

Impacts of Land Use Change on Discharge Regime and Water Quality in a Small Watershed

소유역의 토지이용 변화에 따른 하천 유량과 수질 변화에 관한 연구

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※ Key words : HSPF, Land Use, Nonpoint Source Pollution, Runoff, Stream Buffer,
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I. Introduction

Land use change in a watershed context is especially important. The conversion of land from rural to urban uses usually increases the discharge rate and volume of stormwater in a watershed. In addition, nonpoint source pollutions generated from urban environments are considered one of the most serious forms of contamination threatening the nation's water resources (Griffiths et al. 1997). Urban development has significant influences on flooding and nonpoint source pollution problems in watersheds.

Numerous strategies have been developed to manage stormwater runoff. For several decades, detention basins have been used to mitigate the flood impacts of urban development. However, these measures have been shown to have little influence on storm water quality (Caltrans. 2002).

Landscape architects and urban planners have recently included conservation practices in urban land use planning (Arendt. 1996; Coffman. 2000; Hager. 2003). Conservation practices, such as the preservation of wetlands, forested stream corridor buffers, and forests, are increasingly being proposed in watersheds for the mitigation of flooding and reduction of nonpoint source pollutions. Among them, as the most common practice, forested stream corridor buffer has been

widely practiced through municipalities' zoning or stormwater management ordinance in US. Forested stream corridor buffer is the infiltration based land use technique to protect stream water quality and to reduce flooding event. However, relatively little research has been undertaken regarding the watershed level effects of forested stream corridor buffer implementation on flooding or water quality.

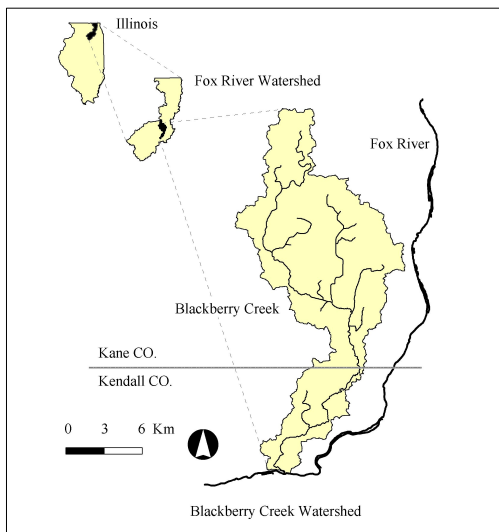
This paper describes an approach taken to assess the incorporation of forested stream corridor buffer to urban land use planning by using Hydrological Simulation Program Fortran (HSPF). The work presented here 1) focuses on the specification and calibration of HSPF for the Blackberry Creek watershed, Illinois, US, and 2) evaluates the model effects of forested stream corridor buffer at the watershed level with urbanization on surface runoff and nonpoint source pollutions including nitrate ($\text{NO}_3\text{-N}$), and orthophosphate ($\text{PO}_4\text{-P}$). The temporal scope of interpretation is determined to be an annual basis to describe the overall functionality of the stream buffer with urbanization.

II. Methodology

1. Blackberry Creek

The 51.5km long Blackberry Creek is a

<Figure 1> The Blackberry Creek Watershed, Illinois. The Blackberry Creek Watershed is a Sub-Watershed of the Fox River Watershed, Illinois, US.



tributary of the Fox River watershed, Illinois, US(See <Figure 1>).

The Blackberry Creek watershed is a largely agricultural area of 186.5km² located on the western edge of the Chicago metropolitan area in Kane and Kendall Counties, Illinois. Recently, the watershed has undergone rapid urbanization with increasing population, number of households, and property size. In 1994, the majority of the land in Blackberry Creek was rural. Land use data for the Blackberry Creek watershed show that 55% of land the watershed is in agricultural use while only 6% is in urban use. The Northeastern Illinois Planning Commission(NIPC), however, projects in urban use will increase to 27% of the watershed by 2010(NIPC. 1987). In

addition, the US Army Corps of Engineers(2002) reported that up to 90% of the wetlands in the Blackberry Creek watershed may have been lost and many of the remaining wetlands are degraded. They reported that wetland degradation would be continued under increasing development.

