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Quantification of nonpoint source pollutants discharged from the combined sewer system in the Nakdong River basin, Korea, using SWMM

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ABSTRACT

This study used the United States Environmental Protection Agency's (US EPA) stormwater management model (SWMM) to quantify nonpoint source (NPS) pollutant load from the combined sewer in the Nakdong River basin, Korea. In the simulation using SWMM, the river basin consisted of 39 subwatersheds with 48 sanitation districts. For each sanitation district, combined sewer overflow (CSO) and bypass flow of the sewer treatment plant (STP) were estimated as NPS discharge. In the simulation, it assumed that a STP can receive up to three times the design peak flow rate of the STP and bypass the remainder of the intercepted stormwater during a storm event. The model was calibrated and validated with the observed water quantity and quality data in 2006 and 2007, respectively. As a result of the simulation, the estimated average load of biochemical oxygen demand (BOD) was 409.5 kg/ha/yr and 62.8 kg/ha/yr for the sanitation coverage (proportion of the area covered by the sewer system in a sanitation district) of above 40% and below 10%. The results showed that different unit loads of NPS can be estimated from each sanitation district depending on the degree of urbanization.

Keywords: Nonpoint source; Sewage treatment district; CSOs; SWMM

1. Introduction

The impacts of urbanization and industrialization are very serious in terms of water resources and environment such as water quality deterioration in rivers. There are two terms to generate water quality pollution, one of which is point source pollution and the other is nonpoint source (NPS) pollution. NPS pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, hydrologic modification, urbanization, which is defined to mean any source of water pollution that does not meet the legal definition of "point source". Although the point source pollutants are specified in certain discharge pathways as water pollutants from an oil refinery wastewater discharge or a single identifiable source of water, the NPS pollutants, unlike pollutants discharged from industrial and sewage treatment plants (STPs), come from many diffuse sources. NPS pollutants are caused by rainfall or snowmelt moving over and through the ground. While flowing, the runoff picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and even our underground sources of drinking water. The contamination caused by point sources can be quantified, allowing easy prediction and preparation for unforeseeable problems through sustainable management. On the other hand, it is extremely difficult to quantify NPS pollutants generated in complicated natural phenomena, sustainable concerns are consistently needed. One of various reasons for pollution caused in the water quality is NPS pollutants which accounted for 42%–69% in 2003, but increased by 65%–70% in 2015. This shows the importance of water management with NPS pollutants. United States Environmental Protection Agency (US EPA) also reports NPS pollutants are affected by 50% of water quality pollution loads with standard of total suspended solid (TSS) and more than 80% of nutrients

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generated from closed watershed. However, until now, the development of an accurate method for quantification of NPS pollutants has been difficult due to irregular patterns generated. Since 1995, Korea has used the expected mean concentration (EMC) method and unit estimation to manage NPS pollutants applying to land use/land cover. Kyung ok [1] quantified NPS pollutants in the Nakdong River using GIS with watershed analysis. They reported on the insufficiency of observed data on hydrological processes. Bo Hyun et al. and Hyungu et al. [2,3] used the soil and water assessment tool (SWAT) to analyze NPS pollutants in the Nakdong River in Korea. Hyungu et al. [3] considered that NPS pollutants affected water quality through connection to QUALKO for analysis of river water quality. Jeonghoon et al. [4] applied the Hydrological Simulation Program-FORTRAN (HSPF) model with observed data in a watershed of the Nakdong River, with the aim of quantifying NPS pollutants with high confidence level of observed data and PEST as the optimal calibration method. Worldwide, NPS problems in rivers have been recognized since 1970, and many researchers have investigated potential solutions using the storm water management model (SWMM), HSPF, HEC5Q, and STORM model. Recently, GIS has been widely used for the calibration of parameters. Guo et al. [5] quantified NPS pollutants by constructing an APPI system based on GIS, but the system required a variety of data for exact quantification of NPS. Gikas et al. [6] selected the Mediterranean watershed as the study area and suggested management methods through analysis of water quality about NPS with the SWAT model. Angela et al. [7] estimated the pollutant loading by dividing into NPS and point source pollutants based on data observed by a real-time hydrologic monitoring system. The estimation of NPS pollutants accompanied uncertainty, which can prevent the considerable occurrence of NPS pollutants in the watershed. Therefore, it needs to quantify NPS pollutants occurring from sewer treatment districts for more effective water management considering the possible effects of the continuous urbanization. In the study, an important area of sewer treatment districts was studied and modeled by SWMM to quantify NPS pollutants considering individual sewer treatment districts in Nakdong River, Korea.

