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A Simulation Framework for Water Allocation to Meet the Environmental Requirements of Urban Rivers

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Outline

- Background
- Simulation approach
- Application
- Conclusions

Background

Background _ troubles

Troubles of urban rivers

Reductions in their rate of flow

Deterioration of the water quality

Background

_ approaches

- 7Q10
- R2CROSS
- IFIM
- Wetted perimeter
- BBM
- Holistic approach

Background

_ handicap in application

Do not consider where water comes from and how to allocate this water for rivers in spatio-temporal scale, **only to solve how much water a river needs theoretically**.

The managers of the rivers have difficulty troubles about how to supply the available environmental flows to rivers **when water resources are deficient.**

Background _ way out

Untraditional water sources should be considered to compensate the deficiency of freshwater in the urban:

- storm water
- reclaimed effluent from WWTPs
- superfluous freshwater from reservoirs or other rivers are potential sources of water.

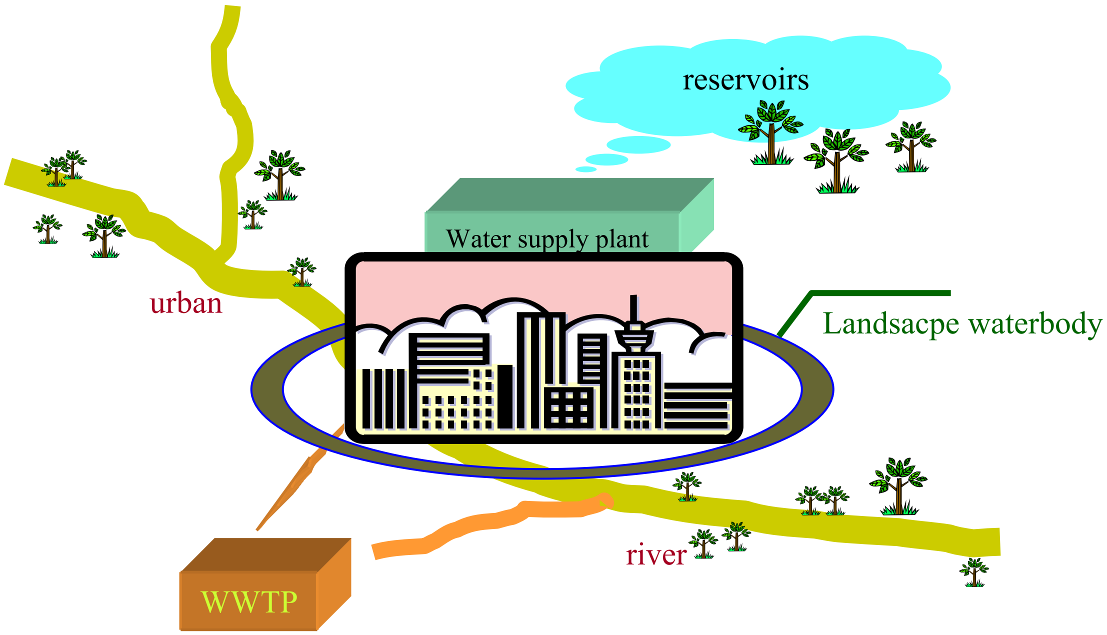
Background

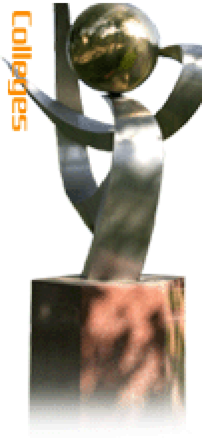
In recent years, some researchers have investigated the possibility of river restoration based on

- supplying storm water or flood pulses (*Beck et al, 1989; Reda, 1996; Thoms and Sheldon, 2002*),
- reclaimed water from WWTPs (Juanico and Friedler, 1999),
- combined sewer overflows (Reda and Beck, 1999),
- water released from reservoirs (Symphorian et al, 2003; Love et al, 2006).

However, there have been few reports on how to allocate these various water sources rationally to restore the rivers in terms of water quality and quantity.

