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AN ANALYSIS OF EXTREME RAINFALLS ON NORTHERN ITALY

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SYNOPSIS

The analysis of about fifty years of short duration rainfalls in Northern Italy was performed deriving isohyetal maps of depths with assigned return period and comparing the mass curves of significant rainfall events responsible of serious damages. Three sub-regions were outlined and mass curves were proposed in order to improve the design of small structures.

1.0 INTRODUCTION

1.1 The catchments of the River Po, of the tributaries to the Northern Adriatic Sea and of the minor streams flowing from the Northern Apennines to the Tirrenian Sea are here considered. The region is about 115 000 km2 (47 per cent of which is above 600 m of elevation) with a population of about 25 millions of inhabitants (43 per cent of the national population) producing 57 per cent of the national gross produce.
The main physical feature is the alluvial plain bordered to the North by the bow-shaped range of the Alps and to the South by the crest of the Apennines.

1.2 Rainfall is highly variable on the region. Average annual precipitation ranges between less than 600 mm/year to more than 3000 mm/year; it is unevenly distributed as affected by orography. From July to October local outbursts may occur.
Heavy rainfalls may induce damage and life losses particularly in the hilly and mountainous areas where investments are growing in spite of the morphology and geology (steepness of the minor streams, type of rock erodibility, presence of unconsolidated materials, etc.).

2.0 RAINFALL DATA.

2.1 Yearbooks of precipitation on the region are available since the second decade of the century on care of the Servizio

Idrografico Italiano. In the twenties, recording rain gauges were set up. The most common type is still now a weekly strip chart tipping-bucket recorder. Only in the last years, magnetic tape or Rainfall on Northern Italy.
solid state memory recorders were put into operation.

2.2 Two types of data are available about short duration rainfalls:

(a) annual maximum values of rainfall with duration of 1, 3, 6, 12 and 24 hours.

(b) rainfall depths with duration less than one hour and heavy intensity. Yearbooks present these data irregularly; thus their frequency distribution cannot be analyzed.

Data are available at 1042 sites with different periods of length (up to 50 years) with a total number of 19506 station-years.

3.0 DATA PROCESSING AND PRESENTATION OF RESULTS.

3.1 Data available in the form cited in 2.2 a) (five series for each site) were processed using the extreme value procedure (Gumbel; maximum likelihood). Stations with at least 15 years of records were selected. The aim of the work was the investigation of the spatial distribution of short duration rainfalls with assigned recurrence time.

3.2 From the point of view of at site analysis, the main problem was the frequent existence of outliers which affected the best fit line particularly if the tecnique of least squares was used to compute the parameters. Thus the maximum likelihood procedure was preferred [1] [2]. The problem of outliers appears still unsolved; anyway the practice of removing them from the series before processing the data is questionable. It must be pointed out, anyway, that the use of maximum likelihood procedure tends to increase the return periods of higher values of precipitation; this fact is not cautious from the point of view of assessing design rainfall depth.

3.3 Two durations were selected as particularly representative of the concentration times of the main catchments in the region. Results are presented in Fig. 1 and 2 showing isohyets of rainfall with duration of 6 and 12 hours and 50 years of recurrence time.

The relationship between terrain profile and 12-hours rainfall distribution is shown in Fig. 3. The higher values of precipitation may be found on the southward sideslope of the reliefs.

