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Maria Almeida Silva, Conceição Amado, Dália Loureiro

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# Propagation of Uncertainty in the Water Balance Calculation in Urban Water Supply Systems – a new approach based on high-density regions

Maria Almeida Silva<sup>1,2</sup>, Conceição Amado<sup>2</sup>, Dália Loureiro<sup>1</sup>

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## Abstract

The water balance calculation is a well-known procedure that allows the water loss performance assessment in urban water supply systems. The International Water Association recommends it for a systematic assessment of non-revenue water volumes, where water losses are, in general, the most significant component. After water balance components calculation, a set of performance indicators can be obtained to support diagnosis and decision-making. Water balance components and performance indicators result from operations between multiple variables with uncertainties associated. Moreover, measurements of input and output volumes are not always available and estimations based on indirect data should be obtained and considered as “best estimates”. Therefore, the analysis of propagation is fundamental to ensure that the water utilities become more confident about the use of water balance outputs in decision-making. Additionally, since water balance is usually calculated using a single measurement or estimate for the annual input and output volumes, the estimation of the uncertainty through the standard deviation is not applicable. Hence, in this study, the uncertainties may be either given by a band, *i.e.*, a minimum and a maximum value for the uncertainty, or may be calculated based on the minimum and maximum values for the variables. Thus, to study uncertainty propagation in the water balance calculation, three methods were explored: Delta method, Monte Carlo simulations and a new proposal based on high-density regions. This novel approach allows the association of an uncertainty measure for the uncertainty values. These methods were tested with water balance data published in previous studies and using data from two real water supply systems. The high-density regions with the uncertainty bands produced the best results as regards to the computation of the total uncertainty. This approach is suitable for general propagation of uncertainty in the annual calculation of the water balance and related performance indicators.

*Keywords:* high-density regions, uncertainty propagation, water balance, water supply systems

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## 1. Introduction

The water balance approach, published by the International Water Association (IWA) [Alegre *et al.* (2016), Lambert and Hirner (2000)], is a representation of the main input and output water volumes in an

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*Email address:* mjsilva@lneec.pt (Maria Almeida Silva)

<sup>1</sup>National Laboratory for Civil Engineering (LNEC), Lisbon

<sup>2</sup>CEMAT, Instituto Superior Técnico (IST), Lisbon

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