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Simulation of flooding in basin of Var river using Mike She programme

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__Abstract:__ **The paper presents the inundation of 1994 in Nice, where was used the model of Mike She 11 and was compared obtained results with the measured results of flood event of November 1994.The Mike She modeling system is able to simulate surface and ground water movement ,the interactions between the surface water and ground water systems, and the associated point and non-point source water quality problems.**

1. INTRODUCTION

The Var is located in the South of France near the city of Nice. The Var catchment has an area of about 2822 km². The elevation varies from 3000 m in the mountains to 0 m at the mouth to the Mediterranean Sea.

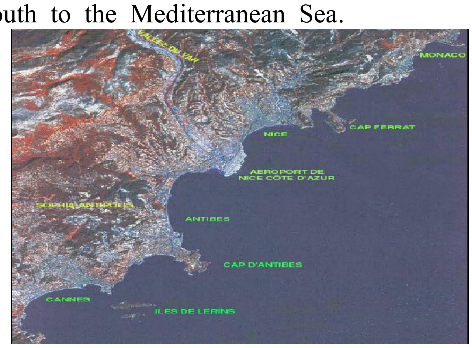

Fig.1 The Var catchment(Google earth)

Nice became a tourist based city, after the Second World War. The airport was built, which reduces the width of the river on that place from 300 m to 200 m. There was a deficit in building materials. People started the exploitation of the gravel from the bottom of the river. This exploitation had start effect the decrease of the groundwater level with severe consequences for the agriculture. The solution for this problem was the construction of dam in the last kilometres of the river, with a height of about 6 m and a distance in between of about 1 km. The meaning of this solution was to bring up the height of the groundwater again.

Some dams are also used for a hydro-electric power plant. Another purpose of dams is to protect the pillars of some bridges. The construction of the dams became a failure. After a while, the dams were filled up with sediments Therefore the bottom became impenetrable and the provision of groundwater became even a bigger problem. As a result of supercritical flow, there was strong erosion at the bottom of the dam. Therefore was a greater decline over the dam, what could lead to instability During the flood of 1994, a peak discharge of 3500 m³/s occurred. This is more than three times the normal discharge. This flood destroyed two dams and led to large flooding areas and several damages on the infrastructure.

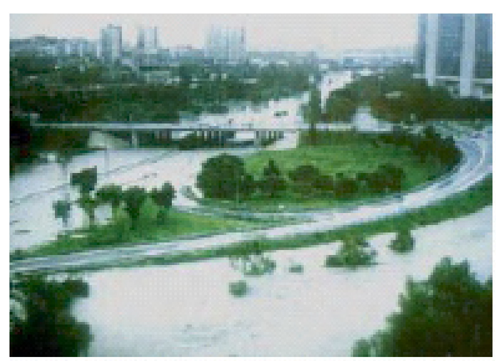

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Fig. 2. Flood of 1994

In the day preceding the mentioned flood event (period including 3rd and 4th November), continuous precipitations events were not characterized by high intensities, however, a large part of the catchment was concerned. This situation leads to a critical situation in terms of saturation conditions of the soil. Consequently, the high intensities of the precipitations of the 5th November lead to an important flood event corresponding to the recorded maximal peak flow discharge. The economic losses caused by flooding were estimated at cca. 22*106 Euros

1.1 Model History [1,8,9]

The original MIKE SHE (DHI, 1998) model was developed and became operational in 1982, under the name of Système Hydrologique Européen (SHE).

The model was sponsored and developed by three European organizations:

-the Danish Hydraulic Institute (DHI),

- the British Institute of Hydrology,

- the French consulting company SOGREAH.

The model was developed for water resource managers who were concerned with rapidly changing landaus practices in agriculture and forestry. In several European countries, surface and ground water resources were being polluted by fertilizers and pesticides associated with intensive agricultural practices. Transport of contaminants from waste disposal sites and the effects of acid rain posed additional threats to water quality. As new modeling ideas developed, DHI continued to enhance the model and currently provides support and service to this evolving modeling system.

The MIKE SHE modeling system consists of a water movement module and several water quality modules.

The water movement module simulates the hydrological components including evapotranspiration, soil water movement, overland flow, channel flow, and ground water flow.

The related water quality modules are:

1) advection-dispersion,

2) particle tracking,

3) sorption and degradation,

4) geochemistry,

5) biodegradation, and

6) crop yield and nitrogen consumption.

