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Investigating effects of low impact development on surface runoff and TSS with a calibrated hydrodynamic model

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ABSTRACT. – The land development and increase in urbanization in a watershed affect water quantity and water quality. Especially, uncontrolled urbanization causes flood and poor water quality which results in an increase in peak flow rate and in Total Suspended Solid (TSS) concentration. Low Impact Development (LID) is a Best Management Practice (BMP) and land planning method which may be used to manage storm water runoff in order to reduce flooding as well as simultaneously improve water quality. In this study, the impact of "LID-BMP" on surface runoff and TSS is investigated by employing a calibrated hydrodynamic model for Sazlıdere Watershed which is located in Istanbul, Turkey. For this purpose, a calibrated hydrodynamic model was developed by using Environmental Protection Agency Storm Water Management Model (EPA SWMM). For model calibration and validation, a rain gauge and a flow meter are set into the field and rainfall and flow rate data are obtained. And then, several LID types are selected such as retention basins, vegetative swales and permeable pavement and their influence on peak flow rate and pollutant buildup and washoff for TSS are obtained. Consequently, the possible effects of LID on surface runoff and TSS in Sazlıdere Watershed are observed.

Key words: Low Impact Development, TSS, hydrodynamic model, SWMM-LID, Sazlıdere, Turkey

Étude des effets d'un développement à faible impact sur le ruissellement de surface et le total des solides en suspension avec un modèle hydrodynamique étalonné

RÉSUMÉ. – L'aménagement du territoire et l'augmentation de l'urbanisation dans un bassin affectent la ressource en eau en quantité et en qualité. En particulier, l'urbanisation incontrôlée produit des inondations et une eau de mauvaise qualité, ce qui conduit à une augmentation du débit de pointe et de la concentration du Total des Solides en Suspension (TSS). Le Développement à Faible Impact (DFI) est une pratique de gestion et d'aménagement du territoire (BMP) souvent utilisée pour gérer les eaux pluviales afin de réduire les risques d''inondation et d'améliorer la qualité de l'eau. Dans cette étude, l'impact de « DFI-BMP »» sur le ruissellement de surface et le TSS a été examiné en utilisant un modèle hydrodynamique étalonné pour le bassin de Sazlıdere situé à Istanbul en Turquie. A cet effet, un modèle hydrodynamique étalonné a été développé en utilisant le Modèle de Gestion des Eaux Pluviales de l'Agence de Protection de l'Environnement (EPA SWMM). Pour étalonner et valider le modèle, un pluviomètre et un débitmètre sont installés sur le terrain et produisent les données utilisées. Ensuite, plusieurs types de DFI ont été sélectionnés tels que les bassins de rétention, les baissières végétatives et les pavés perméables, pour étudier leur influence sur le débit de pointe et l'accumulation et le lessivage de polluants par le TSS.

Mots-clés : Développement à faible impact, Total des Solides en Suspension, modèle hydrodynamique, Modèle de gestion des eaux pluviales, Sazlıdere, Turquie

I. INTRODUCTION

High peak flow rates and huge amount of TSS yield problems such as flooding and poor water quality. These problems are observed more frequently due to extensive urbanization within watersheds. Implementing Low Impact Development (LID) type of storm water Best Management Practices (BMPs) has recently been recognized as a useful solution. LID BMPs is an approach of land re-development in order to manage storm water and water quality. Preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage, which treats storm water as a resource rather than as a waste product, are intended by implementing LID. There are several LID type of storm water BMPs such as bioretention, vegetated rooftops, rain barrels, vegetative swales and permeable pavements [US EPA, 2000]. LID has several benefits such as protecting animal habitats, improving management of runoff and flooding, and reducing impervious surfaces. Furthermore, LID increases surface water quality by reducing TSS and other pollutants.

The importance of LID BMP implementation has been recognized recently in the literature [Ahiablame *et. al.*, 2012; Fassman, 2012; Alfredo *et. al.*, 2010; Elliott *et. al.*, 2010; Lucas, 2010; Gilroy and McCuen, 2009; Bedan and Clausen, 2009]. Zhang *et. al.* (2009) presented a study on the use of BMPs for controlling nonpoint source pollution in the Xikeng Reservoir watershed located in Shenzhen, China. LID types of BMPs are used and good results in reducing TSS are obtained in this study. Haifeng *et. al.* (2012) made an analysis of implementing LID type of BMPs for urban runoff control and obtained the benefits of optimized LID BMP implementation in reducing runoff volume and peak flow rates.