3.4 The pattern of the isohyets induced to distinguish three regions:

(a) the alpine region (upper valleys and inner part of the alpine

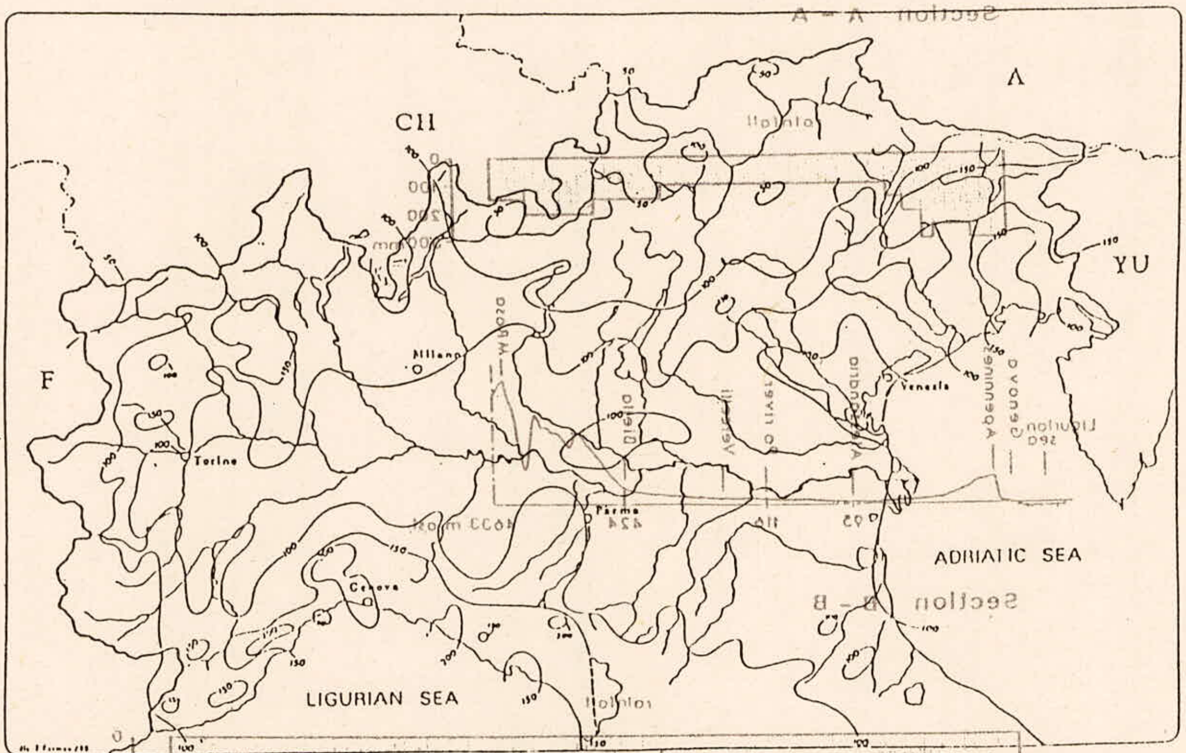


Fig. 1 Isohyets of rainfall with duration of six hours and return period of 50 years.

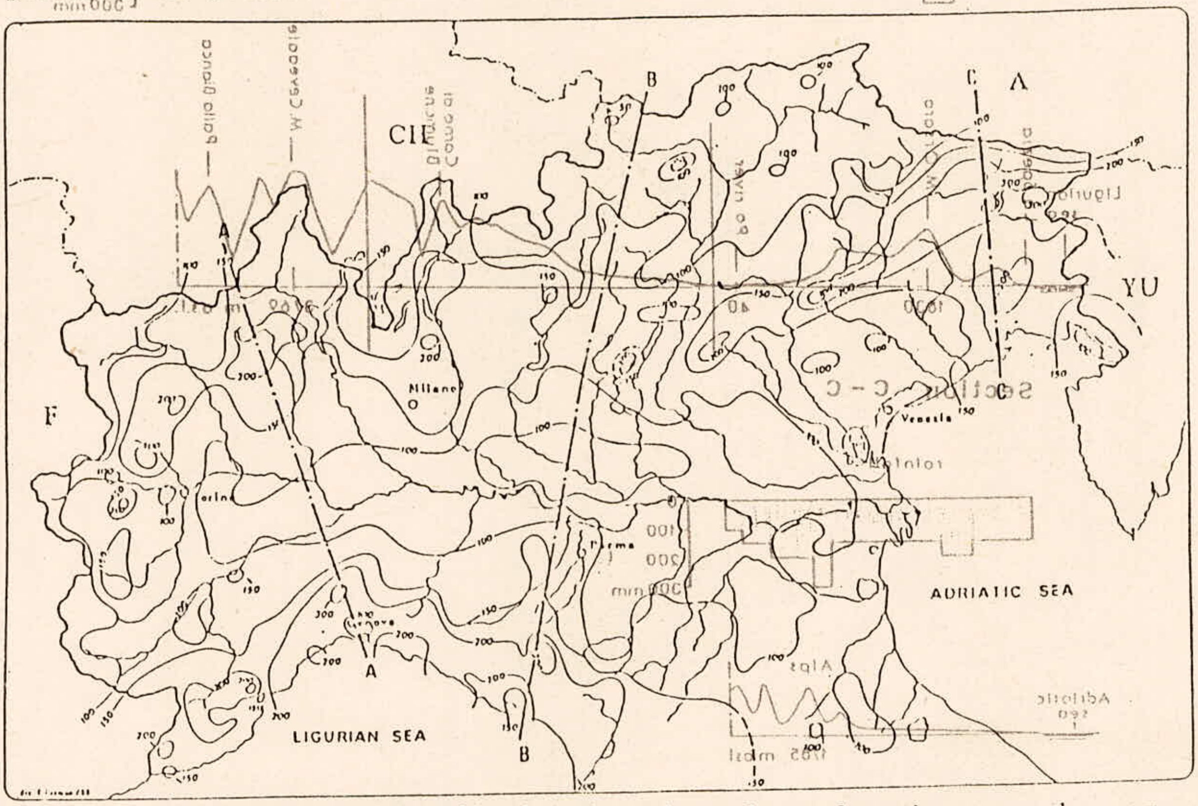


Fig. 2 Isohyets of rainfall with duration of twelve hours and return period of 50 years.

