill it. A drainage channel about 170 meters long, 7 meters wide, and 3 meters deep was build up. [...]"(Ruberti 1787)

"[...]Tra i Laghi, che occupano la contrada detta dello Speziale, avvene uno, che si appartiene a questa prima classe. Egli è di lunghezza palmi 1800, di larghezza palmi 1350, e di profondità palmi 45. Mettendo in questo Lago un gran fiume, non si è stimato procedere al totale suo disseccamento; ma si è lasciata la cura al fiume di riempirlo. Con tutto ciò, […] si stimò quindi effettuare un tal ribassamento per mezzo di un canale lungo palmi 640, largo 26, e profondo 12. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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110 - COLUCE (RC)

The Coluce landslide, occurred in the Oppido Mamertina Municipality after the earthquake of 1783 in southern Italy, consisting of marl and clay materials, has affected, like Speziale and Cucco landslides, the Duverso Torrent, a tributary of the Petrace River.
Ruberti (1787) report as follows:

"[...]In the Sitizzano area, with the ruins of the territories, were formed fifty-five lakes and ponds, 3 large, 14 medium and 38 small. […].

"[...]Nel Ripartimento di Sitizzano colle rovine de' territorj vennero formati cinquantacinque, tra Laghi e Laghetti, tre della prima classe [...].

The lake, which occupies the Contrade Coluce and Arena, lies at the bottom of a deep valley. In this lake enters the same river that feeds the lake of Speziale; and for the same reason was decided to do not proceed to its total desiccation. It is, however, dug a canal 254m long, 12m wide, and deep almost 6m through thanks to which the lake level has dropped by about 4m. The water are from the river so there are not lethal fumes. [...]" (Ruberti 1787).

Il Lago, che occupa le Contrade di Coluce, ed Arena, giace nel fondo di un vallone. Egli è lungo palmi 3200, largo palmi 650, profondo palmi cento e due. In questo Lago mette il fiume istesso, che si scarica nel sopraccennato dello Speziale; e per l'istessa ragione non si è stimato procedere al suo totale diffeccamento. Si è però scavato un canale lungo palmi 960, palmi 46 largo, e palmi 22 profondo; perciocchè con quello canale il pelo superiore delle acque di detto Lago si è ribassato di palmi quindici; e così si sono messi all'asciutto tutti i terreni servibili, occupati da detto Lago. Le acque poi di esso vengono agitate, e mosse dal fiume; e perciò niente letali sono nell'esalazioni. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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111 - S. BRUNO (RC)

The Marro landslide, occurred in the Molonchio Municipality after the earthquake of 1783 in southern Italy, consisting of clay and marl, has affected a tributary of the Petrace River, the Duverso Torrent.
The movement, classified as complex composed by a rotational slide in crown evolving to the foot in a translational slide-flow, fast, dry, has an uncertain volume of approximately 20 x 10^6 m^3, with a catchment area of 5 km^2.
Ruberti (1787) report as follows:

"[...]In the S. Bruno area there were 74 Lakes: 2 large, 9 medium and 63 small. The St. Bruno lake, deserves the name of Prince of Lakes. In fact, Its extension occupied five districts.This Lake had a length of 1405 m; a width of 731m; and a depth of approximately 36m. [...]"(Ruberti, 1787).

"[...]Nel ripartimento di S. Bruno eranvi 74 Laghi: due grandi, nove mezzani, e sessantatré piccoli. Il Lago, propriamente detto di S. Bruno, merita il nome di principe de' Laghi tutti. Il solo Cumi gli è suppare [quasi eguale]: gli altri di lunga mano gli sono inferiori. La sua estensione era tale che occupava cinque Contrade. [...] Questo Lago avea di lunghezza palmi 5300; di larghezza palmi 2760; e di profondità palmi 135. [...]" (Ruberti 1787). [1 palmo = 26,5 cm. n.d.r.]

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112 - TOFILO (RC)

The Coluce landslide, a rotational slide movement, occurred in the Seminara Municipality after the earthquake of 1783 in southern Italy. It was formed by marl and clay materials, has affected Carrà Ditch, a tributary of the Petrace River.
Ruberti (1787) report as follows:

"[...]In Seminara area there were 21 lakes. One large, one medium, and 19 small. Tofilo is the name of the big lake. It was 630 m long, 331m wide and almost 19 m deep. To empty that lake was necessary to use a canal and the interference of the torrent.[...]" (Ruberti 1787).

