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Development of a water quality modeling system for river pollution index and suspended solid loading evaluation

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SUMMARY

The Kaoping River Basin is the largest and most extensively used watershed in Taiwan. In the upper catchment, the non-point source (NPS) pollutants including suspended solid (SS) and ammonia nitrogen (NH_3–N) are two major water pollutants causing the deterioration of Kaoping River water quality. Because SS is one of the four parameters involving in the River Pollution Index (RPI) calculation, it needs to be carefully evaluated to obtain the representative water quality index. The main objective of this study was to develop a water quality modeling system to obtain representative SS and RPI values for water quality evaluation. In this study, a direct linkage between the RPI calculation and a water quality model [Water Quality Analysis Simulation Program (WASP)] has been developed. Correlation equations between Kaoping River flow rates and SS concentrations were developed using the field data collected during the high and low flows of the Kaoping River. Investigation results show that the SS concentrations were highly correlated with the flow rates. The obtained SS equation and RPI calculation package were embedded into the WASP model to improve interactive transfers of required data for water quality modeling and RPI calculation. Results indicate that SS played an important role in RPI calculation and SS was a critical factor during the RPI calculation especially for the upper catchment in the wet seasons. This was due to the fact that the soil erosion caused the increase in the SS concentrations after storms. In the wet seasons, higher river flow rates caused the discharges of NPS pollutants (NH_3–N and SS) into the upper sections of the river. Results demonstrate that the integral approach could develop a direct linkage among river flow rate, water quality, and pollution index. The introduction of the integrated system showed a significant advance in water quality evaluation and river management strategy development.

1. Introduction

Compared to point source pollution, nonpoint-source (NPS) pollution is more diffuse and harder to isolate and control (Markku et al., 2010). The NPS pollution is defined legally as any pollution not originating from a statutory point source, which can be carried over by rainfall and irrigation water to enter a water body dispersedly via surface runoff. It has been well-documented that NPS pollution, such as nutrient runoff and atmospheric deposition, contribute significant pollutant loading to water bodies. The NPS pollutants can cause the deterioration of water quality through the release of suspended solids (SSs), nutrients, pesticides, fertilizer, and other sources of inorganic and organic matter.

Because many factors, such as topography, soil characteristics, and rainfall intensity, affect their quantity and quality, variety types of NPS simulation models have been used to account for the integrated effects of the hydrological cycle and land cover in relation to nutrient yield (Kavvas et al., 2006; Papanicolaou and Abaci, 2005; Xu et al., 2010). With the aid of various environmental models, the improvement of the estimation and control of NPS pollution in watershed has been enhanced greatly in recent years. To assess the effectiveness of land-use-management policy, some applications seek improved modeling approaches for predicting the water quality effects of storm events as a function of land topography, land cover, and land use leading to the development of various applications (Chen et al., 2006; Ouyang et al., 2009). These models, for assessing NPS loads in the agricultural field, generally simulate rainfall, erosion, runoff sediment, temperature, wind speed, atmosphere pressure, and NPS processes (Lin et al., 2010; Luo et al., 2012).

The Kaoping River Basin, located in the southeast region of Taiwan, is the largest and the most intensively utilized river basin in Taiwan. It is 171 km in length, drains a catchment of more than 3625 km^2, and has a mean flow of 239 m^3/s. Fig. 1 shows the location of Kaoping River Basin, Kaoping River, its catchment, and three

