Optimal Rehabilitation of Drainage Networks Using Pipes replacement and Tanks installation

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Introduction

Drainage networks are civil engineering constructions important in the daily life of any city across the world. As any civil engineering construction, they are built for a specific mission and are subjects to many factors whose effects can lead to failure in the operation. Climate change is the main factor affecting drainage networks functioning by inducing floods. To solve floods problem faced by a drainage network, rehabilitation is one of the best options. 3 principal possible rehabilitation scenarios are identified: Pipes substitution, Implementation of Low Impact Development (LID) in this case storage tanks installation and finally the combination of pipes substitution and storage tanks installation.

Previous studies showed that combination of pipes substitution and storage tanks installation gives better results than the 2 other options implemented separately. To obtain an optimal solution a heuristic algorithm is used, this means that there is a solution space with many solutions where the algorithm has to search the optimal one. The third option implies the used of many decision variables which make difficult the finding of the optimal solution. In this work a methodology is proposed and applied to a real world drainage network call "E-Chicó". The methodology aims to reduce the number of decision variables with objective criteria, reduce the computation time and find the optimal solution.

Problematic

Climate Change → Increase rain intensities

Urbanization → Reduce infiltration capacity of soil

→ Increase of water runoff → Drainage network Failure:
- Pipes capacity reduction
- Pipes transport capacity failure.
- Water flowing out of the network

Flood which is the major urban drainage problem induced by increase of runoff leads to economic and environmental problems depending on his level. → Rehabilitation of the drainage network to reduce the flood level and impact →
- Pipes substitution
- Storage tanks installation
- Pipes substitution and Storage tanks installation

Combination of Pipes substitution and Storage tanks installation gives better results than pipes substitution or storage tanks installation applied separately. The problem is the fact that the implementation of this option is numerically costly and the question is: How can we overcome this situation?

Methodology

In this work, Genetic algorithm is used to perform the optimal rehabilitation of the drainage network. The steps of the methodology are:

- The first step is the drainage network calibration and the selection of extremes conditions through a climate change scenario (Gulizia and Camilloni, 2015).
- The second step is the Pre-location of storage tanks for possible installation, through numerical Computation and Qualitative analysis.
  Then, the Pre-location of pipes for possible substitution, through numerical Computation and Qualitative analysis.
- The third step is the selection of decision variables leading to the reduced problem.
- The fourth step is the sizing of storage tanks and pipes through new numerical computation of the reduced problem and selection of final solution based on the Objective Function value.

This methodology is detailed in Ulrich Ngamalieu et al. (2017)

Case Study

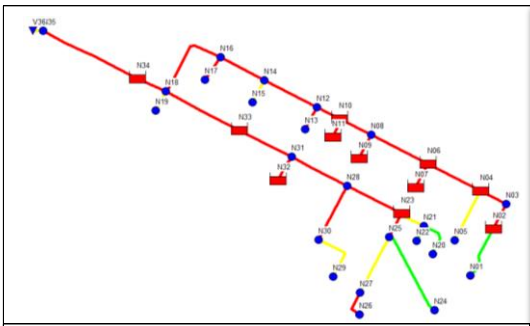

Figure 1: Representation of Flooding Nodes and pipes Capacities during the rainfall event.

Characteristics of E-Chico:
Superficie: 51ha
Sub catchments Number: 35
Network total Longitud: 4993m
Nodes number: 35
Conduits: 35
Diameters range: 300- 1400 m
Height Range: 2548.37 – 2587.65 m

Results

Scenario	Decision variables Number	Objective Function	Floods costs	Storage tanks Costs	Conductuits Costs	Number of installed storage tanks	Number of substituted condu
1	35	763 164	7 622	0	755 542	0	6
2	35	273 459	5 392	268 067	0	16	0
3	70	254 046	8 363	237 457	8 226	4	3
4	30	245 547	8 352	213 133	24 061	4	5
5	23	218 501	12 701	186 353	19 448	3	4

Table: Results summary

Table represents the results of 5 rehabilitation scenarios. Scenario 3 is the complete network resolution while scenarios 4 and 5 are reduced problems obtained by the application of the proposed methodology for the 10 best results of Objective function and the 5 best results. Scenario 5 gives the best result and use less decision variables: 23 against 70 for the whole problem.

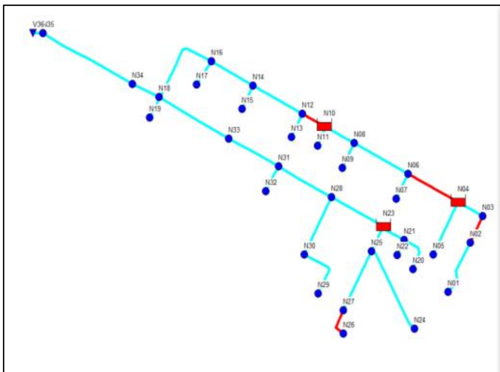

Figure 2: Representation of storage tanks installation nodes and pipes to substitute

The nodes in red on figure 2 represent the location where should be installed storage tanks and the conduits in red represent the locations where pipes should be substitute to reduce Floods according to the scenario 5 presented in Table1. A total of 3 storage tanks to be installed and 4 pipes to be substituted to rehabilitate the network.

Conclusion

The proposed Methodology in this work allows reducing the problem size with objective criteria and obtaining better results than the whole problem resolution. The computation time is also reduced due to the fact that the solution space is considerably reduced.

Bibliography

- Gulizia, C., & Camilloni, I. **Comparative analysis of the ability of a set of CMIP3 and CMIP5 global climate models to represent precipitation in South America**. International Journal of Climatology, (2015), 35(4), 583-595.
- Ngamalieu, U., Iglesias-Rey, P. L., Martínez-Solano, F. J., & Saldarriaga, J. (2017). **Rehabilitation of Drainage Networks Through the Combination of Retention Tanks and Replacement of Pipelines**. SSRN Electronic Journal, (86111). http://doi.org/10.2139/ssrn.3113706