"[...]Nel Ripartimento di Seminara eranvi ventuno Laghi. Uno grande, uno medio, e 19 piccioli. Tofilo è il nome del Lago grande. Esso era lungo palmi 2380, largo 1250, e profondo palmi 71. Per ridurre a secco questo Lago, è bisognato usar due mezzi, il canale cioè, e l'intromiflione della fiumara. [...]" (Ruberti 1787). [1 palmo = 26,5 cm.

n.d.r.]

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142 - CRODO (VB)

On August 27th, 1834 in the village of Crodo, in conjunction with heavy rainfall, a landslide barred the bed of the Alfenza torrent, creating a lake. At 13.00 the dam failed and the water invaded the village. The entire village was flooded, 46 homes destroyed, 12 people died.

The landslide, classified as a complex wet movement, composed by a fall evolving to the foot in an avalanche of blocks of gneiss, had a catchment area of about 4 km^2.

Traces of phenomena even more ancient and not easily datable are spread all over the territory; among the most obvious there is the largest landslide of Fondovalle in Val Formazza and the one of Croveo in Val Divedro.

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157 - LA MAROGNA (VI)

As reported by Dal Pozzo (1910), a huge landslide from the left side of the Astico Torrent blocking the river bed. The water for a long time continued to penetrate underneath the heap of stones, said "le maragne", and was coming out in several gushes just below the Church of Casotto. According to Dal Pozzo (1910) and Carotta (1997), it happened during in the terrible earthquake of January the 3rd,1117; this hypothesis is considered possible thanks to three different radiometric dating, two conducted on woods at the base of the landslide, and a third on peat sediments, that agree with that age.

The massive dam has been failed in 1278 causing a tremendous flood, but fortunately did not produce major damage because at that time the area was not densely populated.

The Marogna landslide, with an approximate volume of 12 x 10^6 m^3 of material, consists of a main body, due to the collapse of a translational slide, and a second lesser body, whose emplacement is following, classified as a rock fall avalanche with a plan view similar to a alluvial fan (Varnes, 1978).

Upstream must have formed a small lake, then filled.

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188 - FORNI DI SOTTO (UD)

The Forni di Sotto landslide is 2.5 km long, occupying the valley floor to a width varying from 600 to 800 m. The total volume was estimated at about 50 x 10^6 m^3, but it is likely to be higher especially considering that most of the landslide material, mainly composed by limestone, has been removed by erosion and runoff. It had a subtended catchment area of about 131 km^2.

As a result of the damming of the Tagliamento River, the waters created upstream a lake, well studied by Martinis (1985). It stretched within the Forni di Sotto valley for more than 6.5 km long, going to the west up to the Marodia Torrent. The depth of the water could be about 40 m while the maximum in the basin could reach 150 m. The perimeter of the lake, very articulate, was evaluated in 19 km and the surface of the maximum storage in 4.5 km^2. The volume of water, estimated at about 250 x 10^6 m^3, makes the Forni di Sotto paleo-lake larger than the Cavazzo Lake or the Tre Comuni Lake, the largest of the current regional lakes.

The sediments deposited on the paleo-lake bottom are represented by thick alternations of clay and sand with occasional gravel beds. The thin alternating dark and light show the seasonal variations of the lacustrine sedimentation. The presence of vegetable remains in silt and clay levels allowed to determine an age between 9770 and 9930 years from the present thanks to the radiocarbon method (C 14).

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191 - SUTRIO (UD)

From the slopes of Mount Riva and Monte Cucco in locality Sutrio, about 10000 years ago, a landslide of rock moved away, with an estimated volume between 50 and 100 x 10^6 m^3.
The landslide, classified as complex fall-avalanche, poured into the valley by blocking the outflow of But Torrent and generating a large lake, with 6 km^2 of surface and over 100 m deep.
Based on Carbon 14 dating (Martinis, 1979) the lake, with a catchment area of 149 km^2, survived for about 5000 years filling with silt and sand carried by tributaries. Finally the obstacle of the landslide was overtaken from the water and the lake (or what was left of it after filling) disappeared. Then the But stream started to flow along the valley, deeply affecting delta-lacustrine deposits and bringing the profile of their course to the levels prior to the creation of the lake.

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192 - VAL ALBA (UD)

Olinto Marinelli (1909) has documented in detail the evolution of a lake which, at the entrance of the Val Alba, has been formed as a result of a landslide occurred on October 20th, 1896. It was the collapse of a slump of debris of about 2 x 10^6 m^3, that had completely blocked the bed resulting in a 200 meters long lake basin that, after a short time, opened a channel in the landslide body. The lake basin underlies a catchment area of 20 km^2 and remains stable until at least 1904 with a continuous filling. In 1905 Marinelli found the riverbed full of sediments, without any trace of the lacustrine basin.