Kane County is one of the top ten counties in the State in population. The Fox River watershed is now one of the most populous in the State(IDNR. 1997). The County experienced 10.92% and 14.03% population increases during 1970 to 1980, and 1980 to 1990, respectively (Kane County. 1996). Kane and Kendall Counties have populations of 443,041 and 61,222 according to the 2002 Census. The Kane County Development Department has projected the 2020 population of the county to be 540,000(Kane County. 1996).

2. Discharge Regime and Water Quality

The mean annual precipitation of the Fox River watershed is 93.68cm. The mean water temperature of the Fox River watershed ranges from -11.7 to -1.7 °C, while the mean summer temperature ranges from 16.7 to 28.9 °C, resulting a mean annual temperature of the Fox River watershed of 9.1 °C. The mean annual temperature of the Blackberry Creek watershed was 9.5 °C in 1993(IDNR. 1998). Soil texture and composition affect the chemistry

and infiltration rate of water. Mollisol, alfisol and ceptisol are the principle soil types in the Blackberry Creek watershed (Arnold et al. 1998). Mollisol generally contains greater than 1% organic matter in the surface horizon. The relative soil permeability of Mollisol is low. General soil permeability for infiltration in the Blackberry Creek watershed ranges from 1.5 to 5.1cm/hr.

Topography of the Blackberry Creek watershed is generally gentle or flat with a minimum elevation of 186.5m and a maximum elevation of 214.9m above sea level. The mean annual stream flow of 1.54m³/s is based on the stream flow records from 1961 to 2000 at Yorkville, Illinois (US Geological Survey gaging station number 05551700).

The primary causes of water quality problems Blackberry Creek are siltation, nutrients, organic enrichment and suspended solids attributed to agriculture, urban runoff, recreational activities, and contaminated sediments (Arnold et al. 1998). A historical study of the surface water of the Upper Illinois River, a receiving water body of the Fox River, from 1978 to 1997 shows seasonal patterns of nutrient concentrations with high concentrations in the winter months and depletion during the spring and summer largely reflecting agricultural practices. Monthly median concentration of nitrate is at the minimum level from July through October,

whereas orthophosphate concentrations does not display strong seasonal trends (Sullivan. 2000). US Army Corps of Engineers (2002) reported that the water quality of the Blackberry Creek is 'good' for its designated uses throughout the watershed. The mean nitrate concentration of 3.13mg/L was calculated for the period from 1977 to 1997 at Yorkville where Blackberry Creek empties to the Fox River. The mean orthophosphate concentration of 0.056mg/L was estimated from 1979 to 1997. The nitrate concentrations do not exceed the drinking water standard (10mg/L) and the orthophosphate concentrations are below the general concentration level (0.1mg/L). In addition, the concentrations of nitrate and orthophosphate have remained stable during the period of record.

3. Watershed Model and Model Parameters

Typically, watershed models can operate on a watershed as a whole, integrating all loads with a watershed, and allow for the subdivision of the watershed to contributing sub-watersheds. HSPF is a continuous simulation model but is capable of simulating individual storm events as well. Even though model can be run for one-minute time step, an hourly time-step is most commonly used (Bicknell et al. 2001). Although HSPF enables users to study both long-term and

short-term impacts, long-term simulation is used in this study. HSPF has three application modules: Pervious Land Segment (PERLND), Impervious Land Segment (IMPLND), and Free-flowing Reach or Mixed Reservoir (RCHRES) (Bicknell et al. 2001). As PERLND simulates the water quality and quantity processes that occur on pervious land areas, it is the most frequently used part of HSPF. IMPLND is used in urban areas where little or no infiltration occurs. The RCHRES module simulates stream behavior. HSPF employs Kinematic wave method and interaction of hydraulic processes to simulate both overland flow and channel flow routing.

