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ORIGINAL ARTICLE

Quantitative Assessment of Nonpoint Source Load in Nakdong River Basin

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Abstract

This study estimates unit for the nonpoint source(NPS), classified according to the existing Level-1(large scale) land cover map, by monitoring the measurement results from each Level-2(medium scale) land cover map, and verifies the applicability by comparison with previously calculated units using the Level-1 land cover map. The NPS pollutant loading for a basin is evaluated by applying the NPS pollutant unit to Dongcheon basin using the Level-2 land cover map. In addition, the BASINS/HSPF(Better Assessment Science Integrating point & Non-point Sources/ Hydrological Simulation Program-Fortran) model is used to evaluate the reliability of the NPS pollutant loading computation by comparing the loading during precipitation in the Dongcheon basin. The NPS pollutant unit for the Level-2 land cover map is computed based on precipitation measured by the Sangju observatory in the Nakdong River basin.

Finally, the feasibility of the NPS pollutant loading computation using a BASINS/HSPF model is evaluated by comparing and analyzing the NPS pollutant loading when estimated unit using the Level-2 land cover map and simulated using the BASINS/HSPF models.

Key words : Nonpoint source, HSPF, Land cover map

1. Introduction

The unit for NPS can be divided into urban, suburban, agriculture, and water areas, where in urban areas are then subdivided into residential, commercial, industrial, and transfer areas, suburban areas are subdivided into rice paddy, farm field, and orchard areas, and agriculture areas are subdivided into forest and grassland. The NPS classification system also uses different precipitation discharge characteristics based on the type of land cover of a basin or region. Thus, reducing the discharge of nonpoint pollutants is now recognized as an important matter for Pollution Total Amount Management, yet establishing a management plan remains difficult due to the limited availability of basic domestic data, which can only be acquired by monitoring. As nonpoint pollutants are discharged during precipitation, this produces significant differences in the daily and seasonal discharge amounts. Furthermore, nonpoint pollutants are largely affected by the climate, topography, land cover, soil type, areal characteristics, and even the basin shape. Therefore, accurate water quality and flow data during precipitation is necessary to quantify the NPS discharge amount.

Various domestic and international studies have already investigated the effects of nonpoint source

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pollutants. Lee et al. (2008) suggested that the precipitation-specific discharge characteristics in suburban areas needed studies on the basin, precipitation, and flow characteristics rather than an initial cleanse phenomenon approach. The soil column was used to examine the basic unit discharge of the NPS. Kim et al. (2002) also studied the precipitation-specific NPS discharge characteristics of Gyeongancheon, where typical land use was used to compute the basin specific discharge basic unit via water quality investigations in the case of precipitation / non-precipitation. Including the study by Shin et al. (2001), there have also been many studies on the NPS pollution load and basic unit. Jewell et al. (1981, 1982) stated that while many studies use a model to predict the precipitation discharge and water quality, invalid models and errors in the measured data cause serious unreliability.

Accordingly, the present study collected existing field monitoring and field survey data for nonpoint pollutants and computed the unit using the Level-2 land cover map. The unit was then compared with unit in existing research references to establish its reliability. In addition, the basin-based nonpoint pollutant load was computed by applying the unit using Level-2 land cover map. The basin model was developed using field survey data for the lower stream, and the precipitation data was input to compute the nonpoint pollutant-specific load. HSPF developed by the U.S. EPA was applied to the actual objected basin and the simulation results compared with the field survey data to compute the load. The HSPF model used in this study was composed of a basin model and water quality model, which allowed a combined simulation of the precipitation-caused nonpoint pollutant discharge process and the interaction of the hydrograph, settlement, and chemical components in the stream. The simulated load was then compared with the field survey-based load to assess the applicability of the model to the computation of the basin NPS load.

2. Materials and methods

The subdivided land cover according to the Level-2 land cover map (i.e. Level-2 land cover classification: orchards, subdivided land cover: vineries, pear orchards, apple orchards, etc.) was determined and precipitation-specific monitoring conducted in each area. To monitor the precipitation and amount of discharge, a rain-intensity gauge and flowmeter were installed at the survey points. The monitoring continued from the start of precipitation to the end of discharge. The rain-intensity gauge used for the field surveys was an RG-20 from Environdata Environmental Monitoring & Management, Australia that uses a Tipping Bucket Mechanism to measure the precipitation at 1-minute intervals. Meanwhile, the amount of discharge was measured using a Flo-Tote3 from McBIRNEY, U.S. that uses an electromagnetic area/velocity flowmeter sensor and performs measurements at 1-minute intervals. The discharge measurement device was installed at the final outlet of the survey point and an initial measurement conducted when there was no external inflow of precipitation discharge. The sample collection and analysis followed the National Institute of Environmental Research revised 'Measurement Method of Precipitation Efflux' and 'Official Test Method on Water Pollution'. When a field survey for precipitation could not be conducted, data from the nearest meteorological observatory was employed. For the Level-2 land cover map, the industry, transfer, orchard, plastic house, and other farm field areas were monitored from 2008 to 2010, while data from 'Major NPS Discharge Long-term Monitoring' from a preliminary environment research project was used for other Level-2 land cover map.

Table 1. Summary of analysis items and description

Items	Description	Unit
Precipitation	Total precipitation	㎜
Discharge	Total discharge	㎥/sec
Origin load	Total amount of water pollutant	㎏/day
Discharge load	Calculated by manual of TMDL	㎏/day
Delivery load	Total amount of water pollutant in stream(river)	㎏/day

2.1. Survey site

The Dongcheon basin used in this study lies adjacent to the Byungseongcheon, one of the main tributaries of the Nakdong river, and has a total area of 107.88 km^2. The Dongcheon, atributary of the Byungseongcheon, runs through the upper basin, forest and farmland occupy 42.49% and 49.69% of the total basin area, respectively, and the town of Sangju is located in the lower basin, adding various Level-2 land cover map. In addition, the Dongcheon basin has no point pollutant source, such as a sewage disposal plant, making it a suitable choice for the NPS simulation.

