

Numerical Simulation for Reducing the Flood Damage of Green Park Using MIKE URBAN

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Abstract

In this study, to resolve flood damage in flood-prone areas around Incheon Bridge landfill, numerical analysis was performed according to change of coefficient of runoff considering underground rainfall storage in surrounding parks and facilities to reduce non-point source pollutants. Use of rainfall retention facility to improve urban flooding reduced peak flow and effectively prevented flooding in the subject areas. In the result according to change of coefficient of runoff considering facilities to reduce non-point source pollutants, control of initial rainfall led to reduce peak water level and secure delay time. Based on the study result, to properly install underground retention storage and apply coefficient of runoff according to facilities to reduce non-point source pollutants within the subject areas, providing accuracy of various parameters necessary for future analysis and measurement data will help design effective multi-functional parks with minimized flood damage and prepare measures to prevent disaster.

Keywords: *Flood damage, MIKE URBAN, MOUSE, Urban disaster prevention, Underground Storage Tank*

1. Introduction

Recently, due to abnormal weather, summer rainfall has been causing substantial damage in the form of torrential rain. Especially, in major cities like the Metropolitan Area, many risk factors can cause serious damage as a result of increase of runoff and sudden torrential rain. Despite the urgent need to prepare measures to prevent flood damage, the rapid increase of impervious areas as a result of urban development led to upsurge of flood peak flow and also reduced the time to reach peak flow, adding to the burden of damage prevention facilities related to runoff. Recently, KMA[12] reported that, in the central region, a large amount of rain, 526.5mm (366.4 mm in common year) was observed during the rainy season that lasted 49 days, which is the longest since 1973, and the torrential rains caused by Typhoon Danas no.24, which affected Korea for the first time in 15 years after 1998, resulted in material damage of 156.6 billion KRW. These disasters are largely caused by problems due to storm sewers designed according to design frequency that have insufficient conveyance, and overflow of storm sewers cause extensive flooding damages in major cities. Although relevant disaster prevention measures have been proposed, few of them are applicable in practice. As one of the most effective measures, to reduce peak flow, installing flood retention facilities around the cities was proposed, and this is expected to minimize damage from torrential rains in city centers and industrial complexes in which impermeable layers are increasing. Ahn *et al.* [1] studied measures to prevent flooding in underground spaces, while Choi *et al.* [3] used

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MOUSE, urban runoff model, to compare difference in water level and peak flow in pipe network before and after installing rainwater storage tanks in flood-prone areas, and verified the effect of installing rainwater storage tanks on reducing water level and peak flow. Choi *et al.* [4] analyzed the effect of installing underground rainfall storage on reducing damage from inland flood within urban areas. Song *et al.* [9] analyzed the effect of underground rainfall storage on reducing rainfall outflow based on conditions including the amount of storage in the storage tanks, level of reduction in peak water level of rainfall outflow, and delay time. Bouwer *et al.* [2] used 42 flood scenarios to examine correlation between the flood damage curve and land use with the cost of flood damage, while Pretenthaler *et al.* [7] built 144 dam collapse scenarios that can be caused by flood and created a flood damage curve. Son and Byun [8] present a new routing algorithm based on data-centric routing and address-based routing schemes, which is that query messages are delivered to target area by using address-based routing scheme, then, broadcast scheme is used in target area by inserting additional information of neighbor nodes into the message payload. Yin and Zhou [13], According to the surfactant flooding mechanism, a mathematical model for three dimension two-phase three-component surfactant flooding have established.

In this study, for the purpose of analyzing effects of installing urban rainfall retention facilities, the status and cases of flood damage in Incheon were analyzed and the park around landfill near Incheon Bridge was selected. In addition, heavy rainfall capacity of a multifunctional park that provides safety, protection, and environmental functions was evaluated, based on analysis of flood reduction effect according to change in coefficient of runoff considering facilities installed to retain rainfall and reduce non-point source pollution within the park.

2. Characteristics of MOUSE

MOUSE is a sewer pipe interpretation model developed by DHI that was founded in Denmark in 1964. MOUSE is composed of the basic program MOUSE–Standard(SRM), and is capable of interpretation in many forms by using expansion modules like MOUSE–RDI, the program for continuous rainfall runoff interpretation; MOUSE-LTS, long-term hydrologic analysis program; MOUSE-RTC, real time operation program; MOUSE-TRAP, program for quicksand and water quality interpretation. Furthermore, auxiliary programs include MOUSE-GM, a GIS-link program and MOUSE-Online, a real-time field link program. It can extend the range of interpretation as it allows choosing status of the flow within pipes such as steady flow and super-critical flow, considering internal boundary condition in the basic data such as manhole, pipe, pump, and manhole, pipe conduit, pump, and retention basin in program configuration, and inputting various forms of cross sections.

2.1. Time-Area Method for Hydrologic Watershed Tracking

The time-area method, a hydrologic watershed tracking method, converts effective-rainfall hyetograph to outflow hydrograph based on the tracking concept of time and area columnar section. This method includes only the translation effect, and not, detention effect, of a drainage area, and, hydrograph induced by the time-area method is devoid of detention and detention and diffusion effects and, therefore, has higher peaks than hydrographs that takes into account detention effect. MOUSE classifies drainage areas into three types, and creates time-area curve accordingly. Figure 1 and Figure 2 show shapes of drainage areas and curves used in MOUSE.