In the literature, there are many studies related to water quantity and quality modeling by using EPA SWMM

[Gülbaz and Kazezyılmaz-Alhan, 2013; Karakoçak *et al.*, 2013]. Chang *et al.* (2008) formed a model by using EPA SWMM for two industrial parks in Taiwan in order to correlate the relationship between pollutant mass and the runoff volume. Aad *et al.* (2010) developed new modeling techniques for two BMPs, which are rain gardens and rain barrels, implemented in EPA SWMM. Surface runoff and several water quality parameters measured on a watershed in Santander (Spain) were modeled by Temprano *et al.* (2006).

In this study, Sazlıdere Watershed located on the European Continental side of Istanbul in Turkey is selected as the study site. Protecting and improving Sazlıdere Watershed have great importance as it supplies a major portion of drinking water of Istanbul. There are some studies related to water quality and quantity of Sazlıdere Watershed [Taner *et al.*, 2011]. Sazlıdere area is composed of mostly low density residential area and some high density residential, commercial, forest and dam areas. And also, LID BMPs application may be used in Sazlıdere Watershed. The aim of this study is to investigate the effects of implementation of LID type of BMPs on amount of surface water and TSS control by using a calibrated hydrodynamic model for Sazlıdere Watershed. For this purpose, EPA SWMM is employed to model Sazlıdere Watershed by using data related to watershed characteristics. The hydrodynamic model was calibrated by using rainfall and flow rate measured on the field site. Then, by using the hydrodynamic and water quality model, the surface runoff and TSS developed over the watershed under measured storm events are simulated. Finally, some LID types of BMPs such as bioretention, vegetative swales and permeable pavement are selected and their influence on surface runoff volume and peak flow rates and TSS loadings are obtained. Consequently, the possible effects of LID BMPs on surface runoff and TSS in Sazlıdere Watershed are observed.

II. MATERIALS AND METHODS

II.1. Governing Equations

EPA SWMM is an event model dynamic simulation for the surface runoff on a watershed [Rossman, 2010; Huber and Dickinson, 1988]. EPA SWMM calculates the quantity and the quality of surface runoff on each subcatchment; the flow rate, depth, and concentration in each conduit and junction. The temporal dynamics of rainfall intensity (hyetograph) is given as input to the program; change of flow rate (hydrograph) and change of concentration (pollutograph) through time are obtained as output from the program. In order to calculate flow rate, EPA SWMM solves the continuity and momentum equations for flood routing. The most general form of the flood routing equations is the dynamic wave equations which describe unsteady non-uniform flow. Kinematic and diffusion wave equations are obtained from dynamic wave equation by neglecting pressure and inertial forces acting in momentum equation. The diffusion wave equation obtained from the dynamic wave equation for flow routing is used in this study and is given as follows [Ponce, 1989]:

$$\left.\begin{array}{l}\dfrac{\partial A}{\partial t}+\dfrac{\partial Q}{\partial x}=0\\ S_f=S_0-\dfrac{\partial y}{\partial x}\end{array}\right\}\Rightarrow \frac{\partial Q}{\partial t}+c\,\frac{\partial Q}{\partial x}=K\,\frac{\partial^2 Q}{\partial x^2}\ \ \}$$
$$\Rightarrow\ c=mV \quad K=\frac{Q}{2BS_0} \tag{1}$$

where Q is the flow rate (L^3/T), A is the cross-sectional area (L^2), y is the water depth (L), S_f is the friction slope (L/L), S_0 is the bed slope (L/L), t is the time (T), x is the distance (L), c is the diffusion wave celerity (L/T), V is the velocity (L/T), K is the hydraulic diffusivity (L^2/T), B is the width (L) and m is given according to the flow rate-friction slope relationship. In order to calculate infiltration, EPA SWMM uses three methods, which are the Green-Ampt method, the Integrated Horton Method, and the Soil Conservation Service (SCS) Curve Number Method. The Green-Ampt Method is selected as the infiltration method because it is more suitable to calculate infiltration in rural areas as in the case of Sazlıdere Watershed. In our study area with high clay content, the infiltration capacity is small and therefore, the rainfall rate typically exceeds the infiltration capacity which results in Hortonian flow.