2. Materials and methods

2.1. Study area and data

Nakdong River is located in the southeast of Korea as shown Fig. 1, where stream network is complex and may consist of a variety of residential and industrial treatment facilities. As the second longest river in Korea with a length of 510.36 km, the basin is 23,790 km^2, which constitutes 25.9% of whole area in Korea. The river functions as an important transportation route through the inland region of Gyeonsang-do to the mouth of the basin. On the other hand, high content of nitrogen and phosphorus in water in the basin for a long time is due to mixing the water of through irrigation with drainage. The river has been administered by the Korean Government for several decades, which is divided by 41 subwatersheds according to Total Maximum Daily Load (TMDL) standards. To meet water quality standard constantly, the Nakdong River Environment Research Center, the Korean Government Agency, manages based on the TMDL for river management. The data of streamflow and factors of water quality is measured at 8-d interval, which was observed during the last 2 years (2006–2007) in the study. Biochemical oxygen demand (BOD), TN, and TP as factors of water quality were considered quantitatively to estimate NPS pollutants including all of the STPs in Nakdong River. Topographic, land use and cover, and soil data required by SWMM for the study were generated from GIS data, which are offered by Water Resources Management Information System (www.wamis.go.kr) to a scale of 1:50,000. The data set was applied to generate a subwatershed map for dividing into 38 subwatersheds based on the TMDL unit watershed.

Fig. 1. Study area: Nakdong River watershed.

2.2. Methods

In the study, SWMM was used for analysis of NPS pollutants considering each sewage treatment district in Nakdong River, which is a dynamic hydrology-hydraulic-water quality simulation model for simulating runoff quantity and quality from primarily urban areas. The SWMM for estimating NPS pollutants with reference to sewer treatment districts was established with river profile of main stream and tributary on the river, several data of topographical characteristics such as land use/cover and soil map, curve number (CN), roughness coefficient of impervious area, and wastewater treatment system outflow on each STP. Fig. 2 shows a process of the quantification of NPS pollutants even considering various pollutants discharged from individual STPs overall.

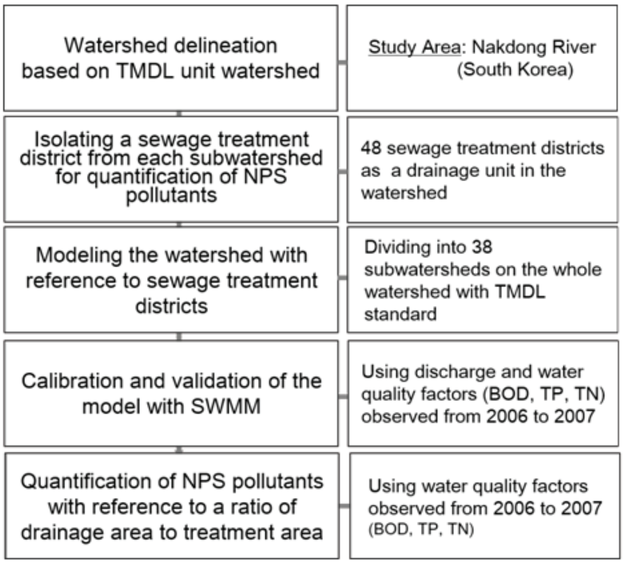
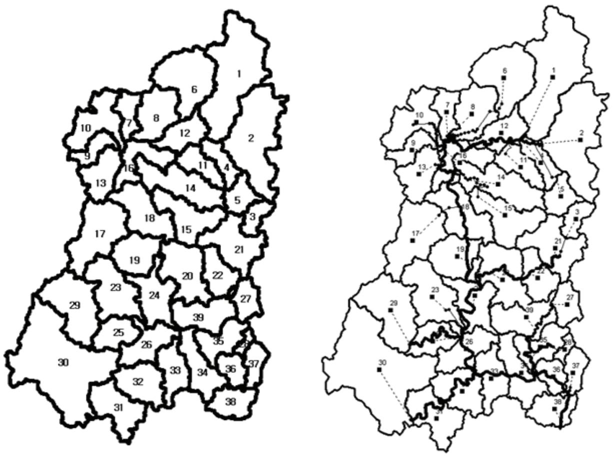


Fig. 2. Flowchart for quantification of NPS discharged from the Nakdong River.



(a) 38 subwatersheds (b) Watershed network

Fig. 3. Watershed delineation of Nakdong River for SWMM.

The Nakdong River was segmented into 38, considering individual sewer treatment districts, based on TMDL unit watershed in the Fig. 3 below. There are seven dams in divided subwatersheds on the whole Nakdong River, an area including each dam, which are named as Andong, Imha, Yeongcheon, Habcheon, Namgang, Unmun, and Miryang dam, respectively, and was integrated into TMDL unit watershed as single subwatershed. In other words, Andong dam area represented the area merged into NakbonA(NB_A), NakbonB (NB_B), and a part of NakbonC (NB_C), Imha dam area represented the area merged into BanbyeonA (B_A), YongjeonA (YJ_A), and a part of BanbyeonB (BB_B) and other area is Habcheon dam which also was integrated into HwanggangA and B (HW_B). Namgang dam was integrated into NamgangA (NG_A), B (NG_B), and C (NG_C).

