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The Application Evaluation of Autodesk Storm and Sanitary Analysis for the Low Impact Development Design in the Park Area

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Abstract

The impermeability layer has decreased the surface storage ability, groundwater level and the time of concentration, and increased the peak flow of storm water runoff and urban floods. Due to the fact that developing the drainage functions in urbanized areas requires a considerable amount of burden in public expenses, which in reality makes it difficult to proceed with, it is necessary to apply the Low Impact Development (LID) concept and transform the drainage-oriented water management to water use and environment-friendly management. As the direction of recent design methods has been shifted to BIM (Building Information Modeling) and GIS (Geographic Information System), it is expected that the LID design will also be shifted to the same direction. Therefore, the related analytical solution is needed, and by using Autodesk® Storm and Sanitary Analysis (SSA) it will enable an interpretation of the city outflow and analysis by making connections with BIM and GIS, and this study's analysis included making a connection with the runoff model of another city SWMM. This study helped to minimize data loss and rework the process of constructing the network data using the BIM design method and the public GIS followed by the analytical work, and to quickly construct the current network writing by utilizing the public GIS.

Keywords: *LI D Design, SSA, GIS*

1. Introduction

By making the hydrologic characteristics that have changed due to the recent developments as similar as they were before their development, minimizing the effect on nature [1], maintaining the system of penetration, undercurrent, and water circulation of rain water to reduce flooding and water pollution, and the development methods to minimize the effect in the corresponding area from floods [2]. These changes are related to the inundation in urban areas caused by weather anomaly: the danger of flooding because of rainfall increased as the expanded impermeability layer is followed by the immediate direct runoff of rainfall to the river, and the total volume of runoff increased, the increasing curve aspect of the discharge curve in urban area formed a steep slope, and then the arrival time for the peak discharge shortened [3]. Hence, the Ministry of Land, Infrastructure and Transport in the "City Plan Guide to Build the Low-Carbon Green City" and the "Sustainable New City Plan Standard" since 2009 has recommended the

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installation of a great number of the rain management facilities, of which scale is relatively small compared to the scales of cities and new cities, including penetration, undercurrent, and usage in the distributed system, but they have not been able to go beyond the planning stage for rainwater management [4].

LID refers to the design that focuses on the processing method before outflow or sand drift happens, and not the design that handles the process afterwards as BMP (Best Management Practices), the much more environment-friendly design that creates both the peak outflow and the flood arrival time, and furthers even the amount of direct outflow with the same characteristics as the hydrologic characteristics before urbanization by securing the penetration area rate in the drainage area and then maintaining the hydrologic characteristics of the soil [5]. By using these LID methods, research about the water circulation restoration in the drainage area and the solution to reduce non-point pollutant sources have been carried out consistently [6], and in general by using SWMMs, research about the urban drainage simulation and hydrogen circulation simulation [4]. The purpose of this study lies in using the design that connects the recently-introduced BIM design, the public GIS and the interpretation methods, and simulating-analyzing the drainage characteristics in urban areas in relation to the LID interpretation method that was applied in previous research, so it enables effective water reuse.

2. Materials and Method

2.1. Target Area and Study Method

This study target area is Yangjae Neighborhood Park with the surrounding areas of Seoul and the drainage area was established in 57ha by analyzing the topographic map. The Yangjae 2-dong community service center area elevation is lowered in the Seocho region and that is why, this area is more frequently flooded than other areas. All the storm water networks are towed to the Yangjae stream and the discharge node where the temporary Yangjae 2-dong community service center area has greater focus on the storm water networks.

For the purpose of disaster protection and lack of pipe flow capacity due to locally heavy rains, an 8,000 ton rainwater detention basin at the neighborhood park is in progress. Also, an 85 ton rainwater storage tanks is to be installed in the second basement of Yangjae 2-dong community service center, where construction design has already been established and construction is in progress.

This study built the drainage network system by connecting the BIM method and the public GIS in the target area, and performed the mapping of the topographic slope and the covered condition by adding the VRS (Virtual Reference Station)'s current estimate data on the accumulated 1000 digital map of the National Geographic Information Institute, and analyzed the amount of the current outflow and the drainage area using the Autodesk Storm and Sanitary Analysis.