Pollutant accumulation (Pollutant Buildup) in EPA SWMM is calculated as proportional to time raised to some power, until a maximum limit is achieved by using Power Function. For Exponential Function, pollutant buildup follows an exponential growth curve. And finally, for Saturation Function, pollutant buildup begins at a linear rate. Furthermore, the amount of pollutant accumulation is a function of number of preceding dry days. In this study, power function is used for pollutant buildup and is given as follows [Rossman, 2010]:

$$B\ = Min\left(C_{1p}, C_{2p}\, t^{C_{3p}}\right) \tag{2}$$

where B is the pollutant buildup (M/L^2), C_{1p} is the possible maximum buildup (M/L^2), C_{2p} is the buildup rate constant (M/TL^2), C_{3p} is the time exponent for the buildup parameter (*dimensionless*) and t is the time (T).

Pollutant washoff in EPA SWMM is calculated as proportional to the product of runoff raised to some power and to the amount of buildup remaining by using Exponential Function. For Rating Curve Function, pollutant washoff is calculated as proportional to the runoff rate raised to some power. And finally, Event Mean Concentration is a special case of Rating Curve Washoff where the Rating Curve exponent is 1. Rating Curve washoff function is used in this study and is given as follows [Rossman, 2010]:

$$W_{rc}=C_{3rc}\,Q^{C_{4rc}} \tag{3}$$

where W_{rc} is the amount of washoff pollutant (M/T), C_{3rc} is the washoff coefficient (M/L^3), C_{4rc} is the washoff exponent (*dimensionless*) and Q is the runoff rate (L^3/T).

II.2. Study Area

Sazlıdere Watershed located on European Continental side of Istanbul, Turkey has 165 km^2 of drainage area and the surface runoff generated over Sazlıdere Watershed flows to Sazlıdere Dam Lake (Fig.1). In this study, part of the Sazlıdere Watershed with a surface area of 38 km^2 is modeled. Although, Sazlıdere Watershed involves mostly low density residential areas, there is a big trend of urbanization due to population increase and migration in this region. Therefore, there is potential risk of flooding and water pollution which creates the necessity of taking immediate precautions.

Fig. 1: *Location and boundary of Sazlıdere Watershed (Retrieved from Google Earth, Imagery provided courtesy of DigitalGlobe ©2012, © 2012 TerraMetrics, © 2012 GeoEye, © CNES/SPOT IMAGE).*

II.3. Model Development

In order to determine the input parameters for hydrodynamic and water quality model in EPA SWMM, topographical map of the modeled area, cross-sectional area of the main stream called Türkköse Stream and soil properties of the study area are used. The hydrodynamic model of part of the Sazlıdere watershed was established by defining 177 subcatchments, 173 conduits, which are approximately 44 km long in total, and 171 junctions, which connect the conduits. In addition, rainfall and flow rate were measured on the field site by setting up a rain gauge in the middle of the watershed and a flow meter near downstream of Türkköse Stream during September 2009-May 2010, which were then used for calibration and verification of the hydrodynamic model (Gülbaz and Kazezyılmaz-Alhan, 2013). The range of the water quantity parameters during the calibration processes is listed in Table 1. In order to establish the water quality model in EPA SWMM, Power Build-up and Rating Curve Washoff functions are defined for buildup and washoff of TSS on low density residential land use, respectively. Then, TSS is selected as the water quality parameter in order to investigate sediment transport in the Türkköse Stream. In order to determine water quality input parameters, buildup rate constant, buildup time exponent, washoff coefficient and washoff exponent are calculated based on the formula given by Tsihrintzis and Hamid (1998). These parameters depend on the rainfall and are also listed in Table 1.