As an analytical tool, the model has been used for flood control planning and operation; river bas and watershed planning; storm drainage analysis; fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances (Donigian et al. 1997); water quality planning and management (Bicknell et al. 1985); point and nonpoint source pollution analyses (Donigian et al. 1991); soil erosion and sediment transport studies; and evaluation of urban and agricultural best management practices (Moore et al. 1992). This model is suitable for both urban and rural areas (Donigian et al. 1991). The HSPF reasonably represents the hydrology and

water quality of an urbanizing watershed (In et al. 2004). It implies that it can be utilized for future assessment of land use impacts on stream water quality concentrations. The HSPF has a reliable capacity in predicting yearly sediment, and nutrient loads. Annual volume, monthly, and daily flow predictions are correlated well with measured flow. However, predictions could be poor during extended dry weather periods in developed watersheds and it was documented in a previous study (Ackerman et al. 2005). It is mainly due to artificially introduced water from various human activities, such as landscape overwatering during dry weather periods. That would be difficult variable. HSPF also has the limitation of predictions for months having extreme storm events and hydrologic conditions (Borah et al. 2004).

As the most currently available data, land use of the year 1994 is determined to be used. Point source discharge data are not applied here. In the Blackberry Creek watershed only two discharging facilities were active during the calibration years of 1992 to 1995. Neither had significant impacts on hydrology, nitrate and orthophosphate levels. For a meteorological dataset, the gaging station at Chicago Midway Airport is selected since the station is the nearest to the study site and it has the most complete historical records from the year 1970 to 1995, especially, for hourly

<Table 1> Annual Values of INTERCEP and LZETP from international Best Management Practice Database

Land Use	INTERCEP(mm)	LZETP(mm)
Residential	58.4	8.1
Commercial	55.9	7.1
Industrial	50.8	6.4
Cropland	60.0	8.5
Grassland	61.0	8.9
Forest	62.0	10.2

(<http://www.bmpdatabase.org>, accessed May, 2005)

precipitation. A simulation time period of 1970 to 1995 is used based on the availability of hourly precipitation records.

The watershed hydrology is affected by numerous parameters, including interflow and infiltration parameters in PERLND and flow routing RCHRES module. All appropriate modules are selected from PERLND, IMPLND, and RCHRES modules of HSPF. In a PERLND module, lower zone evapotranspiration parameter and interception storage capacity are determined to be constant because monthly variances are not an issue in this study. The sensitive parameters for watershed hydrology are identified as follows(USU, 2003 ; USEPA, 2002b): lower zone nominal storage(LZSN), index to the infiltration capacity of the soil(INFILTR), monthly interception storage capacity (MON-INTERCEP), monthly upper zone nominal storage(MON-UZSN), monthly

interflow recession parameter (MON-IRC), monthly lower zone evapotranspiration parameter dex(MON-LZETP), and interflow flow parameter index(TFW). Among them, MON-INTERCEP and MON-LZETP are the most sensitive parameters. <Table 1> shows the annual values of interception storage capacity (INTERCEP) and lower zone

evapotranspiration parameter(LZETP) referenced from international Best Management Practice Database for this modeling purpose(See <Table 1>). In addition, both general and site-specific parameters required for simulation are added to the model. The Quality Constituents Using Simple Relationships(PQUAL) and Washoff of Quality Constituents Using Simple Relationships (QUAL) modules are selected for the nitrate and orthophosphate simulations. To characterize behaviors of nitrate and orthophosphate, the followings are simulated monthly for each land use type and constituent: initial storage(SQO), maximum storage(SQOLIM), washoff potency factor indicating the ratio of constituent yield to sediment outflow (POTFW), scour potency factor(POTFS), rate of accumulation(ACQOP), rate of surface runoff which will remove 90% of constituent per hour(WSQOP), concentration of the constituent interflow outflow(IOQC), and concentration of constituent in active

<Table 2> Calibration and Validation Targets indicating Percentage Differences between Simulated and Recorded Values from Calibration and Verification Issues. In HSPF Training Workshop Handbook

Calibration Constituent	Very good(%)	Good(%)	Fair(%)
Hydrology / Flow	< 10	10~15	15~25
Sediment	< 20	20~30	30~45
Water temperature	< 7	8~12	13~18
Water quality /Nutrients	< 15	15~25	25~35

groundwater outflow (AOQC) (Bicknell et al. 2001). These modules simulate nitrate, and orthophosphate from pervious and impervious and segments using relationships with water and sediment yield. For the calibration purposes, the observed streamflow, nitrate, and orthophosphate data are added the model. The flow data are obtained from National Hydrography Dataset and water quality data are collected from US Environmental Protection Agency(USEPA) and USGS.