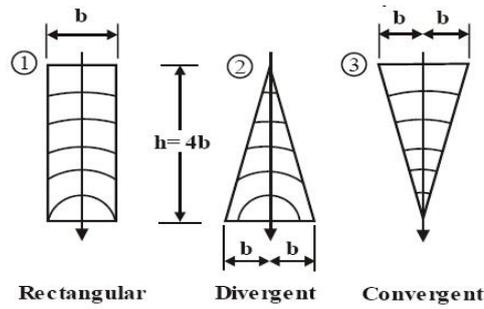


Figure 1. Shape of the Basin for the MOUSE

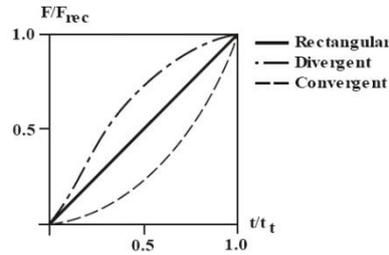


Figure 2. Abstract Shape of the Time-area Curve on the MOUSE

2.2 Non-Linear Reservoir Analysis

Reservoir analysis by MOUSE is performed based on surface runoff model. Non-linear reservoir analysis uses kinematic wave equation for calculating the solution. Moving gravity and frictional force acts as major variables, and pressure and inertial force does not have a significant effect on this flow, and gravity and frictional flow create equilibrium and, thereby, uniform flow. Although flood wave includes both kinematic wave and dynamic wave, in most cases, gravity and frictional force act as a more dominant force according to momentum equation with steeper waterway, and, here, most flood waves move in the form of kinematic wave. Kinematic wave is tracked by finding a solution in continuity equation and momentum equation of uniform flow. Non-linear reservoir analysis of MOUSE also is performed according to this principle, and main hydraulic factors used to perform kinematic analysis interpretation in MOUSE include wetting loss, detention loss, peak infiltration, Horton index, and Manning’s roughness coefficient, based on the mechanism shown in Figure 3. Linear retention basin method performs calculation based on behavioral process like a linear reservoir. It induces continuity equation considering the correlation between delay and attenuation in a virtual linear reservoir in which the amount of detention (S) is proportional to discharge (Q), and uses this for outflow interpretation. Figure 4 is the conceptual diagram of linear reservoir analysis in MOUSE.

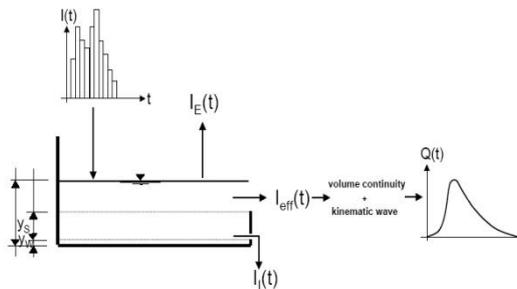


Figure 3. Concept of Kinematic Wave Method

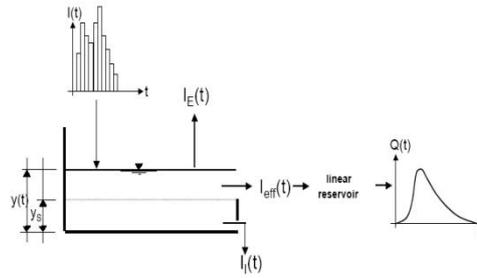


Figure 4. Concept of Linear Reservoir Method

2.3. Flow Interpretation in Conduit

To interpret complex flow within a conduit, MOUSE uses Saint Venant Equation. The following conditions must be satisfied for proper interpretation using MOUSE.

- Water is assumed to be incompressible and isotropic matter.
- Smaller gradient is more advantageous for interpretation (because of the case in which cosine function is used to create an angle to maintain with a horizontal plane)
- Waveform that is longer than depth of water is more advantageous for interpretation.
- Sub-critical flow is more advantageous for interpretation.

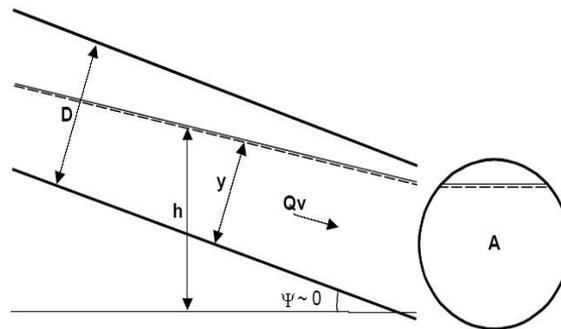


Figure 5. Basic Model for Flow Analysis in Pipe

Although MOUSE is capable of flow interpretation of super-critical status, interpretation in a more limited situation enables more clear flow interpretation, and, therefore, interpretation of sub-critical status is recommended. Also, MOUSE uses kinematic wave approximation, diffusive wave approximation, and dynamic wave approximation. These three cases can be applied flexibly and, basically, all of the kinematic wave, diffusion wave, and dynamic wave theories that were used in the runoff model are commonly applied. It is advisable to approach kinematic wave in MOUSE by assuming the case when frictional force and gravity are in mutual balance. This means that, in interpretation based on kinematic wave equation, effect analysis based on back water is impossible. Therefore, when using kinematic wave approximation, back water should not have an effect. Diffusion wave equation can be used when the user fully considers boundary condition of the downstream. In this case, effect of back water can be considered as well, but it is used as a limited interpretation method. When using dynamic wave equation, perfect momentum equation including accelerating potential can be used. Therefore, by using this method, it is possible to produce correct simulation regarding rapid water hammering or back water. In dynamic flow, time-dependent spatial displacement takes an important position.

