# IDENTIFICATION OF HIDROLOGICAL RISKS IN CIVIL ENGINEERING PROJECTS. PARTICULARIZATION FOR PHOTOVOLTAIC GENERATION PROJECTS.

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## 1. INTRODUCTION

Evaluating the hydrological risk is indispensable in every civil engineering project in order to maximize its lifespan and avoid future flooding damages in the projected infrastructure. Last year, floods cost more than 70.000 M€ worldwide, which evidences the need of an adequate and accurate evaluation of hydrological risks.

Orbis Terrarum is highly worldwide experienced in developing hydrological studies and evaluating flooding hazard. Basing on that experience, we can claim that technological advances (GIS tools, hydrologic and hydraulic modelling software, BIM methodology, etc.) are fundamental to perform a correct evaluation of risks. Therefore, we use the latest software technologies to evaluate those risks and advise our clients for the correct definition of their projects.

## 2. METHODOLOGY DESCRIPTION

In order to identify risks associated with floods that may occur in a project, it is necessary to develop these types of studies during the preliminary design phase, since a late study can identify risks that force the redesign of the project, which results in unwanted overruns (time and cost).

A scheme of three interconnected phases can be followed for any project: a hydrological planning that allows identifying the watersheds and their characteristic parameters for the calculation of hydrographs; a hydraulic simulation that allows evaluating the risks associated with possible floods; and a final phase of definition of an adequate drainage system and actions to mitigate the hazard level.




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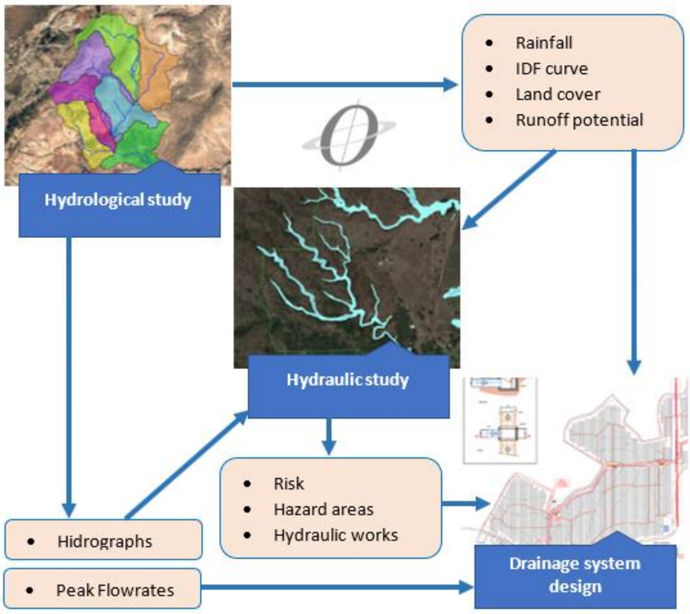
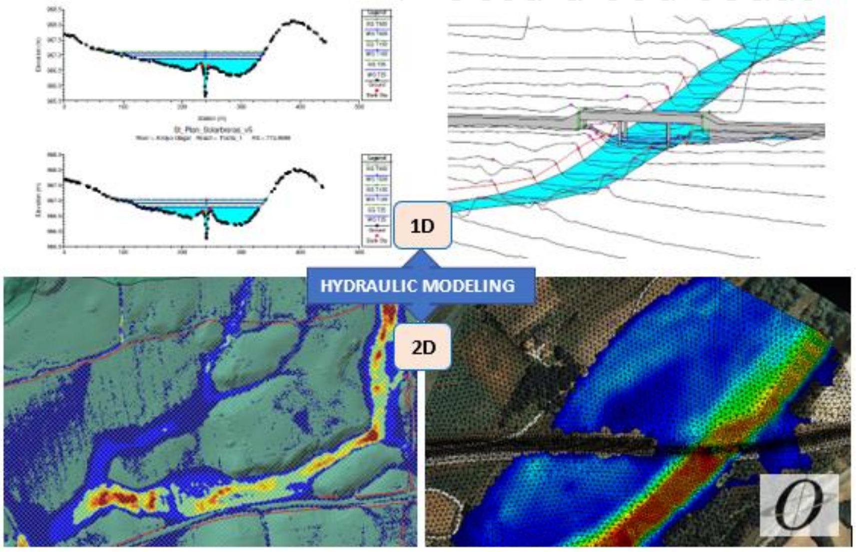
Nowadays it is possible to have a multitude of geospatial information in almost every country (cartography, altimetry, land use, aerial orthophotos, etc.), so a good knowledge of GIS tools is essential to perform an efficient hydrological characterization. Regarding this, Orbis uses the latest tools (LIDAR flights, specialized software, etc.) available to obtain DTMs that allow defining the watersheds in the studied area and perform a correct hydraulic model. In addition, from satellite images, we can define the level of vegetation cover for large areas and be much more precise estimating the expected water runoff.