Simulation approach





Simulation approach

Physical modeling

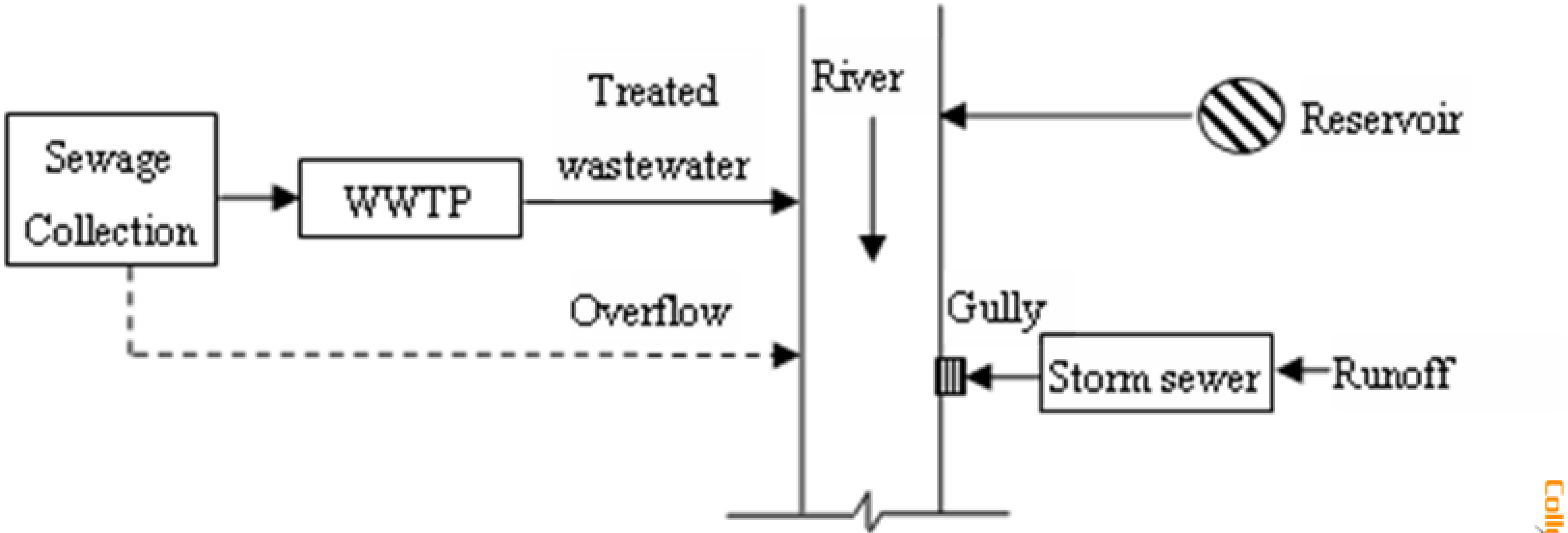


Fig. 1. Schematic representation of a hypothetical river system.

Simulation approach

The river system simulated under the following hypotheses:

- Reclaimed wastewater, storm water, and freshwater from the reservoir are all feasible sources of water to meet the environmental water requirements of the river.
- For a WWTP, the overflow is admitted to the target river in the conditions of storm water up to its peak values.
- For gullies, rainwater flows directly into the river during storm events.
- Freshwater from the reservoir is released when the river flow is less than the river's environmental water requirements or when the river's water quality falls below the legislated levels.