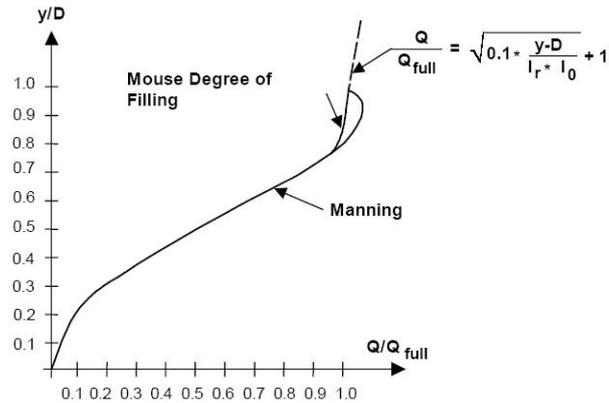


Figure 6. Internal Flow Growth Curve of Tube

2.4. Interpretation Algorithm

To interpret a conduit, MOUSE performs various interpretations based on continuity equation and momentum equation. Double Sweep algorithm, which is one of the algorithms within MOUSE, is applied for calculating branch matrix. Figure 7 is an overview of the branch matrix calculation for interpretation of manhole and node connection, and shows finished elimination within the matrix. While, for single pipe conduit, a matrix with a particular form is interpreted, matrix interpretation in a pipe network with intersections has a more complex form.

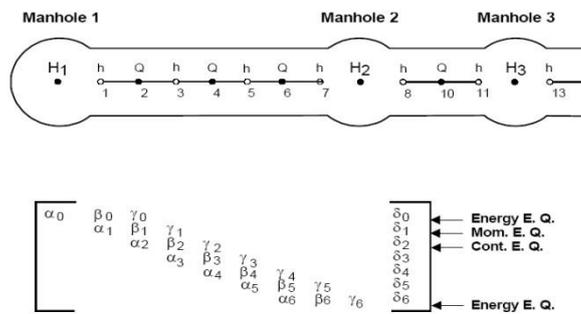


Figure 7. Branch Matrix Calculation Overview

3. Current Status of Subject Area

Flood damage of the subject area was researched based on the data of flood-prone area between 1997 and 2001. Damage in the flood-prone areas within the subject drainage area were divided by sub-drainage area into drainage area flowing into Incheon bridge landfill Sewer pipeline, Seoknam waterway drainage area, and Hwasu drainage area. Table 1 shows flooded areas according to division of drainage areas in Incheon. Figure 8 shows location of flood-prone areas in the subject drainage area. Flood damage in Incheon are assumed to be caused by rise of sea level due to proximity to the sea, aging of existing sewage conduit, and lack of capacity.

Table 1. The Flooded Area by the Target Basin within the Watershed Classification

Basin	Area	Flooded area	Flooding Year
Incheongyo Reclamation area sewer main Entering basin (973.7ha)	Dohwa-dong, Seoul-Incheon Subway around and Juan Station around	11.8ha	1997, 2001
	Sipjeong-dong, Ganseok-dong around	15.4ha	1997, 1998 1999, 2001
	Gajeong Girls Middle School around , Gajwa-dong	8.5ha	1997, 1998 1999, 2001

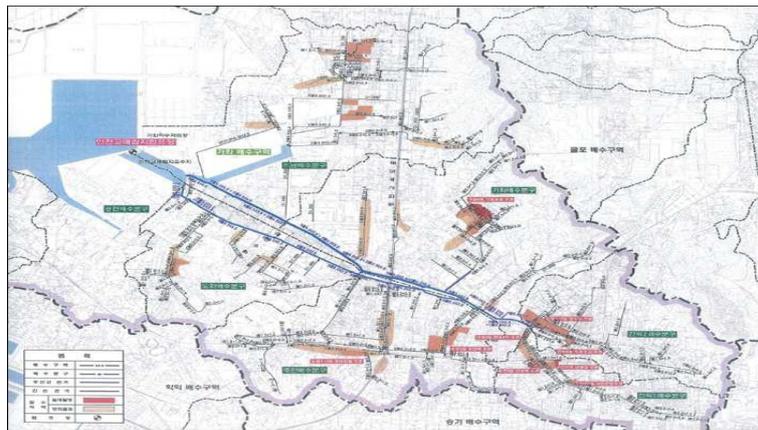


Figure 8. Habitual Inundation Area in the Range of Research (Park, [6])

In the Seogu area in Incheon, based on analysis of disaster occurrence after designation of Natural Disaster Risk Zones in the city, Buffer Green Space around Seokjeong Girls' High School, Gajwa and Gajeong Girls' Middle School, Seogu, and Sipjeong Green Park, Bupyeonggu were selected. To evaluate simulation for response against heavy rain in central urban areas, inundation reduction effect of installing detention tank within the selected parks was analyzed. Areas around Gajwa Buffer Green Space and Sipjeong Green Park were designated as flood-prone areas in February and January 2004, respectively, and these areas are often flooded by countercurrent caused by raised water level of sewage conduit installed in the Incheon Bridge landfill when the sea level rises. Also, these areas suffer flood damage from torrential rains every year, due to poor gradient of the existing sewage conduit and lack of conveyance power.

4. Analysis Method

4.1. Applied Frequency and Critical Duration

In this study, MOUSE module of the Mike Urban model ICUH [10], was selected for interpreting characteristics of complex urban runoff and hydraulic states in a comprehensive sewage conduit. Also, the effect of installing underground rainfall storage in the chosen parks was taken into account, and, based on the range of coefficients of runoff according to land use, proposed by KWWA [11], simulated conditions were created to evaluate flood response capacity according installation of facilities for non-point source pollutant reduction. Flood response capacities around the main lines of Incheon Bridge landfill, which were surveyed by Incheon between 2006 and 2011, were compared to understand capacity of the drainage system in the subject areas and limits of

existing conduit facilities. In order to verify flood improvement effect, through numerical simulation, boundary condition was set at 100-year frequency for the design probable rainfall of the conduit and 60 minutes for critical duration. The status before and after improvement by flooded areas will be compared and reviewed based on numerical simulation.

In this study, simulation was performed based on rainfall data of KMA between 1970 and 2013 and calculation made by Incheon University, and Table 2 shows probable rainfall by duration.