Based on the results of the hydrological study, it its possible to define with a high precision the expected flood in a studied area, obtaining data of water depths and their associated velocities. However, the correct definition of the flood requires a deep knowledge of hydraulic models. The most suitable models are the bidimensional ones, that allow estimating the flow velocity in its two flat dimensions (x and y). These models has several advantages, since allow to characterize the flow behavior more precisely in the main streams and also allow identifying small streams or subsidiary flows that may affect the construction of the infrastructure.




The last stage is the design of and adequate drainage system. In the case of non-linear infrastructures such as photovoltaic power plants, this phase should be carried out in the last stages of the project design, since the final layout of the facilities and its possible earthworks will greatly vary the construction needs of the drainage network and its dimensioning.

3. RESULTS FOCUSED ON DESIGN

As a result of the hydrological characterization and the subsequent hydraulic simulation, it is possible to define the expected flooded areas for different return periods.

A return period "T" refers to the probability that a flood episode occurs every "T" yeas. For example, a return period T=100 years means that the rain episode studied will occur, on average, once every 100 years.

Therefore, the understanding of the concept "return period" is especially important to evaluate the hydraulic results and understand how they can conditionate the design of the project.



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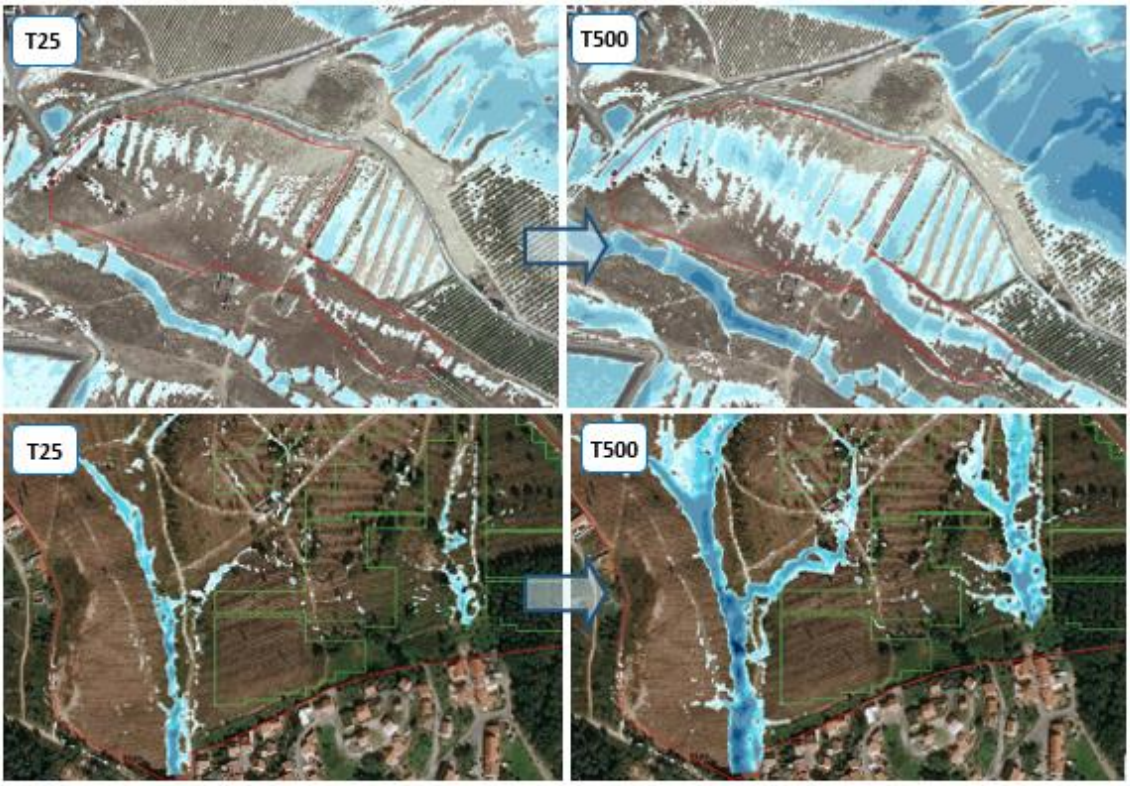