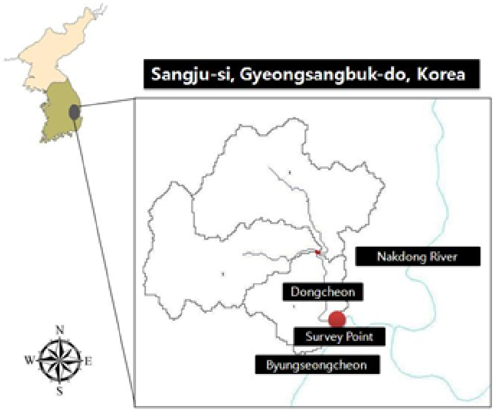


Fig. 1. Dongcheon basin survey point.

Table 2. Land cover map in Dongcheon watershed

Land Coverage		Area(%)
Level-1 land cover map	Level-2 land cover map	
Sites	Residential	2.89
	Industrial	0.10
	Commercial	0.04
	Traffic	1.10
	Public	0.05
Paddies	Rice paddies	35.11
Farm Fields	Farm fields	9.93
	Plastic Houses	0.11
	Orchards	4.34
	Other	0.23
Woods and Fields	Forest	41.32
Other	Natural Grassland	0.10
	Other Grassland	1.09
	Interior wetland	0.65
	Other bare land	0.95
	Fresh water	1.99

2.2. Computation of basic unit for NPS

Essentially, the basic unit for NPS refers to the amount of pollutants discharged from a unit land area per unit time. This unit is normally expressed as the NPS load (kg or tons)/area (ha or km^2)/time(year or day). Despite on going controversy, the land-cover-specific basic unit for NPS is commonly used due to ease of application and existing data. The NPS model uses a land-cover-specific basic unit equation that includes land-cover, soil characteristics, and hydraulic and hydrologic factors. Plus, the computation method uses an empirical formula, while the field survey method actually measures the flow and pollution loads in a basin for the basic unit computation.

2.2.1. Calculation

The most basic unit computation is conducted separately for permeable and impermeable surfaces. The USLE(Universal Soil Loss Equation) is employed to calculate the size of erosion per unit area for a permeable surface. The basic unit is then calculated using the relationship between the amount of erosion of a particular nonpoint pollutant and the phosphorus percentage. Meanwhile, for an impermeable surface, the pollutant retention rate and disappearance rate are used.

2.2.2. Actual survey method

According to the measurement method, the actual measurements can be classified into three types. The first method measures the total pollutant amount on a surface, and then applies an accumulation ratio and decomposition efficiency. This method is mainly used to compute the basic unit for NPS in an urban area. The second method compares the water qualities of upper and lower streams that pass a particular area during precipitation and converts the water quality difference to compute the nonpoint pollutant discharge basic unit. The third method directly collects the land-cover-specific discharge matter during precipitation and then measures the concentration rates. This is the most reliable method if the measured number is high enough. This method measures the land-cover-specific amount of discharge and pollutant load during precipitation to compute single, monthly, seasonal, and annual basic units. It is also used to establish an interrelation between various regression equations based on the flow, precipitation, and amount of pollutant discharge.

The basic unit computation methods used by developed countries are determined by each country's respective measurement accumulation status. In the case of the U.S., which has a long series of data, quantity data from several consecutive years of water quality measurements for a specific pollutant are used to compute the basic unit. An automatic sample collector and automatic flowmeter are used for automatic and remote transmission of the flow data, the temperature and dissolved oxygen are measured and transmitted from the field, the pH, turbidity, and akalinity are measured right after the sample collection, and the SS, varied nitrogen (NH_4^+-N, dissolved organic nitrogen, sediment adhered nitrogen, etc.), and phosphorus (dissolved phosphorus, sediment adhered phosphorus, etc.) samples are collected and kept in a freezer to transport to the laboratory for concentration analyses. There after, the flow and concentration data are combined to compute the single, seasonal and annual basic unit. Furthermore, the U.S. also uses several years of data from the automatic measurement devices to compute the basic unit and the equation is as shown below:

$$Basic\ Unit((kg/ha)/year) = \sum C_i \bullet q_i / A \qquad (1)$$

Where, ci is the concentration, qi is the discharge, and A is the basin area.

In the case of Japan, the annual basic unit for NPS is computed using the annual precipitation or discharge from several precipitation-discharge-pollutant survey data rather, than long-term time series data, and its equation is as shown below:

$$Basic\ Unit((kg/ha)/year) = k\sum C_i \bullet q_i \bullet t_i \times 365/\sum t \qquad (2)$$

Where, ci is the concentration, qi is the discharge, ti is the sample-related time interval [(previous sample collection point - current sample collection point)/2 + (current sample collection point - next sample collection point/2)], k is the conversion factor, and is the annual unit conversion factor. Since this method cannot perform actual consecutive surveys during one year, the computed value for the sample collection period is converted into the annual value using the number of precipitations, precipitation-aggravated concentration, or run-off aggravated concentration as the conversion method.

Table 3. Basic unit for NPA conversion

Conversion method	Equation
Number of direct precipitation	$L = NI$
Available precipitation ratio	$L = I_a(P_a/P_a)$
Effusion ratio	$L = I_m(Q_m/q_m)$
Effusion-Aggravated concentration	$L = N[I_a(Q_a/q_a)]$

Note) L: annual load, N: number of discharge per year, : average load per sunrise, : annual average effective precipitation, : average effective precipitation per sunrise within sample, : annual discharge, : discharge during survey period, : average flow aggravated concentration during survey period, : average discharge per sunrise within population, : average discharge per sunrise within sample

This study employed the actual survey basic unit computation method, and the basic unit for NPS computation for the map was based on the 'precipitation outflow survey method'. For the basic unit computation, the typical precipitation ratio was applied. This study selected a particular basin, instead of the entire Korean peninsula, in order to the compute NPS load in basin. Precipitation data for 2001~2010 from the Sangju observatory located in the Dongcheon basin was used to compute the typical precipitation ratio.

2.3. HSPF model

To analyze the water quality and basin, the BASINS analysis system includes the National Environmental Database, Assessment tools, Utilities, Watershed Characterization Reports, Water Quality Stream Models, Watershed Models, and Post processors.

Based on GIS(Geographic Information System), BASINS was also linked to a water quality model, QUAL2E, and basin models, SWAT, and HSPF. First, a stream map was created using a numerical altitude model and the basin was then extracted using the DEM(Digital Elevation Model) and stream map. Finally, the basin characteristics were established by overlapping a land-use map and soil map using GIS.