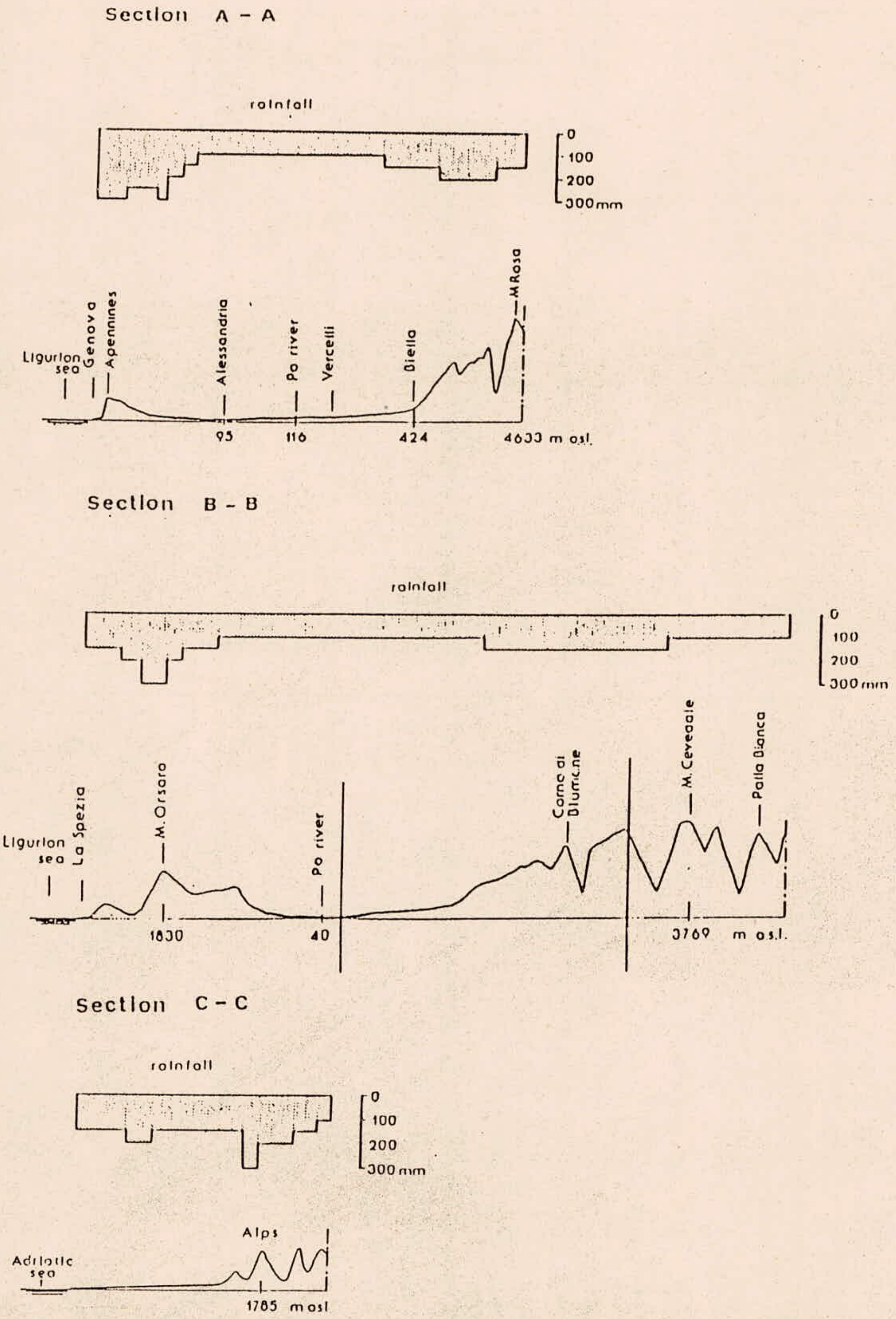


Fig. 3 Relationship between terrain profile and 12-hours distribution

range);

(b) the prealpine area (the southward sideslope of the mountains facing to the plain);

(c) three areas with heavy rainfalls (the Apennines North of Genova; the southern slope of Mt. Rosa massif; the southern slope of Eastern Alps).