The study for quantification of NPS pollution assumed that the outlet at sewer treatment district was only to be NPS pollution discharged by just CSO and bypass. The model using SWMM was established for quantitatively estimating NPS pollutants discharged from individual area of STP located in each subwatershed and area in each subwatershed. The most important thing in the study is that the model was capable of considering CSOs and the bypass of STPs in the TMDL watershed. NPS pollutants were quantified by modeling each point of the outlets discharged from individual STPs in the Nakdong River; the flow during the dry period was estimated using measured STP data and surface runoff, which is regarded as CSOs and bypass, was analyzed (Fig. 4). In other words, in Fig. 4, an outflow from each subwatershed was classified as intercepted flow and CSO; after that, an intercepted flow was classified as bypass and flow treated from STP once again.

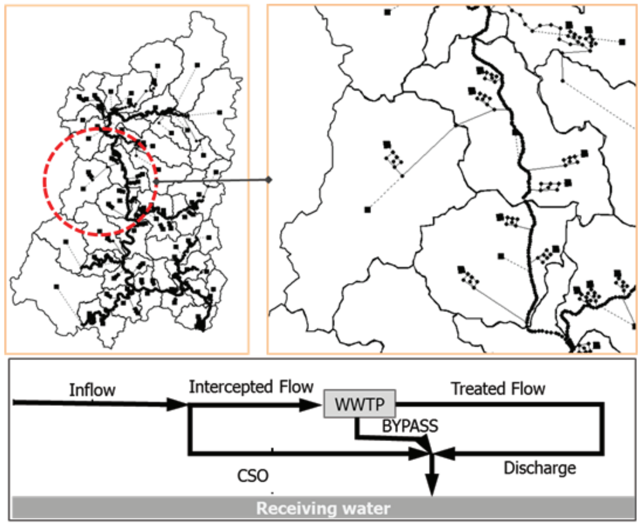


Fig. 4. Method of modeling the outlet of the sewerage treatment area.

For calibration and validation of the model, it needed that a large number of parameters are defined in SWMM to characterize watershed properties and hydrologic processes, as well as water quality processes. Observed flow data from Nakdong River Environment Research Center on all the TMDL unit watershed of the river were used for model calibration and validation. Three points selected in the watershed were used with 2 years (2006–2007) of continuous observed daily rainfall data, which represented each one portion of upstream, midstream, and downstream as Nakbon D (NB_D), Nakbon F (NB_F), and Nakbon I (NB_I), respectively, in the main channel (Fig. 5). As these points were gradually calibrated and validated from upstream to downstream, a variety of parameters estimated in the upstream were fixed and then the next point was calibrated. After modeling, it was regarded as inflow generated during the dry period considering pattern of monthly inflow and average inflow estimated by analyzing the inflow of each STP, during rainfall, the inflow should be mixed with rainfall-runoff generated from sewage treatment districts. As shown in Fig. 4, an inflow of subwatersheds regarded outflow exceeding an inflow as CSO and three times flow of a quantity of baseflow as intercepted flow, especially a baseflow was treated as

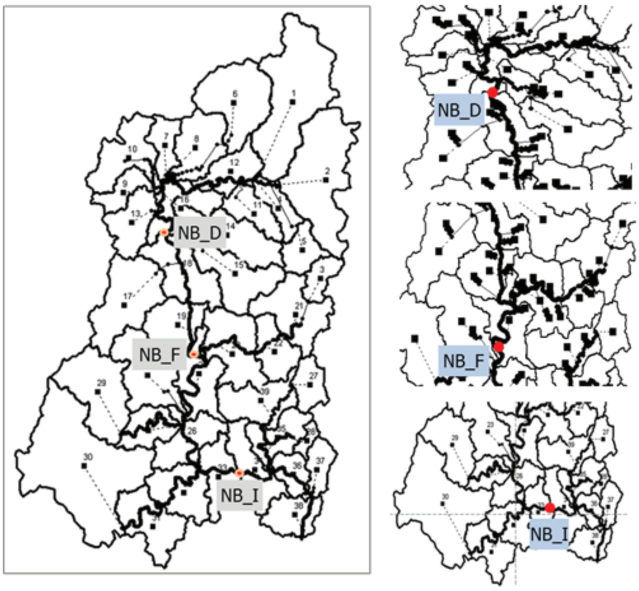


Fig. 5. Calibration points located at upstream, midstream, and downstream for Nakdong River model.

a part of intercepted flow and the remaining flow was considered as bypass. For the quantification of NPS pollutants, each subwatershed from the results was classified into rural area and urban area, and NPS loads from each subwatershed were estimated and analyzed with urban area.

3. Results and discussion

3.1. Calibration and validation

The Nakdong River model was calibrated and validated on water quantity and quality using observed daily streamflow and water quality data at 8-d interval measured from Nakdong River Environment Research Center during 2006 through 2007. The model was calibrated with the data observed in 2006 and validated with the data observed in 2007 at three locations as Nakbon D (NB_D), Nakbon B (NB_F), and Nakbon I (NB_I) of the TMDL unit watershed (Table 1). Nash–Sutcliff coefficient (NSC) and Integral Square Error (ISE) were used to evaluate the accuracy of the models. Table 1 and Fig. 6 show the results of both of the calibration and validation for three locations, the simulation result is respectably good; a value of NSC was more than 0.9 and ISE was within range of 8.47~11.84 corresponding to a section between "Good" and "Fair".