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196 - TORRE (UD)

From the northern slopes of Mount Tanavasagio (1025 m) a few thousand years ago, perhaps as a result of an earthquake of great intensity, a huge portion of 8 x 10^6 m^3 of rock broke away.
The landslide, classified as complex movement, began as a topple, thanks the dip slope structure of outcropping limestone, is accumulated on the bottom of the Mea Torrent, in the confluence with the Torre Torrent, evolving into an avalanche of rock.
The huge mass came up on the other side, on the eastern slopes of Mount Sorochiplàs, and provoked a temporary dam on the Mea Torrent, with the consequent stagnation of water upstream and formation of a lake basin.
Remains of the rock mass are clearly visible close to the Torrente Mea, where the morphology of the body collapsed is still detectable. The formation of a lake basin is evidenced by the presence of lacustrine sandy silt. These contain organic remains dating them back to 3990 ± 190 years BP by radiocarbon dating (Garofalo & Pugliese, 1990). The lake, with a catchment area of 26 km^2, has probably ephemeral life, as water flooding out soon by the crowning of the landslide body, raised a few tens of meters above the present river bed.
Emptying occurred for both erosion of the spillway by the waters of the Mea Torrent, who tended to fill the lake, and regressive erosion of the waters of the head of Torre Torrent, also thanks the intense lifting geodynamic which undergoes this subalpine sector.

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200 - BRAIES (BZ)

A landslide of about 50 x 10^6 m^3 of material from the Sasso del Signore dammed the Rio Braies. It formed the still existing lake that lies at the foot of the Croda del Becco (German, Seekofel) rocks and is located within the natural park Fanes - Senes and Braies.

It has a catchment area of 30 km^2 and covers an area of about 3 x 10^5 m^3 with a length of 1.2 km and a width of 300-400 m. It is one of the deepest lakes in the Bolzano province, with a 36 m maximum depth and an average depth of 17 m.

Several C14 dating of the lake deposits date it back to about 2250 years ago (Irmler et al., 2006).

The legend tells that some ugly wild inhabited the valley of Braies who guarded gold in the nearby mountains. When some farmers appeared in the valley with their livestock, the wild figures presented them some gold objects. The farmers seeing such an abundance of gold became greedy and started to take control of the raw material, stealing the people of savages. The population of wild decided to prevent farmers to reach the mountains and did pour some water sources, which created downstream Braies Lake, which prevented farmers to steal the gold of the savages.

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201 - NIBBIO (VB)

On April 19th, 2005, in the narrow valley near the Nibbio village, in the municipality of Mergozzo (VB) from the southern side of the Pizzo Lesino, a big landslide was triggered (at an altitude of around 1000 m above sea level), which partially occluded the Rio Nibbio.

The movement, classified as a topple of rock, has a volume of approximately 5 x 10^5 m^3, with a catchment area of 2 km^2.

Although it formed a dam in the riverbed, the landslide body with a grain-supported texture consists mainly of metric blocks, allowed the drainage of meteoric and melting waters, constantly monitored by technicians of the Province of Verbano-Cusio-Ossola.

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221 - LA FRANA DI RANDAZZO (CT)

The area affected by the instability is located between the towns of Randazzo (CT) and Santa Domenica (ME). The massive landslide resulted in the obstruction of the Alcantara riverbed and the interruption of an extensive stretch (about 1 km) of the SS 116 road linking the towns above.

The movement is classified as a complex rotational slide, wet, in the release area and flow of earth and debris downstream (Amanti et a.l, 1998).

The phenomenon evolution has been relatively rapid. The first movement was on 20 March 1996. The instability quickly propagates upstream involving the SS 116 road with a series of multiple retrogressive rotational slides that formed two main landslide bodies. Between 26-28 March, the crown of the landslide moves back to 100 meters with an average speed of 2 m/h and the landslide proceeds rapidly downstream with a speed of 30 to 40 cm/h. On 29 March 1996 the riverbed of Alcantara River is blocked by the landslide body for a distance of 100 m, resulting in the formation of a dammed lake with volume of 3,75 x 10^5 m^3 and a height of 17 m (Basile et al., 1996). In May 1998 the landslide undergoes a reactivation.

The landslide has an average thickness of 20 m and has mobilized a total volume equal to about 20 x 10^6 m^3 of material.

In the area involved by the landslide were identified detrital layers belonging to landslides that occurred several times at different times. The alternation of alluvial terraces of the Alcantara River with the deposits of landslides is a clue that points out that in the past have occurred several phenomena of river damming and allows to attribute the movement to the Late Pleistocene (Ferrara & Pappalardo, 2000).