Figure 1. Study Area Location Map (Yangjae Neighborhood Park, Seoul, Korea)

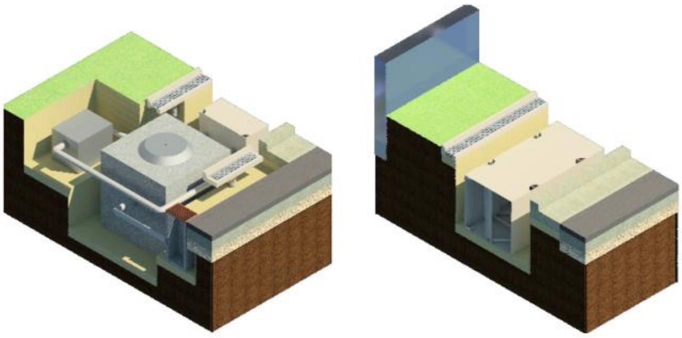

Figure 2. Concomitant Filter & Detention Basin BIM Model, This Figure Shows a Cleaning Filter System of Ground Rain Water, Underground Detention Basin, and Permeable Block with Infiltration Trench

By reflecting the design plans that have proceeded in the Yangjae Neighborhood Park, the big scale undercurrent detention facility was constructed by using the Autodesk Storm and Sanitary Analysis interpreted with a rational formula and SCS, and compared the results with the EPA-SWMM. Also, the LID facilities including the water penetration block, small scale permeation retention, and the band green area was put into a distributed arrangement and the drainage reduction was interpreted.

2.2. Interpretation Software Selection

SSA, as a comprehensive analysis program for urban rainfall or wastewater system design, and rainfall system analysis, can handle the complicated hydrological and mathematical analysis and the water quality model at the same time and has been used for a variety of excellent research all over the world. Since the BIM network model can be created by designing with Autodesk® Civil3D and can be analyzed by creating the current network system as the network system to the current BIM model by using the public GIS, it has been applied in the analyses of the network system and the undercurrent area, and the first-dimensional drainage interpretation.

EPA-SWMM, as a kinematic discharge simulation program that calculates the amount and quality of the outflow in urban areas, allows for the use of the model built in Autodesk SSA in the EPA-SWMM immediately, so its compatibility is high. Also, this study used it because the upgraded functions added in 2014 includes interpretations of various LID facilities.

2.3. Overview of the Run-Off Model

The SSA (Storm and Sanitary Analysis) model to be used in this study was developed using the SWMM model of the EPA. This model can be applied to urban areas and the urban drainage system can also be applied to small scale drainage areas as well as the large scale drainage area. The SSA can calculate the runoff discharge and water quality from storm water BIM (Building Information Model) data and GIS network data. Precipitation information for analysis can be import analyzed rainfall hyetograph or the rainfall time series.

SSA data can be divided into three types, such as meteorological data, parameter data, and data output data. Meteorological data is concerned to precipitation. Parameter data are related to the hydrological characters and the materials associated with the physical characters of the watershed. The data related to the physical characters of the drainage area, slope, impervious area, width, length, and local pipe networks are obtained from the digital map, topographic survey and public GIS data. An infiltration factor is related to the permeability of the drainage area and pipe roughness from which information is obtained from the soil map and land coverage map.

SSA output data can be compatible with the EPA-SWMM and GIS data for the analysis result verification, GIS data update, and project owner's purpose. Also, the SSA analysis result model can change the original BIM model by the imported analysis model.

3. Input Data Writing

3.1. Rainfall Analysis

Data used for this study measured the maximum amount of rainfall in each continuous time period (10min, 1hr, 2hr, 3hr, 4hr, 6hr, 9hr, 12hr, 18hr, and 24hr) by using the data for the last 53 years (1961-2013) of the Seoul Meteorological Agency Administration, and calculated the maximum annual rainfall data for each random continuous time period by applying the fixed and sliding duration time conversion factors and the rarely-analyzed formula. Although the parameter estimations of the applied probable precipitation distribution type and probable precipitation distribution type vary widely, this study used the moment method as the ideal possibility distribution type among the probable precipitation among the Gumbel distribution types.

