

Estimation of storm runoff loads based on rainfall-related variables and power law models – Case study in Alexandra

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Abstract

This paper compares the use of simple regression equations of three commonly used pollutant build-up and wash-off functions, namely linear, power and exponential functions, to estimate event pollutant loads. The comparative study indicated that, event loads are better estimated as power functions of storm-related independent variables. On the notion that rainfall data are more readily available, easy and less expensive to collect than runoff data, the calibrated model was verified using rainfall volume as independent variable. The verified model was then used to develop load-duration-intensity curves to serve as predictive tools. Planners and engineers can use these predictive tools to obtain an approximate estimate of event pollutant loads in storm runoff from Alexandra (and also other townships with similar physical, land-use, climatic and hydraulic characteristics and water quality issues) for the purpose of managing or improving drainage conditions in the township.

Keywords: event loads, power functions, modelling, load-duration-intensity curves

Introduction

Inadequate sanitation and drainage is one of the major environmental and health problems facing high-density low-income settlements in South Africa today. The backlog in sanitation and drainage includes solid waste, sewage, grey-water and severely contaminated stormwater runoff. In these areas (as noted in Alexandra) the paths are often merged; sewage, grey-water, solid waste and contaminated runoff enter surface drains, eventually discharging into streams, rivers and impoundments that are used for drinking water supply and recreation. These cause water quality problems, pose potentially serious human and environmental health risks through contact recreation and through the use of untreated water, result in high drinking water purification costs and cause a loss of amenity value and diminished recreation potential (Ashton and Bhagwan, 2001).

The unprecedented population growths in these settlements have severely strained the ability of municipalities to meet the need for drainage and treatment. As local governments have tried to cope with insufficient services, priority has been given generally to high-income areas where full or partial cost-recovery is considered feasible. Low-income areas are often left unserved or served by woefully inadequate drainage and treatment facilities. The principal reason for this situation is the high cost of conventional drainage and treatment practices. It is for this same reason that the Water Research Commission of South Africa initiated a project to look into appropriate technology options that are feasible for rural and peri-urban drainage. The project, among other things, seeks to identify potential management interventions (e.g. ponds, vegetated biofilters and wetlands) and appropriate technology for treating runoff and grey-water. To achieve this objective, a technique needs to be developed to estimate storm runoff loads in view of limited data available.

Previous studies conducted in South Africa have concentrated on the use of linear regression techniques/models to

estimate storm loads. This paper compares three different regression models commonly used in pollutant load estimation. The best regression model (involving rainfall-related variables) is further used to develop load-duration-intensity (LDI) curves for prediction of storm runoff loads. Vase and Chiew (2003) also used rainfall-related variables to develop similar characteristic curves based on laboratory experimental runs using rainfall simulators. The data and information used in this paper were compiled by Wimberley (1992), which to date, stands out as one of the most comprehensive studies in South Africa that contribute meaningful data on the subject concerning water quality and flow measurements in urban settlements.

Catchment description

The Alexandra township is located 12 km north-east of central Johannesburg and 4 km east of Sandton central business district. The township is split into the west and east bank by the Jukskei River; the west bank is completely developed whereas the east bank is undeveloped. The west bank, which is principally the focus of this study covers a total surface area of about 350 ha. The official population of Alexandra is estimated as 166 971 according to the 2001 population census of South Africa. This translates to a population density of 477 persons/ha and 80 dwelling units/ha (assuming 6 persons/dwelling unit). This suggests that every person in Alexandra has, on average, about 16 m² of living space, accepting that roads, businesses, schools, and other open spaces take up 20% of the area. If the relatively small number of storeyed buildings in Alexandra is further taken into consideration, this figure becomes even more alarming.

Land-use characteristics are being dominated by a high-density residential development. Stormwater drains service the township. Most of the drainage network consists of underground pipe network with an outfall into the Jukskei River. A water-borne sewage system services the formal settlements whereas in the informal settlements, sewage is removed in buckets, and taken to the Alexandra Sewage Works. The area slopes steeply in a west-east direction towards the Jukskei River, with slopes

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