HSPF is a semi-distributional long-term effusion model developed by the U.S. EPA and USGS(United States Geological Survey) to simulate precipitation-specific flow and water quality in a basin with complex land coverage. Based on SWM(Stanford Watershed Model) developed in the 1950s, a water quality processing module was added in the 1970s, while pre- and post-processing software, enhanced algorithms, and WDM(Watershed Data Management) were added in the 1980s. Moreover, the HSPF model has been applied for various purposes, including the assessment of changes in land-use, reservoir existence, pollutant source treatment methods, and changes in stream flow.

HSPF processes separate simulations for the PERLND module, the permeable layer, and IMPLND, the impermeable layer. This data is then used as the input

Table 4. HSPF meteorological data

Parameter	DSN	Parameter type	Unit	Method
PREC	1	hourly precipitation	in/hr	observed
EVAP	2	daily evaporation	in	computed
ATEM	3	hourly air temperature	deg F	disaggregated
WIND	4	hourly wind speed	mph	disaggregated
SOLR	5	hourly solar radiation	ly/hr	disaggregated
PEVT	6	hourly potential evaportranspiration	in/hr	disaggregated
DEWP	7	hourly dewpoint temperature	deg F	disaggregated
CLOU	8	hourly cloud cover	tenth	disaggregated

Table 5. HSPF application module

PERLND	IMPLND	RCHRES
Water budget	Snow	Hydraulics behavior
Snow accumulation & melt	Water	Water temperature
Sediment production & removal	Solids	Inorganic sediment behavior
Nitrogen & Phosphorous behavior	Quality	Chemical behavior
Pesticide behavior		BOD & DO balances
Tracer chemical movement		Inorganic Nitrogen & Phosphorus balances Plankton population pH, Carbon, alkalinity

for the RCHRES module, which simulates the hydrograph and water quality of the water body. Each module is sectionalized into parts that simulate the effusion, soil loss, DO, water temperature, BOD, NO_3^--N, NH_4^+-N, Organic N, PO_4^{3-}-P, Organic P, nutrient salts, and plankton. In addition, an invariable relationship is assumed between the water surface area, water body depth, and storage amount. Plus, a one-way flow is assumed in the case of an in-stream simulation, and a single-point inflow with multi-directional effusion.

Time series data, such as the precipitation, temperature, solar radiation, wind speed, evaporation loss, cloud cover, and dew point, is used as the input data. Such data is stored in another module, WDM Utility, in order to process the simulation using GIS data from BASINS. The hydrological budget equation for the basin simulation is as shown below:

$$P + SWI + GWI = ET + SWO + GWO + \triangle S \quad (3)$$

Where P is the precipitation, SWI is the surface water inflow, SWO is the surface water outflow, GWI is the ground water inflow, GWO is the ground water outflow, ET is the evaporation rate, and S is the change in the storage amount. The hydrological budget equation for the water body is represented by Equation (2), and the water quality equations can be presented as Equations (3) and (4).

$$VOL - VOL = IVOL + PRSUPY - VOLEV - ROVOL \quad (4)$$

Where VOL is the final flow, VOLS is the initial flow, IVOL is the water income, PRSUPY is the precipitation, VOLEV is the evaporation loss, and ROVOL is the effusion.

$$RELBOD = (BRBOD(1) + BRBOD(2) \cdot \mathrm{EXP}(-\mathrm{EXP}\ddot{y} \cdot DOX)) \cdot SCRFAC \quad (5)$$

$$BODOX = (KBOD20(TCBOD^{TW-20})) \cdot BOD \quad (6)$$

Where RELBOD is the BOD (mg/m^2/interval) from the settlement bottom, EXPREL is the exponential factor, DOX is the dissolved oxygen concentration (mg/l), SCRFAC is the scouring factor based on the mean current velocity, BODOX is the amount of oxygen needed for BOD decomposition (mg/l/interval), KBOD20 is the BOD decomposition efficiency at 20℃ (/interval), and TCBOD is the temperature calibrating factor (default value=1.075) (HSPF User's Manual, 1996).

3. Results and discussion

3.1. Basic unit computation using Level-2 land cover map

The measurement method was employed for the basic unit computation of the Level-2 land cover map. The computation process was based on the revised 'Precipitation Discharge Test Method' of the National Institute of Environmental Research. The typical precipitation ratio was computed using the 2001~2010 precipitation data from the Sangju Meteorological Observatory in the Dongcheon basin. Based on this data, the precipitation ratio is shown in Table 6.

The basic unit for NPS using the Level-2 land cover map is shown in Table 7. The basic unit for NPS from previous studies showed large gaps between the minimum and maximum, and included large errors due to user misjudgment. Plus, the previously calculated basic units for NPS were computed using 5~6 Level-1 land cover map. As a result, it was difficult to apply such previous results to the current subdivided land cover map. Notwithstanding, the basic unit for NPS used in this study was included within the value range from previous studies yet lower than the Level-1 value. Furthermore, the basic unit for NPS used for previous land load computations only utilized precipitation periods with discharge, whereas this study also included precipitation periods without

Table 6. Typical precipitation ratio in Dongcheon basin(2001~2010 Sangju observatory)

Precipitation	Frequency	Precipitation (㎜)	Precipitation ratio (fy)	Annual average (mm)
0-10㎜	959	1896.4	0.18	210.7
10-30㎜	183	3265.2	0.30	362.8
30-50㎜	49	1897.5	0.18	210.8
50<㎜	50	3756.5	0.35	417.4
Total	1241	10815.6	1.00	1201.7

Table 7. Basic unit for NPS comparison for Level-2 land cover map (Unit : kg/ km^2 · day)