The effects of LID's on Sazlıdere watershed are investigated by incorporating them into the SWMM model. EPA SWMM is capable of assessing the hydrological impacts of LID to storm water management systems. Several LID systems such as bioretention, infiltration trench, porous pavement, rain barrel and vegetative swale, may be modeled with EPA SWMM. As the final step of this study, LID BMPs are introduced into the calibrated model. Three types of LID are defined which are Bioretention, Vegetative Swale and Permeable Pavement. In order to implement these three types of LID into the model, the LID parameters listed in Table 2 are defined to the model. These parameters depend on the surface, pavement, soil, and storage layers for each LID type. The values for these parameters are selected

Table 1: *Water Quantity and Quality model parameters and coefficients used in EPA SWMM (*modified after *Gülbaz and Kazezyılmaz-Alhan, 2013).*

Water Quantity Parameters for subcatchments, open channels and soil		**Range**	**Value**
Manning's roughness coefficient for impervious area *(N)*	Concrete	0.011-0.013	0.012
Manning's roughness coefficient for pervious area *(N)*	Cultivated soils	0.06-0.13	0.1
	Grass	0.15-0.41	0.15
Depth of depression storage on impervious area *(d) (mm)*	Concrete		0.127
Depth of depression storage on pervious area *(d) (mm)*	Cultivated soils		0.15
	Grass		0.175
Manning's roughness coefficient for the open channel *(n)*		0.040-0.10	0.09
Suction Head (S_u) *(mm)*		49-320	240
Hydraulic Conductivity *(K) (mm/hr)*		0.254-120	0.508
Initial Soil Moisture Condition			0.426
Water Quality Parameters for TSS		**Rainfall I**	**Rainfall II**
Buildup Time exponent C_{3p} *(dimensionless)*		1.65	3.64
Buildup Rate Constant C_{2p} (M/TL^2)		1.45	3.49
Washoff Exponent C_{4rc} *(dimensionless)*		1.74	0.45
Washoff Coefficient C_{3rc} (M/L^3)		187.52	489.83

Table 2: Properties of surface, pavement, soil and storage layers for LID implementation (Rossman, 2010).

Layer	Parameters	Bioretention	Vegetative Swale	Permeable Pavement
Surface Layer	Storage Depth *(mm)*	300	500	30
	Vegetation Volume *(Fraction)*	0.2	0.2	0.0
	Surface Roughness *(Manning's N)*	0.0	0.24	0.15
	Surface Slope *(Percent)*	0.0	1.0	1.0
	Swale Side Slope *(Run/Rise)*	NA	1.0	NA
Pavement Layer	Thickness *(mm)*	NA	NA	150
	Void Ratio *(voids/solids)*	NA	NA	0.17
	Impervious Surface Fraction	NA	NA	0
	Permeability *(mm/hr)*	NA	NA	2500
	Clogging Factor	NA	NA	0
Soil Layer	Thickness *(mm)*	750	NA	NA
	Porosity *(volume fraction)*	0.45	NA	NA
	Field Capacity *(volume fraction)*	0.19	NA	NA
	Wilting Point *(volume fraction)*	0.085	NA	NA
	Conductivity *(mm/hr)*	11	NA	NA
	Conductivity Slope	10	NA	NA
	Suction Head *(mm)*	110	NA	NA
Storage Layer	Height *(mm)*	250	NA	250
	Void Ratio *(voids/solids)*	0.6	NA	0.6
	Infiltration Rate *(mm /hr)*	0.508	NA	0.508
	Clogging Factor	0	NA	0

NA= Not Applicable

by using EPA SWMM manual and are given in Table 2 (Rossman, 2010). LID BMPs are performed on 1.14 km^2 of an area which corresponds to about 3% of the modeled watershed. The surface layer properties are used to describe the surface properties of bioretention, permeable pavement, and vegetative swales; the pavement layer properties are used to define values for permeable pavement LID; the soil layer properties are used to describe the properties of the engineered soil mixture used in bioretention types of LIDs; the storage layer properties are used to define the properties of the crushed stone or gravel layer used in bioretention and permeable pavement systems.

III. RESULTS AND DISCUSSION

The simulation results are presented for the storm event observed during March 06-09, 2010 and September 07-09, 2009 to model low and high (extreme) rainfall intensity impacts, respectively. The change in surface runoff and change in TSS concentrations with LID BMP implementation and with no LID BMP implementation are observed and compared. Effects of LID BMP implementation on runoff volume and peak flow rate and pollutant buildup and washoff for TSS are predicted.

III.1. The Impact of LID BMP Implementation on Water Quantity

In this part of the study, impacts of LID BMP implementation on runoff volume and peak flow rate are predicted. The flow developed over Sazlıdere Watershed is simulated under 2 rainfall events. The first one has a low intensity measured by our rain gauge set on the field site and the second one has a high (extreme) intensity recorded at Florya Meteorological Station in Istanbul, Turkey. These rainfall events are occurred on March 06-09, 2010 and on September 07-09, 2009.