Table 1
Performance of calibration and validation on discharge of the Nakdong River model

Model performance	NSC			ISE		
	NB_D	NB_F	NB_I	NB_D	NB_F	NB_I
Calibration	0.92	0.93	0.96	9.74	8.67	8.47
Validation	0.94	0.97	0.91	11.84	11.69	11.38

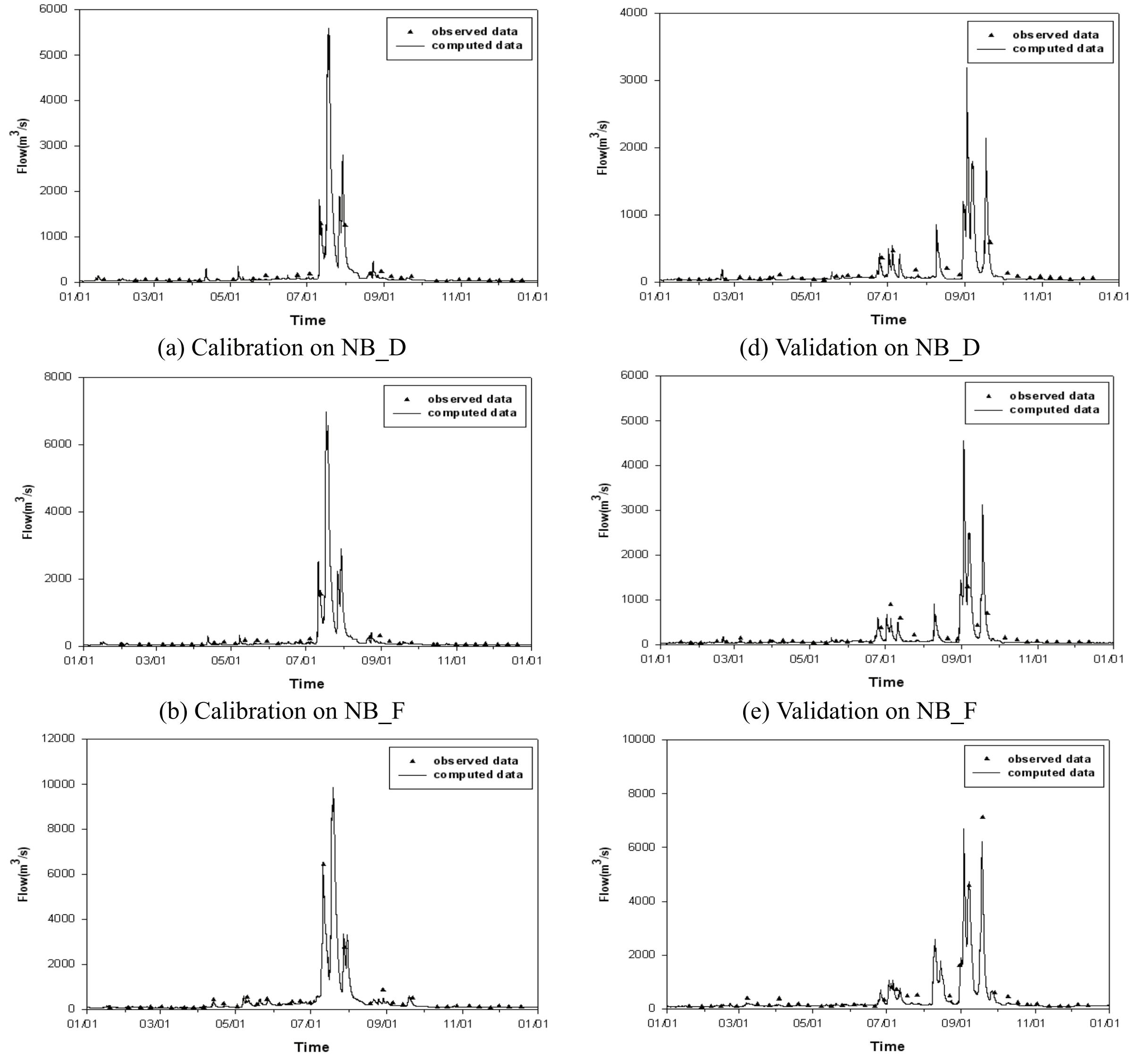
After calibration and validation of streamflow, the water quality simulation of the model was conducted for calibration and validation in advance to quantify the NPS loads, such as BOD, suspended solid, total nitrogen, and total phosphorus, at the same locations on main channel in Nakdong River. The results were shown in Tables 2 and 3, and Fig. 7; NSC was found to be within a reasonable range of 0.77–0.87 and ISE indicated more than "Fair" under 25 for BOD, TN, and TP, but slightly "Poor" at 39.18 for SS in Table 2 and Fig. 7.

3.2. Quantification of NPS from sewer treatment plants (STPs)

Table 4 shows the results of NPS loads in 24 subwatersheds among all the subwatersheds estimated by SWMM, and 24 subwatersheds were made of relatively urban area than rural area.