1.2.Model Description

The MIKE SHE modeling system is able to simulate surface and ground water movement, the interactions between the surface water and ground water systems, and the associated point and non-point source water quality problems. The MIKE SHE modeling system simulates hydrology components, including the movement of surface water, unsaturated subsurface water, saturated ground water, and exchanges between surface water and ground water.

With regard to water quality, the system simulates sediment, nutrient, and pesticide transport in the model area.

The model also simulates water use and management operations, including irrigation systems , pumping wells, and various water control structures.

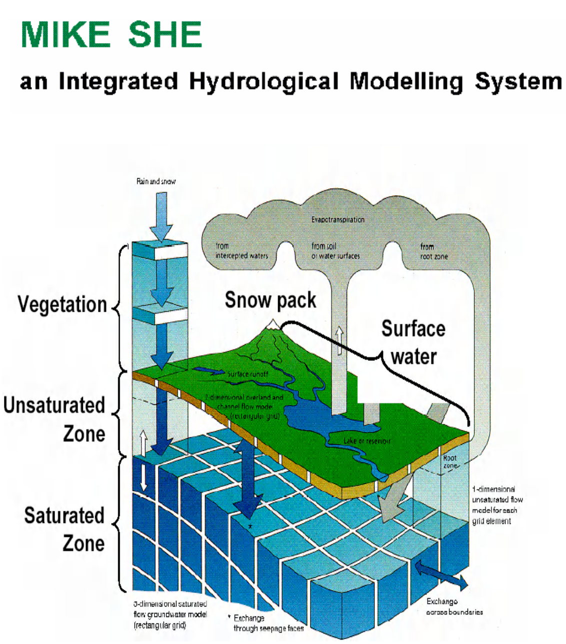

Fig. 3. Hydrologic processes simulated by MIKE SHE [1,8,9]

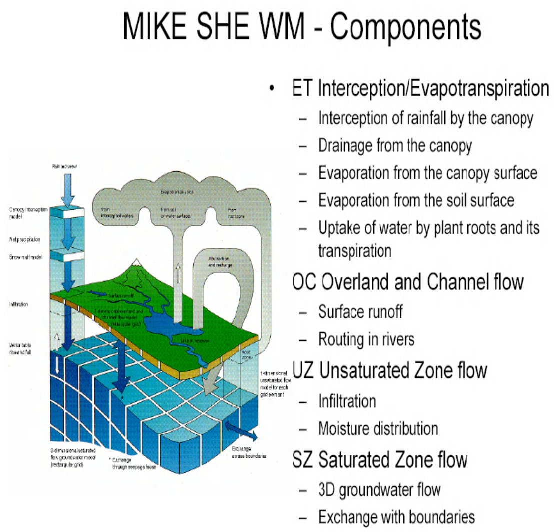

Fig. 4. Scheme of the Mike She component [1,8,9]

Presentation of the pogram

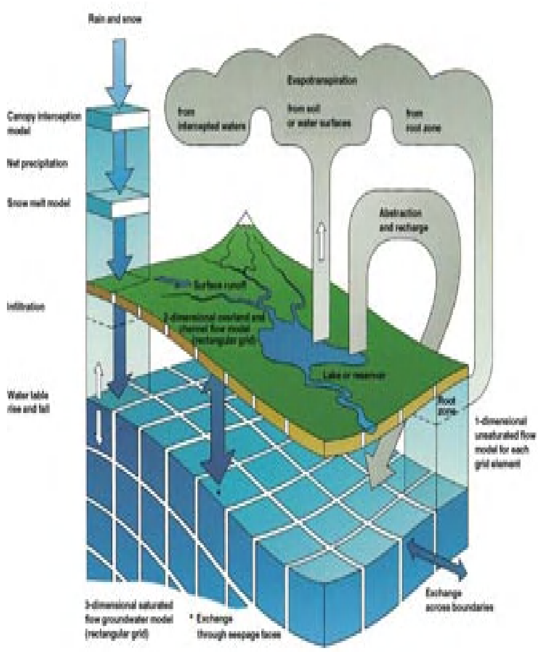

Fig. 5.Generel scheme [1,8,9]

The MIKE SHE modeling system is a complex system, developed with the water movement module as it's foundation. It is capable of performing a variety of functions housed in its modular structure. Reviewing such a complex modeling system requires a great deal of effort. The MIKE SHE modeling system can be a very useful tool for projects associated with water management and water quality controls.

