A PROCEDURE FOR EVALUATING THE VULNERABILITY OF HYDRAULIC CONSTRUCTIONS IN FLOOD PRONE AREAS

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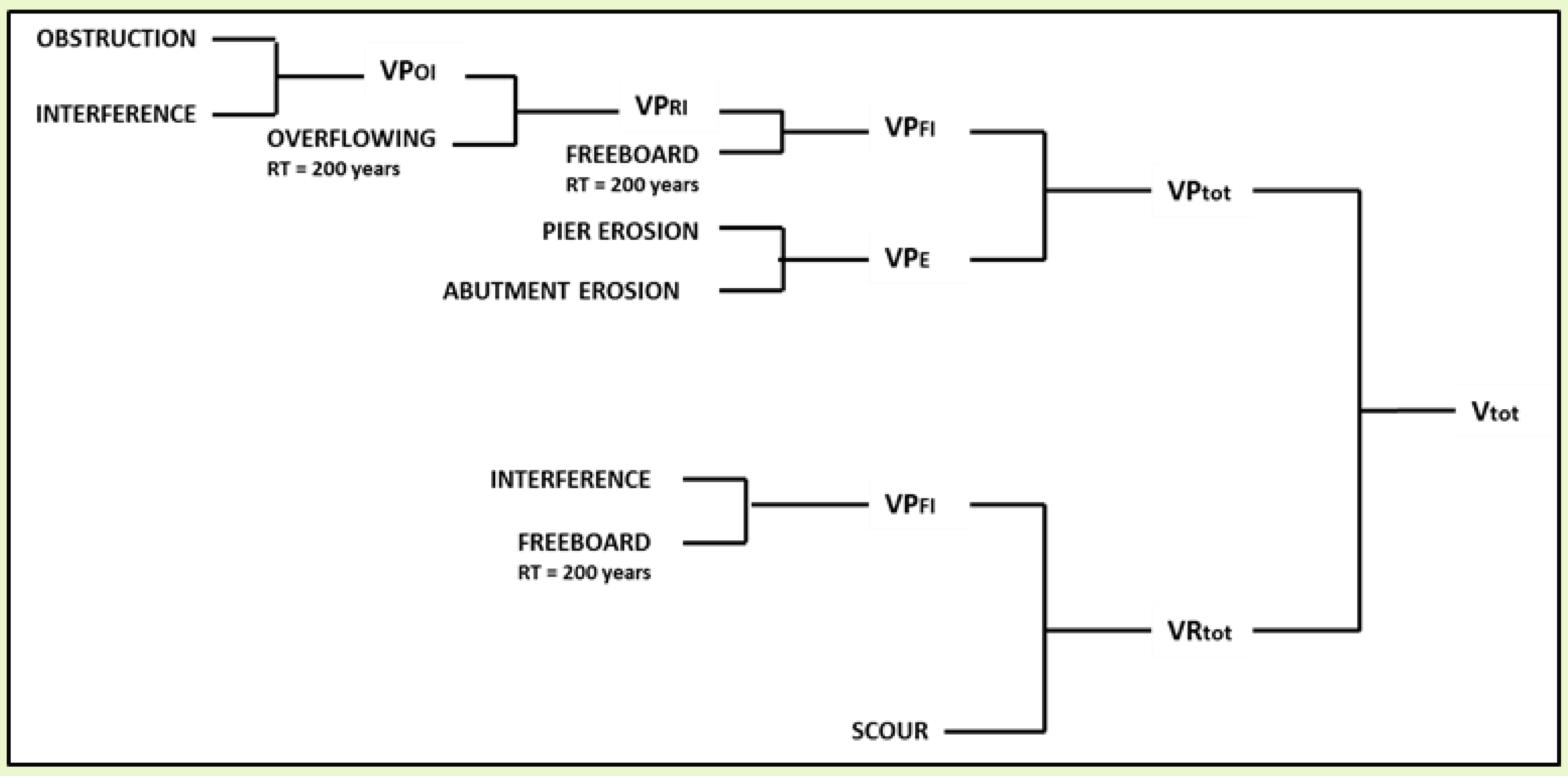
Introduction

This study is part of the obligations imposed by article 33 of the Technical Implementation of the PAI (hydrogeological system plan) concerning the basin of the Tiber River about the assessment of the vulnerability of hydraulic constructions in flood prone areas. The result of the study, which takes into account 82 structures (67 bridges and 15 road embankments) along the Tiber River network, is a concise evaluation of the degree of vulnerability of each examined structure according to the following classes: *adequate, average, high, very high*.

