Development of watershed water quality model in Banten Province, Indonesia

インドネシアバンテン州における流域水質モデルの構築

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Introduction The present study tries to establish a watershed water quality model by integrating the water quality components such as dissolution type or LQ type into a sub-catchments application of modified tank model. Those water quality components were simplest and broadly used for modeling water quality parameters, such as Total Nitrogen load or COD. The model is crucially important tool for understanding and reducing pollutant flow in a developing watershed consisting of broad rural lands and rural villages.

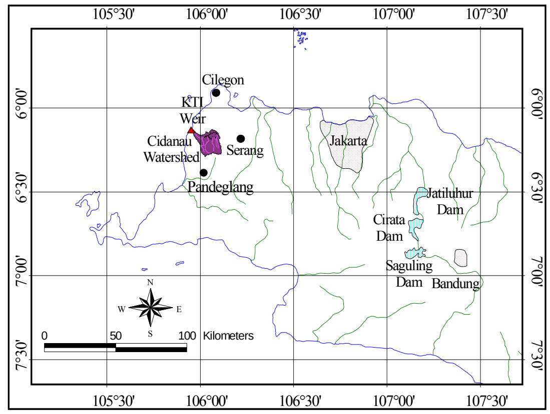

Figure 1. Cidanau Watershed

Objectives of the study

- ✓ To develop watershed water quality models based on specific formulation of water quality components that match with runoff model.
- ✓ To test the watershed water quality model.

Study Area Cidanau watershed (221.1 km^2) is one of priority watersheds in Indonesia to be given special attention for its handling and management, because of the high population pressure, the recent economic growth, and the developments in the catchments. It is located at 6^{o}7'-6^{o}18' South and 105^{o}51'-106^{o}3' East (**Fig.1**), surrounded by mountainous area and densely populated area of Banten Province. A swamp protection area (Rawa Danau) is located in the middle of the watershed also. The outlet of Rawa Danau becomes the Cidanau River which is a water source of Cilegon Industrial Estate.

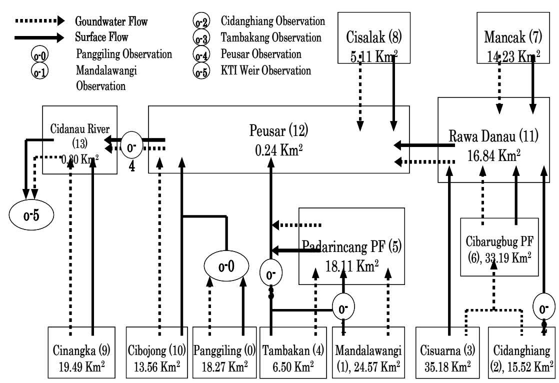

Figure 2. Water movements of each sub catchments

Methodology

Structure of watershed runoff model The watershed runoff model consists of fourteen modified tank models (**Fig.2)** corresponding to the sub-catchments which were categorized into land, swamp, and river sub-catchments. For land sub-catchments, 4 layers modified tank model was employed, while 2 and single layers for swamp and river sub-catchments respectively. It produces good enough model performance (**Tab.1**.) and reasonable groundwater daily fluctuation.

Tabel 1 Runoff Model Performances

Observation Name	*ME*	*MRE*	*BE*	Periods
Cikalumpang Weir (o-0)	0.57	0.20	0.06	Sep 00 - Oct 01
Cidanghiang (o-1)	0.52	0.52	0.13	Sep 99 - Aug 00
Tambakan (o-2)	0.44	0.46	0.34	Sep 00 - Oct 01
Peusar (o-3)	0.63	0.28	0.08	Aug 02 - Aug 03
KTI Weir (o-4)	0.65	0.60	-0.14	Sep 96 - Aug 04