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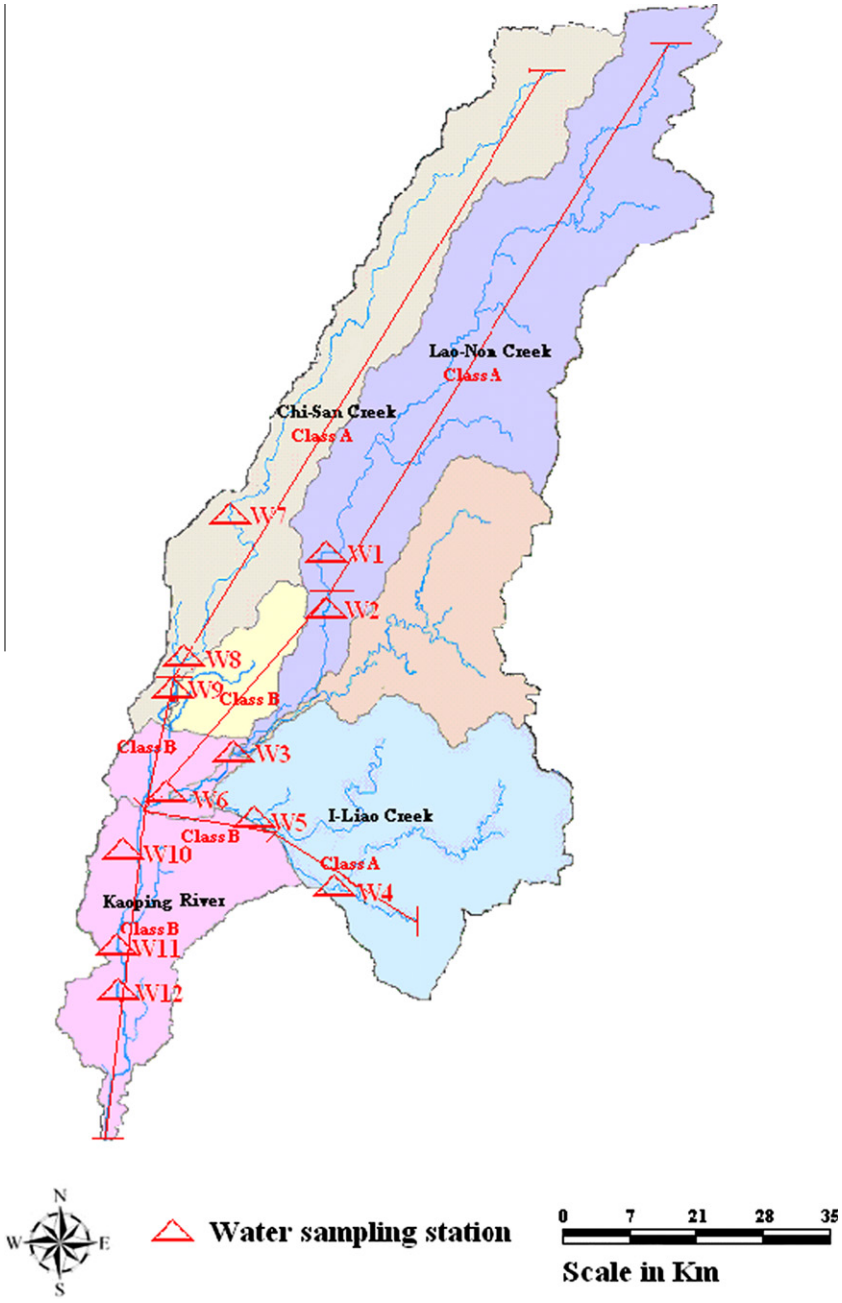

Fig. 1. Kaoping River Basin and three major reaches.

major reaches (Chi-San Creek, I-Liao Creek, and Lao-Non Creek). Although the mean annual rainfall in this river basin is close to 3000 mm, over 90% appears in the wet season. The period of high flow rate in the stream usually occurs in the late spring and summer due to the impacts of monsoon and typhoon (Lin, 2010; Lai, 2010).

NPS SS pollutants due to the severe storm events would cause significant adverse impacts on the river water quality of Kaoping River, and also cause the increased turbidity of the river water at the intake location of the downstream water treatment plant. Thus, the NPS SS pollution should be effectively evaluated and controlled. Taiwan Environmental Protection Administration (TEPA) has developed a River Pollution Index (RPI) classification system for river water quality evaluation based on the purpose of water usage and degree of protection for each stream section (TEPA, 2002). The RPI involves four parameters: dissolved oxygen (DO), biochemical oxygen demand (BOD), SS, and ammonia nitrogen (NH_3–N), each of which is ultimately converted to a four-state quality sub-index (1, 3, 6, and 10). The overall index is then divided into four pollution levels. Table 1 presents the equation for RPI calculation and criteria for the four RPI classes (good, slightly polluted, moderate polluted, and gross polluted). Table 2 shows the classification system for the Kaoping River developed by TEPA. Basically, the upstream is classified as good water quality and mid to downstream is classified as slightly polluted quality. Thus, the highest degree of protection is given to the upstream section. The concentrations of some major water quality indicators (e.g., SS, NH_3–N) are much higher than the Kaoping River water quality criteria (good or slightly polluted) developed by TEPA (TEPA, 2009). Among the four parameters, SS is one of the important factors and