Figure 2 shows the predicted flow rate versus time at the outfall of the Sazlıdere Watershed with LID BMP implementation and with no LID BMP implementation occurred during the rainfall event on March 06-09, 2010. As it can be seen from this figure, for the case with LID BMPs, peak of the hydrograph decreases from 7.45 m^3/s to 6.52 m^3/s. Furthermore, the total amount of surface water decreases from 252,768 m^3 to 218,357 m^3 (Table 3). In other words, when 3% of LID area is considered, the total amount of surface water generated over the catchment decreases 13.61%. The simulations are repeated for the storm event occurred on September 07-09, 2009 and the result is presented in Figure 3 and summarized in Table 3. As it can be seen from this figure, for the case with LID BMPs, the peak of the hydrograph decreases from 107.70 m^3/s to 94.78 m^3/s. Furthermore, the total amount of surface water decreases from 3,818,080 m^3 to 3,370,576 m^3 (Table 3). In other words, when 3% of LID area is considered, the total amount of surface water generated over the catchment decreases 11.72%.

While the reduction in water quantity is 34,411 m^3 for low rainfall intensity, it is 447,504 m^3 for high rainfall intensity. Thus, reduction in water volume for high rainfall intensity after LID implementation is about 13 times bigger than the reduction for low rainfall intensity. When the LID performance is compared, we observe that the reduction in water quantity

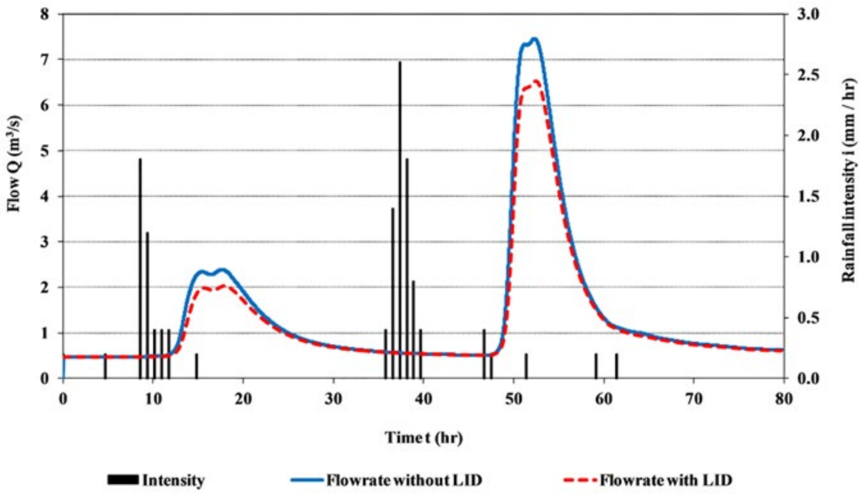

Fig. 2: *Predicted flow rate versus time at the outfall of the Sazlıdere Watershed with LID BMPs and with no LID BMPs during storm event observed between March 06-09, 2010.*

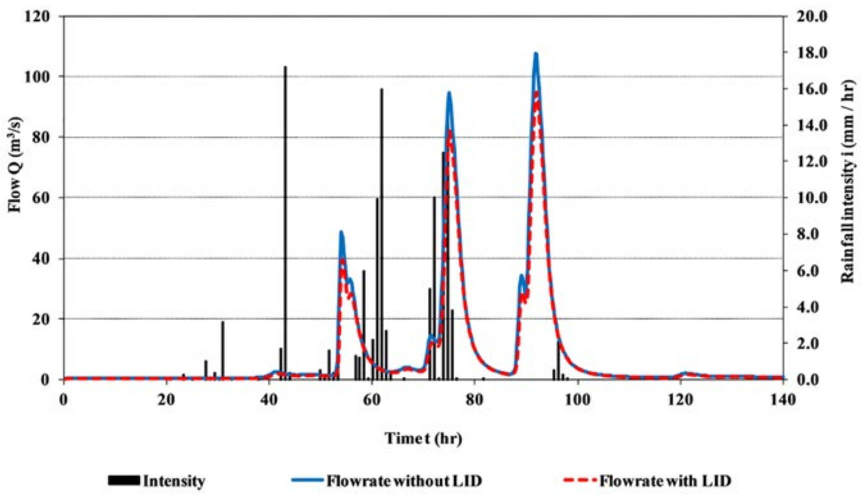

Fig. 3: *Predicted flow rate versus time at the outfall of the Sazlıdere Watershed with LID BMPs and with no LID BMPs during storm event observed between September 07-09, 2009.*

Table 3: Amount of water and flood generated on Sazlıdere Watershed during rainfall events I-II.