4. Model Calibration

The calibration and validation of discharge, stream temperature, nitrate, and orthophosphate ensure that the model produces a reasonable prediction of water quality at the watershed scale. All of them are calibrated and validated at Yorkville, Illinois, US. The year 1992 and 1993 datasets are used for the model calibration and 1994 and

1995 datasets are used to validate the model. The table indicates the referenced model calibration and validation targets(See <Table 2>)(Donigian. 2000). A measure of R^2 is adopted for the calibration and

validation targets for monthly discharge. When R^2 is 0.9, 0.8, and 0.7, the agreement between simulated and observed monthly discharge is very good, good, and fair, respectively(Donigian. 2000).

Annual calibration is conducted first followed by monthly calibration. The percentage differences between the simulated and the measured annual discharges are 13% and 3% for 1992 and 1993, which are classified as 'very good' to 'good' calibration. The monthly R^2 is 0.9 for the year 1992 and 0.6 for 1993 indicating 'very good' to less than 'fair'. The percentage differences between the simulated and the measured annual discharges are 25% and 31% for 1994 and 1995. These are considered 'fair' to lower than 'fair' for purpose of validation. Monthly R^2 is 0.5 for the year 1994 and 0.6 for 1995 indicating less than 'fair'. The lack of agreement between simulated and observed monthly discharge does not necessarily

indicate poor model performance. The model output is useful as it can provide an adequate representation of general watershed behavior. The differences are due to several factors. For example, the distance from the study site to the meteorologic data station can result in distorted weather patterns of the site, such as convective events.

The model simulates instream temperature with a 'very good' fit to the monitored dataset for the year 1992 and 1993. The percentage differences between the simulated and the measured mean values are 1.8% and 1.9% for 1992 and 1993 respectively. For the validation period, the model shows 'very good' fits between simulated and observed values. The percentage differences between the simulated

and the observed mean values are 1.8% for both 1994 and 1995.

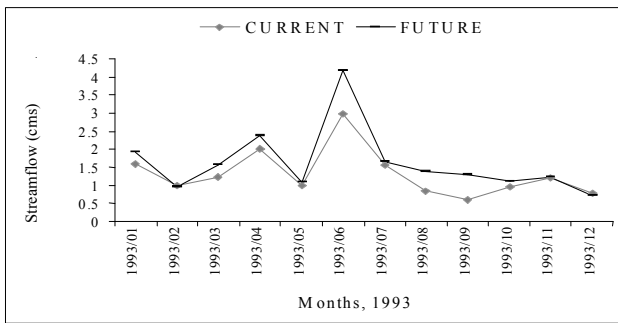
For nitrate and orthophosphate calibration, annual calibration is used because the nutrient dataset from the US Geological Survey(USGS) does not have sufficient records for monthly calibration. The calibration results for nitrate show that the percentage differences between the simulated and the measured annual mean concentrations are 28% and 65% for 1992 and 1993, which are considered 'fair' to lower than 'fair'. In validation, the percent differences between the simulated and the measured annual mean values were 22% and 67% for 1994 and 1995, respectively, which are considered 'good' and lower than 'fair'.