Land coverage		BOD			T-N			T-P		
Lvel-1 Classification	Level-2 Classification	Level -2 Class.	Lvel-1 Class.	Ref.	Level -2 Class.	Lvel-1 Class.	Ref.	Level -2 Class.	Lvel-1 Class.	Ref.
Sites	Residential	7.48	85.90	9.16 ~ 106.03	8.97	13.69	0.86 ~ 2520.0	0.48	2.10	0.19 ~ 448.0
	Industrial	25.03			5.70			0.46		
	Commercial	41.21			5.36			0.55		
	Recreational	19.59			7.80			0.84		
	Traffic	11.53			4.08			0.30		
	Public	7.72			4.84			0.35		
Paddies	Rice paddies	6.14	2.30	1.51 ~ 10.96	3.59	6.56	0.08 ~ 13.70	0.50	0.61	0.03 ~ 4.49
Farm Fields	Farm fields	3.41	1.59	1.8 ~ 9.28	0.92	9.44	1.81 ~ 7.17	0.53	0.24	0.08 ~ 1.09
	Mountainous fields	24.07			3.21			4.16		
	Plastic Houses	23.79			8.02			3.72		
	Orchards	1.73			0.82			0.17		
	Other	0.37			1.04			0.17		
Woods and Fields	Forest	0.79	0.93	0.70 ~ 11.65	1.32	2.20	0.30 ~ 7.46	0.03	0.14	0.01 ~ 0.25
Other	Golf	3.35	0.96	0.82 ~ 560.82	4.04	0.76	0.44 ~ 6.48	0.92	0.03	0.03 ~ 0.30
	Other Grassland	1.02			0.59			0.12		
	Mining	24.67			4.16			0.97		

discharge in the basic unit for NPS computation, where the NPS EMCs for the precipitation periods without discharge were assumed to be '0'. Thus, due to this difference, the basic unit for NPS had a lower value than the previously reported Level-1 value.

3.2. Dongcheon basin NPS load

3.2.1. Origin load computation

The previously computed basic unit for NPS was applied to each land cover map in the Dongcheon basin to compute the NPS origin load. The results are shown in Table 6. For the Level-1 land cover map, the BOD load in the basin was 391.4 kg/day, which was higher than the BOD loads for the Level-2 land cover map, which were 23.65 kg/day, 2.70 kg/day, 1.78 kg/day, 13.68 kg/day, 0.42 kg/day for the residential, industrial, commercial, traffic, and public areas, respectively. As such, the BOD loads were quite different according to the land cover, even within the same Level-1 land cover map, as the amount of pollutants in the discharge varied based on the management and cleaning condition of each relevant area. Therefore, the degree of error for the computation of the NPS discharge amount for the Level-1 land cover map largely depended on the user judgement. For the other areas, Level-1 land cover map showed 4.95 kg/day, whereas the Level-2 land cover map, including natural grassland, other grassland, interior wetland, other barren ground, and fresh water, showed 0.10 kg/day, 1.20 kg/day, 0.67 kg/day, 0.98 kg/day, and 2.06 kg/day, respectively. Likewise, the subdivision produced a difference in

Table 8. NPS origin load in Dongcheon basin (Unit: kg/day)

Land coverage		BOD		T-N		T-P	
Lvele-1 Class.	Level-2 Class.	Level-2 Class.	Lvele-1 Class.	Level-2 Class.	Lvele-1 Class.	Level-2 Class.	Lvele-1 Class.
Sites	Residential	23.65	391.14	28.36	62.34	1.52	9.56
	Industrial	2.70		0.62		0.05	
	Commercial	1.78		0.23		0.02	
	Recreational	-		-		-	
	Traffic	13.68		4.84		0.36	
	Public	0.42		0.23		0.02	
Paddies	Rice paddies	232.47	87.08	135.92	248.38	18.93	23.10
Farm Fields	Farm fields	36.50	25.05	9.85	148.71	5.67	3.78
	Plastic houses	2.82		0.95		0.44	
	Orchards	8.10		3.84		0.80	
	Other	0.09		0.26		0.04	
Woods and Forest	Broadleaf Conifer Mixed Stand	35.20	41.44	58.82	98.04	1.34	6.24
Other	Natural grassland	0.10	4.95	0.08	3.92	0.00	0.02
	Golf	-		-		-	
	Other grassland	1.20		0.69		0.14	
	Inland wetland	0.67		0.67		0.67	
	Coastal wetland	-		-		-	
	Mining	-		-		-	
	Other bare land	0.98		0.78		0.03	
	Fresh water	2.06		1.63		0.06	
	Saltwater	-		-		-	
Total Loads		362.44	549.66	247.81	561.38	30.10	42.69

Table 9. Discharge load in Dongcheon basin administrative districts (Unit : kg/day)

Administrative districts	BOD	T-N	T-P
Gonggeom-myeon, Sangju-si, Gyeongsangbuk-do	506.96	278.55	25.85
Naeseo-myeon, Sangju-si, Gyeongsangbuk-do	76.43	70.96	5.26
Sabeol-myeon, Sangju-si, Gyeongsangbuk-do	538.26	306.06	29.61
Oiseo-myeon, Sangju-si, Gyeongsangbuk-do	532.76	361.74	31.34
Euncheok-myeon, Sangju-si, Gyeongsangbuk-do	56.31	37.53	3.30
Ian-myeon, Sangju-si, Gyeongsangbuk-do	62.08	31.48	3.23
Habchang-eup Sangju-si Gyeongsangbuk-do	185.63	127.29	11.26
Dongcheon basin discharge load	1958.42	1213.62	109.86

the load. The T-N and T-P load also changed when subdividing the land cover map classification. Thus, since the Level-2 land cover map produced differences in the precipitation discharge characteristics, it was necessary to apply the basic unit for NPS using Level-2 land cover map for the basin load computation in order to represent the characteristics of the relevant land coverage.

3.2.2. Discharge load computation

Table 7 shows the administrative district discharge loads for the Dongcheon basin. The administrative districts in the Dongcheon basin include 7 administrative districts for Sangju city. The pollutant source discharge loads were computed according to the "2009 National Pollutant Source Research", where the discharge load is the pollution load amount that causes water pollution in a stream, i.e. the discharged load from a pollutant source, such as a treatment or septic tank. According to the computation result, for the Dongcheon basin, the highest BOD load was 1958.42 kg/day and the highest T-N and T-P were 1213.62 kg/day and 109.86 kg/day, respectively.

3.2.3. Delivery ratio computation

The delivery ratio was estimated using the measurement and origin load computed by the basic unit for NPS using Level-2 land cover map for the Dongcheon basin.