Table 2. Probable Rainfall with Frequency or Sustainment Time using Formula of Incheon uviv. (Unit: mm)

Sustainment time Return periods	10min	1hr	2hr	3hr	4hr	6hr	9hr	12hr	18hr	24hr
2 year	14.3	43.8	64.0	76.7	86.6	100.7	115.6	126.9	140.7	150.9
3 year	16.3	51.3	75.6	91.0	102.7	119.7	138.7	153.3	170.7	185.4
5 year	18.5	59.6	88.5	106.8	120.7	140.9	164.4	182.7	204.0	223.8
10 year	21.3	70.0	104.7	126.8	143.3	167.6	196.7	219.6	245.9	272.0
20 year	23.9	80.1	120.3	145.9	165.0	193.1	227.6	255.1	286.1	318.3
30 year	25.5	85.8	129.3	156.9	177.5	207.8	245.5	275.4	309.3	344.9
50 year	27.4	93.1	140.5	170.7	193.1	226.2	267.8	300.9	338.2	378.1
70 year	28.6	97.8	147.8	179.7	203.3	238.3	282.4	317.6	357.1	400.0
80 year	29.1	99.6	150.7	183.3	207.4	243.1	288.2	324.2	364.6	408.6
100 year	30.0	102.8	155.6	189.2	214.2	251.0	297.8	335.3	377.2	423.0
200 year	32.5	112.5	170.6	207.7	235.1	275.7	327.8	369.5	416	467.7
300 year	34.0	118.1	179.4	218.5	247.4	290.2	345.2	389.5	438.7	493.8
500 year	35.9	125.2	190.5	232.1	262.8	308.3	367.3	414.7	467.3	526.7

4.2 Application Method of Numerical Model

To consider the method of installing underground rainfall retention facility in the parks, infiltration improvement effect was analyzed based on infiltration by detention of the waterscape facility and infiltration by green tract in the park. After researching methods to utilize all of the ground and underground spaces to prevent damage from torrential rainfall in the parks, parks in Seogu, Incheon, were selected. Methods to detain rainfall in Gajwa Buffer Green Space and Sipjeong Green Park were studied. In these parks, rainfall detention facilities of various forms were installed, and a method of detaining rainfall by connecting waterways along the pond and trail was applied to this model. As shown in Table 3, a flood prevention scenario was built to prevent overflow including inland flood by using rainfall retention facility.

Table 3. Scenario Composition

Division	Content Analysis
Scenario-1	Compare flooding conditions according to 5, 10, 100-year return period
Scenario-2	Comparison of flooding conditions after installing the underground storage tank
Scenario-3	Comparison of flooding conditions associated with the change the runoff coefficient Considering the non-point source pollution treatment facilities
Scenario-4	Compare flooding conditions considering underground storage tank and non-point source pollution treatment facilities

Scenario-1 took into account impermeable layer materials that cover the predominant part of the parks in the city and frequent inland flood and rainfall overflow in the city caused by torrential rainfall. And, to prepare for storm sewer against torrential rainfall,

torrential rainfall with frequency of 5, 10, and 100 years, flooded areas were examined and compared.

Scenario-2 looked into rainfall exclusion capacity of drainage system in Gajwa Buffer Green Space and Sipjeong Green Park and flooded area in order to calculate the suitable capacity of detention tank for torrential rainfalls, based on numerical simulation related to installation of underground detention tank in the center of the parks.

Scenario-3 selected a flood-prone park between two parks, after reviewing rainfall exclusion capacity of the drainage system, and compare detention capacity for torrential rainfalls considering non-point pollutant treatment facilities of the parks, in order to analyze change of rainwater flow according to change of coefficient of runoff from installation of the facilities.

Scenario-4 was designed for numerical simulation and comparison relating to suitability of underground rainfall storage and coefficient of runoff, in order to compare Scenario-2 and Scenario-3 in an economical and efficient way.

5. Analysis Result

5.1. Gajwa Buffer Green Space

Gajwa Buffer Green Space is located at 318~464, Gajwa 4-dong, Seogu, Incheon, and was built from 2007 and finished in 2011. The area is 45,000 m² and it is surrounded by residential area, industrial area, and educational facilities. This park was selected as it has the potential to cause severe damage in the event of inundation (Figure 9).



Figure 9. Gajwa Buffer Green Space

(1) Scenario-1

Figure 10 is comparison of conduit states in the event of rainfall based on the frequencies of storm sewer, 5, 10, and 100 years, and when the torrential rainfall was applied.

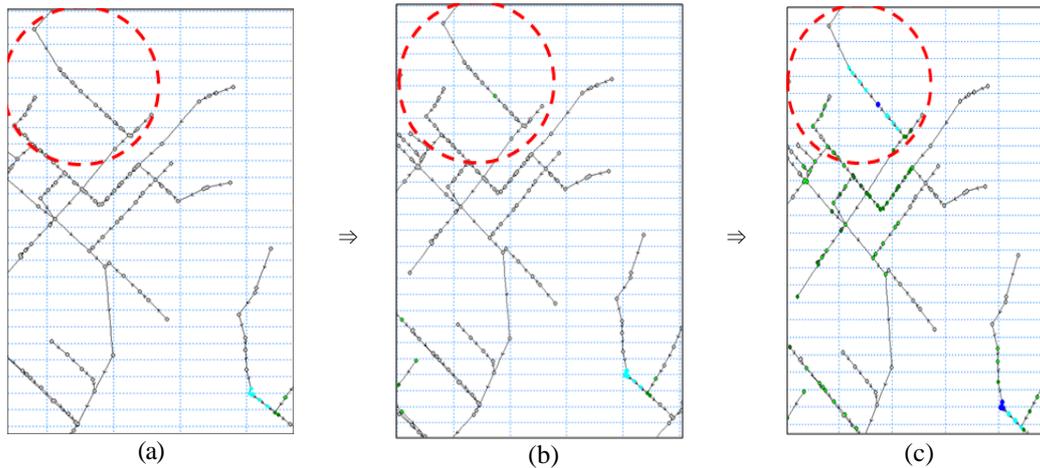


Figure 10. Pipe States According to the Frequency Gajwa Buffer Green Space (Scenario-1): (a) 5-year Return Period, (b) 10-year Return Period, (c) 100-Year Return Period