The calibration results for orthophosphate show that the percentage differences between the simulated and the measured annual mean concentrations are 5.3% and 15.7% for 1992 and 1993, which are considered a 'very good' to 'good' calibration. The percentage differences between the simulated and the measured annual mean values are 5.4% and 1.3% for 1994 and 1995,

<Table 3> Different Land Use Proportions in the Current and Future Land Use Plans

Land Use	Current Land Use(%)	Future Land Use(%)
Cropland	54.6	44.7
Grassland	29.1	21.6
Forested land	6.0	5.8
Barren land	0.5	0.5
Low density residential	2.8	7.3
Medium density residential	2.0	4.4
High density residential	0.9	17.6
Wetland	4.2	2.9
Total	100.0	100.0

<Figure 2> Different Mean Streamflows from the Current and Future Land Uses at Yorkville, Illinois



5. Simulation

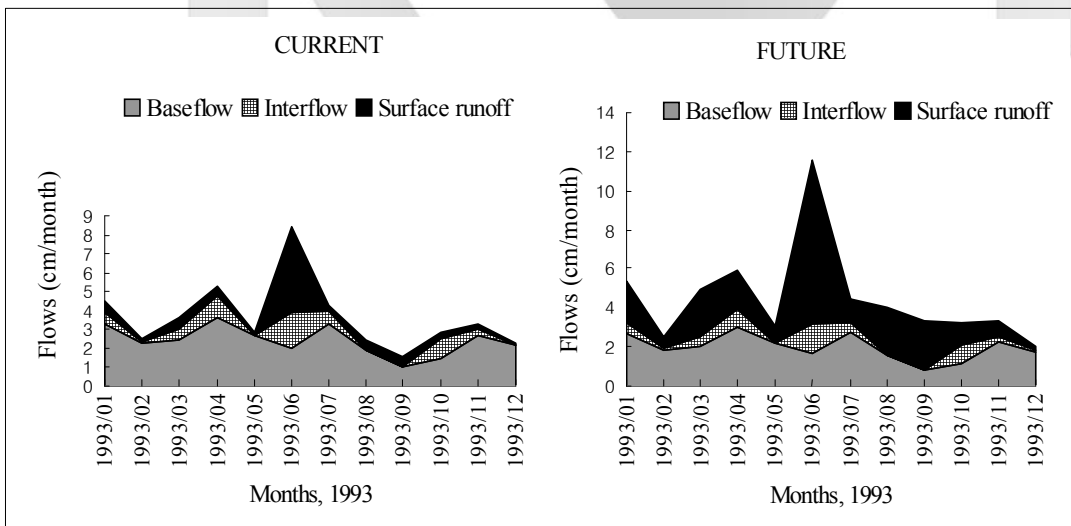
Two scenarios are developed based on two land use plans: 1) current agricultural land use with existing forested stream buffer, and 2) future urbanized land use with preserved forested stream buffer. The current land use plan of the year 1994 is used to represent the agricultural land use.

which are considered ‘very good’ validation for this study. Sediment calibration is not conducted due to the absence of historical sediment data. However, sediment simulation is assumed to be good enough for the scenarios comparison because orthophosphate exported with sediment and the calibration of orthophosphate is successful.

The 2020 Land Resource Management Plan(LRMP) of the Kane County is used to represent a future land use plan. The LRMP employs conservation practices through the preservation of forested stream corridor buffers for water resource management and environmental protection.

Physical characteristics of the stream buffer included in the LRMP are addressed in

<Figure 3> Different Seasonal Flows from the Current and Future Land Uses at Yorkville, Illinois



municipalities' zoning, and stormwater management plans crossing over the Blackberry Creek watershed including Kane County, Kendall County, and Village of Sugar Grove. Most plans regulate preservation of existing riparian zone. Village of Sugar Grove addresses their existing riparian zone in their zoning ordinance that it has natural vegetation along the edge of a stream that modulates temperature, that provides nutrient input into the stream system, that provides a buffer for interception of surface runoff filtering out sediments and pollutants, and that serves habitats and mitigation corridors for wildlife. In size, Sugar Grove's zoning ordinances(Sec. 7.1E) address that when surface waterbody has either floodplain, high quality native plant communities, major stands of trees, or riparian zone, a minimum width not less than 60 m shall be set aside for stream corridor buffers. Kane County stormwater ordinance(Sec. 418) regulates 15 m of stream buffer. Kendall County specifies a native riparian buffer with 7m in length and 23 m in width(Kane County. 2004). Overall, the corridor buffer in the study site has functionally sound mechanism as described in Sugar Grove's zoning ordinances.