The results were analyzed for all the STPs in each subwatershed of 6, 8, 10, 12, 13, 14, 17, 18, 19, 20, 21, 23, 25, 26, 31, 32, 33, 34, 36, 37, 38, and 39. The results estimated BOD, TN, and TP as NPS loads considering bypass and CSOs on each sewer treatment district in all the subwatersheds of the Nakdong River shown in the Table 4. The subwatershed 18 and 19 showed relatively high NPS loads than other subwatersheds, NPS loads in subwatershed 18 were estimated 388.46 kg/ha/yr, 154.75 kg/ha/yr, 17.8 kg/ha/yr on each BOD, TN, and TP for bypass and CSO, and the loads in subwatershed 20 showed 2316.26 kg/ha/yr, 681.34 kg/ha/yr, and 79.93 kg/ha/yr on each BOD, TN, and TP. Table 5 indicated a relationship between rural and urban area and NPS loads, especially NPS loads resulting from sewage treatment districts. The ratio of discharge and NPS pollutant loads generated from sewer treatment districts in the TMDL watershed was examined according to the area ratio of sewer treatment districts on the unit watershed and natural watersheds from the subwatershed of 18, 20, and 32 as shown in Table 5. The results revealed that the discharge ratio exhibited a linear relationship with the area ratio of sewer treatment district in the TMDL watershed. When the area ratio on BOD and TP was close to 10%, the ratio of NPS pollutant loads was 80%. The result revealed a much higher ratio of NPS pollutant loads from sewer treatment districts for all NPS pollutant loads generated in the unit watershed. The ratio of NPS pollutant loads generated in sewer treatment districts increased when the area ratio of sewer treatment districts in the unit watershed was more than 10%.

Fig. 8 shows the cross correlation of runoff, BOD, TP, and TN ratio from STPs according to the area of sewer treatment district. In comparison with previous study results, as shown in Table 6, the present results were in the range of average to maximum among the previous studies, but all water quality variables were less than the previous results. The previous studies were concentrated on large sewer treatment areas, whereas this study was conducted on a sewer treatment district area less than 10% of the total drainage area. The results drawn from SWMM revealed a BOD average of 101.6 kg/ha/yr, which was similar to previous results such as 107.6 kg/ha/yr (in 2002) at the Korea Environment Institute (KEI). The present TN result of 38.4 kg/ha/yr was similar with the minimum 32 kg/ha/yr of Seoul. The present TP result of 4.7 kg/ha/yr was similar with the minimum value of Seoul [8].



(a) Calibration on NB_D
(d) Validation on NB_D
(b) Calibration on NB_F
(e) Validation on NB_F
(c) Calibration on NB_I
(f) Validation on NB_I

Fig. 6. Calibration and validation of discharge with observed data for 2006–2007.

Table 2
Result of calibration of water quality for three points in 2006

Performance of model	Point	Factor			
		BOD	SS	TN	TP
NSC	NB_D	0.63	0.82	0.59	0.49
	NB_F	0.70	0.85	0.79	0.93
	NB_I	0.84	0.77	0.85	0.87
ISE	NB_D	22.04	30.85	25.20	33.50
	NB_F	11.44	25.62	18.02	9.49
	NB_I	13.38	39.18	15.97	13.47

Note: BOD – biochemical oxygen demand; SS – suspended solid; TN – total nitrogen; and TP – total phosphorus.

Table 3
Result of validation of water quality for three points in 2007

Performance of model	Point	Factor			
		BOD	SS	TN	TP
NSC	NB_D	0.68	0.43	0.11	0.54
	NB_F	0.42	0.69	0.27	0.47
	NB_I	0.71	0.57	0.44	0.33
ISE	NB_D	14.33	27.99	20.48	20.36
	NB_F	17.69	22.76	21.05	23.58
	NB_I	16.61	48.79	28.09	42.18

Note: BOD – biochemical oxygen demand; SS – suspended solid; TN – total nitrogen; and TP – total phosphorus.

