Development of Taoyuan smart drainage management system

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Highlights

- Taoyuan government develop a web system to support the review of runoff control plan.
- Taoyuan smart drainage management system helps the assignment of runoff control criterion.
- Taoyuan smart drainage management system devote urban water issues involved by land developement.

Introduction

Climate change and urbanization have become two important global issues in recent decades. Increase in storm runoff quantity caused by these two processes usually exceeds the water discharge capacity of river channel, drainage and sewer systems in urban areas, generating severe flood events. These pose a major threat to people's life and properties. However, high urbanized development and anthropogenic land use generally leads to difficulties in the adjustment of drainage system capacity especially nearby river channels. Hence, runoff control and drainage plans need to be proposed and approved before land and site development in Taiwan, respectively. Runoff control plans should clearly describe rainfall-runoff characteristics pre- and post- land development, assigning the objective and operation of surplus runoff reducing and its countermeasures. This arise that the standard operation principal setting is a key factor for those hydrologic assessment and plan review.

The Taoyuan City of Taiwan has fast, high urbanization in recent years, leading to evident increase in the amounts of proposed runoff control plans (also drainage plans) the need to be reviewed. Here we develop the Taoyuan smart drainage management system (denoted by TSDMS) to clarify incremental surface runoff quantity entering into due to change in land use, supporting the review of those above mentioned plans for the Department of Water Resources, Taoyuan City. The TSDMS is a web system that can be categorized into two modules (i.e., runoff control and rainwater outflow restriction), obeying calculation methods published by the water law of Taiwan and the reference handbook of rainwater outflow restriction of Taoyuan City, respectively. The runoff control module can be utilized to analyse design hyetographs, the change in surface runoff pre and post land development in a certain area (more than 2 ha), the criterion of runoff control quantity, runoff reducing operated by controlling practices (e.g., detention ponds and low-impact design) and its consequent budget. In other words, the rainwater outflow restriction module can be utilized to analyse design hyetographs, runoff peaks, the minimum water retention and tolerable outflow quantity operated by restriction practices in a site.

The objective of this paper is to establish an appropriate platform to evaluate urbanized rainfall-runoff characteristics and to review the aforementioned plans for professional technicians and government officials. We examined a case study of land (resp. site) development accompanied with its corresponding runoff control plan (resp. drainage plan) on the basis of this management system showing that can devote useful information on the development, management and regulation of urban water issues.

Methodology

1. Design hyetograph

The design hyetograph was constructed in the study area using classic Hornor's equation for the rainfall records obtained from each rain gauge stations within the Taoyuan City. On the TSDMS, users can choose an appropriate rainfall stations to create the corresponding design hyetograph for different rainfall duration. Mathematically, Horner's equation can be defined as follow.

$$I_t=a/(t+b)^c, \tag{1}$$

where I_t is the rainfall intensity (mm/h) for the rainfall duration t, a, b, and c are constants that refer to the values reported by Water Resources Agency (WRA), MOEA, Taiwan (2018).

2. Curve Number Hydrology

In this study, SCS curve number method was used to compute surface runoff amounts and its corresponding hydrograph generated by storm water in the region of land development. Natural Resources Conservation Service (NRCS), US curve number hydrology was empirically developed to characterize the rainfall-runoff relationship of small watersheds. Originally, on the basis of observed storm depth and storm runoff data from monitored watersheds, the curve number parameterizes the maximum potential storage (after initial abstractions) S (mm) in a catchment as

$$S = 25.4(1000/CN)-100 \tag{2}$$

Where CN is the curve number the can simultaneously characterise land use and soil properties. Curve number hydrology assumes no runoff is generated from rainfall depths less than a catchment-specific initial abstraction, I_a, parameterized by the curve number via (2) as I_a=βS. Increasing rain losses control the runoff volume for large storm depths, with the change in expected runoff asymptotically approaching dQ/dP=1 as the storm depth increases (Hawkins 2001). Obeying the assumptions, direct runoff Q (cms) can be calculated by SCS curve number method as

$$Q = (P-0.2S)^2/(P+0.8S) \tag{3}$$

where P is the rainfall depth (mm).