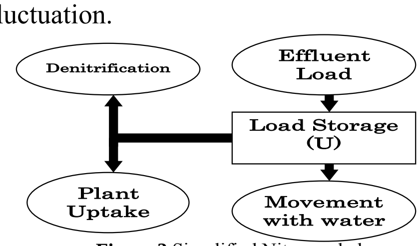

Figure 3 Simplified Nitrogen balance

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Water Quality Processes COD is a representative water pollution indicator. But it is difficult to model since mass preservations are not maintained. Therefore Total Nitrogen (TN) was considered as important step for COD modeling since organic matters can be included in its balance (**Fig.3**). Nitrogen movements and transformation (denitrification or plant uptake) were replicated on that balance. As formulation of nitrogen movements with hydrological processes, both of LQ-Type and Dissolution Type of water quality components were employed corresponding with the types of sub-catchments (**Fig.4**, **Tab.2** and **Eq.1-Eq.3**). Where, L is load ($M \bullet L^{-2} \bullet T^{-1}$), U is load storage ($M \bullet L^{-2}$), q_f is discharge ($L \bullet T^{-1}$), C is concentration, SN is dissolved load storage ($M \bullet L^{-2}$), X is water storage (L), and α_1, β_1, α_2, β_2, γ are the calibrated parameters.

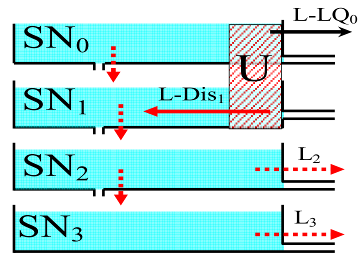

Figure 4 Water quality components

Table 2 Formulation of nitrogen movements

Sub-catchments type	LQ Type on 1st layer (LQ_0)	Dissolution Type
Land	OFF	ON
Swamp	ON	ON
River	ON	OFF

$$L_{LQ} = \alpha_1 \times U \times q_f^{\beta 1} \quad \text{.... (Eq.1)}$$
$$L_{Dis} = \alpha_2 \times U \times X^{\beta 2} / (1 + \gamma C) \quad \text{.... (Eq.2)}$$
$$C = SN / X \quad \text{.... (Eq.3)}$$

Optimization of model parameter Random search method was selected for optimizing the model parameters. The calibrated sets of parameters were categorized into four groups, such as paddy field, mountainous, swamp and river area parameter sets, then parameters set for each sub-catchments were calculated based on their portions in the sub-catchments.

Result and discussion The performances of the watershed water quality model were good as presented in **Fig.5**. The model also produces reasonable pattern for daily hydrograph TN and un-dissolved storage, except in Swamp sub-catchment. Their fluctuation were small but simulated perfectly the water quality dilution related to rainfall event phenomena (**Fig.6**). The discrepancy and mismatch in Rawa Danau (swamp sub-catchment) may be attributed to the number of water quality samples. The values of the calibrated water quality parameters were found to be reasonable. The paddy field area has the highest de-nitrification rate. The same condition exists for the α-coefficient and β-coefficient; the paddy field is higher than a mountainous area, and has a β-coefficient higher than one. In general, the model was able to simulate the spatial and temporal variability of Total Nitrogen. However, it is necessary to find the relationship between parameter values and the property of each sub catchment to increase the understanding of water quality processes in watersheds having swamp area.

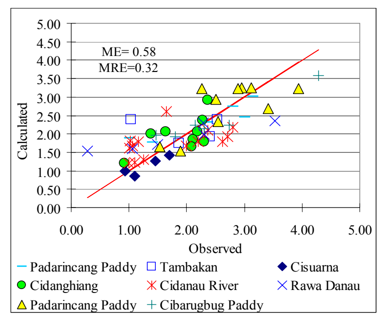

Figure 5 Comparison between observed and calculated Total Nitrogen (mg/l) in several location inside the watershed

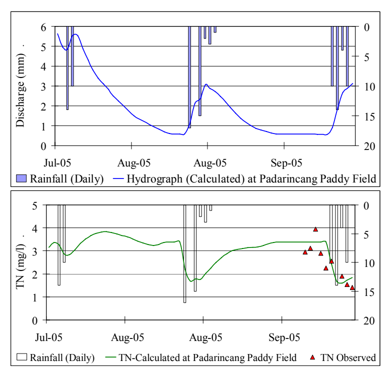

Figure 6 TN concentrations in paddy field sub-catchments

Conclution

- ✧ The model can calculate daily change in total nitrogen, with a small number of parameters, and showed fairly good agreement with the observed TN values.
- ✧ The model was expected to be suitable as a simulation tool for the identification of the most influential factors on water pollution

References

Heryansyah, Arien., GOTO, Akira., MIZUTANI, Masakazu., and Yanuar, MJP. 2004. Appropriate Watershed Runoff Modeling in a Developing Watershed in Indonesia. Transaction of JISDRE no.240 (2005.12). p117-124.