The result of applying rainfall at different frequencies did not show urban flooding at 5-year frequency. Sufficient storage is secured if the rainfall is not excessive. And, although there was no overall flooding when 10-year frequency was applied, about 20cm flooding appeared in the conduit area with altitude. However, it does not seem likely to cause damage in the surrounding areas. When rainfall at 100-year frequency was applied, overall flooding was observed and, as this amount was discharge condition that can cause damage in the surrounding areas, 100-year frequency will be applied to the scenario.

(2) Scenario-2

Underground retention tank was installed around flooded areas in Gajwa Buffer Green Space based on the 100-year frequency, for the purpose of preventing flood from torrential rain on impermeable layers in the park and detaining rainfall by using flow. The capacity of the detention tank was decided at 20% of catchment area based on the research by Han *et al.* [5]. Table 4 shows capacity in underground rainfall storage, and the capacity was liberally calculated for safety from rainfall at 100-year frequency.

Figure 11. shows the result according to detention tank capacity. When comparing before and after the application, underground detention tank had a significant effect for flood prevention even at 20% of catchment area. Arranging detention tanks of small capacity sparsely was found to be more effective than arranging ones of large capacity closely in one area.

Table 4. Capacity Calculation for Underground Storage Tank of Gajwa Green Park

Division	Catchment area $\times 0.2$ (m ²)	Underground Storage Tank capacity (m ³)
Before applying	8,699	0
After applying	8,699	10,000

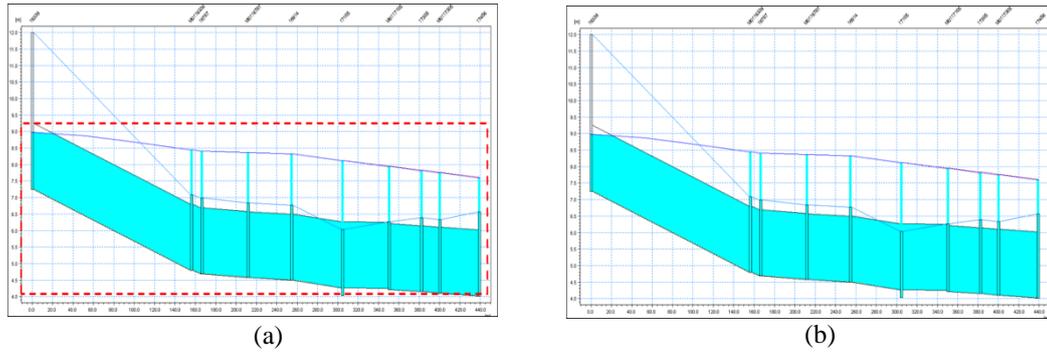


Figure 11. Retrogression of Level according to the Capacity of the Underground Storage Tank in Gjawa Green Park (Scenario-2): (a) Before, (b) After

(3) Scenario-3

Based on Scenario-1, to apply non-point source pollution in flooded areas in Gajwa Buffer Green, coefficient of run off will be changed according to Table 5 and the range of coefficient of runoff was between 0.5 and 0.7 in the commercial area and 0.1 and 0.25 in areas with much grass and many trees.

Table 5. Application of Runoff Coefficient

Land use		Runoff coefficient
commercial area	Neighborhood district	0.7~0.5
park, green tract of land	Grass, Many a tree, Nonpoint pollution source treatment plant Installation	0.25~0.05

As explained in Table 6, coefficient of runoff in Gajwa Buffer Green Space was set at 0.15 as 70 to 80% of the entire park is of green areas. And, to analyze the level of inundation reduction based on coefficient of runoff, coefficient of runoff was applied to neighborhood and 50-60% of green areas, in order to compare inundation reduction effect when coefficient of runoff is 0.15.

Based on the coefficient of runoff at 0.5 in neighborhood around the commercial area, when the coefficient of runoff was changed to 0.15 considering the green park with much grass and many trees, 0.6 m³/s was reduced in comparison to before applying coefficient of runoff. Although this amount is not likely to control flooding caused by torrential rainfall, it may control the initial rainfall and delay peak flow, thereby, controlling flooding (Figure 12).

Table 5. Runoff Coefficient According to the Green Area of the Park

Range	Runoff coefficient	Application
50~60	0.25	
60~70	0.2	
70~80	0.15	Gajwa green Park
80~90	0.1	Sipjeong green Park
90~100	0.05	

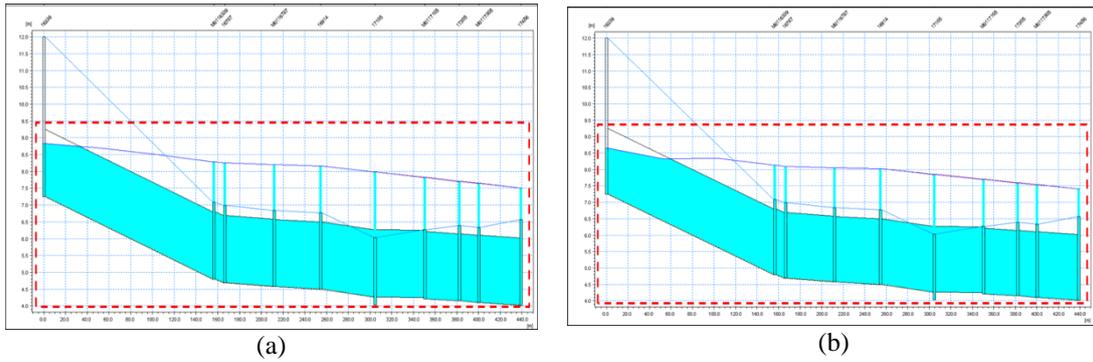


Figure 12 Comparison of the Simulation Results of Considering the Non-point Source Pollution Treatment Facilities in Gjava Green Park (Scenario-3): (a) Before, (b) After

(4) Scenario-4

When the results from Scenario-2 and Scenario-3 are combined, torrential rainfall can cause flooding and damage in the surrounding area, and, when underground rainfall storage or treatment facilities for non-point source pollutant are used, peak flow time is reduced and rainfall capacity of the conduit stabilized. Based on these points, underground rainfall storage and coefficient of runoff will be used together.