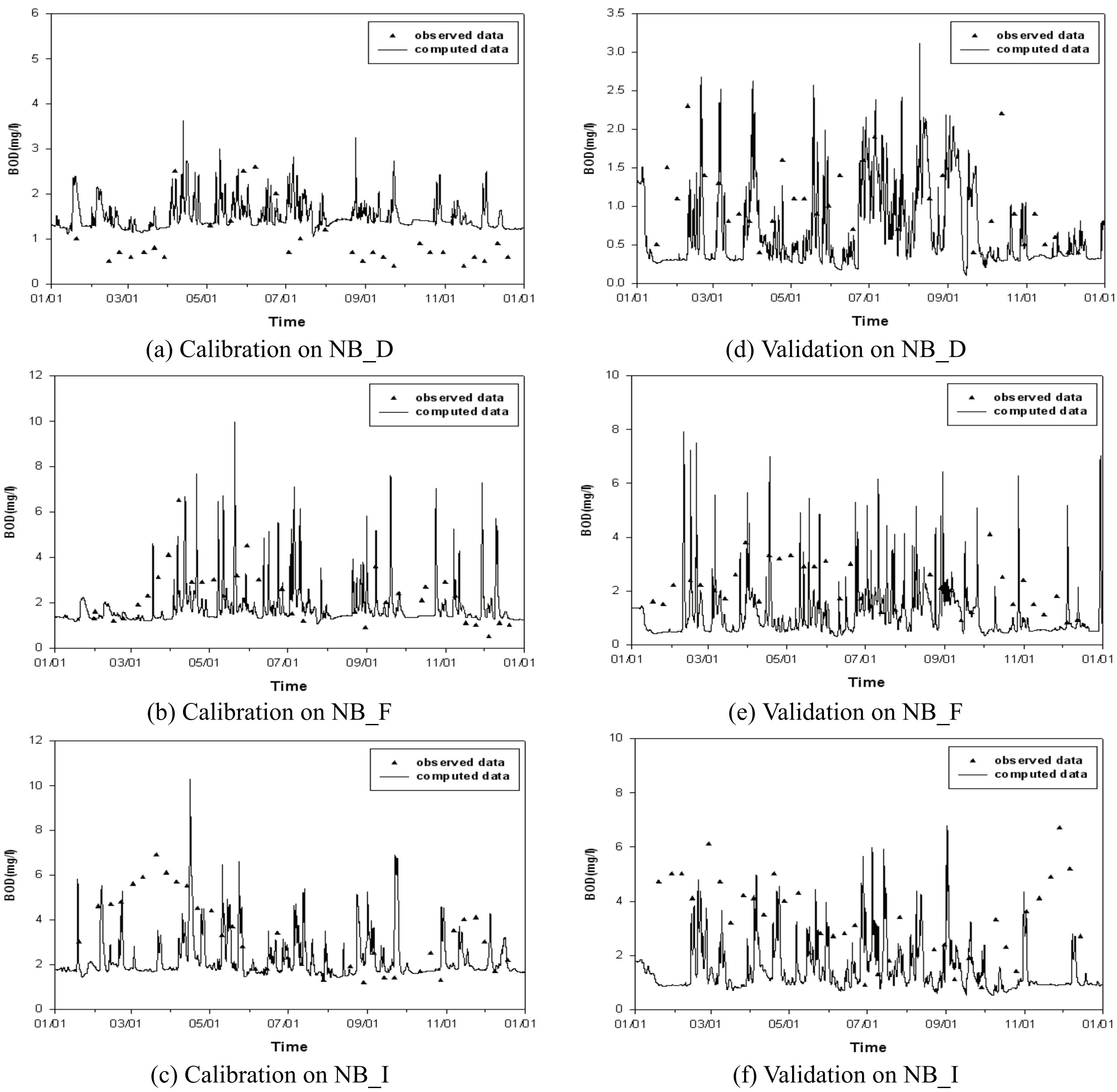


Fig. 7. Calibration and validation of BOD with observed data for 2006–2007.

Table 4
Results on estimating nonpoint source (NPS) loads from WWTP by SWMM

Subwatershed – Sewer treatment district	BYPASS+CSO (kg/ha/yr)			Subwatershed – Sewer treatment district	BYPASS+CSO (kg/ha/yr)		
	BOD	TN	TP		BOD	TN	TP
NB_C-(a)_12	182.68	63.40	7.51	WC_B-(a)_14	93.02	39.96	5.29
NS_A-(a)_6	54.39	28.73	3.68	WC_B-(b)_14	20.07	6.69	1.29
NS_B-(a)_8	74.62	40.06	4.71	HW_A-(a)_23	4.70	2.41	0.44
YG_A-(a)_10	26.72	10.76	1.51	HG_B-(a)_25	51.32	20.08	2.85
YG_A-(b)_10	52.06	31.28	3.50	NB_H-(a)_26	14.56	6.96	1.26
YG_A-(c)_10	6.15	3.42	0.59	NB_H-(b)_26	5.78	3.73	0.80

(Continued)

Table 4 (*Continued*)

Subwatershed – Sewer treatment district	BYPASS+CSO (kg/ha/yr)			Subwatershed – Sewer treatment district	BYPASS+CSO (kg/ha/yr)		
	BOD	TN	TP		BOD	TN	TP
NB_E-(a)_18	79.23	46.71	4.74	NG_D-(b)_31	18.87	9.24	1.60
NB_E -(b)_18	80.10	39.34	5.15	NG_D-(c)_31	167.60	85.82	9.82
NB_E -(c)_18	3.18	1.91	0.40	NG_E-(a)_32	5.31	3.62	0.80
NB_E -(d)_18	225.95	66.79	7.51	NG_E-(b)_32	9.53	5.44	1.07
NB_F-(a)_19	77.29	32.11	4.01	NG_E-(c)_32	51.51	27.05	3.83
NB_F-(b)_19	3.89	2.34	0.45	NB_I-(a)_33	21.40	9.75	1.63
NB_F-(c)_19	123.81	58.02	6.17	NB_I-(b)_33	106.82	61.56	6.96
GC_A-(a)_17	41.15	12.76	1.86	NB_J-(a)_34	121.17	63.32	7.50
GH_A-(a)_21	152.26	72.56	8.31	NB_J-(b)_34	72.52	33.32	4.22
GH_B-(a)_21	24.03	12.33	1.82	MY_A-(a)_39	58.25	24.61	3.53
GH_C-(a)_20	185.63	68.16	8.15	MY_A-(b)_39	6.99	2.89	0.58
GH_C-(b)_20	317.29	103.16	12.45	MY_B-(a)_35	29.20	13.08	1.89
GH_C-(c)_20	233.97	92.77	9.53	NB_K-(a)_36	66.49	36.78	4.90
GH_C-(d)_20	383.63	116.94	12.97	NB_L-(a)_37	115.47	46.75	5.60
GH_C-(e)_20	553.47	130.45	15.78	NB_MN-(a)_38	69.58	25.38	3.43
GH_C-(f)_20	443.95	85.97	12.06	NB_MN-(b)_38	20.95	9.87	1.62
GH_C-(g)_20	198.32	83.89	8.99	NB_MN-(c)_38	140.75	68.13	7.76