At the top of the slope emerge the top terms of the flyshoid succession of *Monte Soro* Formation, formed by quartzarenite thick ayers intensely fractured with high permeability, which resulted in the storage of appreciable volumes of infiltration meteoric water. The waters, emerging at the contact with the underlying pelitic terms, have given rise to springs for the different permeability of the layers composing the slope (Amanti et al., 1998). The water circulation is deep and follows the system of discontinuity.

The formation of the landslide dam on the Alcantara River led to the intervention of the Department of Civil Protection of Catania who acted with extreme urgency. The level of the dammed lake was artificially stabilized with the use of powerful dewatering pumps, each with a capacity of 200 l/sec, and by providing a drainage channel. Later the lake was emptied by removing the damming body, to avoid the risk of sudden failure of the dam (Basile et al., 1996).

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223 - MONTE SAN MARCO (CT)

The surveyed event took place in 1986 near the town of Randazzo (CT). The landslide affected the slope of Mount San Marco and has partially blocked the Alcantara River.
It was a complex landslide, formed by a rotational slide in the upper part and a flow of earth and debris in the lower part. It was 70 m long, 110 m wide.
The side involved by the landslide, is formed from materials belonging to the Flysch of *Monte Soro* Formation (Lower Cretaceous) and the *Argille Varicolori* (Oligocene-Miocene).

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228 - CONTR. VETTRANA (ME)

The territory of San Fratello Municipality (ME) is located in Nebrodi Mountains, fragment of the Apennine-Maghrebian Chain of North-eastern Sicily, and develops between the bed of the Furiano creek and the river bed of the Inganno Torrent.
The first information on destructive landslides that have affected the area date back to 1745. Since 1745 there have been other landslides and in 1896 and 1905 a landslide caused the destruction of several buildings located downstream (Crinò, 1922).
The most impressive landslide has occurred on January 8, 1922 preceded by a particularly rainy period and unusual and heavy snowfall (Crinò, 1922). This is the reactivation and extension of the movement of 1745.
The length of the landslide reached 3000 m, the average width of 900 m, while the volume was estimated at around 6 x 10^6 m^3, with a catchment area of 140 km^2. The movement can be interpreted as multiple rotational slides with superficial flows and falls of carbonate blocks in the crown area.
The movement persisted for three days during which, have produced many effects including the formation of counterslopes and ponds, that the following summer became malarial areas, and partial obstruction of the riverbed of the Furiano Torrent.
In November 1963, a rotational slide movement resulted in a partial reactivation of the event of 1922.

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234 - CASA FIRRIONELLO (PA)

The landslide is placed on the right bank of the Northern Imera River in the Scillato Municipality (PA) and it was triggered by a fault line that runs parallel to the Scillato-Polizzi Generosa road and extends SE up to Vallone Firrione.
During the night between March 22 and 23, 1969 a landslide with a volume of 3 x 10^4 m^3 that partially blocked the Imera River, that in this point has a catchment area of 91 km^2.

The movement was classified as complex landslide composed by a rotational slide in the upper part and an earth flow in the middle-lower part. It was caused by the fluvial erosion of the slope foot (Albanese & Colosimo, 1971). The involved materials were mainly clay and sandy clay of the *Numidian Flysch* Formation (Upper Oligocene -Miocene).
Following the diversion of the river, some gullies and small landslides have formed to lower the steepness of the slope, in order to stabilize it. At the pylons of A19 Palermo-Catania highway were made weir to avoid the undermining of their basis.
Currently the foot of the landslide has been remodeled with steps for crops and in the area was made a reforestation with eucalyptus.

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235 - Vallone Ginestra (PA)

The landslide is placed on the right bank of the Northern Imera River in the Polizzi Generosa Municipality and develops on the slope of Vallone Ginestra basin.
In April 1969 a mass movement fall down into the riverbed blocking it for two days, then the river erosion break the dam.
The movement was classified as earth flow, has a length of about 1000 m, a maximum width of about 375 m and involved clay and clay-sand soils.
The involved materials belong to the *Complesso Sicilide*, composed by marly limestone of the *Polizzi* Formation, marl and clay (Upper Cretaceous-Oligocene) in overthrust on clays *Numidian Flysch* Formation (Upper Oligocene -Miocene).
The landslide was described in the work of Albanese & Colosimo (1971) in which illustrates the results of the study conducted in the central stretch of the Northern Imera River Basin, affected by the building the Palermo-Catania highway. The construction of this infrastructure presented some technical problems due to the mediocre geomorphological and geotechnical characteristics of the land to cross.
The causes of reactivation of the landslide body are to be found in marly-clayey soil nature, in their chaotic structure and tectonics that affected them, the morphological and climatic conditions of the area as well as in the anthropic intervention (Agnesi & Lucchesi, 1988).