3. Computation of detention ponds

Detention ponds is usually utilized to mitigate increase in surface runoff volume driven by land development in urban regions. Here we use the Puls routing method (Puls et al., 1928) in the design and evaluation of stormwater management ponds. Neglecting precipitation, evaporation, infiltration and tributary inflow, the continuity (mass balance) equation is given by:

$$I(t)-O(t) = \frac{dSp}{dt} \tag{4}$$

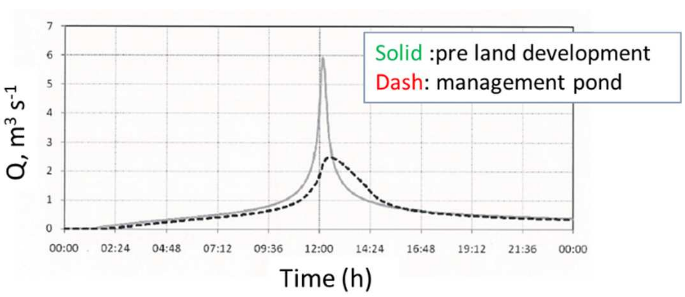
where I(t) is the inflow equivalent to direct runoff computed by curve number hydrology, O(t) is the outflow and Sp is the storage in ponds. According to the Puls method, (4) can be rewritten as

$$\frac{I1+I2}{2}\triangle t + S1 - \frac{O1}{2}\triangle t = S2 - \frac{O2}{2}\triangle t \tag{5}$$

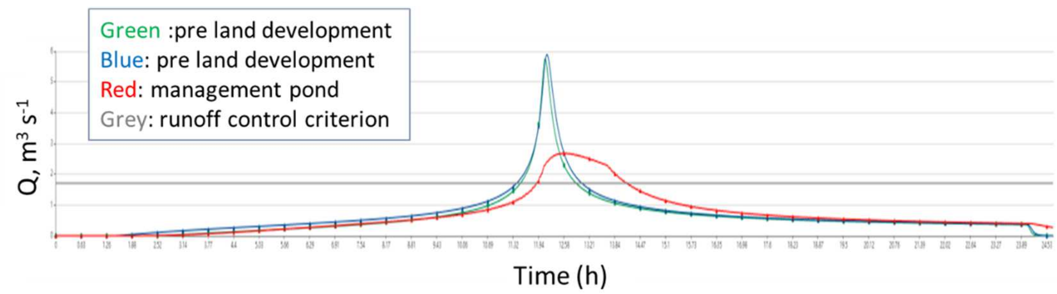
Results and discussion

The TSDMS is a web system, which has many different toolboxes, not only containing the aforementioned design hyetograph, rainfall-runoff characteristics and the operation of management ponds, but also land development area mapping and the database of runoff control criteria for the downstream of river channels in Taoyuan City. The runoff control criteria are collected from the each planning report of its corresponding river. Users can manipulate the TSDMS on website, outputting the calculation results, figures and tables. These patterns can support the review of runoff control plans for technicians and government officials.

Here we examined a land development case in the Caota Taoyuan City using the TSDMS and compared with its runoff control plans (**Figure 1**). All the parameters used in hydrologic assessment and management pond construction is obtained from the plan report. Results show that the TSDMS reports the similar surface runoff peaks and hydrographs pre- and post- land development for 50-year return period. Moreover, the TSDMS can consider the runoff control criterion for the downstream of river channel (1.71 $m^3 s^{-1}$), indicating that the runoff control plan overestimated runoff control criterion only based on the data of local drainage system (2.35 $m^3 s^{-1}$).



(a) Runoff control plan



(b) TSDMS

Figure 1. The Rainfall-runoff characteristics of Caota in Taoyuan City reported by (a) Caota runoff control plan, comparing with (b) TSDMS.

Conclusions and future work

Results show that Taoyuan smart drainage management system (TSDMS) can provide useful information on the development, management and regulation of urban water issues. The TSDMS can be improved by increase in multi-operation pond toolbox, integrating suitable flood simulation models that leave these topics aside in the future work.

References

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