To compute the delivery ratio, flow and water quality tests were conducted in the lower Dongcheon basin. However, since the test period was limited to April, May, June, and July, the typical delivery ratio for the Dongcheon basin could not be computed. The test period was only during the rainy season, and no delivery ratio tests were conducted for the dry season, i.e. the Korean fall and winter. Thus, annually measured flow and water quality values still need to be established for the Dongcheon basin in order to compute the appropriate delivery ratio.

Table 10. Delivery ratio of pollutant sources in Dongcheon basin

Survey period	Precipitation (mm)	Flow (m3/sec)	Delivery ratio		
			BOD	T-N	T-P
2010-06-25	12	0.98	0.06226	0.10326	0.19268
2010-07-02	18	1.12	0.06819	0.08851	0.19378
2010-07-16	8	0.57	0.04225	0.10632	0.09862
2010-10-29	4	0.24	0.00413	0.04289	0.00567
2011-04-26	7	0.34	0.02606	0.05614	0.01776
2011-05-26	8	0.34	0.04059	0.07437	0.02589
2011-06-23	27	3.27	0.58571	0.53730	0.68406
2011-07-26	3	0.24	0.01747	0.03971	0.01340
Average	12	0.98	0.10583	0.13106	0.15398

Using 8 flow and water quality measurements for the lower Dongcheon basin from 2010 to 2011 and previously computed delivery loads, pollutant sources delivery ratios were computed and the results are shown in Table 10. According to the results, the values were proportional to the time, precipitation, and flow measurements. The Dongcheon basin showed a low average flow of 0.25 m^3/sec without any precipitation. Therefore, the flow change was significant in the case of precipitation. In addition, the water quality concentration changed significantly with a precipitation event. Therefore, this indicates that the Dongcheon is a small stream without a particular pollutant source and hugely affected by nonpoint pollutant sources surrounding the stream.

Among the delivery ratios computed using the measurements and NPS loads for the Dongcheon basin, the results for 2011 were classified into four cases. The computed results for the time-series delivery load for the Dongcheon basin are shown in Table 11. The delivery load computation for 2010 was excluded due to the lack of regular field surveys. As the field survey was limited to the rainy season, from April to July, the typical load for Dongcheon basin could not be computed. Thus, prolonged field monitoring would facilitate a more reliable pollutant source load calculation for the Dongcheon basin. For Case 3, the BOD, T-N, and T-P were 212.28 kg/day, 133.15 kg/day, and 20.59 kg/day, respectively. As the precipitation during Case 3 was 80 mm, which was higher than that for Cases 1, 2, and 4, this resulted in a high pollutant source-specific delivery load. As the Dongcheon basin is relatively small in size with a usual flow of 1.5~2.0 m^3/sec, the delivery load was changed by precipitation. In addition, since the basin has no point pollutant source, most loads occurred from nonpoint pollutant sources, such as farms and grasslands, surrounding the stream.

Table 11. NPS delivery load in Dongcheon basin

(Unit: kg/day)

Item	Case 1	Case 2	Case 3	Case 4
BOD	9.44	14.71	212.28	6.33
T-N	13.91	18.43	133.15	9.84
T-P	0.53	0.78	20.59	0.40

3.3. BASINS/HSPF application

For efficient basin management and highly reliable point and nonpoint pollutant source quantification, it is important to calibrate and validate the effusion and water quality for complex land coverage basins, including Level-2 land cover map. Therefore, this study used the HSPF model as the basin model and applied it to the Dongcheon basin related to the Nakdong River based on processing an NPS discharge simulation in the case of precipitation. The input data for the flow and water quality simulation of the Dongcheon basin used 4 flow and water quality field surveys from 2011 (Cases 1~4, Table 10) and meteorological data from field surveys conducted during the same time period. In the case of 2011, the monitoring results have various precipitation and flow variation more than 2010. So this study used 2011 monitoring results for modeling calibration.

The simulation then classified the four cases. The basin data used to define the discharge characteristics included the altitude, a land coverage map, and soil map. The altitude and land coverage map were retrieved from the Environmental Geography Information, while the soil map was acquired from a reconnaissance soil map from the National Institute of Agricultural Science and Technology.

3.3.1. Precipitation & Meteorological data

Precipitation data is the variable with the most significant effect on effusion. The present simulation used precipitation data surveyed from the Dongcheon basin for the four cases. The meteorological data required for the HSPF model includes the hourly average temperature, daily evaporation loss, hourly wind speed, daily dew point, hourly evapotranspiration, hourly average cloud cover, and hourly sunshine. However, most data from the Meteorological Administration was daily data with very little hourly data. Thus, the highest and lowest temperatures, average wind speed, and average cloud cover were input to the WDMUtill and hourly data calculated using an internal calculation function. The Sangju Observatory was selected for the meteorological data.

3.3.2. Model application results

The calibration and validation of the model parameters was based on trial and error, and the results are shown in Figures 2 and 3. The margin of error is presented in the measurement according to each error. As the discharge simulation was short-term, the effect of precipitation was significant.

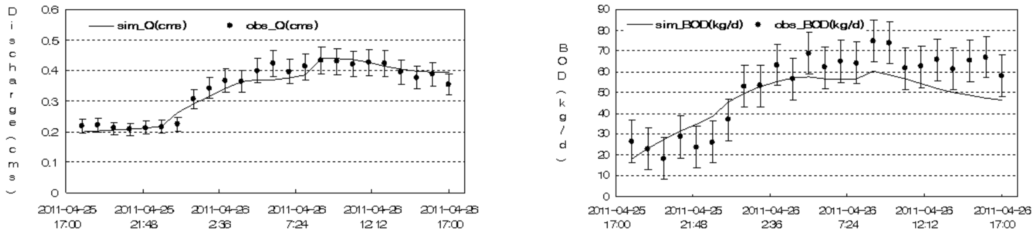
According to the precipitation field measurement application, the case discharge amounts were very similar to the field survey values. The BOD was compared according to the load. Although it differed slightly with the time series survey values, it still showed an analogous trend. The T-N also showed a similar trend, except for the initial period, and its error was small. Meanwhile, the T-P oscillated during the initial 4 hours and produced a larger error when compared to the other sections, yet it also followed the same trend. In particular, Case 3 showed a difference with the field survey values in the latter stage, yet its trend and margin of error were authentically accurate. Plus, including the simulation period, the effusion amount was significantly larger than that for the other cases due to a high precipitation before and after the simulation. As a result, the BOD, T-N, and T-P loads were all high.