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236 - Vallone San Nicola (PA)

The landslide extends between Vallone San Nicola and the Mulino di Fiume Grande, with a front along the Northern Imera River extended for more than 1 km.
In 1959 the reactivation of the landslide body pushed the bed of the Northern Imera River to the left bank. For a distance of 250 m, the riverbed is not more than 4 m wide; the area has a development of more than 2,5 x 10^5 m^2, the slope is not very steep (10 °) (Albanian & Colosimo, 1971).
This landslide is part of the great landslide Portella Colla widely described by Ogniben (1960).
The materials affected by the landslide belong to the *Numidian Flysch* Formation. It is clay and sandy clay more or less silty (Oligocene Miocene support).

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237 - PORTELLA COLLA (PA)

The landslide Portella Colla, Polizzi Generosa, represents one of the most impressive phenomena that have affected the Madonie mountain range.

It was a complex phenomenon characterized by gravitational deformations, both superficial and deep, whose origin and evolution are related to the geological structure of the area, neotectonic activity and climatic variations Pleistocene (Agnesi et al., 1996).

The landslide develops between Portella Colla and the Northern Imera River with a maximum length of 6250 m in the NE-SW direction, 2000-3000 m wide and average thickness can be estimated at about 60 m.

The landslide has evolved over a period of time between the Upper Pliocene and the Present.

The activity of the landslide is linked to seasonal wettest cycles and the exceptional weather events (Agnesi et al., 1998).

During the flood of 21-23 February 1931 there was a reactivation of much of the landslide that caused horizontal displacements of about 60 m, the deviation of the Rio Secco and the temporary damming of the Northern Imera River, with formation of a small lake (MM LL PP, 1933), damage to many houses, the road network and loss of agricultural field. The landslide was active for a few weeks after the flood event.

The geological-structural setting of the area is characterized by the thrust of the *Panormide Dominion*, represented by carbonate platform deposits (blocks of limestone and dolomite of *Fanusi* Formation, in turn moved on marly limestone of *Mufara* Formation) on clays of *Numidian Flysch* .

News related to the landslide in the area have been reported in the literature by Crinò (1921), while Ogniben (1960) identified the largest landslide Portella Colla, recognizing in the structural geology setting the main cause of triggering and evolution of the movement.

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239-240 - PORTELLA LUPO I, II (PA)

The town of Alia is situated on the ridge of a watershed, between two large valleys, right tributary of the Torto River: Rociura Walloon north and Zappalanotte Walloon south.

The material affected by landslides consist of a series marl and sandstone of the lower part of the Miocene, the terms of which are more typical quartz sandstone and clay or sandy marl.

Two major landslides affect the Alia village: the Caprarella landslide, north east of the town and the landslide of S. Rosalia, which covers the southern part.

The Caprarella landslide (Portella Lupo I) is the reactivation of an older movement with a volume of about 6×10^5 m^3. In 1963 an earth flow involved a stretch of the Alia-Montemaggiore road, stopping in the valley of the Rociura Walloon. During the December 1997-Genuary 1998 the landslide moved again, damaging some buildings and roads stretches.

The S. Rosalia landslide (Portella Lupo II) led to the partial obstruction of the Zappalanotte Walloon. This landslide, occurred in 1963, was the reactivation of older complex movements, composed by a translational slide and a flow of rock and debris, and involved the Alia village and damaged the SS 121 highway.

The causes that led to the reactivation of the landslide bosy, about 1100 m long and 600 m wide, were the water circulation, worse by losses from the fountains and the sewers, and the deepening of the river network. Also in this case, during the December 1997-Genuary 1998 a partial reactivation of the sliding occurred, involving the middle portion of the landslide, damaging the SS 121 highway.

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241-242 - CIMITERO DI RAGUSA, CAVA SAN LEONARDO (RG)

The Ragusa cemetery is placed on a planar surface related to the frontal part of a landslide, as another plain on the side of the valley.
The movements are classified as rock rotational slides with seismic trigger (Nicoletti et al., 1999).
The involved slope is formed by the *Ragusa* Formation, composed, from the bottom, by: alternating limestone with flint and marly limestone, grayish-white calcarentie and calciruditi bancks.
The landslide on which is located the cemetery seems to have caused a dam on the San Leonardo River, but there are insufficient data to confirm this hypothesis. The dam is therefore suspect, while the landslide have produced a clear deviation of the riverbed (Nicoletti et al, 1999).
The dates of movements are unknown. They are, however, ancient landslides currently quiescent and, a possible reactivation would cause damage to the cemetery of Ragusa with its access road and risk for some settlements.