Simulation approach

Simulation procedure

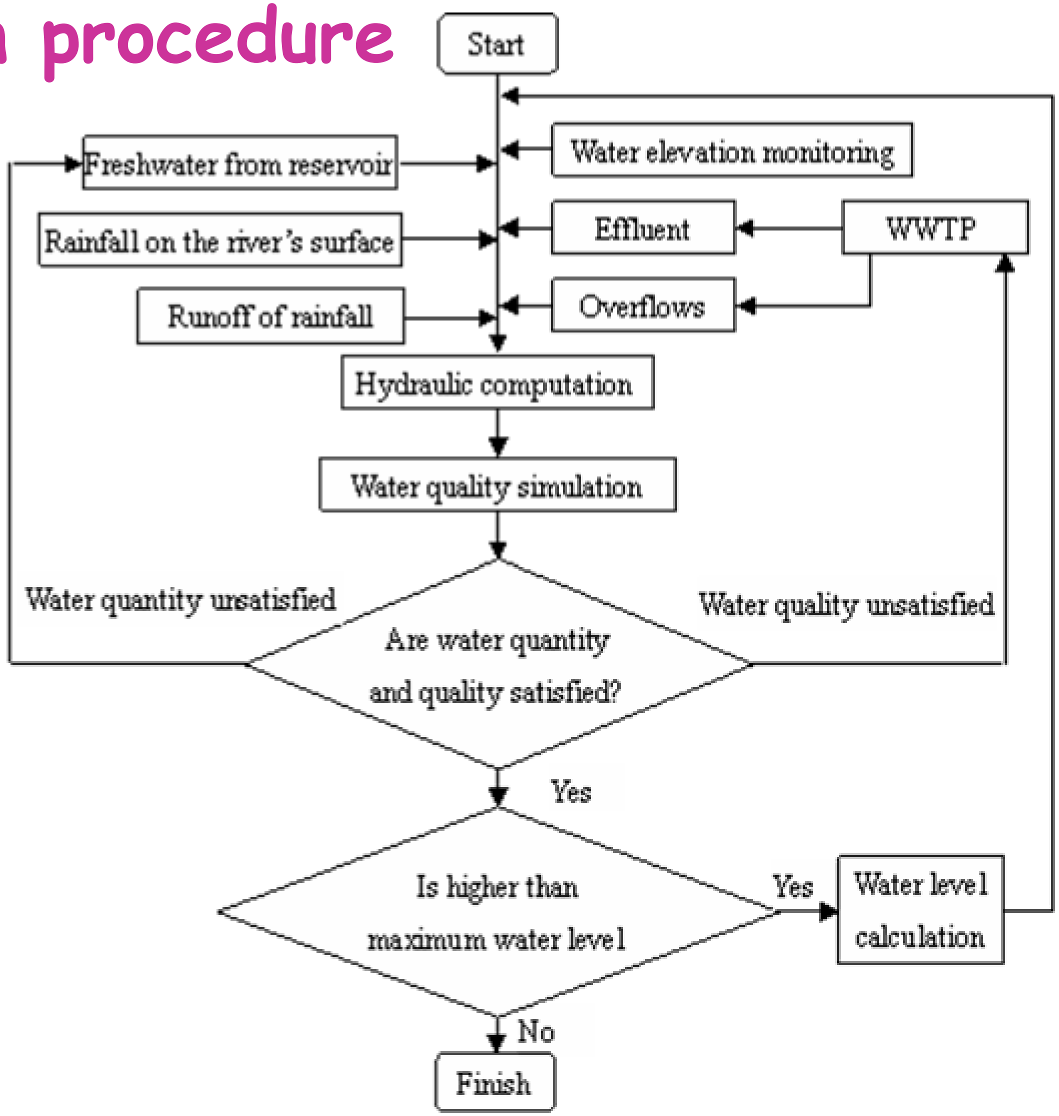


Fig. 2. Illustration of the simulation process used to determine the environmental water allocation to the river illustrated in Figure 1

Simulation approach

Simulation strategies

We used the following simulation strategies:

(1) To simulate the release of water from the reservoir when the WWTP is operating at full capacity

(2) To simulate the operation of the WWTP and its influence on the water quality

(3) To simulate the influence of storm water on the release of freshwater and on the operation of the WWTP.

Simulation approach

Mathematical modeling

(1) Calculation of the WWTP effluent quantity and quality

$$C=C_0(1-\eta+\lambda\eta) \qquad (1)$$

where C_0 is the pollutant concentration of the influent that will be treated by the WWTP, C is the pollutant concentration of the effluent that is released into the river water, and λ is the proportion of total water accounted for by overflow from the WWTP. η is the pollutants treatment efficiency of the plant.

Simulation approach

Mathematical modeling

(2)Rainfall-runoff model

we used the Soil Conservation Service curve number (*CN*) runoff-estimation approach (Soil Conservation Service, 1972)

$$Qr = (P - 0.2S)^2 / (P + 0.8S) \qquad (2)$$

where *Qr* is the amount of runoff (mm), *P* is the rainfall depth (mm), and *S* is the maximum retention estimated for dry-soil antecedent moisture condition I (AMC-I), and can be calculated using the following equation:

$$S = (25400 / CN) - 254 \qquad (3)$$

where *CN* is the curve number used for the AMC-I soil moisture condition.