Key Features and proprieties of Mike She;

- is unique (1. Can simulate all the major processes in the land phase of the hydrologic cycle

2. Is applicable on spatial scales ranging from single soil profiles (for infiltration studies) to regional watershed studies)

-is computationally efficient (1.Includes both simple and advanced process descriptions to maximize computational efficiency

2.Has a flexible modular structure that allows users to include only the necessary processes

-is versatile (1.Can be linked to ESRI's ArcView for advanced GIS applications

2.Includes alternate process descriptions for different applications)

- is easy to use (1.Links to original data rather than importing the data

2.Allows you to update your original data and your model is automatically updated

3.Includes a dynamic data tree that gives you a precise overview of all your data

4.Has automatic data and model verification routines

5.Includes sophisticated output tools, including animations

- **includes advanced tools for(**Manipulating time varying data ; Model calibration ; Water and mass balance analysis)

1.3.Mike SHE modeling

To carry out the hydrological analysis with Mike She th following data were used(Figure 6):

- The grid
- The rainfall
- The topography
- The time series

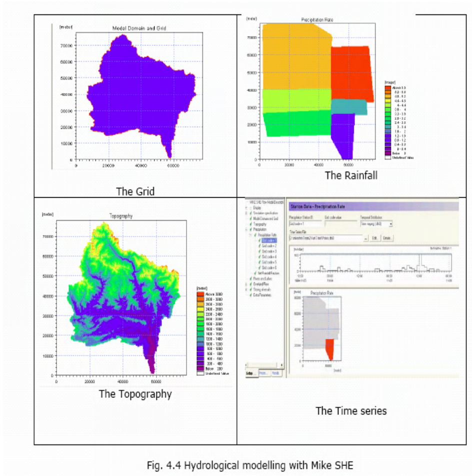

Fig. 6 Hydrological modelling with Mike She [1]

2. Study case on Var Basin River [1]

Was simulate the runoff for our catchment with the rainfall date of the big flood of 1994. We compare the results and try to find the reasons for certain anomalies. Setup of the model Was used a 300 m DEM to define the Var catchment. We take the Var catchment and apply the rainfall for the different sub catchments as shown on Fig.7

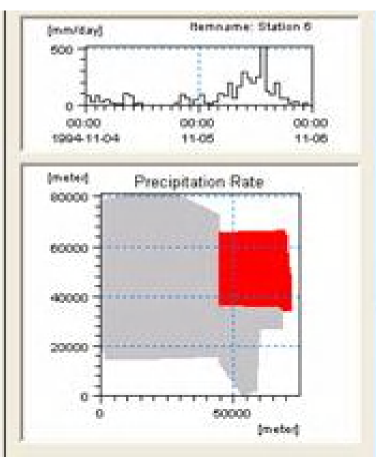

Fig 7 Application of rainfall for all the sub catchments [1]

Was use a DEM grid of 300 m and so we put some equidistant points at a distance of 300 m at each other at the outlet of the catchment as we demonstrate in Fig. 8.

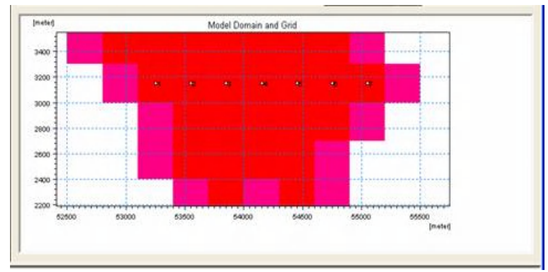

Fig. 8 Points at the outlet at a distant of 300 m [1]

After running model and compare obtained results with the measured results of the flood event of November 1994, it was notice that the results were too small. What could be the reason for that?

The reason for that was:

- Changing the runoff coefficient from 0.9 to 1?
- Changing the manning coefficient to an extremely high value like 100?

No satisfying result, shown in Fig 9.

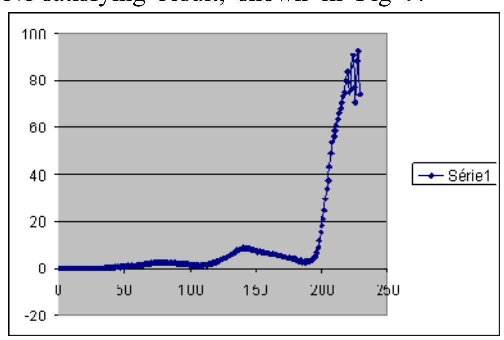

Fig 9: Accumulated discharge after some modifications [1]

There is water stored in sinks and holes, so we can run a longer simulation time in order to fill up all these holes, or fill the holes with ArcGIS hydrology tool ?