Field Activities

Field activities of inspection and assessment involved exhaustively all the structures object of the study and developed through various stages such as the acquisition of georeferenced photographic material; observations concerning the presence of civil works for the hydraulic protection of the structures; embankments; hydraulic works; photogrammetric surveys of the grain size of the bottom of the river bed; observations on the possible presence of erosion.

Figure 1: Evaluation steps for the vulnerability of a bridge structure:



Morphological, hydrological and flow conditions

The morphological, hydrological and flow conditions were obtained by means of a procedure specially developed using GIS technology based primarily on the open-source module r.basin, adapted and tested for the purposes of this study. To evaluate the spatial distribution of the Curve Number (CN), used for the estimation of runoff coefficent, the procedure overlaps map information of land use (Corine Land Cover 2006) and those related to the permeability of the soil derived from the Geological Maps (Geological Map of Italy) to find the value of CN for each unit (raster size 20x20); the average CN of each basin was then obtained by weighting with respect to the values of CN relating to the single cell.
For hydraulic calculations, the HEC-RAS software (Hydrologic Engineering Center - US Army Corps of Engineers, version 4.1.0) has been used.

The estimation of potential erosion of foundations of piers and abutments of bridges, mainly follows the directions of the circular HEC (Hydraulic Engineering Circular) No. 18 (FHWA, 2001). The value of general scour, connected the concept of slope compensation or slope of equilibrium, can be derived from the slope of the watercourse itself by means of a linear correction factor.

The evaluation of contraction scour, was carried out with the program HEC-RAS; the formulas used vary depending on whether there is (live bed) or there is not (clear water) sediment transportation. The estimate local scour at the piers is evaluated using an equation proposed by Richardson and Davis, 1995, called formula CSU (Colorado State University), also recommended in the circular HEC-18 and used by the FHWA program HEC-RAS.

Hydraulic Vulnerability Assessment

The procedure for assessing the hydraulic vulnerability of the structures is based on the choice of parameters that can determine critical conditions; then to each parameter of each structure a vulnerability value has been assigned. Such a judgment has been given with regard to the criteria established by law (as in the case of the freeboard), in accordance with other assessments dictated by experience or followed in practice (as in the case of overflow). The methodology followed to obtain the total degree of vulnerability of the structure (in the particular case, a bridge) is represented in the flow chart in Figure 1.
The procedure that evaluates the total vulnerability of a bridge (V_{tot}) begins comparing two of the selected parameters (in our case the initial parameters are the potential obstruction of the openings and the interference of the structure with the water flow, the morphology and other civil works, in order to obtain a preliminary degree of vulnerability VP_{OI} which is then compared with a third parameter (overflow RT = 200 years) to obtain a second partial degree of vulnerability VP_{RI} and so on until obtaining V_{tot}. The comparison between two parameters or between a parameter and a partial degree of vulnerability takes place via suitable matrices of combination, all characterized by the same structure, regardless of the terms of a comparison.

Figure 2: Matrix for the evaluation of VPOI

VP_{OI}		Interference with outflow, morphology, other Hydraulic works			
		Adequate	Average	High	Very High
Potential obstruction	Adequate				
	Average				
	High				
	Very High				

Conclusions

Analysis of the results of this study shows that 74% of the structures taken into account (bridges and road embankments) have a *very high* vulnerability value, 20% a *high* value, 5% an *average* value, and finally only 1% an *adequate* value (see Figure 3).

The high incidence of structures with very high vulnerability is not only due to real hydraulic and geometric conditions observed especially along the secondary river network, but also because the methodology adopted is extremely conservative and safety conditions are preferred.

Figure 3: Distribution of vulnerability assessment over the structures studied