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243 - CONTR. MONTE (RG)

The landslide affects a small tributary of the River Irminio left and is visible in the Contrada Monte locality.
The landslide was caused by a complex movement, a translational slide of rock that evolves into a flow of debris, dry and extremely rapid (Terranova & Nicoletti, 1998). The date of the movement is not precisely known, but from what is reported in the work of Boschi et al. (1995) it can be assumed that the occurrence of the landslide is due to the earthquake of January 11, 1693, which severely struck southern eastern Sicily. From the work of Nicoletti & Terranova (1998), however, we learn that the considerable amount of filling and the limited extent of the subtended basin (6.4 km^2) suggest a very old age, estimated to be about 5000 years.
The landslide that affected the left bank tributary of the Irminio River, caused the dam and planting upstream.
The involved slope is formed by the *Ragusa* Formation, composed, from the bottom, by: alternating limestone with flint and marly limestone, calcarentie and calciruditi bancks, with sub-horizontal stratification.
The landslide had a volume of about 10-12 x 10^6 m^3, approximately 800 long m and 1100 m wide. The maximum thickness is estimated at 60-70 m. The sliding surface was a planar surface, probably with structural origin because the normal fault involving the slope, and the movement then evolved in a rotational slide.
In the dammed basin there are filling deposits that extend upstream for about 1000-1500 m with a maximum width of about 200 m, maximum thickness of 60 m and an estimated volume of 2,2 x 10^6 m^3.

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244 - CONTR. UFRA (RG)

In Contrada Ufra, a Modica locality, a big landslide movement, of about 30-40 x 10^6 m^3, had been recognized and classified as a rock translational slide. A wide flat surface upstream of the landslide can suggest could be part of a damming event occurred in an unknown time. The landslide, placed at the boundary of Modica city, is still evident and currently dormant but its reactivation could threaten a great risk (Nicoletti et al., 1999).
The involved slope is formed by the *Ragusa* Formation, composed, from the bottom, by: alternating limestone with flint and marly limestone, calcarenite and calciruditi bancks, with sub-horizontal stratification.
The area looks tectonically disturbed by the presence of several normal faults with NE-SW, NNE-SSW trending.

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246 - COZZO PIRATO GRANDE (RG)

Down the road Modica-Scicli (RG) the landslide body of a translation slide of a large rock mass is visible on the left.
The landslide had dammed the Fiumara di Modica stream in an unknown time forming a lake, but it have leaved several traces. The river section is narrowed and, upstream of the landslide, the riverbed is flat and wide. The formed lake must have lasted long to fill the basin and leave a thick layer of lacustrine deposits. This point of the valley is linked with the downstream stretch with a waterfall (Nicoletti et al., 1999).
The landslide had a volume estimated at about 25 x 10^6 m^3 and the area of the catchment area subtended by the landslide was 43 km^2.
The involved slope is formed by the *Ragusa* Formation, composed, from the bottom, by: alternating limestone with flint and marly limestone, calcarentie and calciruditi bancks, with sub-horizontal stratification.

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248 - CONTR. BILLONA (RG)

The landslide placed close to Vittoria town (RG) in Contrada Billona locality, is classified as rock translational slide. It dammed the valley of a tributary of Ippari River in an unknown time (Nicoletti et al., 1999).
The landslide had a volume estimated at about 2 x 10^6 m^3 and the area of the catchment area subtended by the landslide was 53 km^2.
The slope affected by the landslide is formed by calcareniti and marly limestone.

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249-250 - CONTR. UTRA I, II (RG)

The landslide affected the course of the Rio Amerillo, a left tributary of the River Amerillo. It was a translational slide of about 40–50 x 10^6 m^3 of rock. This mass could be part of a bigger landslide extending northwards.
The movement, classified as multiple rock rotational slide, has affected the Contrada Utra, in the Municipality of Monterosso Almo, and although the dam is no longer visible, the toe of the landslide is fringed by terraces (Nicoletti et al., 2000).
The involved slope is formed by the *Ragusa* Formation, composed by alternating limestone with limestone and marly limestone and calcarenite.
The dammed basin was 2000 m long, 200 m wide and, at the beginning, 40 m deep. The date of formation of the lake is unknown, but now it is filled and the volume of the engraved filling deposits is about 4,4 x 10^6 m^3; according to the amount of lacustrine deposits, the lake was dated 6500 years ago (Nicoletti et al., 2000).
The old movement has suffered a reactivation during the 1693 earthquake, as reported by Nasetti (1931), when the Utra River changed its path.