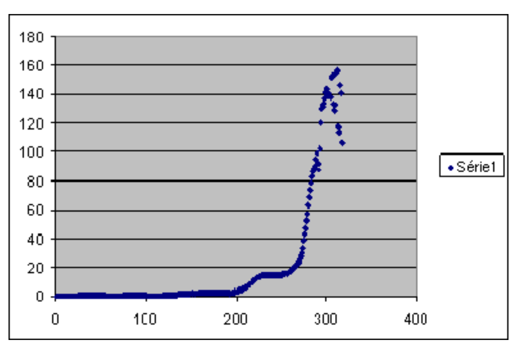

Fig 10 Accumulated discharge after some modifications [1]

It's sure that the water is staying somewhere in the catchment, and not running down as fast as it did in reality. The reason could be the velocity of water. Actually, the water velocity is given by the Strickler formula:

$$Q = K_S S R_h^{2/3} I^{1/2}$$

The wave propagation though, is given by another formula:

$$c = (gA/b)^{1/2}$$

If it were a perturbation like a wave, you can see intuitively that a wave will propagate faster in a small channel than in a large channel. You can easily observe the experiment. But also if you apply the formula mentioned above, you will find this result. Because of the difference between a real channel and the simulation we made, the wave is propagating much slower in the model. As a result we cannot reconstruct the same hydrograph. We hope to obtain better results by changing the shape of the section by a more realistic one. Was need a riverbed to make a simulation that simulates the wave propagation properly. To do this, we include a river in our Mike SHE model. The river is determined in Mike 11 and can be edited there. As we run the first simulation with the given river network we get the following results, as shown in Fig. 11. We remark that this is again no satisfying result: the discharge isn't high enough at all.

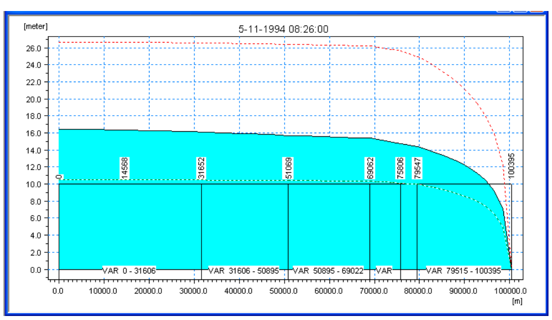

Fig 11. Results of the first simulation [1]

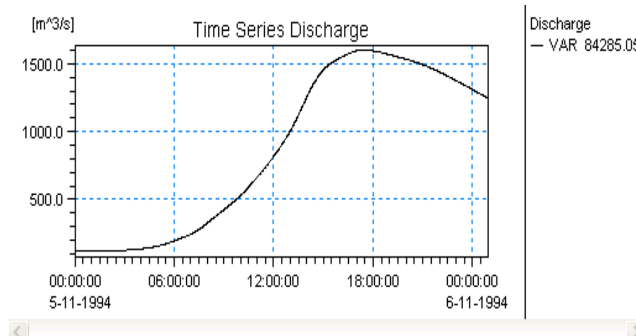

Fig 12 Results of the first simulation [1]

Was have a closer look at the Mike 11 river network and we notice that all the cross sections have the same altitude! Of course this isn't the case in reality. It is also easy to understand why we don't have enough discharge.

Changing the cross sections

There are several ways to find the new cross sections, but before doing this, we must make some remarks.

Tthe exact shape of the cross sections wasn't known. The DEM has a grid smaller than 75m. Since a mountain river like the Tinée or whatsoever isn't larger than 75m far upstream, it's impossible to find a detailed cross section, it must contain a triangular shape that has more or less the right altitudes. This is shown in Fig. 13.