3.3.3. Validation assessment of simulation results

To assess suitability of the simulation results, a scatter diagram analysis of the measurement and simulation results was processed, as shown in Figure 5 and Table 13. To interpret the calibration/validation of the simulation results, the Nash-Sutcliffe coefficient was applied to understand the degree of prediction of the model. The Nash-Sutcliffe coefficient exists between $-\infty$ and 1. Normally, the Nash-Sutcliffe coefficient is used to quantitatively explain the accuracy of a model as long as there is a comparable measurement. If the coefficient is higher than 0.75, the simulation is considered accurate, whereas if the coefficient is between 0.75 and 0.36, the simulation needs to be complemented. Figure 5 shows the correlation distribution chart for the simulation and measurement values. For the suitability assessment in Table 13, the coefficient for the flow was an average of 0.85, which was high. Plus, for the water quality section, the coefficients for the BOD, T-N, and T-P were 0.82, 0.85, and 0.79 respectively, also representing a high suitability. Furthermore, in Table 14, the Nash-Sutcliffe coefficient for the flow was an average of 0.78, while the coefficients for the BOD, T-N, and T-P were 0.67, 0.81, and 0.71, respectively, which were comparably high. However, the BOD showed a low

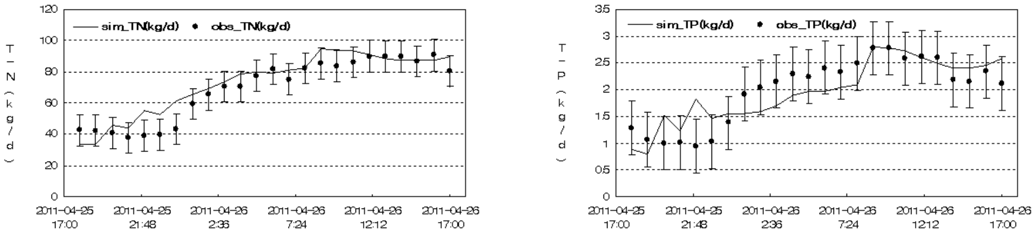
Table 12. Calibration of HSPF/Basin parameters

Parameter	Description	Model range	Initial range	Final value
LZSN	Lower zone nominal storage	0.01~100	4~6.5	0.1~15
INFILT	Index to infiltration capacity	0.0001~100	0.16	0.16~10
KBOD20	BOD decay rate at 20℃	Min : 1E-30	0.1	0.04~10
KODSET	BOD setting rate	Min : 0	8.0	0.27~5
KNO220	Nitrification rates of nitrate at 20℃	Min : 9.99E-04	0.002	2.5~9.5
KNO320	Denitrification rate at 20	Min : 9.99E-04	0.002	0.027~0.92
SEED	The minimum concentration of plankton not subject to advection	Min : 0	1	0~9.5

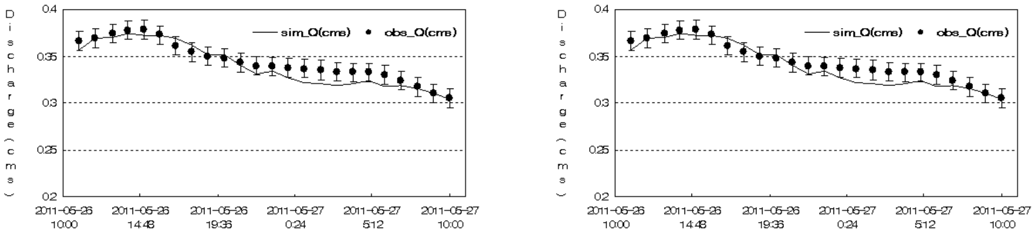


a) Flow b) BOD Load

CASE 1

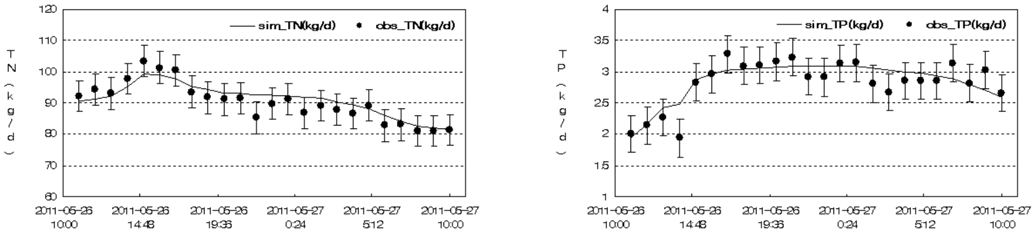


c) T-N Load d) T-P Load



a) Flow b) BOD Load

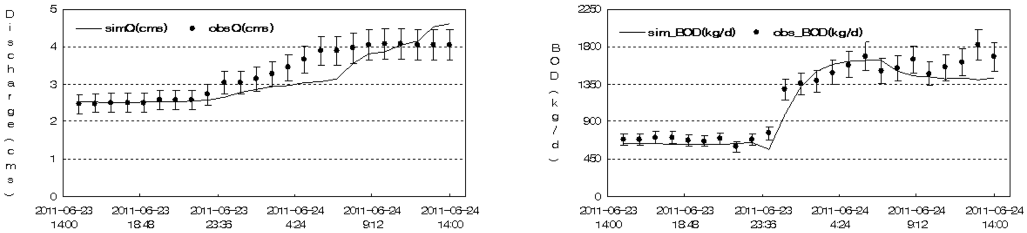
CASE 2



c) T-N Load d) T-P Load

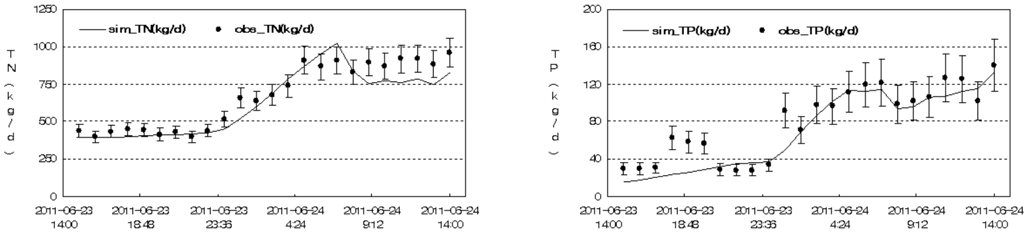
Fig. 2. Dongcheon basin cases 1 & 2 calibration/validation results.