Water Quantity	Rainfall Event I March 06-09, 2010 (m^3)	(%)	Rainfall Event II September 07-09, 2009 (m^3)	(%)
Total volume of water before LID	252,768		3,818,080	
Total volume of water after LID	218,357		3,370,576	
Reduction in water quantity after LID	34,411	**13.61**	447,504	**11.72**

is 13.61% for low rainfall intensity, whereas it is 11.72% for high rainfall intensity. In fact, infiltration process plays an important role in runoff retention. During low rainfall intensity events, LID facilities can readily capture a major portion of inflow volume. On the other hand, the infiltration capacity of LID decreases during high rainfall intensity events which causes more surface runoff. Consequently, LID capacity decreases slightly when rainfall intensity increases.

III.2. The Impact of LID BMP Implementation on Water Quality

In this part of the study, impacts of LID BMP implementation on pollutant buildup and washoff for TSS are predicted. The pollutograph at the outlet of Sazlıdere Watershed is simulated under the same rainfall events which are used in water quantity analyses.

Figure 4 shows the predicted TSS concentration versus time at the outfall of the Sazlıdere Watershed with LID BMP implementation and with no LID BMP implementation. As it can be seen from this figure, for the case with LID BMPs, the peak of the pollutograph decreases from 38.16 mg/L to 36.62 mg/L. Furthermore, the total amount of TSS washoff over the watershed decreases from 6,952 kg to 5,779 kg (Table 4). In other words, when 3% of LID area is considered, the total amount of TSS washoff over the catchment decreases 16.87%. The simulations are repeated for the storm event occurred on September 07-09, 2009 and the result is presented in Figure 5 and summarized in Table 4. As it can be seen from this figure, for the case with LID BMPs, peak of the pollutograph decreases from 121.15 mg/L to 99.55 mg/L. Furthermore, the total amount of TSS washoff over the watershed decreases from 38,070 kg to 35,574 kg (Table 4). In other words, when 3% of LID area is considered, the total amount of TSS washoff over the catchment decreases 6.56%.

Slight to moderate level sheet, rill and channel erosions are observed in the Sazlıdere Watershed. There are some enlarged rills on the hill slopes but gully erosion is not the case. The major land use types are farmlands and pastures and the degradation level is not so severe to cause gullies. According to the observations at the site, grazing is not intensive and the pastures are in good condition. However, the indicators of channel erosion such as undercuts, stream bank collapses, and debris discharge are clear and frequently seen on the stream banks including Türkköse Stream. On the other hand, there is not a significant level of wind erosion in the watershed though some wind breaks are established at the borders of farms. Thus, sheet erosion on the slopes and channel erosion during high flows are the major causes of erosion and sedimentation in the Sazlıdere Watershed. Figure 6 shows photos of sheet and channel erosions taken at the field site.

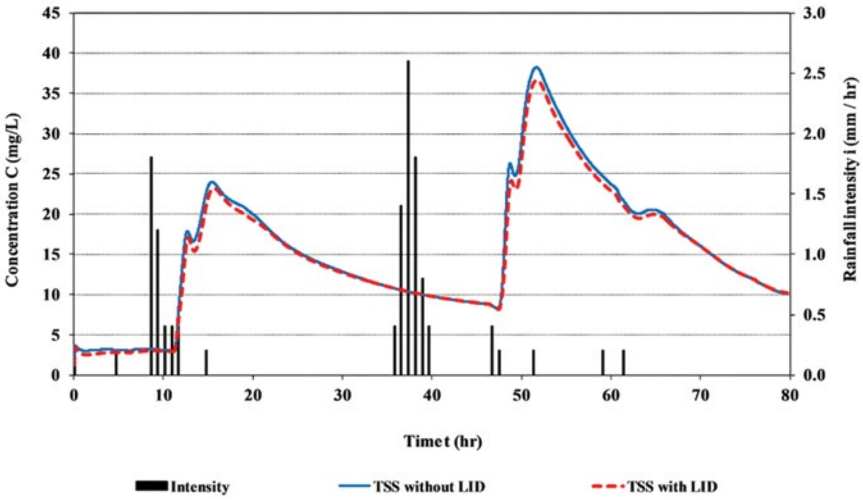

Fig. 4: *Predicted TSS concentration versus time at the outfall of the Sazlıdere Watershed with LID BMPs and with no LID BMPs during storm event observed between March 06-09, 2010.*