Simulation approach

Mathematical modeling

(3)Hydraulic model

The motion of bodies of water in open channels can be described using the Saint-Venant equations , which express the conservation of mass and momentum (Lopes et al, 2004).

(4)Water quality model

In our model, the transport of pollutants is modeled using a finite-difference approximation to the one-dimensional advection–diffusion equation (Siegel et al., 1997)

Application

Application_background

Table 2. Effluent quantities and water quality at the two WWTPs in the Liming River basin in 2006.

WWTP	Water quantity (m^3/d)	COD (mg/L)	
		Inflow	Effluent
WWTP for oil wastewater	10 000	158	80
WWTP for domestic sewage	1000	172	60

How to use the various water sources fully?

Application_Results and discussion

Strategy 1_releasing water from the reservoir

During the low-water period

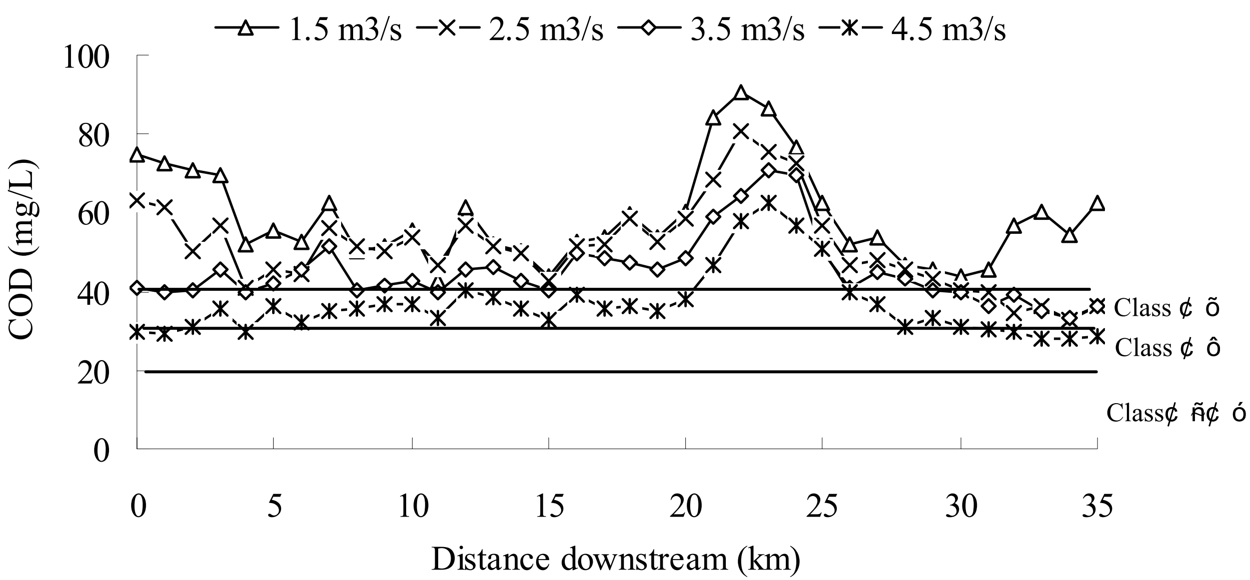


Fig. 7. Simulated COD values in the Liming River for four levels of water release from the reservoir (assuming operation of the WWTPs at full capacity and no rainfall runoff).