Table 1. Parameter Estimate of the Probability Weighted Moment Method (Gumbel)

Duration	XLO	XSC	XSH	Test
10 min	15.344	4.112	0.000	O
60 min	43.415	14.956	0.000	O
120 min	62.698	21.803	0.000	O
180 min	75.387	29.181	0.000	O
360 min	83.226	32.961	0.000	O
540 min	98.996	37.217	0.000	O
720 min	115.271	40.562	0.000	O
1080 min	123.940	45.405	0.000	O
1440 min	129.707	51.271	0.000	O

Table 2. Goodness of Fit Test for the Probability Weighted Moment Method (Gumbel)

Duration	CHI			KS			Cramer			PCC		
	Com	Tbl	Chk	Com	Tbl	Chk	Com	Tbl	Chk	Com	Tbl	Chk
10 min	1.91	7.81	O	0.08	0.16	O	0.07	0.46	O	0.99	0.97	O
60 min	2.13	7.81	O	0.07	0.16	O	0.06	0.46	O	0.99	0.97	O
120 min	1.00	7.81	O	0.08	0.16	O	0.07	0.46	O	0.99	0.97	O
180 min	2.13	7.81	O	0.05	0.16	O	0.02	0.46	O	0.99	0.97	O
360 min	1.23	7.81	O	0.06	0.16	O	0.02	0.46	O	0.99	0.97	O
540 min	1.23	7.81	O	0.08	0.16	O	0.04	0.46	O	0.99	0.97	O
720 min	7.11	7.81	O	0.09	0.16	O	0.05	0.46	O	0.99	0.97	O
1080 min	2.13	7.81	O	0.1	0.16	O	0.06	0.46	O	0.99	0.97	O
1440 min	1.68	7.81	O	0.1	0.16	O	0.07	0.46	O	0.99	0.97	O

In this study, the probability rainfall intensity of Seoul station was selected for the Full-Log type, with the equation as follows:

Table 3. Probability Rainfall Intensity Formula (Full-Log Type)

RT	Rainfall Intensity Formula
10	In(*I*) = 4.34481-0.56751In(t)-0.25001(In(t))2+0.10542(In(t))3+0.07084(In(t))4-0.04517(In(t))5+0.00640(In(t))6
20	In(*I*) = 4.47479-0.59698In(t)-0.32082(In(t))2+0.13256(In(t))3+0.03748(In(t))4-0.05705(In(t))5+0.00322(In(t))6
30	In(*I*) = 4.54305-0.61795In(t)-0.36132(In(t))2+0.14449(In(t))3+0.09759(In(t))4-0.06311(In(t))5+0.00908(In(t))6
50	In(*I*) = 4.62269-0.64386In(t)-0.41322(In(t))2+0.16142(In(t))3+0.11033(In(t))4-0.07124(In(t))5+0.01027(In(t))6
80	In(*I*) = 4.69007-0.65548In(t)-0.43985(In(t))2+0.17090(In(t))3+0.11690(In(t))4-0.07560(In(t))5+0.01092(In(t))6
100	In(*I*) = 4.71997-0.66440In(t)-0.45855(In(t))2+0.17739(In(t))3+0.12128(In(t))4-0.07853(In(t))5+0.01135(In(t))6
200	In(*I*) = 4.80857-0.67214In(t)-0.47356(In(t))2+0.17896(In(t))3+0.12575(In(t))4-0.08018(In(t))5+0.01149(In(t))6
500	In(*I*) = 4.91457-0.69877In(t)-0.53177(In(t))2+0.20117(In(t))3+0.13939(In(t))4-0.08994(In(t))5+0.01300(In(t))6