Note: BOD – biochemical oxygen demand; TN – total nitrogen; and TP – total phosphorus.

Name of subwatershed-STPs-Number of subwatershed:
NB_C-(a): Andong
NS_A-(a): Youngju/
NS_B-(a): YCH
YG_A-(a): Jeomchon /-(b) : Masung /-(c) : Gaeun
BS_A-(a): Sangju
NB_E-(a): Gumi 4/-(b) : Seonsan/-(c) : Dogae/-(d) : Gumi
NB_F-(a): Yakmok/-(b) : Sungju /-(c) : Waegwan
GC_A-(a): Kimcheon
GH_A-(a): Youngcheon
GH_B-(a): Geumho
GH_C-(a): Kyoungsan/-(b) : Jisan /-(c) : Dalseocheon /-(d) : North Daegu /-(e) : West Daegu /-(f) : Sincheon /-(g) : Ansim
WC_B-(a): Euisung /-(b) : Geumsung
HW_A-(a):Goryoung
HG_B-(a): Habcheon
NB_H-(a): Changnyoung /-(b) : Bulim
NG_D-(a): Sabong /-(b) : Munsan/ -(c) : Jinju
NG_E-(a): Hamandaesan /-(b) : Hamangaya /-(c) : Euiryoung
NB_I-(a): Changnyoungbugok /-(b) : Namji
NB_J-(a): Milyanghanam /-(b) : Jinyoung
MY_A-(a): Shinwon /-(b) : Cheongdo
MY_B-(a): Milyang
NB_K-(a): Samrangjin
NB_L-(a): Yangsan
NB_MN-(a): Jangyu /-(b) : Gangdong /-(c) : Hwamok

Table 5
Nonpoint source (NPS) ratio of urban and rural areas on unit watershed (unit: %)

Number of Subwatershed	Area		Flow volume		BOD load		TP load	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
4	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
5	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
6	94.0	6.0	91.9	8.1	34.9	65.1	29.7	70.3
7	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
8	99.3	0.7	98.8	1.2	74.2	25.8	69.9	30.1
9	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
10	91.4	8.6	89.4	10.6	38.5	61.5	34.3	65.7
11	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
12	96.6	3.4	93.6	6.4	18.0	82.0	34.4	65.6
13	92.7	7.3	91.6	8.4	39.7	60.3	38.1	61.9
14	97.0	3.0	95.9	4.1	51.8	48.2	47.8	52.2
15	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0

(Continued)

Table 5 (*Continued*)

Number of Subwatershed	Area		Flow volume		BOD load		TP load	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
17	92.5	7.5	91.2	8.8	29.4	70.6	32.1	67.9
18	80.6	19.4	74.5	25.5	6.6	93.4	8.7	91.3
19	88.5	11.5	87.8	12.2	32.6	67.4	30.6	69.4
20	81.5	18.5	62.9	37.1	2.4	97.6	4.7	95.3
21	99.1	0.9	97.3	2.7	49.4	50.6	47.8	52.2
22	96.8	3.2	95.3	4.7	68.3	31.7	60.0	40.0
23	91.6	8.4	92.1	7.9	76.6	23.4	64.1	35.9
24	100.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0
25	98.7	1.3	97.9	2.1	76.0	24.0	87.5	12.5
26	88.6	11.4	84.1	15.9	58.1	41.9	39.6	60.4
31	94.3	5.7	90.6	9.4	28.1	71.9	26.4	73.6
32	68.1	31.9	64.1	35.9	28.1	71.9	16.5	83.5
33	97.2	2.8	94.8	5.2	59.4	40.6	55.9	44.1
34	98.5	1.5	97.5	2.5	65.6	34.4	64.0	36.0
35	91.0	9.0	88.2	11.8	45.6	54.4	41.1	58.9
36	99.0	1.0	98.5	1.5	83.2	16.8	77.9	22.1
37	91.4	8.6	84.2	15.8	22.9	77.1	25.6	74.4
38	50.9	49.1	39.9	60.1	6.2	93.8	7.1	92.9
39	75.9	24.1	74.9	25.1	47.4	52.6	35.8	64.2

Urban: watershed of WWTP, Rural: area exclusive of urban.
Note: BOD – biochemical oxygen demand; and TP – total phosphorus.