"[…]the fountain of Scurzanera disappeared,
the river of Utra lost its path,
it was borne below Vizzini, at the corner,
because a big sliding broken stone! […]"
(Nasetti, 1931)

"[…] Spriu la funtana di la Scurzanera
Lu sciumi d'Utra persi la so via,
Nasciu sutta Vizzini, a cantunera,
Di 'na timpa spaccata ca pinnìa! […]"
(Nasetti, 1931)

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251-252 - CONTR. PIANO DEGLI ANGELI I, II (RG)

The landslide placede in Piano degli Angeli locality, in the Municipality of Monterosso Almo, had dammed the Rio Amerillo stream and a right tributary in an unknown time.
The movement was a rock translational slide with a volume of 50 x 10^6 m^3 of material and a catchment area subtended by the landslide of 9 km^2.
The creation of a river blockage by this landslide remains doubtful. The northernmost portion of the landslide body is in contact with filling deposits, formed by the damming of the river by the landslide of Contrada Utra (249 ID event).
The involved slope is formed by alternating limestone and marly limestone topped by calcarenite sometimes marly and calcareous marl (*Ragusa* Formation).

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260 - CONTR. BELLICCI I (SR)

The landslide, located near the Avola Antica village (Municipality of Avola, SR) is one of the few documented cases due to the earthquake of January 11, 1693, which completely destroyed the town of Avola and Noto.
The landslide blocked the course of Pisciarello Torrent, determining the formation of a temporary pond. Direct evidence of the effects produced by the earthquake in Avola is reported by the nineteenth-century transcription of the manuscript of the Priest Pietro dell'Arte lived between 1673 and 1704 (Gringeri Pantano, 1996).
The landslide classified as rock translational slide, dry, and fast. The volume of rocks involved in the slip was estimated approximately in 2 x 10^6 m^3 and the area of the catchment area subtended by the landslide was 6 km^2. The involved slope consists of alternating limestones and marly limestones (*Ragusa Formation*) topped by thick layers of calcarenite (*Palazzolo Formation*), with sub-horizontal stratification.
This event had a catastrophic impact on the local economy because caused the destruction of three mills and the death of those who were working and also stopped the supply of water for the plantations of sugar cane downstream (Nicoletti & Parise, 2002).
The lake has lasted 300 years and lacustrine deposits extend upstream to 500 m with a volume of 1,8 x 10^5 m^3. On accumulation is present a spillway channel, presumably artificial, whose entrance is located about 20 meters higher from lacustrine deposits.
What is left of the lake basin is an ephemeral lake that is prone to flooding during intense rainfall events (the last time in the winter of 1995-96).

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263 - CONTR. LENZEVACCHE (SR)

The landslide has affected the right side of the Cava Santa Chiara in the municipality of Noto.
It is probably a rock rotational slide with multiple surface. The landslide extends for a length of 220 m and a width of about 350 m; the volume of involved material is estimated about 2 x 10^6 m^3 (Nicoletti et al., 1999).

The detachment slope consists of alternating limestones and marly limestones (*Palazzolo* Formation) with sub-horizontal trim. A stretch of suspended flat riverbed precedes it and is connected with waterfalls. This is probably the remains of a whole landslide dam deposits, with a cut landslide body. Silt deposits, hidden by vegetation and travertine deposits, are now hanging and their length estimated in 1 km, with a maximum width of the order of 70 m (Nicoletti et al., 1999).

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266 - CONTR. OLIVA (SR)

The landslide, classified as rock translational slide, dry and fast, has affected the Cava di San Calogero (subtended catchment area 5.6 km^2) and Cava Carosello (subtended catchment area 4.6 km^2) in a stream at their confluence.
The slope is formed by alternating limestone and marly limestone, topped by calcarenite in massive layers (*Palazzolo* Formation), with sub-horizontal trim.
The landslide has the following dimensions: length of about 450 m, width of 600 m and a maximum thickness of about 40 m. The volume of rock involved in the movement is of the order of 1,5 x 10^6 m^3 now, but presumably greater in origin.
The engraved lacustrine deposits, are suspended and connected to the stretch in front of the landslide with waterfalls. These deposits extend along the Cava S. Calogero for about 1000 m along the Cava Carousel for 200 m and have a maximum width around 40-50 m.

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267-268 - CAVA SAN GIUSEPPE (SR)

Along the Cava of San Giuseppe, in the municipality of Noto, is located, facing each other, two landslides. They are immediately downstream of a confluence, blocked the quarry itself (subtended catchment area 0.6 km^2) and an unnamed tributary in the left bank of the quarry (subtended catchment area 2.8 km^2).
They are classified as singular slides movements, translation for the landslide on the left side of the stream and rotational for the one on the opposite side, which involved a volume of 1-2 x 10^6 m^3 of rock.
The slopes along which occurred landslides consist of alternating limestone and marly limestone topped calcarenite in thick banks belonging to *Palazzolo* Formation; the layering is sub-horizontal.
Filling deposits are visible for a distance of 200 m along the Cava of San Giuseppe and extend for about 300 m along the unnamed tributary stream; in both valleys reach a maximum width of 50 m. Currently they are engraved, suspended and connected with waterfalls to the front section of the landslides (Nicoletti et al., 1998).
con cascate al tratto di talwegs antistanti le frane (Nicoletti *et al.*, 1998).