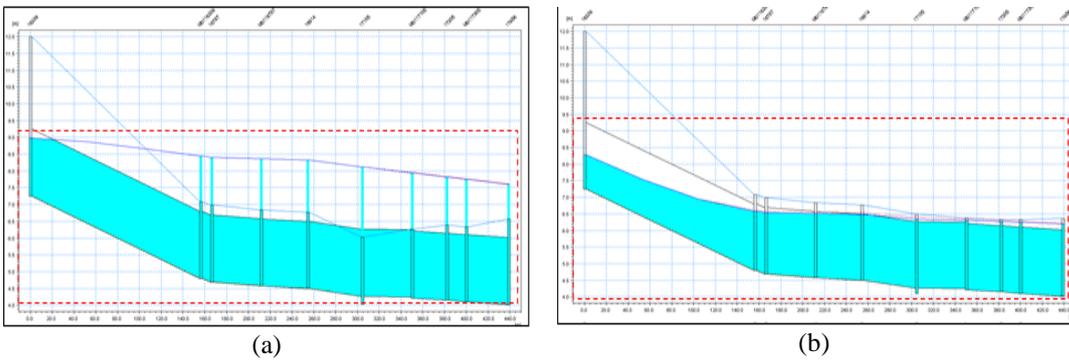


Figure 13. Apply Result of the Underground Storage Tank and Runoff Coefficients in Gjava green park (Scenario-4): (a) Before, (b) After

When underground detention tank and coefficient of runoff was applied, even a detention tank of small capacity lowered the water level during heavy rainfall by 3 m. However, flooding of about 0.2m was observed in low-altitude area in Gajwa Buffer Green Space, and flooding in low areas was prevented by installing detention tanks of various capacities at various positions.

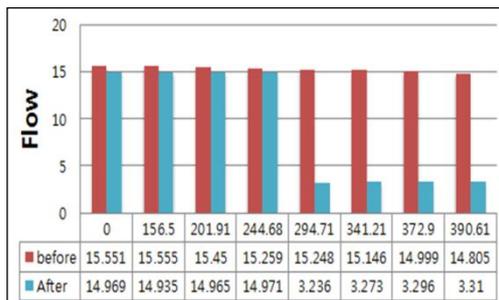


Figure 14. Numerical Result for Scenario- 4

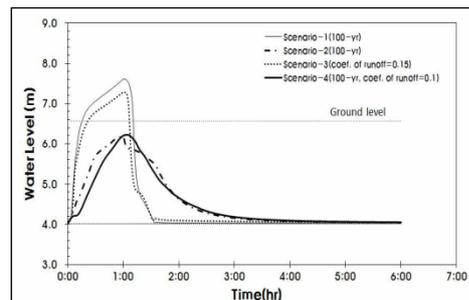


Figure 14. Numerical Result for Gajwa Green Park

Simulation of Gajwa Buffer Green Space showed that, at the frequency of 100 years and for duration of 1 hour, in Scenario 1, the water level was up to 1.05m higher than the ground height. In Scenario-2, the water level was reduced by up to 13.8% from Scenario-1.

This means reduction of flooding. However, in Scenario 3, the water level was up to 0.72m higher than the ground height, and, although Scenario-4 showed similar result to that of Scenario-2, as shown in Figure 15, the difference between Scenario-2 and Scenario-4 was that the initial rainfall was controlled by coefficient of runoff and the peak flow time was slightly delayed, resulting in clear improvement of flooding.

5.2. Sipjeong Green Park

Sipjeong Green Park in Figure 16 is located at 273, Sipjeongdong, Bupyeonggu, Incheon, and was built from 2006 and finished in 2008. The surrounding area includes residential area and industrial area, and there are many sports facilities for the residents. In the south of the park is an artificial waterway. The area is 43,500 m² and, as Sipjeong Green Park is often overflowed and flooded by rainwater, because of its low topography compared to the surrounding area, a program was used to propose an alternative to prevent flood from torrential rainfall.



Figure 15. Sipjeong Green Park, Seo-gu, Incheon

(1) Scenario-1

Comparison of conduit states was made between rainfall based on the frequencies of storm sewer, 5, 10, and 100 years, and when the torrential rainfall was applied. The result is shown in Figure 14.

As a result of applying rainfall by frequency, at 5-year frequency, urban flooding was observed in the lower outflow point, and urban flooding was observed despite the moderate amount of rainfall. Also, the result of applying 10-year frequency was similar to the 5-year frequency. When rainfall at 100-year frequency was applied, overall flooding was observed and, as this amount was discharge condition that can cause damage in the surrounding areas, 100-year frequency will be applied to the scenario.