Application_Results and discussion

Strategy 1_releasing water from the reservoir

During the low-water period

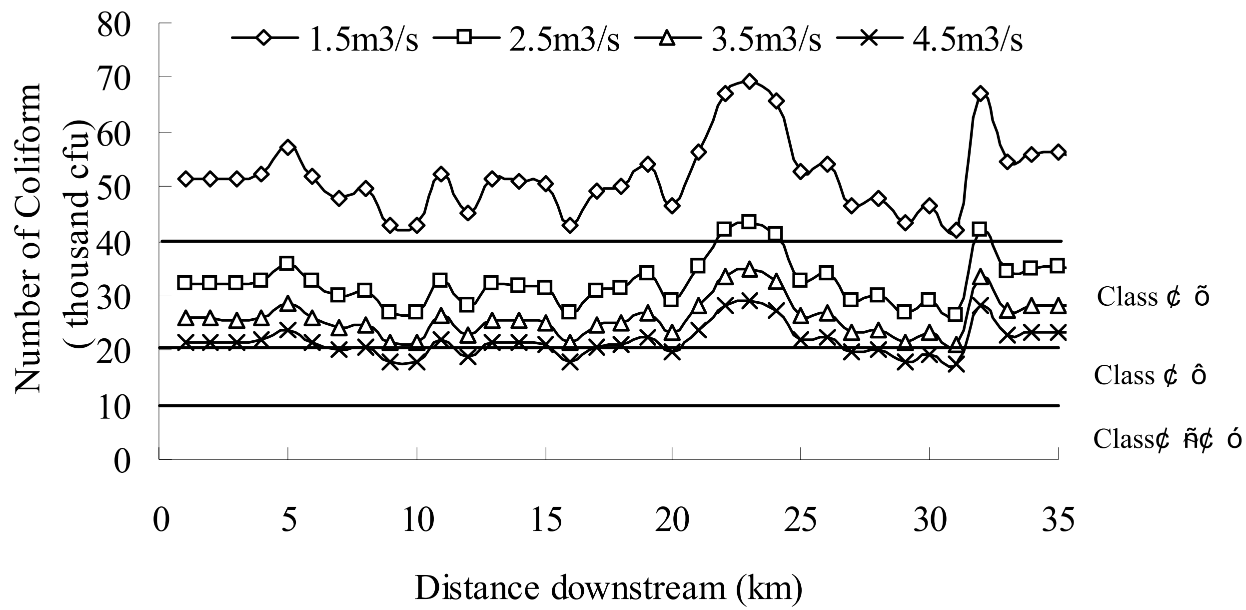


Fig. 8. Simulated number of coliform bacteria in the Liming River for four levels of water release from the reservoir (assuming operation of the WWTPs at full capacity and no rainfall runoff).

Application_Results and discussion

- **Strategy 1_releasing water from the reservoir**

During the high-water period

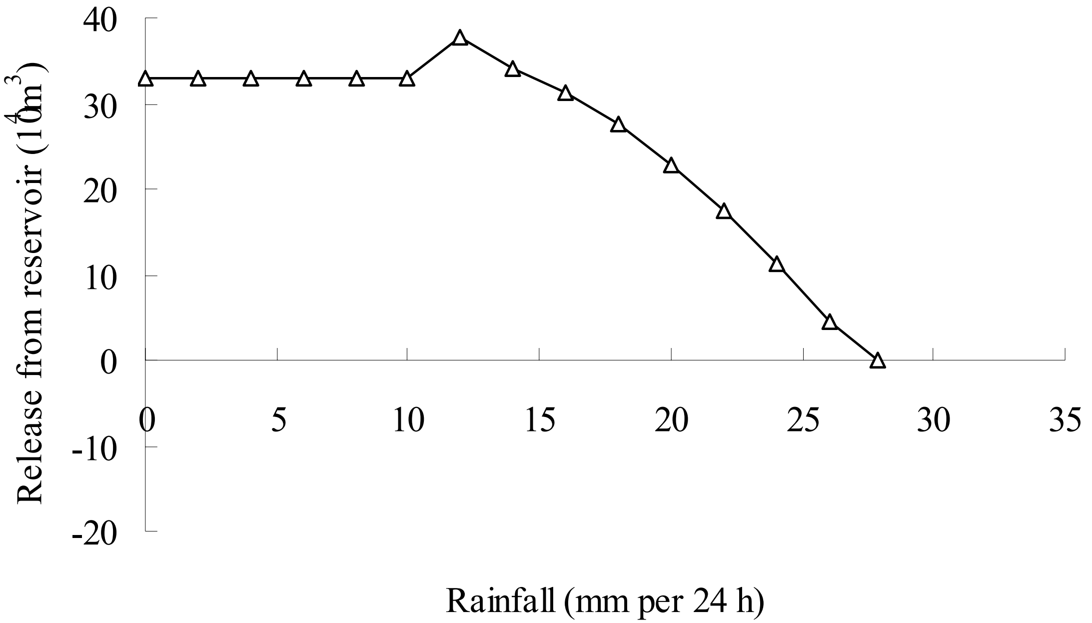


Fig. 9. Recommend water release from the reservoir during various storm events.