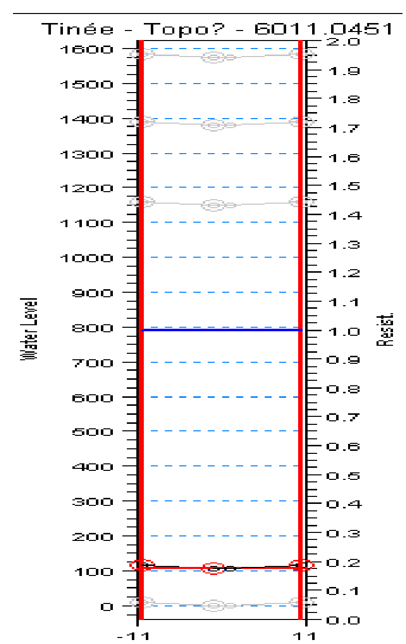

Fig. 13 New cross sections [1]

We're not going to introduce a cross section every 10 meters, but rather every 10 km. This means it's no use to find the exact coordinates of the cross sections given in Mike11. Although we'll try to make a good estimation as it will be explained later. If there are some areas with a very small slope, these areas have to be detected, because they can flood very easily and form lakes that contain a lot of water. We have to incorporate this in our cross sections because this can have a large influence on our simulation. Three new cross sections are sufficient to simulate a floodable zone. Since triangular cross sections are used we have to watch out not to make a cross section that reaches higher than the ground level at those points. If we don't, the water will be trapped in the volume between the ground surface and the cross section. . Cross sections can be found using several ways:

One option is to use the Topography given in Mike SHE to find the elevation of the points and the cross sections. See Fig. 14.

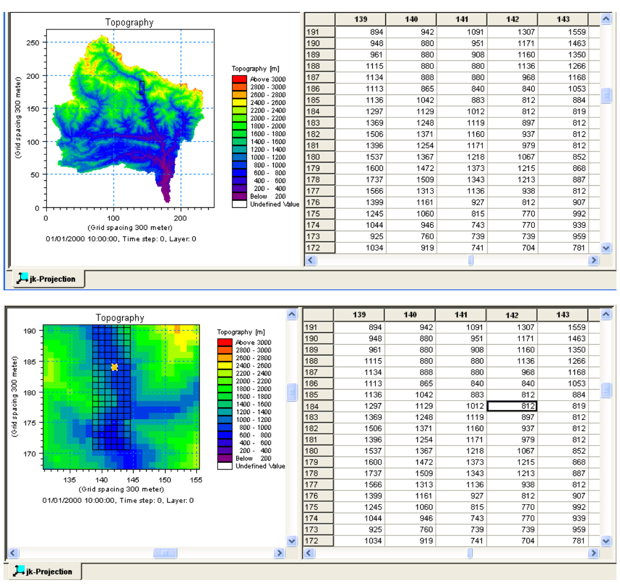

Fig. 16 Cross section elevation using Mike SHE [1]

The disadvantage of this method is the grid of 300m.

MikeShe topology and Excel were used to do so. For each cross section we took the elevation of 3 or 4 points at the grid. These points are named z1, z2, z3, z4 in the Excel file and are 300m separated from each other since we work with the 300m grid. A graph was made in Excel to have an idea about the topography of the terrain at the places where we introduce cross sections. The slopes were also calculated , the slopes were found and a cross section. was determined.

The lowest point was looked and it was supposed it is placed in the river bed at most 3m higher . When the slopes and the point height were found the width of the river bed was found to. The base width for the trapezoid is set to 2m upstream and larger downstream.

3. CONCLUSION

3.1 Hydrological solution

In order to high water levels even during heavy rain events, dams N° 9 and 10 should be lowered, so that the discharge will increase above them and the river upstream will not flood .

The sediment problem could also be solved faster. Without lowering the dams, it would take aproximatively 60 years to get the original bed levels along the river, but if the dams are lowered, that time is reduced to 20 years. Restoring the original bed level will also bring back the natural interaction between the river level and the groundwater. Figure 20 shows different cross-section shapes that could be implemented, keeping in mind the goal of lowering the water depth. These correspond mainly to the vertical type weirs.

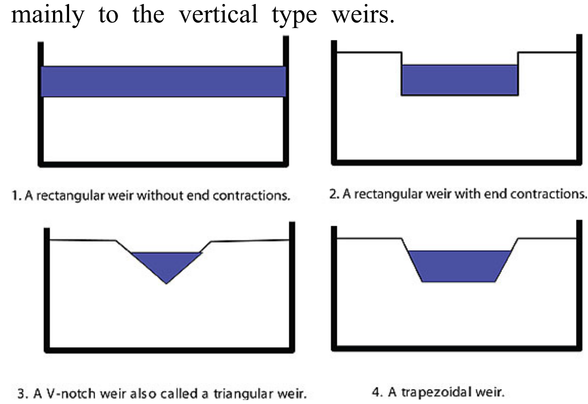

Fig. 20:Scheme of different type of weirs on the dam [1]