The assessment of the statistical characteristics of these areas is in progress; a regional analysis of frequency has been undertaken using the five parameters Wakeby distribution [4].

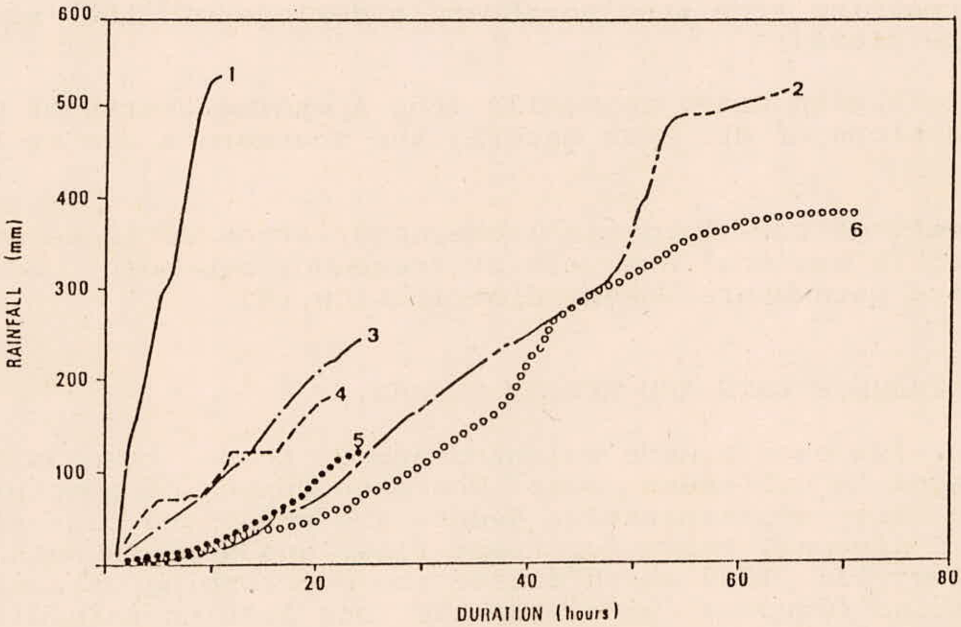
4.0 EXTREME EVENTS AND DESIGN STORMS.

4.1 A few events were selected among those responsible of serious damages in different areas. The mass curves of precipitation recorded on six representative events are presented in Fig. 4. Events 1 to 5 are well known for flood flows and damages such as the storm on August 13, 1935 which caused the overtopping of a side dam at Sella Zerbino (Genova) (curve 1); the long lasting rainfall which on November 2-3, 1968 ruined a prealpine area in the North-West (curve 2); the worst event ever recorded in a very large area in Eastern Alps on November 1966 (curve 3; the date is well known for the flooding of Venice) quite similar to a previous event on September 1920 (curve 4); a recent event in the upper valley of the River Adige at the border between Italy and Austria.

4.2 Flood events are typically characterized in the alpine environment by soilslips on the sideslopes, intense bank erosion and bedload transport in the streams, frequent debris flows in minor tributaries, alluvial deposition on fans. These consequences are observed after different depth and intensity of rainfall according to the geographical area (compare for example the curve no. 4 with curve no. 2 in Fig. 4).
The mass curve no. 6 is referred to the rainfall recorded in a large prealpine area of North-western Alps at the end of April 1981 which caused long lasting bankfull flows in many catchments without inducing the consequences listed above.
The difference between the curve no. 2 and no. 6 is considered responsible of the the different consequences induced by the events. There are several examples of such a behavior.