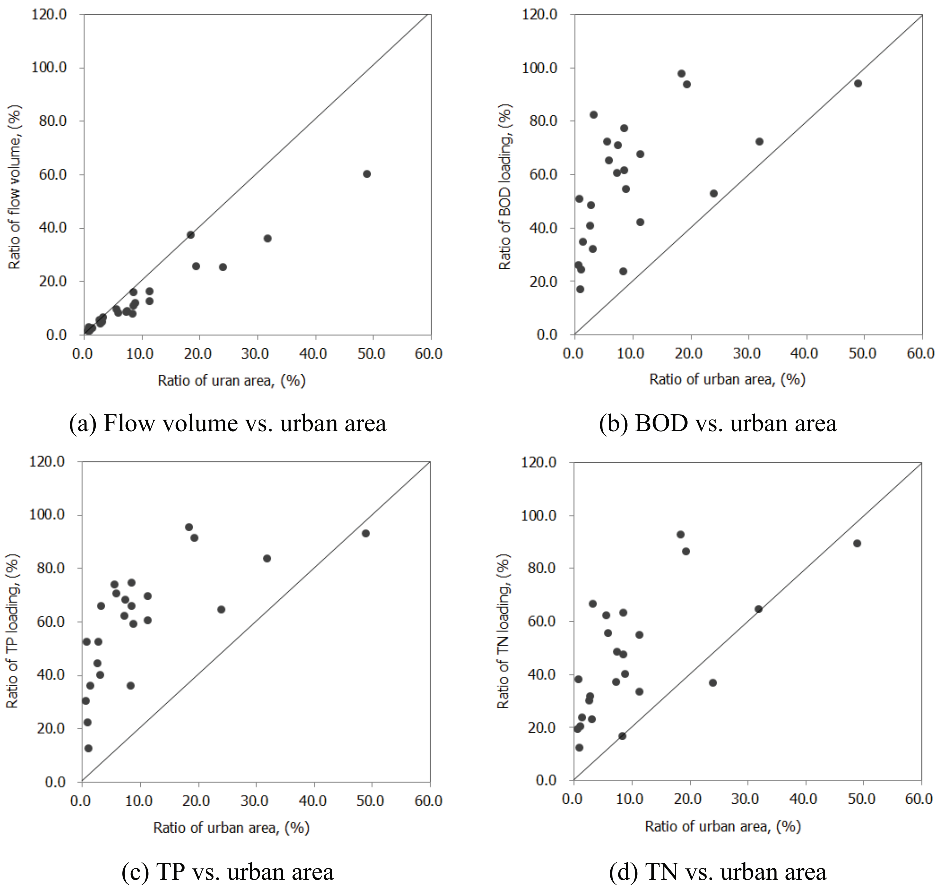


Fig. 8. Ratio of flow and NPS pollutants to urban area.

Table 6
Comparison of results from previous methods and this study

Government agency		BOD (kg/ha/yr)	TN (kg/ha/yr)	TP (kg/ha/yr)
Korea Environment	Average	107.6	76.45	2.95
Institute (KEI),	Max	153.2	119.8	4.8
(2002)	Min	61.9	33.1	1.1
Seoul [8]	Average	417.5	89.5	29.5
	Max	590	147	54
	Min	245	32	5
The Present Study	Average	101.6	38.4	4.7
	Max	553.5	130.4	15.8
	Min	3.2	1.9	0.4

Note: BOD – biochemical oxygen demand; TN – total nitrogen; and TP – total phosphorus.

4. Conclusions

In previous studies, NPS loads were estimated in accordance with land use, such as industrial, urban, and natural areas. The study, however, aimed to develop a model with superior methodology to quantify NPS loads. In comparison with previous studies, the results were in the range of average to maximum among the previous studies, but all water quality variables were less than the previous results. The study was conducted with SWMM on a sewer treatment area less than 10% of the whole watershed, in contrast to previous studies that concentrated on large sewer treatment districts. Therefore, the proposed model might be very useful for effective treatment on NPS pollutant loads generated from the TMDL watershed in the Nakdong River and for selecting the order of priority among STP applications. Previous studies suggested representative values of NPS pollutant loads after dividing the area into industrial, urban, and natural areas according to the type of land use. In contrast, the present study quantified the NPS pollutant loads depending on the treatment districts ratio and considering the drainage area and level of urbanization specific in representing the boundary of rainfall collecting area. This proposed method has the potential to be very useful for quantitatively estimating NPS for treatment districts area ratio onto the drainage area. In addition, the method might be used to assess more accurate pollutant loads about urbanization. Although the observed data used in the study lacked a high level of confidence and accuracy, the proposed model demonstrated its potential for accurately estimating and specifying NPS loads, with its ability to quantify NPS pollutant loads according to the urban area ratio, the method very important to maintain and manage the water environment and water resources.

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