CASE 3



e) Flow

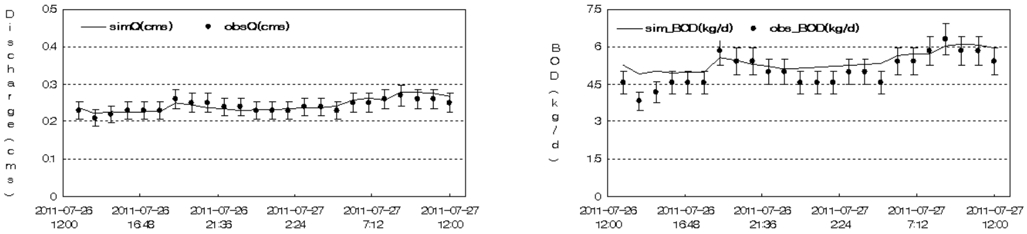
f) BOD Load



g) T-N Load

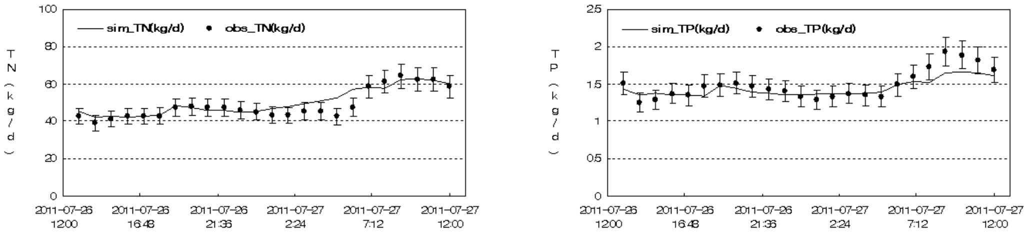
h) T-P Load

CASE 4



e) Flow

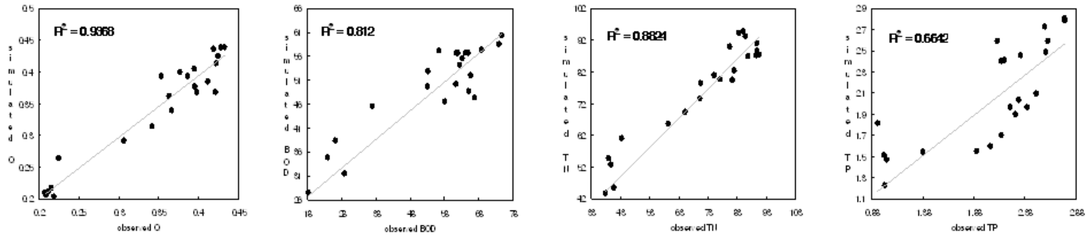
f) BOD Load



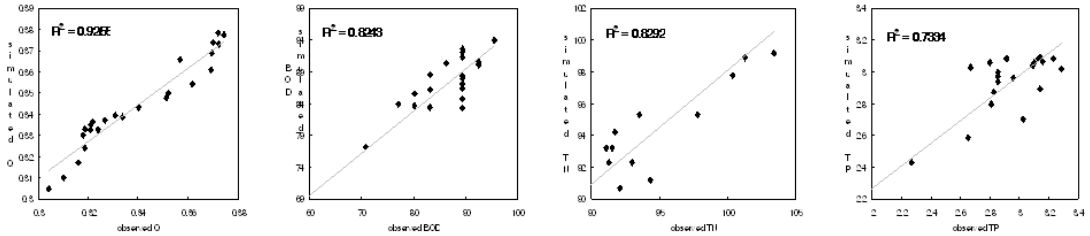
g) T-N Load

h) T-P Load

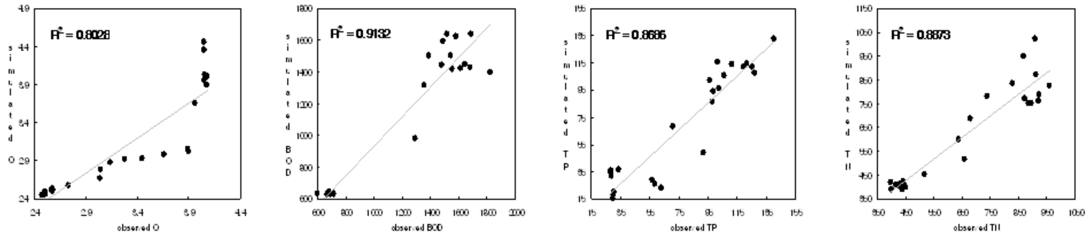
Fig. 3. Dongcheon basin cases 3 & 4 calibration/validation results.



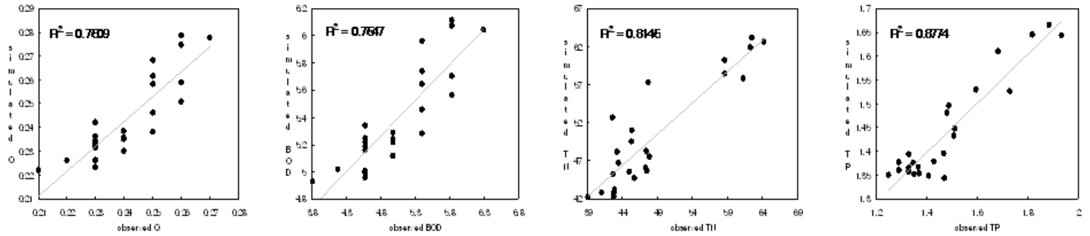
a)Flow b)BOD c)T-N d)T-P



e)Flow f)BOD g)T-N h)T-P



i)Flow j)BOD k)T-N l)T-P



m)Flow n)BOD o)T-N p)T-P

Fig. 4. Analysis of simulation and survey value correlations(a~d: Case1, e~h: Case2, i~l: Case3, m~p: Case4).

suitability in Case 4, because then a little precipitation and flow. Precipitation and flow are important thing to modeling input data. A quantity of precipitation and flow contribute much to the result of calibration and validation.

