THE EFFECTS OF CULVERTS IN HYDRAULIC MODELING FOR FLOOD RISK MITIGATION

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Presentation Outlines

1. **Computational Techniques**
2. **Flow through culvert under unsteady conditions**
3. **Setting the problem**
4. **Numerical approach**
5. **Outcomes and Conclusions**

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Computational Techniques

Not always the computational techniques are easy to apply in extensive areas

Extended network infrastructures and structural/hydraulic discontinuities heavily influence the computational process.

In this work will be highlighted how the gradient of the flood hydrograph influences:

i) the solution to the differences with the first order approximation;
ii) the solution to the differences of the fourth order (Runge Kutta);
iii) the length of the integration step (Δt)

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Flow Through Culverts

The study of the hydraulic state upstream of the culvert during a flood was carried out under unsteady flow conditions simulating the amount of water stored by the floodplain.

The problem rises a particular numerical difficulty since the flow rate through the culvert itself and the water depth in the depressed area are not known a priori.

Conceptual difficulties were then amplified by the slowness of the change of the hydraulic head that required the use of very small integration steps.

Setting the Problem

The equations describing the process are represented by the equation of motion through the culvert and the equation of the floodplain under conditions synchronous with the depression.

$$Hm - Hv = \overline{J} \cdot L + \Delta H_i + \Delta H_u$$

Hm, Hν are the total load upstream and downstream of the culvert;
J is the friction slope;
ΔHi, *ΔHu* losses at the inlet and outlet.

Setting the Problem

Assuming, to a good approximation, that the losses at the inlet and outlet are calculable proportionally to the kinetic high of the flow, the equation of motion can be written as follows:

$$Hm - Hv = Q^2 \left[\frac{4L}{(km - kv)^2} + \frac{1}{2g} \left(\frac{\alpha_m}{Am^2} + \frac{\alpha_v}{Av^2} \right) \right] = \beta Q^2$$

where L is the length of the culvert; *Q* is the flow rate of the culvert; km, kv are the conveyance upstream and downstream; *Am, Av* is the hydraulic sections upstream and downstream, αm, αv are inlet and outlet coefficients of the flow.

Setting the Problem

The equation of the reservoir is as follows:

$$\Omega \frac{dHv}{dt} = Q$$

where Ω is the horizontal surface of the basin volume. Combining the two previous equations, we obtain the following differential equation:

$$\frac{d[hm(t), Hv]}{dt} = \frac{1}{\Omega(Hv)} \sqrt{\frac{Hm(t) - Hv}{\beta[Hm(t), Hv]}} = f[Hm(t), hv]$$

Numerical Solution

The previous relation can be numerically solved at the differences as follows

$$Hv_{i+1} = Hv_i + \Delta Hv_i$$

The ΔHvi difference can be evaluated, with Eulero first order approximation:

$$Hv_{i+1} = Hv_i + f[Hm(t), hv]_i \Delta \mathrm{t}$$

In order to have a more accurate solution and a quicker convergence, the integration process can be conducted with an approximation of the fourth order (Runge Kutta)

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Numerical Solution

Assumed that:

$$\Delta_1 Hv_i = f(t_i; Hv_i)\ ,$$
$$\Delta_2 Hv_i = f\left(t_i + \frac{\Delta t}{2}; Hv_i + \frac{\Delta_1 Hv_1}{2}\right),$$
$$\Delta_3 Hv_i = f\left(t_i + \frac{\Delta t}{2}; Hv_i + \frac{\Delta_2 Hv_1}{2}\right),$$
$$\Delta_4 Hv_i = f(t_i + \Delta t; Hv_i + \Delta_3 Hv_1).$$

the final increment is evaluated with the following equation:

$$\Delta Hv_i = \frac{1}{6}(\Delta_1 Hv_1 + 2\Delta_2 Hv_1 + 2\Delta_3 Hv_1 + \Delta_4 Hv_1)\cdot \Delta t$$

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Outcomes

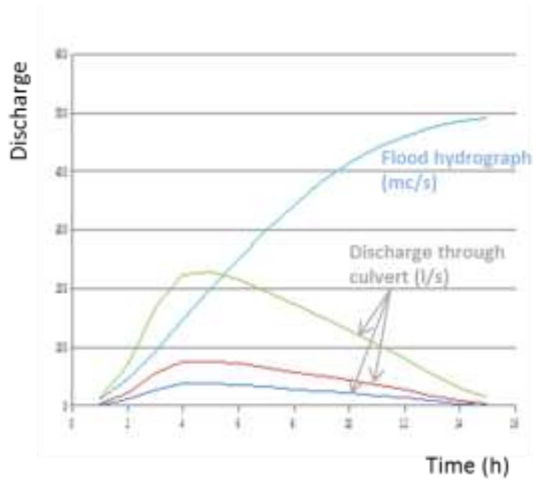
In order to achieve a numerical solution, the first-order Euler method and the fourth-order Runge Kutta analysis have been implemented.

However the convergence of the Euler method required an ad hoc calculation procedure so that longer integration steps could be chosen.

The adopted integration steps dependent on the Return Time (RT) of the flood wave passing through the main riverbed are as follows: Δt: i) Δt = 0.5 sec for RT = 500 y; ii) Δt = 0.2 s for RT = 200 y; iii) Δt = 0.1 s for RT = 50 y

For the sake of brevity, only the values of flow rate Q calculated for a flood with RT = 500 years parametrized over the width of the culvert are reported

Outcomes



Conclusions

This procedure has allowed to evaluate the influence of the dimensions of the culvert on the withdrawn flow.

This study also showed that the effectiveness of the culvert depends on the volume that is available in the floodplain.

The proposed model and its solution is also a robust tool to verify both the influence of culvert dimensions and the volume of fringe areas for the mitigation of hydraulic risk.

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Conclusions

Thank you

for the attention