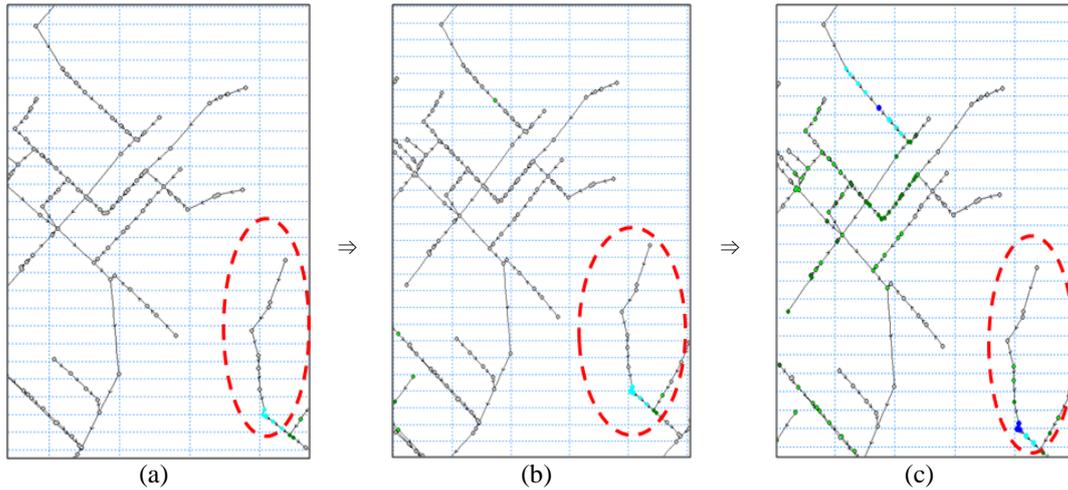


Figure 16 Pipe States According to the Frequency of Sipjeong Green Park (Scenario-1): (a) 5-year Return Period, (b) 10-year Return Period, (c) 100-year Return Period

(2) Scenario-2

Underground retention tank was installed around flooded areas in Sipjeong Green Park based on the 100-year frequency, for the purpose of preventing flood from torrential rain on impermeable layers in the park and detaining rainfall by using flow. The capacity of the detention tank was decided at 20% of catchment area based on the research by Han *et al.* [5]. Figure 18 shows the result according to capacity of detention tanks. When comparing before and after the application, underground detention tank had a significant effect for flood prevention even at 20% of catchment area, and reduced the water level by up to 2 m.

Table 6. Capacity Calculation for Underground Storage Tank of Sipjeong Green Park

Division	Catchment area \times 0.2 (m ²)	Underground Storage Tank capacity (m ³)
Before applying	8,853	0
After applying	8,853	9,000

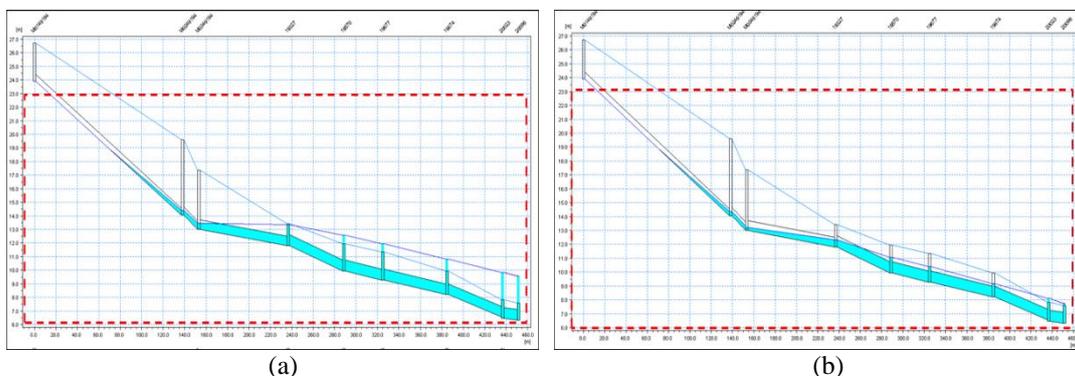


Figure 17. Retrogression of Level According to the Capacity of the Underground Storage Tank in Sipjeong Green Park (Scenario-2): (a) Before, (b) After

(3) Scenario-3

Based on Scenario-1, to apply non-point source pollution in flooded areas Sipjeong Green Park coefficient of run off will be changed according to Table 8 and the range of coefficient of runoff was between 0.5 and 0.7 in the commercial area and 0.1 and 0.25 in areas with much grass and many trees.

As explained in Table 9, coefficient of runoff in Sipjeong Green Park was set at 0.15 as 80 to 90% of the entire park is of green areas. And, to analyze the level of inundation reduction based on coefficient of runoff, coefficient of runoff was applied to neighborhood and 50-60% of green areas, in order to compare inundation reduction effect when coefficient of runoff is 0.1.

Based on the coefficient of runoff at 0.5 in neighborhood around the commercial area, when the coefficient of runoff was changed to 0.1 considering the green park with much grass and many trees, up to 0.9 m³/s was reduced in comparison to before applying coefficient of runoff. Although, due to the small size of conduit in Sipjeong Green Park, this amount is not likely to control flooding caused by torrential rainfall, it may control the initial rainfall and delay peak flow, thereby, controlling flooding. And it has the advantage of conveying the discharge to rainfall because of steep gradient and pipe diameter of 0.5m (Figure 19).