This figures explain the mode in which we can reduse the slope of the weirs. Lowering the weir all along the cross section as in sub-figure 1 would be problematic in the Var as a result of the “Sugar”flood protection. If the entire cross section is lowered and sediments will wash off the banks, the sugar cubes will be left hanging on a little limb and become unstable. Lowering only in the middle (sub figures 2 and 4) could work in the Var but have to be planned carefully to reduce sedimentation in parts of the cross section due to differences of velocities. Partial sedimentation might induce the stream to flow diagonally to the banks thus attacking them more vigorously. In the case of the Var, that problem could be handled as all the banks are already well protected, but it could raise the maintenance costs of the dykes. A triangular lowering as in sub-figure 3 is impractical in a river the size of the Var. It is designed for small stream not wider than a few meters.

3.2 Hydraulic/Structural solution

The absence of the destroyed dams N° 2 and 3 has provoked the sediment to be washed away from its downstream part. Together with the active thrust of both water and sediments accumulated on its upstream part, this can induce the collapse of the structure with the consequent loss of life and properties. To avoid this problem, the implementation of a so-called “counter-weir”downstream the dam no. 4 could be considered. This counter-weir should be constructed in a way that will allow the dissipation of the energy immediately after the dam to create a hydraulic jump. That will decrease the pounding of water on the lower parts of the large dam.

Such a solution is relatively cheap, easy to construct, and effective. Designing it could pose a problem though. There are no satisfactory equations to calculate the energy dissipation in a hydraulic jump and the consequence it will be on sediment transport .Therefore, no numeric models can be utilized to solve that problem and a scale model would have to be built for each case.

3.2.1 Stepped dam could be another solution. It’s a similar approach to the vertical type dam, only it achieves energy dissipation thrrough the small steps on the recessing limb (next figure). Stepped dam is cheap, easy to construct and to design. A large flood however would render it useless as the massive volume of water will not be affected by the small steps. Nevertheless, massive floods are rare and stepped dams will be able to mitigate the constant pounding of water on the lower part of dams 4 and 16. This type of weir could also be coupled with other types of solutions and does not have to stand in by itself.

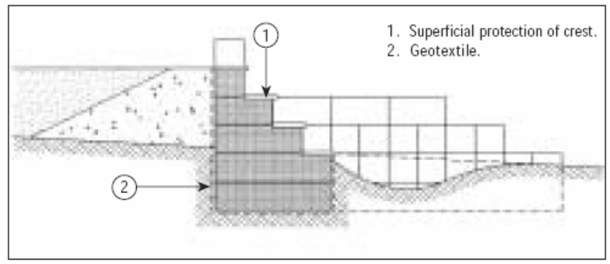

Figure 21.Dam with stepps [1]

3.3.3 Dam with a low slope and a hydraulic jump downstream

Another solution could be to increase the recessing limb of the dam and stretch it in a way that will decrease the slope. That will slow down the water flow on the dam thereby controlling the energy of the flow. Lowering the slope is easy and effective but very expensive to construct as it involves large amounts of new material. Next figure shows such a dam with a low slope coupled by a small pool that creates a hydraulic jump that further dissipates the energy.

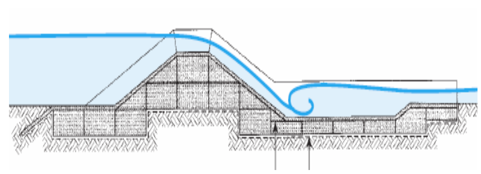

Figure 22. Dam with a low slope and a hydraulic jump downstream. [1]

Also another solution was construction of marginal dikes over a distance of 1.5 km.The earth dikes were verified for stability and infiltrations .For stability Felenius method was used and 1.4 stability coefficient , not 1.25 as it should be the normal coefficient.

Infiltration was verified with 3 methods :

-Casagrande

-Szalay si Iga

- Infbmloc

-The results obtained were very similar :1.7 (Casagrande) ; 1.75 (Szalay si Iga) and 1.16(Infbmloc)

After the study the obtained results were presented of Nice City Hall for choosing the solution which depends on available funds.
Variants were:
- different type of weirs on the dam and marginal earth dikes;
-rock filled dam with a low slope and a hydraulic jump downstream
- stepped dam could be another solution

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