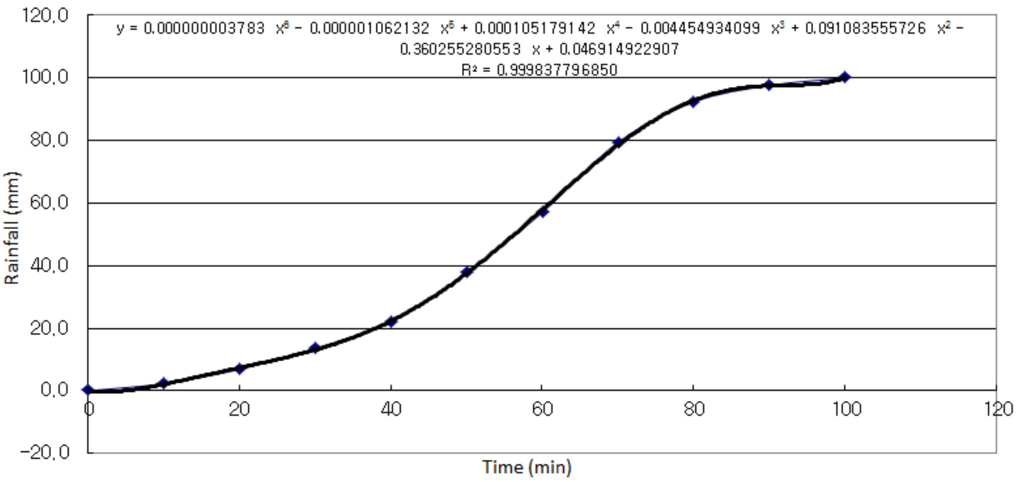

Figure 3. Huff Method Storm Distribution, 3rd

3.2. CN Value

CN (Curve number) was calculated by overlapping the land coverage map, detailed soil map, and drainage basin drawing using the Autodesk Map3D that has been generally used in engineering firms. The study site land coverage is composed of pavement and the residential area as urbanized has been completed. Each type of land coverage CN value under AMC II is in accordance with the Natural Resources Conservation Service, Urban Hydrology for the small watershed, Technical Release 55,USDA and calculate the AMC-II value. The study site average CN is calculated as 89.88.

3.3. SSA Analysis Model

To bring the public GIS data of the target area to Civil3D or write it as the interpretation model, the GIS field should be matched with SSA or Civil3D to take it. The rainfall-related GIS field list belongs to the list of the characteristics of the manhole, culvert, and pipe and should be matched with information such as the diameter, depth of the beginning and ending points, and altitude of manholes. In this research, the outflow model was created as in Picture 3 and the outflow model of the SSA consists of the manhole building the network system, culvert pipe, rainfall undercurrent detention facility, and basin.

Figure 4. Autodesk Map3D Catchment Basin

Figure 5. Civil 3D Pipe Networks

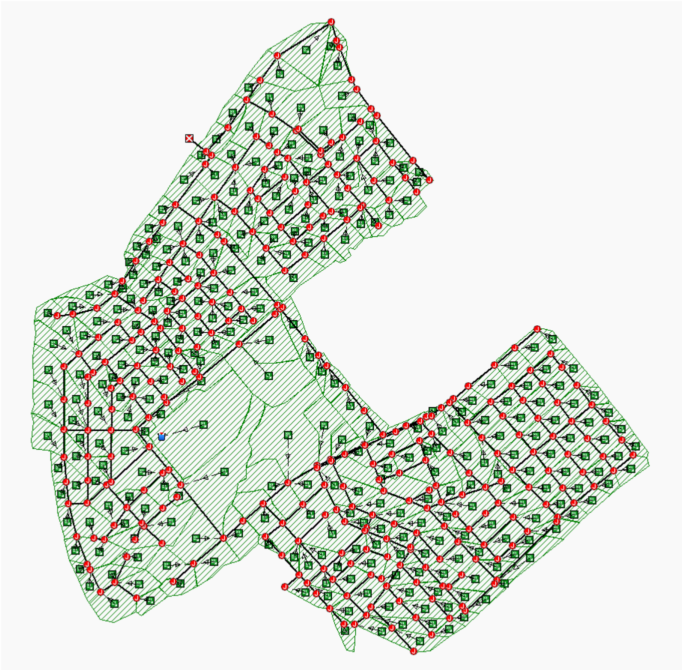

Figure 6. SSA Analysis Model

4. Results and Discussion

4.1. Analysis of Yangjae Neighborhood Park (SSA)

The undercurrent detention facility in this study area was planned to be 8,000 tons in the Yangjae Neighborhood Park and the drainage network data near Yangjae 2-dong was obtained from the public GIS to create the BIM model and SSA analysis model. The analysis of the model was performed the SCS analysis and the measurements of the time of deliberation were calculated using the Kirpich method. The hydraulic analysis method used the hydrodynamic method and the exfiltration of the undercurrent detention facility was not considered. Due to the installation of detention basins, the study site flow rate was reduced 12,498.21 m^3 to 8,470.64 m^3, the flow velocity was reduced 1.26 m/sec to 0.78 m/sec, and the total inflow was reduced 2.3 cm.

Table 4. SSA Analysis Result at 0085-200 Node

Method	Event	0085-200 Max HGL	Max Q (cms)	Max V (m/sec)	Remark
Rational	Before installation	16.87	4.49	1.51	
SCS		17.32	4.01	1.26	
Rational	After installation	16.10	2.43	0.85	Q=2.06▽
SCS		16.92	1.66	0.78	Q=2.35▽