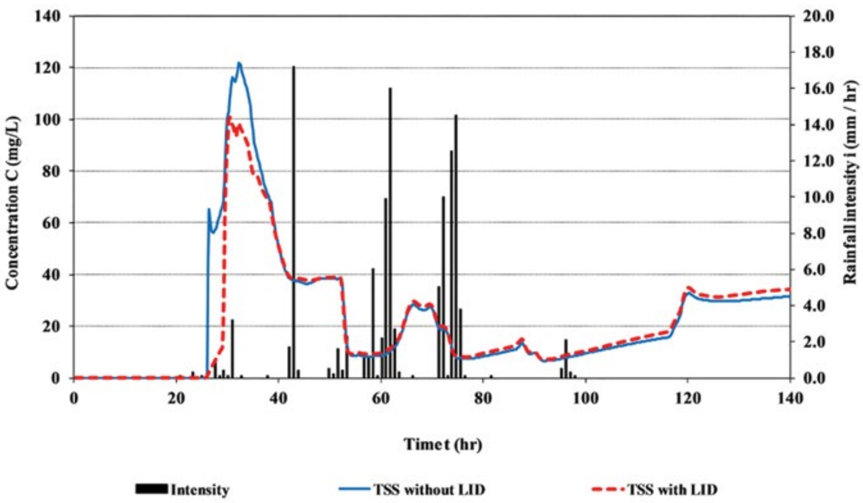

Fig. 5: *Predicted TSS concentration versus time at the outfall of the Sazlıdere Watershed with LID BMPs and with no LID BMPs during storm event observed between September 07-09, 2009.*

Table 4: Amount of TSS generated on Sazlıdere Watershed during rainfall events I-II.

Water Quality	**Rainfall Event I March 06-09, 2010 (kg)**	**(%)**	**Rainfall Event II September 07-09, 2009 (kg)**	**(%)**
Total amount of TSS before LID	6,952		38,070	
Total amount of TSS after LID	5,779		35,574	
Reduction in amount of TSS after LID	1,173	**16.87**	2,496	**6.56**

Fig. 6: *Sheet and Channel Erosions near the Türkköse Sream in Sazlıdere Watershed.*

IV. CONCLUSION

In this study, a hydrodynamic and water quality model is developed for Sazlıdere Watershed in Istanbul, Turkey by using EPA SWMM. Rainfall and flow rate at downstream of Türkköse Stream have been measured with rain gauge and flow meter set into the field site for calibration and verification purposes of the hydrodynamic model. Then, change in flow rate and TSS concentration are predicted with no LID BMP implementation over the Sazlıdere Watershed under typical rainfall events by using the measured data set on the site and extreme rainfall events recorded at Florya Meteorological Station in Istanbul, Turkey. In addition, the total amount of water and TSS washoff on the watershed are also calculated. After implementing LID type of storm water BMPs which are bioretention, vegetative swales and permeable pavement, flow rate and TSS concentration with LID BMPs and with no LID BMPs are compared. Moreover, total amount of water and TSS washoff on the watershed after LID BMP implementation are obtained and results are compared. It is found that LID BMP implementation in the Sazlıdere Watershed results in a decrease in the peak of the hydrograph and pollutograph (TSS) and total amount of surface water and TSS over the catchment. Thus, LID implementation controls surface runoff and water quality considerably in Sazlıdere Watershed. Further research area of this study would include developing a calibrated water quality model for the Sazlıdere Watershed and testing other LID BMP's.