Application_Results and discussion

- Strategy 2_Operation of the WWTPs

During the low-water period

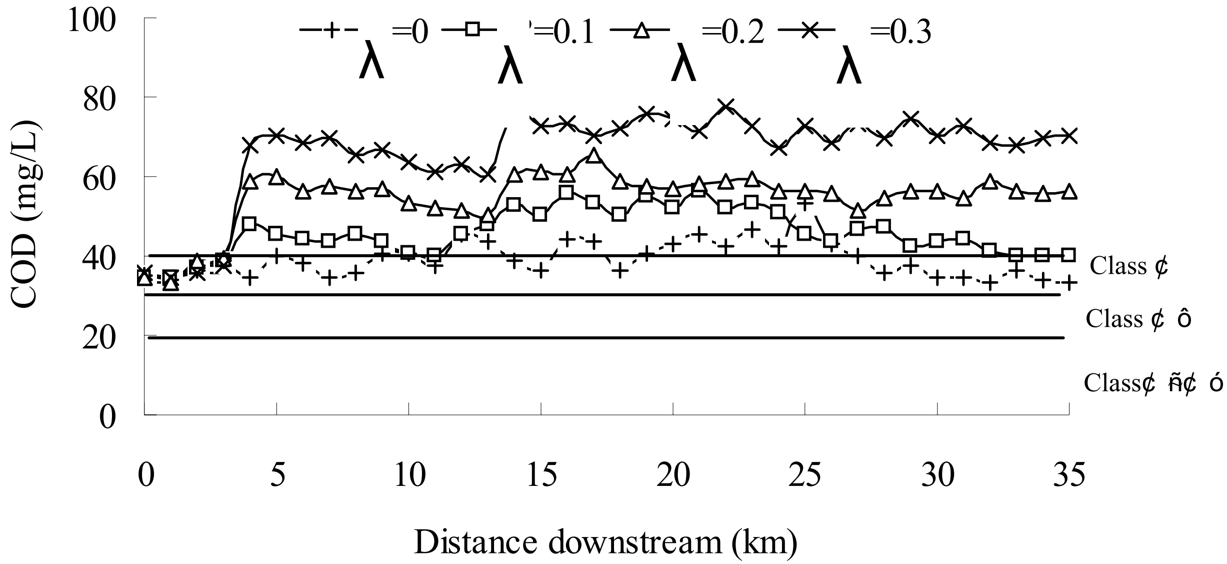


Fig. 10. Simulated COD in the Liming River at various points as a function of different raw wastewater proportions for a water release rate of 3.92 m^3/s from the reservoir.