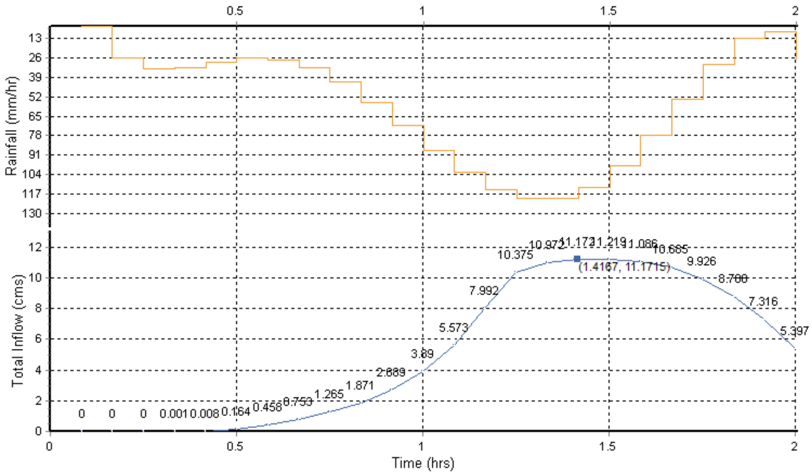

Figure 7. Before the Outlet Node Discharge Flow

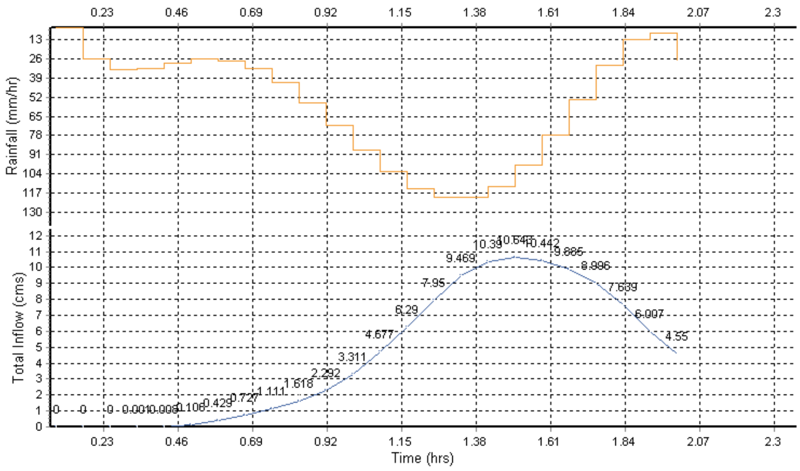

Figure 8. After the Outlet Node Discharge Flow

4.2. Analysis of Yangjae Neighborhood Park (EPA-SWMM)

To compare the consistency of the SCS analysis, the comparative analysis using the EPA-SWMM was performed. The source composition of the SWMM model was based on the SCS-analysis data and the basic width and the impermeability area ratio used the GIS data which was calculated in the previous step. In addition, this study compared the analytical value of the EPA-SWMM method provided in SSA and the analysis value of the EPA-SWMM. The result after performing the SCS analysis and the EPA-SWMM analysis using the Autodesk Storm and Sanitary Analysis did not reveal a big difference in their results. Also, the result after modelling using the EPA-SWMM5 revealed the same result as the one analyzed in the SSA as well. However, in some areas, the result of the EPA-SWMM analysis appeared to be a little bigger than the result of the SCS analysis, and through this we can assume that the result was caused by the difference between the SWMM's analysis method and the SCS's analysis theory.

4.3. LID Control (EPA-SWMM)

The EPA-SWMM method detention basin analysis result model of the SSA is exported to SWMM 5 to the analysis permeable LID block effect. A permeable block section uses a 60mm thickness block and a 40mm base course. A porosity of the block and base course is applied to 15% and 75%. The site outlet flow was reduced 4.7 to 5.1% when replacing the 20% of the impervious area to the permeability block. This reduced rate is similar with the 4.1 to 4.6% reduction [7] of the Tangjeong region, Asan.

5. Conclusion

1) In the process of constructing and analyzing the network data using the BIM design method and the public GIS, data loss and reworking could be minimized and by using the public GIS, the creation of the current network could be built up quickly. Also, expanding the existing design and analytical methods that have been analyzed in rational methods only provided more accurate results.

2) This study analyzed the effects from the undercurrent detention facility of 8,000 tons that is to be built in the Yangjae Neighborhood Park with the Autodesk Storm and Sanitary Analysis, and the result was analyzed that there was 32% of the runoff reduction effect. Yet, it revealed that building just one undercurrent facility did not affect the runoff reduction in the distribution basin, so, the distributed arrangement of small- and medium-size undercurrent detention facilities is needed.

3) From calculating the BIM-based analytical results in the EPA-SWMM5 and performing the LID analysis, the penetration block had the reduction effect of 4.7% to 5.1% inflows, and compared to previous research data, I was able to attain the logical results.

Acknowledgements

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