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VI. REFERENCES

AAD M.P.A., SUIDAN M.T. AND SHUSTER W.D. (2010) — Modeling Techniques of Best Management Practices: Rain Barrels and Rain Gardens Using EPA SWMM-5. *Journal of Hydrologic Engineering.* **15 (6)** 434-443

AHIABLAME L. M., ENGEL B. A. AND CHAUBEY I. (2012) — Effectiveness of Low Impact Development Practices: Literature Review and Suggestions for Future Research. *Water Air Soil Pollutution.* **223 (7)** 4253–4273

ALFREDO K., MONTALTO F. AND GOLDSTEIN A. (2010) — Observed and Modeled Performances of Prototype Green Roof Test Plots Subjected to Simulated Low- and High-Intensity Precipitations in a Laboratory Experiment. *Journal of Hydrologic Engineering.* **15 (6)** 444-457

BEDAN E. S. AND CLAUSEN J. C. (2009) — Stormwater Runoff Quality and Quantity From Traditional and Low Impact

Development Watersheds. *Journal of the American Water Resources Association (JAWRA).* **45 (4)** 998-1008

Chang C.H., Wen C.G. And Lee C.S. (2008) — Use of Intercepted Runoff Depth for Stormwater Runoff Management in Industrial Parks in Taiwan. *Water Resources Management.* **22 (11)** 1609-1623

Elliott A.H., Spigel R.H., Jowett I.G., Shankar S.U. And Ibbitt R.P. (2010) — Model application to assess effects of urbanisation and distributed flow controls on erosion potential and baseflow hydraulic habitat. *Urban Water Journal.* **7 (2)** 91-107

Fassman E. (2012) — Stormwater BMP treatment performance variability for sediment and heavy metals. *Separation and Purification Technology.* **84 (SI)** 95–103

Gilroy K.L. And Mccuen R.H. (2009) — Spatio-temporal effects of low impact development practices. *Journal of Hydrology.* **367 (3-4)** 228–236

Gulbaz S. And Kazezyilmaz-Alhan C.M. (2013) — Calibrated Hydrodynamic Model for Sazlidere Watershed in Istanbul and Investigation of Urbanization Effects. *Journal of Hydrologic Engineering.* **18 (1)** 75–84

Haifeng J., Yuwen L., Shaw L. Y. And Yurong C. (2012) — Planning of LID–BMPs for urban runoff control: The case of Beijing Olympic Village. *Separation and Purification Technology.* **84 (SI)** 112–119

Huber W.C. And Dickinson R.E. (1988) — *Storm Water Management Model, Version 4, User's Manual. Athens, GA. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency (EPA)*

Karakoçak B. B., Yenigün O. And Toraman R.T. (2013) — An integrated approach to water management in Kayseri: rainwater collection and use in an amusement park. *Water Science and Technology.* **67 (5)** 1137–1143

Lucas W.C. (2010) — Design of Integrated Bioinfiltration-Detention Urban Retrofits with Design Storm and Continuous Simulation Methods. *Journal of Hydrologic Engineering.* **15 (6)** 486-498

Ponce V. M. (1989) — *Engineering hydrology: Principles and practices. Prentice-Hall, Englewood Cliffs, N. J*

Rossman, Lewis A. (2010) — *Storm Water Management Model, User's Manual, Version5.Water Supply and Water Resources Division National Risk Management Research Laboratory, Cincinnati, Ohio, U.S. Environmental Protection Agency, EPA/600/R-05/040*

Taner M.Ü., Üstün B. And Erdinçler A. (2011) — A simple tool for the assessment of water quality in polluted lagoon systems: A case study for Kucukcekmece Lagoon, Turkey. *Ecological Indicators.* **11 (2)** 749-756

Temprano J., Arango O., Cagiao J., Suarez J. And Tejero I. (2006) — Stormwater quality calibration by SWMM: A case study in Northern Spain. *Water SA.* **32 (1)** 55-63

Tsihrintzis V. A. And Hamid R. (1998) — Runoff quality prediction from small urban catchments using SWMM. *Hydrological Processes.* **12 (2)** 311-329

United States Environmental Protection Agency (Usepa). (2000) — *A Literature Review. EPA-841-B Low Impact Development (LID) 00-005. USEPA Office of Water: Washington, D.C*

Zhang R., Zhou W.B., Field R., Tafuri A., Yu S.L. And Jin K.L. (2009) — Field test of best management practice pollutant removal efficiencies in Shenzhen, China. *Frontiers of Environmental Science & Engineering in China.* **3 (3)** 354-363