The data used for the calibration, validation, and suitability assessment of the HSPF model was measured between April and July, which is the rainy season. Therefore, the measured flow was higher than usual due to the influence of precipitation. Thus, it would be hard to apply the developed model to the dry season in spring or winter.

The Dongcheon is a tributary of the Byungseongcheon and usually has a small flow. Since Korea has no precipitation in fall and winter, the flow is 1.5~2.0 times lower than usual, resulting in a quite different characteristic compared to that for the rainy season. When the flow is lower than usual, the delivery load is significantly affected by the concentration of inflow matter. Thus, if such results were applied to the model, they would show a far different suitability compared to the results of the present study. Consequently, for a higher reliability of the NPS load computation during precipitation, periodical field surveys need to be conducted to represent the seasonal variation and the model then calibrated/validated based on the results.

Table 13. Correlation between simulation and survey values

	Flow	BOD	T-N	T-P
Case 1	0.94	0.81	0.88	0.66
Case 2	0.93	0.82	0.83	0.73
Case 3	0.80	0.91	0.87	0.89
Case 4	0.75	0.75	0.81	0.88
average	0.85	0.82	0.85	0.79

Table 14. Nach-Sutcliffe coefficient

	Flow	BOD	T-N	T-P
Case 1	0.93	0.67	0.84	0.65
Case 2	0.88	0.77	0.79	0.73
Case 3	0.70	0.88	0.85	0.79
Case 4	0.60	0.35	0.77	0.67
average	0.78	0.67	0.81	0.71

3.4. NPS delivery load assessment

When applying the basic unit for NPS using Level-2 land cover map applied NPS load and basin models, BASINS/HSPF, the computed NPS loads were compared and analyzed. The applicability of the NPS load computation using the basin model was analyzed based on comparison. Furthermore, the application of the land cover map subdivision method was assessed for the basin NPS load computation.

According to the delivery load in the Dongcheon basin shown in Table 15, NPS load was influenced by flow variation. Flow variation was changed by permeability of land cover map in basin. Therefore, reliability of NPS load was riding on the subspecialized land cover map. And the basin model simulation had higher values than the basic unit application method. This was because the model values tended to be higher than the measurement values. However, when applying the basic unit load computation to the delivery load, there was a periodical difference with the basin model values, as the input was based on 2009 National Pollutant Source Data. Therefore, instead of applying the pollutant discharge load data for the simulation period, data from the previous year was applied. When comparing the two results, there was a definite value difference based on the case computation method, yet the correlation between the simulation and the measurement was higher than 0.9, except for Case 4, indicating an identical occurrence tendency. Thus, if the basin model with proper parameters were applied to the NPS load and a deliberate calibration/

Table 15. Comparison of NPS delivery load

Computation method	Item	Case 1	Case 2	Case 3	Case 4
Level-2 Classification unit	BOD	9.44	14.71	212.28	6.33
	T-N	13.91	18.43	13.31	9.84
	T-P	0.53	0.78	20.59	0.40
Basin model	BOD	47.31	85.08	26641.20	129.50
	T-N	72.79	91.10	15028.10	1205.90
	T-P	1.97	2.85	1682.50	34.60

validation conducted for various measurements, a high level of applicability and highly reliable results could be derived.

4. Conclusion

Instead of using the existing Level-1 land cover map, this study computed the basic unit for NPS when classifying the land coverage based on Level-2 land cover map field monitoring. The computed basic unit was applied to the Dongcheon basin to compute the basin NPS load. In addition, the basin models BASINS and HSPF were utilized to determine the NPS load for an identical basin, and the two results compared to assess the validity.

1) When using discharged water monitoring data, the basic unit for NPS using Level-2 land cover map was computed. The computed basic units were within the numerical value range of previous studies, yet slightly smaller than the water pollution total amount thresholds. Furthermore, the basic unit values for the Level-2 classifications in the Level-1 classification varied from each other, indicating the need for subdivision of the land cover map.

2) According to the NPS load in the Dongcheon basin, the BOD load was 391.4 kg/day, which was higher than the BOD loads for the Level-2 classification sites at 23.65 kg/day, 2.70 kg/day, 1.78 kg/day, 13.68 kg/day, and 0.42 kg/day for residential, industrial, commercial, traffic, and public areas, respectively. The results showed distinct values for different land coverage, even within the same rough classification. Plus, the T-N and T-P loads differed when changing the Level-1 classification to Level-2 classification.

3) The delivery load in the Dongcheon basin was computed for four time series cases. The four cases delivery loads were as follows: Case 1: BOD 9.44 kg/day, T-N 13.91 kg/day, T-P 0.53 kg/day, Case 2: BOD 14.71 kg/day, T-N 18.43 kg/day, T-P 0.78 kg/day, Case 3: BOD 212.28 kg/day, T-N 133.15 kg/day, T-P 20.59 kg/day, and Case 4: 6.33 kg/day, 9.84 kg/day, 0.40 kg/day.

4) The validity of the HSPF model for the Dongcheon basin was assessed using four time series cases. Assessment results: Case 1: Flow 0.94, BOD 0.81, T-N 0.88, T-P 0.66, Case 2: Flow 0.93, BOD 0.82, T-N 0.89, T-P 0.73, Case 3: Flow0.80, BOD 0.91, T-N 0.87, T-P 0.89, and Case 4: Flow 0.75, BOD 0.75, T-N 0.81, T-P 0.88. This implies the high suitability of the field measurements for the model simulation.

5) The basic unit using Level-2 land cover map applied NPS load was compared with the NPS load computed using the BASINS/HSPF models. The basic unit application had a higher value than the basin model simulation. According to the correlations between the cases of simulation and measurements, all the cases showed a fixed occurrence tendency of 0.9, except for Case 4.

To suggest a future study direction for NPS monitoring, due to the unequal concentrations of certain Level-2 land cover map, the areal limitations need to be reduced through a cross investigation of organizations. Plus, the land coverage subdivisions in the Level-2 classification need to be expanded to establish diversity for the monitoring points. Instead of a short-term investigation, a long-term study will abate the current uncertainty and limitations of the basic unit. With prolonged investment and effort to establish basic data, a typical NPS basic unit can be computed for Korea, and such groundwork can lead to an appropriate basin management plan for NPS pollutants.

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