SINERGEA - Energy: Modelling energy consumption in wastewater systems during rainfall events

Luís M DAVID[1], Armando PINTO[2], Anabela OLIVEIRA[3], António MARTINS[4]; Alexandre ATAÍDE[5]; Osvaldo SILVA[6]

[1,2,3] Laboratório Nacional de Engenharia Civil, Portugal
email: ldavid@lnec.pt
email: aoliveira@lnec.pt
email: apinto@lnec.pt

[4,5,6] Águas do Algarve S.A., Portugal
email: antonio.m.martins@adp.pt
email: a.almeida@adp.pt
email: osvaldo.silva@adp.pt

ABSTRACT

1. Introduction

The urban water cycle infrastructures are important consumers of electricity. Thus several efforts have been made recently to increase their energy efficiency. During rainfall events, the increase in flows pumped by interceptor sewers and treated in wastewater treatment plants (WWTP) can lead to significant increases in energy consumption. These flow increases occur not only in the combined sewer systems, but also in separate wastewater systems, due to water infiltration into the sewers, the rainfall-derived infiltration and inflow (RDII) component, and illicit misconnections between stormwater and sewage systems. Controlling rainfall-derived inflows into wastewater systems is a difficult challenge that has received increasing attention.

However, in coastal urban areas, it is also a common practice to store and transport stormwater from ephemeral watercourses to the WWTP to protect bathing water quality during small rainfall events. Coastal wastewater systems often require multiple pumping stations (PS) along the coast, each with its own sanitary sewer overflow (SSO). Most PS are designed considering only the dry weather flows and their flow measurement considers only the pumped flows, i.e., it completely ignores the discharged SSO. Thus, increasing the energy efficiency of these systems requires the knowledge on three key issues: the flows pumped and treated during wet weather; the impact on receiving water bodies of the SSO discharged at each pumping station; the potential to improve the energy efficiency of the system as a whole.

Within the SINERGEA Project, an intelligent real-time decision support system was developed, aiming at the management of emergencies of flooding and bathing water contamination, and the efficient use of energy (David et al, 2022). This system is being demonstrated at the city of Albufeira, Portugal, and its coastal neighbourhood. This paper describes the objectives and methodology developed to model energy and its application to the demonstration case.

2. Integrated modelling of energy consumption and wet weather discharges

The integrated management of the energy efficiency of waste water systems and the quality of water bodies must include the integrated modelling of both systems. It should also take into account tariffs, potential for improvement in each equipment or station in the system and alternatives for the design and management of the entire sanitation infrastructure. Given that currently few deterministic modelling programs include energy consumption modelling, the well-known SWMM model is used herein to model the hydrodynamic component and a generic, new tool was developed to calculate energy consumption in pumping stations and WWTP using Python.

The calculation of energy consumption in pumps is based on the results of flow rates and water heights provided by SWMM. The calculation of the energy consumption of the remaining drainage and treatment equipment is carried out in a simplified way, taking into account different types of functions: fixed consumption (or consumption that varies depending on the month); consumption as a function of the flow provided by SWMM during a set of previous calculation steps; consumption as a function of flow and external variables such as temperature and previous rainfall. In the mass balances, it also allows for considering the contribution of energy production equipment by alternative energy sources, such as photovoltaic panels (depending on the atmospheric radiation of long and short waves) or the use of biogas in WWTP. The model provides energy consumption, cost and carbon footprint results by equipment, by station and for the overall system. In practical applications, the equipment to be modelled in each pumping station or WWTP will depend on the quantity and quality of the existing information on the operation and energy consumption of each equipment.

An important challenge for the success of these approaches is related to the estimation of flows discharged by sanitary sewer overflows, since these discharges are usually not monitored. An innovative methodology was developed that uses a lumped conceptual model to estimate the useful area of the catchment and the flows discharged by SSO from the flows measured in pumping stations. The parameters obtained for the conceptual model serve as a basis for the SWMM model calibration.

3. Demonstration case

The SINERGEA system is being demonstrated on the city of Albufeira, Portugal, and its coastal neighbourhood, where the stormwater separate network, the interceptor sewer system, and coastal bathing waters were modelled in detail (David et al, 2022). Figure 1 shows the SWMM model of the interceptor sewer system, which serves several coastal urban-tourist developments. It has a WWTP, ten pumping stations (some with variable speed drive) and two submarine outfalls.

Figure 2 shows results of the energy consumption model in a pumping station. Figure 3 shows the results of the calibration of the flows pumped in a pumping station, where the estimation of the flows discharged by SSO is also obtained. The model is currently being calibrated and will soon be validated for other rainfall events, providing results on energy consumption, costs and carbon footprint by equipment, by season and for the overall system. The model will then be used to study alternatives that promote energy efficiency.

Fig. 1. Map of the interceptor sewer system and WWTP.

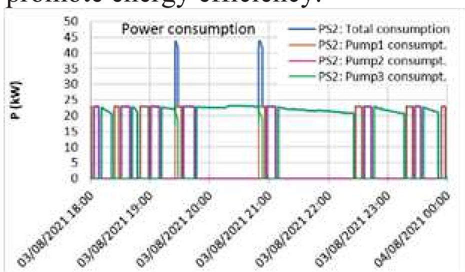

Fig. 2. Energy consumption at a pumping station.

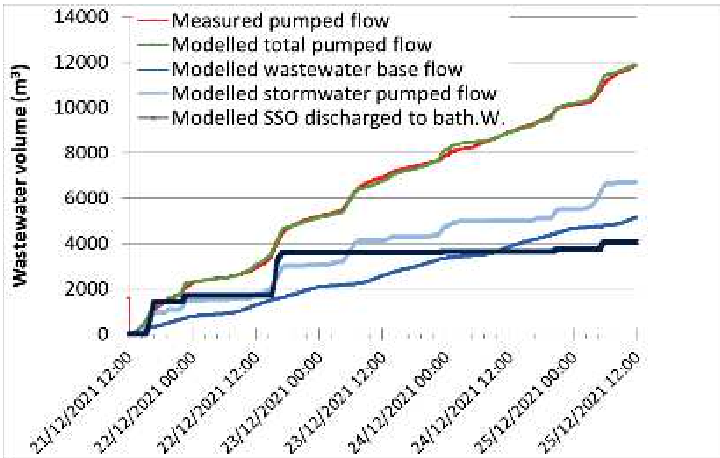

Fig. 3. Calibration of flows pumped at a pumping station and estimation of SSO discharges.

Acknowledgements

This work was co-funded by the European Regional Development Fund (FEDER), under programs POR Lisboa2020 and CrescAlgarve2020, through Project SINERGEA (ANI 33595).

References

David et al. (2022). SINERGEA - Real-time forecasting system for managing floods, bathing water quality and wastewater energy consumption. Submitted to the 7th IAHR Europe Congress.