In the current land use, 55% of the land in the watershed is in agricultural use while only 6% is in urban use. In the future land use plan, 45% of the watershed is in agricultural use and 30% is in urban use. In the future land use, high density residential is greatly increased to accommodate the increasing numbers of people

in the watershed(See <Table 3>). However, forested stream corridor buffer remains unchanged.

The first scenario is simulated for the model calibration and validation purposes. All parameters used for the current land use model are used equally for the second scenario. Thus, there is no difference between the current land use and the future land use plan models except the land use managements.

III. Results

Precipitation is the most important factor affecting the hydrologic cycle in a watershed. As one of most deterministic inputs in HSPF, precipitation is used as the major criterion to select the modeled year. Since 1993 has the most complete precipitation data from 1992 to 1995, two models are compared at the year 1993 to see the changes of discharge, sediment, instream temperature, and nutrients. Each has a small number of samples(12 months of the year 1993), thus, a one tail paired T-test is used to see if one is greater than the other with statistical significance. The confidence level is set to 0.2 because the calibration resulted with approximately 20% differences.

The mean streamflow at Yorkville is $1.31\text{m}^3/\text{s}$ in the current land use and $1.62\text{m}^3/\text{s}$ in the future land use plan. The future land use plan generates more streamflow than the current

land use with statistical significance ($P < 0.01$) (See <Figure 1>).

Surface runoff, interflow and baseflow from the two scenarios are compared. The mean baseflow at Yorkville is 2.4 cm/month in the current land use and 1.98 cm/month in the future land use plan. The future land use plan causes less baseflow than the current land use with statistical significance ($P < 0.01$). The mean interflow at Yorkville is 0.54 cm/month in the current land use and 0.44 cm/month in the future land use plan. The future land use plan generates less interflow than the current land use with statistical significance ($P < 0.01$). The mean surface runoff at Yorkville is 0.71

cm/month in the current land use and 2.08 cm/month in the future land use plan. The future land use plan generates more surface runoff with statistical significance ($P < 0.01$). In the current land use, baseflow is 72%, interflow is 12% and overland flow is 16% of total runoff. In the future land use plan, baseflow and interflow are decreased to 51% and 9%, respectively. However, the proportion of overland flow is increased to 40%. Seasonally, the effect is especially noticeable in the growing seasons since many places were converted from agricultural to residential uses (See <Figure 3>).

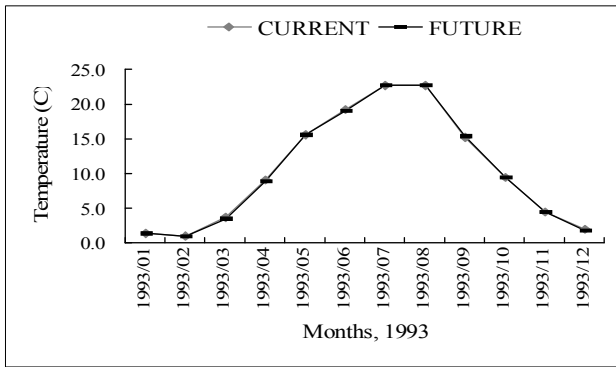
The total sediment load from the whole watershed is 15,594 and 18,201 tons/year under the current land use and future land use plan, respectively. The mean sediment load is 1,949

and 2,275 tons/month for the current land use and future land use plan, respectively. However, the amount of sediment from the future land use plan is not significantly greater than the amount from the current land use with statistical significance ($P = 0.32$). Increased sediment generation comes from urban development, especially high-density residential. Increased sediment from urban areas may have offset decreased sediment yield from agricultural areas.