*Examples of depths distribution in two photovoltaic power plants (red boundary lines) placed in Spain and Portugal. Results for T=25 years at left and for T=500 years at right.*

As shown in the images above, there are several differences between the range of the flooded areas depending on the return period considered. Because of that, the election of an adequate return period is fundamental for the correct evaluation of the hydraulic risk, so it is necessary to know the most suitable return periods to be studied depending on the type of project. For example, the risks for a non-critical infrastructure (such a park or similar) are not needed to be studied for high return periods such 500 or 1.000 years.

Regarding photovoltaic facilities, it is recommendable to analyze results for a return period T=100 years. This recurrence interval is the most suitable to design infrastructures and delimit the risky areas, so its flooded boundary should be an avoided area. However, there are some elements that are compatible with light floods (20-25 cm water depth with associated velocities of 0.5-1.0 m/s), such as trackers and solar panels. In other hand, there are some critical elements, such as an electric substation, which must be placed out of the flooded area expectable for a return period of T=500 years.

In addition to the above, a return period T=25 years should also be considered and analyzed. This return period is the most suitable to define and size the drainage system, so it is useful to know the flow behavior in natural conditions in order to optimize the design.

In case of the drainage system, it is very important to be aware of the type of infrastructure projected before the beginning of the design. In linear infrastructures such as roads or railways, the drainage is very important in two ways: longitudinal drainage system to protect the stability of the platform and transversal drainage works to ensure the continuity of flow in the identified streams. Nevertheless, the design of a drainage system in non-linear infrastructures requires more logical thinking and sometimes not to follow the strict guidelines of the technical standards (usually intended for roads).



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When designing a drainage system for a photovoltaic plant, one of the first things to consider is "water always follow its own natural path". Because of that, we highly advise against great earthworks that may result on erosion and instability phenomena.

Example of erosion in anthropic landfill.

Moreover, perimetral gutters are also quite inefficient where there are well defined streams, so we also advise against them. In this facilities it is quite more recommendable to allow the natural runoff to freely flow and avoid the hazardous flooded areas for the layout.

In addition, in these power plants it does not make sense to apply the restrictions of the usual regulations and guidelines (as said, intended for linear infrastructures), since the drainage must be designed only to protect the internal land-roads and paths that allow the operation of the plant. Therefore, it is much more logical to invest in the maintenance of a land drainage system rather than projecting large and very invasive networks made of concrete, which only serve to concentrate the flow and increase its velocity, increasing the hazard level in the areas located downstream.

## 4. CONCLUSIONS

One of the most important conclusions that can be drawn from our own wide experience is that, unfortunately, in most cases the hydrological studies are carried out when the design phase of the project is too advanced and there a few options to apply solutions to negative conclusions.

In case of photovoltaic power plants, this situation may result in undesired consequences, such as loss of generation power, restrictions from the local water authorities or cost overruns (need of lamination and/or dissipation works, hydraulic works, engineering redesign, etc.). Because of that, it is highly recommended to carry out this studies during the previous design stadia.

Both for risk assessment and for drainage design, it is necessary to correctly choose the return periods 'T' to be used. In the case of photovoltaic plants, it is advisable to know the results for T=25-100-500 years. The most suitable period to set the restrictive measures for implantation is T =100 years, while T=25 years is the most suitable return period for drainage design. These return periods are defined based on the usual regulations, but also based on common sense.

Regarding the admissible uses in flooded areas, the type of foundations of the photovoltaic panels makes them compatible with certain water depths (less than 25 cm) and flow velocities (less than 0.5 to 1.0 m/s depending on land cover) expected for T=100 years. However, other facilities such as inverter cabins are more susceptible to these depths, so it is more advisable to place them outside of flooding boundaries or raise them slightly from the natural terrain level. In addition, when projecting an electrical substation, it is necessary to place it outside the flooded area for T=500 years.

Finally, it is important to remark that the drainage system should be designed during the final stages of the project development because it is very susceptible to changes in the layout or earthworks. In addition, it is recommendable to allow the non-concentrated runoff to freely flow instead of designing large and invasive drainage systems that concentrate the flow and may increase its associated risk. Therefore, these drainage systems should only be considered for protecting the internal paths of the plant and ensure its operation activities.







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