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Pacino, V. (2002). *Censimento degli sbarramenti da frana in Sicilia*. Unpublished Bachelor's degree thesis, University of Florence, pp. 211.

269 - NOTO ANTICA, VALLONE PISCIATURA (SR)

The landslide, where currently the connecting road Noto-Noto Antica passes, was referenced by the Boccone (1697) citing a dislocated road and by Bottone (1718), telling about the formation of a lake for a river deviation and the emergence of a new spring along the road.
The landslide is classified as rock rotational slide; about 420 m long, 550 m wide, 60 m thick, with a volume of about 4 x 10^6 m^3 and a subtended hydrographic surface of less than 1 km^2.
There are no recognized filling deposits, so it is likely that the landslide has partially blocked the valley of the Vallone Pisciatura river (Nicoletti et al, 1998; 1999a).

The detachment slope consists of limestones and marly limestones alternating, topped by large banks of calcarenite belonging to *Palazzolo* Formation.

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273 - COSTA SAN NICOLA (SR)

Evidence of this landslide occurred in the Cassaro Municipality (Siracusa Province, in southern Italy) were collected by Boccone (1697) in his "Osservazioni" about the 1693 earthquake.

The landslide, classified as rock fall, has determined the damming of the river Anapo.

The slope involved by the landslide is composed from the top by: white greyish calcarenite and calcirudites irregularly stratified (*Monti Climiti* Formation) and massive grayish-white calcarenite (*Palazzolo* Formation).

The body of the dam, consisted of limestone blocks, must have been quite long-lived, to allow the deposition of large lacustrine deposits. The dam was breached in unknown date and part of the silting sediments were removed (Nicoletti et al., 2000).

After World War II the valley cut was occupied by an artificial dam. The purpose of this basin was to ensure better water availability of the surrounding area. The basin of the underlying section of dam is 90 km^2. The excavations and surveys carried out for the construction of the foundations of the artificial dam met several meters of lacustrine clay deposits that give confirmation of the formation of a reservoir dam (Nicoletti & Parise, 2002).

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287 - CAVALLERIZZO (CS)

Following very heavy rains, up to 645 mm in 60 days, corresponding to the 72% of the average annual rainfall (Toscano, 2009) and heavy snowfall, on March 7th, 2007 a large landslide, departing from Cavallerizzo in the Municipality of Cerzeto (CS), poured out into a small stream tributary of the Crati River, with a catchment area of approximately 3 km^2. The event destroyed 10 buildings and damaged many others, making half of the town of Cavallerizzo uninhabitable. Therefore, the Civil Defence Department decided to move and to rebuild the houses in the nearby village of Pianette, in accordance with the population.

The landslide had a volume of about 5 x 10^6 m^3, which began as a rotational slide, evolved into a debris flow over 900 m long in the riverbed, forming a small pond of short duration.

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288 - TESTI (FI)

From the mid-80s the Testi Hill was used by the nearby industrial cement plant as storage of waste materials coming from the adjacent quarry, from which were extracted every year 700,000 tons of marl.

On January 18th, 2001, after a period of heavy rains part of a hillside, significantly called "*Le Spugne*" ("*The Sponge*") slid into the valley of the Fosso di Storno, a tributary of the Greve River. A mass of about 1.2 x 10^6 m^3 of marl debris occluded the valley. Soon, a drainage canal was built to prevent water stagnation and the formation of a reservoir, in order to safeguard the many companies in the valley.

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289 - DAGLIO (AL)

On October 12th, 1872, at the point where the high valley narrows, just below the town of Daglio, because of a violent storm, the large landslide, remembered as the "*Cussei's landslide*", partially involved the town and destroyed the municipal road.

A mass calculated in 10×10^6 m^3 beat down on the bottom of the valley and into the torrent forming in that way a dammed lake, called "Daglio Lake". The landslide came up on the other side for about 60 m.

The lake disappeared seventeen years later with the storm of October 29th, 1889 that took away the mass of rocks and mud, opening a path for the waterflow.

It was a complex movement fall-slide, and the preferential movement surface can still be recognized. In addition, the riverbed, for a few kilometers, is flattened and widened.