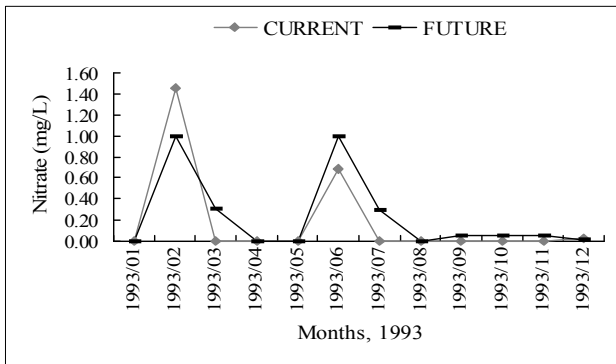
The mean in stream temperature at Yorkville is 10.51 and 10.45 °C for the current land use and the future land use plan, respectively. Although there are no dramatic differences, the future land use plan decreases instream temperature with statistical difference ($P < 0.01$). This is expected because instream temperature is decreased when inflow is increased under equal amount of solar energy (See <Figure 4>).

The mean nitrate concentration at Yorkville is 0.18 mg/L and 0.30 mg/L for the current land use and the future land use plan, respectively. However, the difference in concentration is not statistically significant ($P = 0.25$) (See <Figure 5>). The mean orthophosphate concentration at Yorkville is 0.04 mg/L and 0.04 mg/L for the current land use and the future land use plan, respectively, and is not statistically significant ($P = 0.46$) (See <Figure 6>).

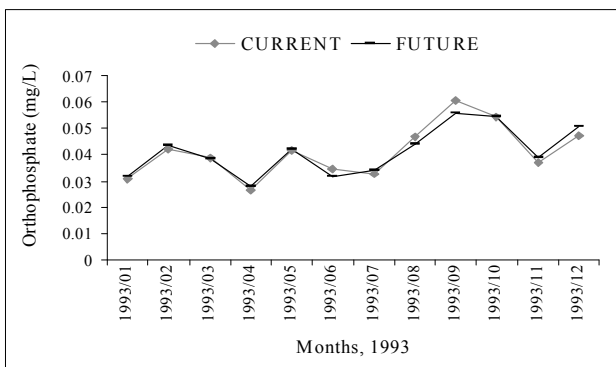
<Figure 4> Different Instream Temperature from the Current and Future Land Uses at Yorkville, Illinois



<Figure 5> Different Nitrate Concentrations from the Current and Future Land Uses at Yorkville, Illinois



<Figure 6> Different Orthophosphate Concentrations from the Current and Future Land Uses at Yorkville, Illinois



IV. Discussion

The results report that discharge rates increase following development. This calls into question whether the forested stream corridor buffer included in the future land use is sufficient. While infiltration and subsequent subsurface storage increases, the change is insufficient to maintain or reduce average runoff.

Orthophosphate is found not to change between scenarios. This may be due to offsets in loading between displaced agricultural land uses and addition of residential land uses in that orthophosphate from urban land uses are stemmed from use of fertilizers and detergents. Nitrate is found to be slightly increased in respond to the simulated urbanization.

The future land use increases the surface runoff in Blackberry Creek watershed. However, the future land use does not increase the instream concentrations of nitrate and orthophosphate in the watershed. The increase of surface runoff heightens the risk of flooding in the watershed. Under the future land use, the watershed is not able to avoid flooding events occurred during the past few years in the

watershed. In this study, in the absence of more intensive land use management strategies, urbanization, even if including extensive land acquisition for the forested stream corridor buffer, still increases surface runoff.

The impact of future land use on sediment and nutrients is neither positive nor negative in this study. Both agricultural and urban land uses may have similar effects on water quality. The current land use and the future land use generate the same seasonal pattern in orthophosphate concentrations. However, nitrate concentrations show each different pattern between current land use and future land use. In the current land use, the nitrate concentrations reflect the typical agricultural environments with high concentrations at the winter season and low concentrations at the crop-growing season. In contrast, the future land use shows a pattern that is not governed by the crop.