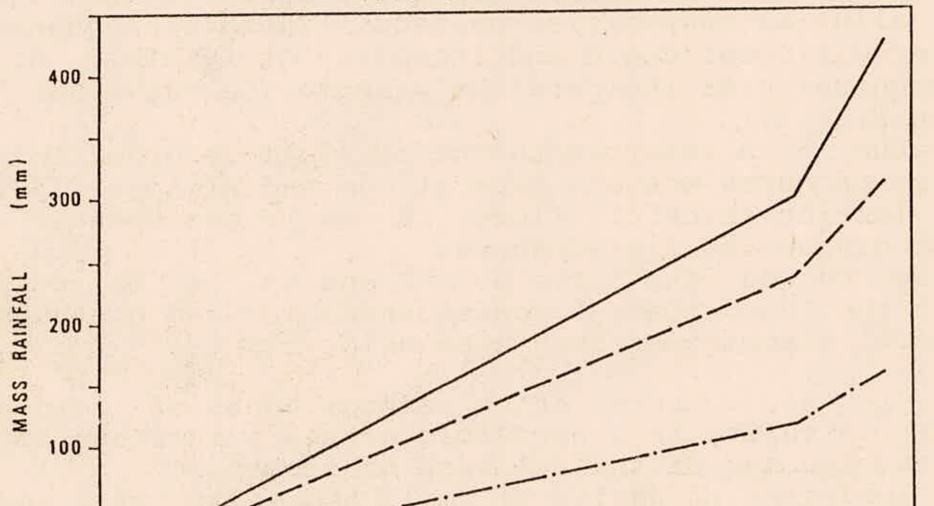
4.3 An intense outburst after several hours of rainfall at steady, heavy intensity is responsible of sharp increase of water stage in the streams and of the collapse of slopes.
The ordinary practice of design of small hydraulic structures on small catchments, in absence of observed flows, is the so called "rational" method. The procedure consists of deriving the concentration time according to empirical relationships with physical parameters of the watershed, then introducing the rainfall depth of assigned return period and duration equal to the

Fig. 4 EXTREME EVENTS MASS CURVES



1 LAVAGNINA 13 8 1935
2 TRIVERO 2 11 1968
3 CAORIA 3 11 1968
4 UDINE 19 9 1920
5 PREDOI 5 8 1985
6 LUSERNA S G 28 3 81 — event wich did not produce damage

Fig. 5 DESIGNED STORMS
50 YEARS RETURN PERIOD



concentration time.
In such a way, the effect of initial rainfall is neglected even if it is enough to cause flows close to the bankfull stage.

4.4 The rainfall events presented in Fig. 5 prove the existence of a common pattern of rainfall mass curves, but the total amount is quite different according to the sub-region. This fact suggested the proposal of different mass curves to be used in design practice for different sub-regions. The "design storms" have been generated with reference to the return period of 50 years which may be accepted for small structures. The mass curve consist of the 24 hours rainfall followed by a storm with a duration of three hours. The 24 hours duration was selected because able of producing, in the alpine catchments, high water stages. The following 3 hours rainfall can induce morphological effects both in streams (fluvial processes) and on slopes (mass movements) with consequences for human settlements.
The patterns are deduced from the data of raingauges representative of the three sub-regions cited in 3.4.
The use of the rational method modified in order to produce a complete hydrograph rather than only the peak value is then recommended. Such methods have been developed [3] even with regard to the variability of the runoff coefficient with rainfall intensity and cultural development.

5.0 FINAL REMARKS.

5.1 A few considerations are remarkable for design oriented instructions.
Three different environments must be distinguished:

a) the plain, where short duration storms induce rapid flooding of level areas. Available data on very short duration rainfall are generally inadequate, keeping in mind the increase of paved, impervious areas.

b) the hilly areas, generally in more or less cemented sandy or marly rocks producing fine sediments. The most serious danger is the concentrated delivery of water on the sideslopes where rill or gully erosion may me induced.

c) the mountains, where short duration rainfalls are responsible of mud- and debris-flows ,particularly in the minor order streams (according to Horton), where lithological and structural conditions produced large amounts of coarse, loose materials.

The scenery is commented in the following scheme:

Environment	Plain	Hills	Mountains
Geology	Alluvial sediments	Sedimentary rocks (sandy and marly)	Calcareous or metamorphic fractured rocks
Response to short duration rainfalls	Flooding	Rill erosion, soilslips	Bed load transport, debris floods
Mitigation means	Floodways, waterproofing, forecasting	Correct design of culverts, control on land use	Zoning of residential areas, waterproofing

The role of a more correct design of small structures is evident everywhere excepting mountainous areas, where the occurrence of debris flows may induce extremely serious damages and costly repairs to local communities. In these areas planning, waterproofing and eventually relocation of human activities are more effective means.

6.0 REFERENCES.

1. Kaczmarek, Z., (1958), 'Efficiency of the Estimation of Floods with a Given Return Period', Proc. IASH General Assembly of Toronto, 1957, vol. 3, pp. 144-159.

2. Kite, G.W., (19), 'Frequency and Risk Analyses in Hydrology', Water Resources Publications, Fort Collins.

3. L.A.C.F.C.D. (Los Angeles County Flood Control District), (1971), 'Hydrology Manual'.

4. Wallis J.R., (1982), 'Probable and impropable Rainfall in California', IBM T.J. Watson Research Center, Yorktown Heights.