Application_Results and discussion

Strategy 2_Operation of the WWTPs

During the low-water period

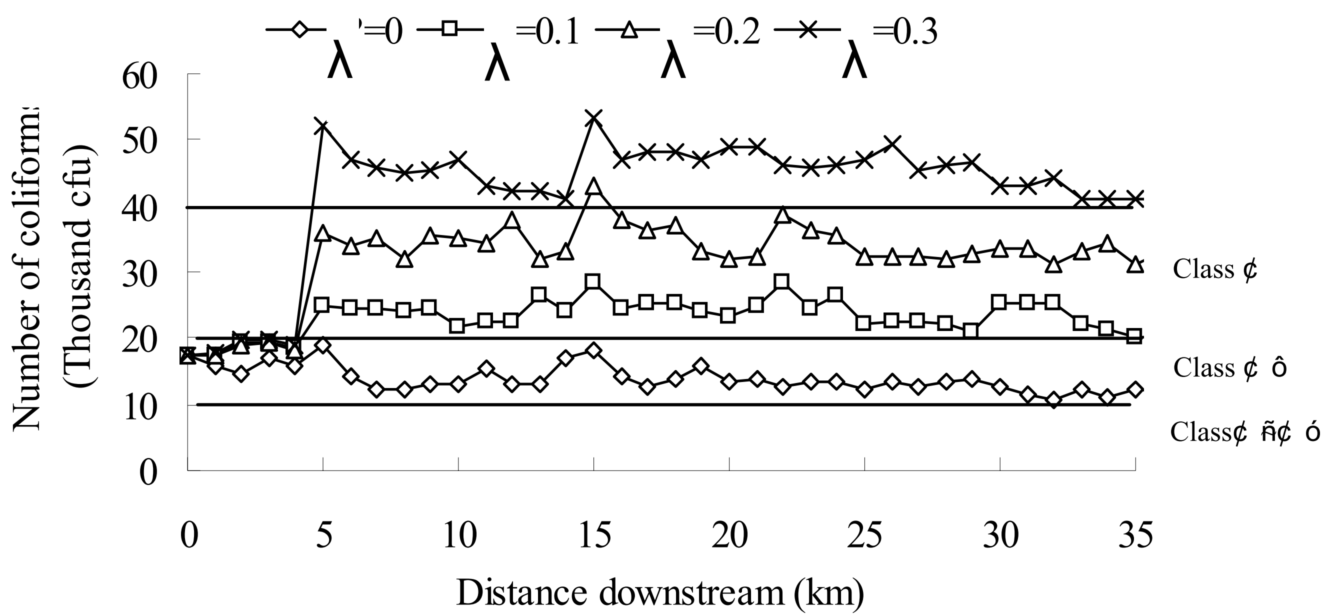


Fig. 11. Simulated number of coliform bacteria in the Liming River at various points as a function of different raw wastewater proportions for a water release rate of 3.92 m3/s from the reservoir.

Application_Results and discussion

Strategy 2_Operation of the WWTPs

During the high-water period

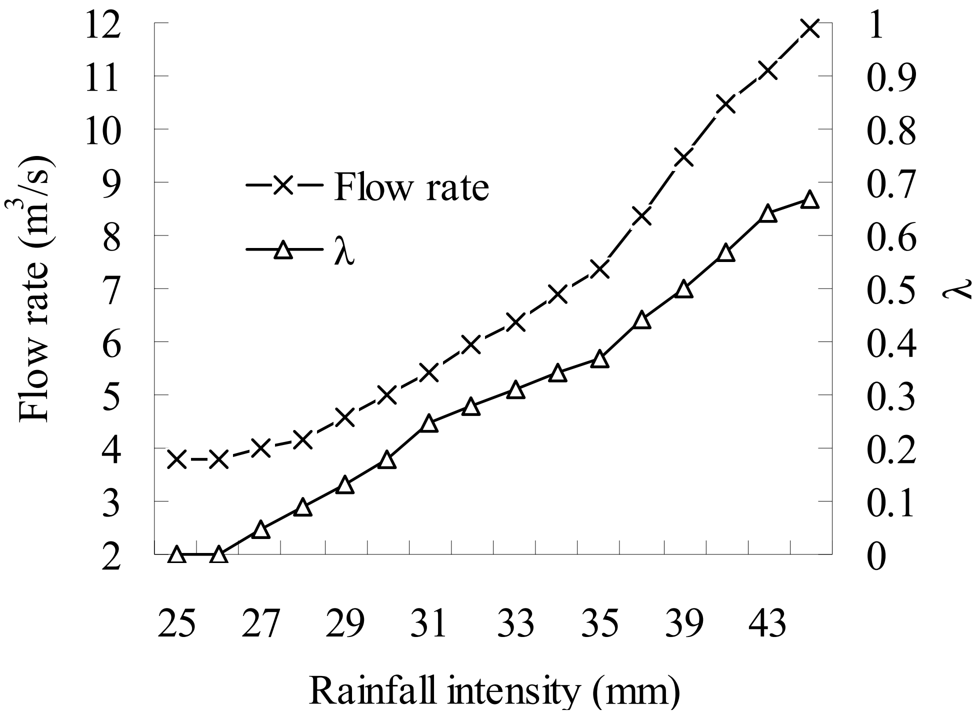
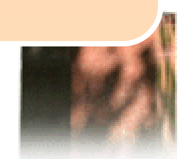


Fig. 12. Relationships between rainfall intensity and the raw wastewater proportions of the WWTPs and the flow rate in the river

Conclusions

- Untraditional water sources should be fully used to allay the pressure of freshwater resources.
- A simulation approach has been developed to help water managers allocate different sources of water effectively without compromising river water quality.
- The case study for the Liming River demonstrates that an effective compromise can be achieved in which managers of the water environment combine storm water with effluent from WWTPs and fresh surface water.



Thanks for your attention！