A study previously conducted for Polecat Creek watershed in Caroline County, Virginia, US showed a similar result (In et al. 2003). They reported that urbanization from undeveloped lands increased sediment loads mainly due to increases in channel erosion. Nitrate loads increased for a future land use scenario reflecting urbanization, as compared to the undeveloped lands. The increases in nitrate loads may result from increases in residential land and associated fertilizer use

and concurrent decreases in forested land.

This study addresses that 1) the preserved buffer is not sufficient and it should be increased as urban area increases to manage the increased volume of surface runoff, 2) the stream buffer may be not a sufficient strategy and there is a need to examine other infiltration based land use strategies in the overall watershed rather than the stream corridor only. Planning strategies that reflect conservation practices are thought to help ameliorate the negative aspects of urbanization through techniques such as acquisition of preservation areas, especially along riparian corridors. If the practices are effective, then storm water runoff should not increase, and the water quality of receiving waters should not be decreased relative to present conditions.

A variety of land use scenarios can be simulated through the HSPF modeling to test their effectiveness in a watershed context. Under this model environment, the functionality of wetlands, riparian buffers, retention ponds, terraces, can be assessed in future studies. It is invaluable to provide a technical tool for demonstrating and experimenting numerous plans to different stakeholder groups to allow them see the trade-offs among land use management alternatives.

To support the implementation of

sustainable development with the reduction of flooding and nonpoint source pollution problems, further study will be necessary in urbanizing watersheds to consider more effective implementation of land use techniques or urban development patterns.

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초 록

소유역의 토지이용 변화에 따른 하천 유량과 수질 변화에 관한 연구

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근래 미국에서는 각 지방 행정기관의 토지이용구역(Zoning) 및 우수관리 조례 (Stormwater Management Ordinance)에 의거 하천 녹지대가 광범위하게 입안 및 시행되어지고 있다. 하천 녹지대는 지표면에 존재하는 유출(Surface Runoff) 과 비점오염(Nonpoint Source Pollution)의 지반 흡수를 통해 하천의 수질 보호와 홍수의 주요소인 유출량 감소를 목적으로 하는 하나의 토지 이용 기법으로 받아들여지고 있다. 이 논문은 소유역의 토지이용 변화에 따른 하천 유량과 수질의 변화에 관한 내용을 다루고 있다.

분석 방법으로는, Hydrological Simulation Program Fortran(HSPF) 프로그램을 사용하여 미국 일리노이 시카고시와 인접한 한 유역을 선정, 모형을 하였다. 하천 유량과 수질변화 분석을 위해서는 다음 두 종류의 토지이용계획이 모형 되었다: 1) 현재 토지 이용계획으로서 기존의 하천 녹지대를 포함한 농지 중심의 토지이용, 2) 예측된 토지 이용계획으로서 보존된 하천 녹지대를 포함한 도시화된 토지이용. 하천 녹지대를 포함하는 도시화의 영향을 나타내는 지표로서 다음 두 가지가 분석되었다: 1) 홍수 방지 실효성의 지표로서 지표 유출량(Surface Runoff), 2) 비점오염 실효성 지표로서 질산염 (Nitrate)과 인산염(Orthophosphate).

분석된 결과는 다음과 같다. 예측된 토지 이용계획은 현재 계획과 비교해 볼 때, 더 많은 양의 지표 유출량을 나타내고 있으나, 두 계획 간의 질산염과 인산염의 차이는 나타나지 않았다. 이를 통해 다음 두 가지 사실을 유추할 수 있다: 1) 기존 하천 녹지대의 보존만으로는 도시화에 따라 증가하는 지표 유출을 적절히 대처 할 수 없으며, 도시화가 되는 만큼, 하천 녹지대의 크기 역시 증가되어야 한다 2) 하천에 인접해야 하는 위치적인 특성을 고려해 볼 때, 하천 녹지대의 보존이 지표 유출과 비점오염 흡수에 대한 충분한 기법이 아닐 수도 있다. 따라서 효과적인 지표 유출 및 비점오염 흡수를 위해서, 하천 주변에만 의존하기 보다는 전반적인 도시 유역 내에 입지 할 수 있는 다른 형태의 토지이용 기법 및 개발방식에 관한 연구가 필요하다.