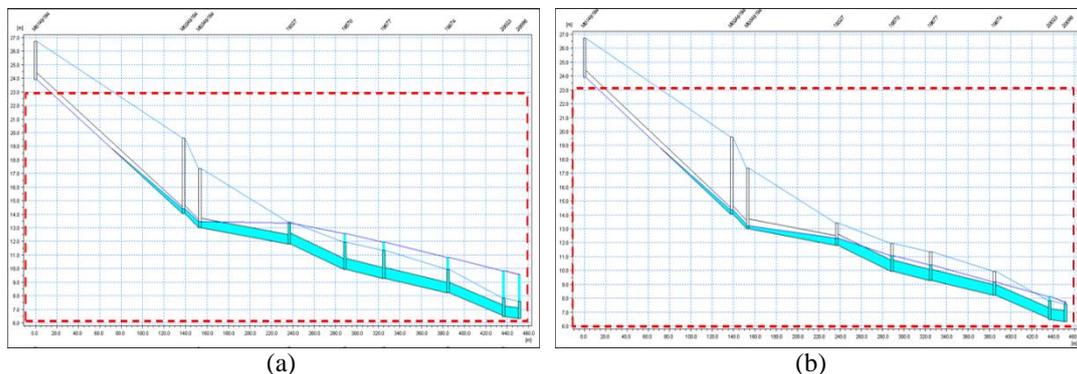


Figure 18. Comparison of the Simulation Results of Considering the Non-point Source Pollution Treatment Facilities in Sipjeong green Park (Scenario-3): (a) Before, (b) After

(4) Scenario-4

When the results from Scenario-2 and Scenario-3 are combined, torrential rainfall can cause flooding and damage in the surrounding area, and, when underground rainfall storage or treatment facilities for non-point source pollutant are used, peak flow time is reduced and rainfall capacity of the conduit stabilized. Based on these points, underground rainfall storage and coefficient of runoff will be used together.

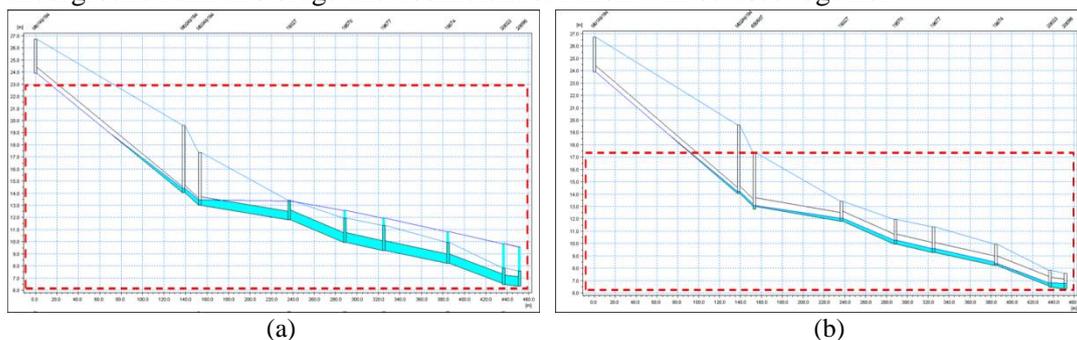


Figure 19. Apply Result of the Underground Storage Tank and Runoff Coefficients in Sipjeong green Park (Scenario-4): (a) Before, (b) After

When underground detention tank and coefficient of runoff was applied, even a detention tank of small capacity lowered the water level during heavy rainfall by 1 m. However, flooding of about 0.2m was observed in low-altitude area in Sipjeong Green Park, and flooding in low areas was prevented by installing detention tanks of various capacities at various positions.

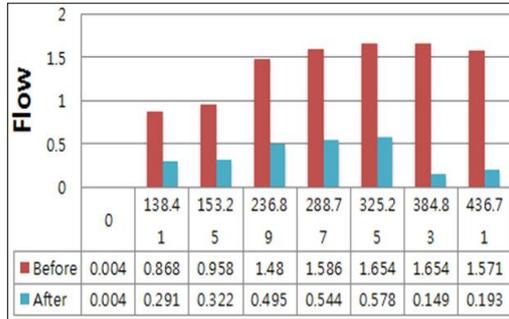


Figure 20. Numerical Result for Scenario-4

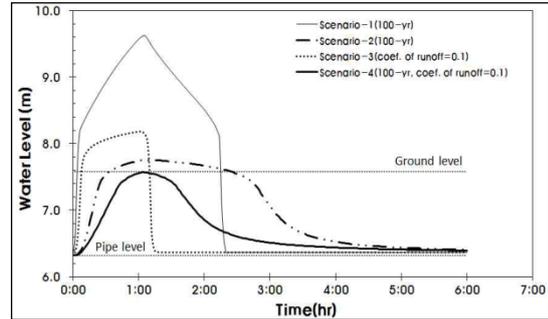


Figure 21. Numerical Result for Sipjeong Green Park

Figure 21 shows the result of Scenario-4 simulation of Sipjeong Green Park. As shown in Fig. 22, in Scenario 1, the water level was up to 2.0m higher than the ground height. In Scenario 2 and Scenario 3, the water levels were reduced by 19.6% and 15.6%, respectively, but flooding was not improved because they were higher than the ground height. However, in Scenario 4, flooding was fully reduced. As shown in Figure 15, the difference between Scenario-2 and Scenario-4 was that the initial rainfall was controlled by coefficient of runoff and the peak flow time was slightly delayed, resulting in clear improvement of flooding.

6. Conclusion

In this study, to resolve flood damage in flood-prone areas around Incheon Bridge landfill, numerical analysis was performed according to change of coefficient of runoff considering underground rainfall storage in surrounding parks and facilities to reduce non-point source pollutants. The following conclusions were drawn:

1. Use of rainfall retention facility to improve urban flooding reduced peak flow and effectively prevented flooding in the subject areas.
2. In the result according to change of coefficient of runoff considering facilities to reduce non-point source pollutants, control of initial rainfall led to reduce peak water level and secure delay time.
3. Based on the study result, to properly install underground retention storage and apply coefficient of runoff according to facilities to reduce non-point source pollutants within the subject areas, providing accuracy of various parameters necessary for future analysis and measurement data will help design effective multi-functional parks with minimized flood damage and prepare measures to prevent disaster.

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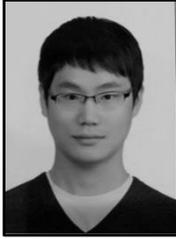
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