Analyzing Sewer Rehabilitation of Erbil in Iraq and Cheongju in Korea Using MOUSE S/W

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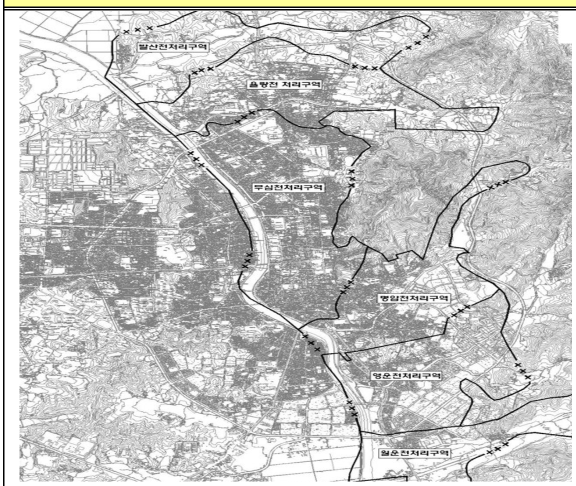
1. Introduction

As of 2006, there are 331 sewage treatment plants (STPs) treating 22,755,000ton of sewage on a daily basis across the country. However, it is hard to improve water quality of downstream or discharging areas because of low treatment efficiency. Major cause for low treatment efficiency is known as poor condition of sewer pipelines. Currently numbers of turn key and built-transfer-lease (BTL) projects are coordinated by governments to mitigate this problem.

Generally, the magnitude of a sewer project is determined based on the results of modeling of sewer pipes using software such as MAKESW, which is widely used in many engineering companies in Korea. The size of the project is often overestimated because MAKESW utilizes rational formula and maximum rainfall discharge in calculating rainfall discharge without considerations in slow down of flowrate due to local conditions or rainfall distribution. For accurate estimation of the magnitude of the project, it is necessary to adopt advanced measures and site-specific parameters including local conditions, characteristics of pipes, time-series precipitation.

The purpose of this study is in reviewing the magnitude of project specified in planning and design report based on modeling using 2 computer applications, MAKESW and MOUSE. MAKESW is software widely used in most engineering firms to estimate the magnitude of project. Demand for MOUSE is increasing in Korea because it enables a user to integrate time-series hydraulic analysis in modeling.

Sangdang-gu Chongju, Korea	Erbil, Iraq



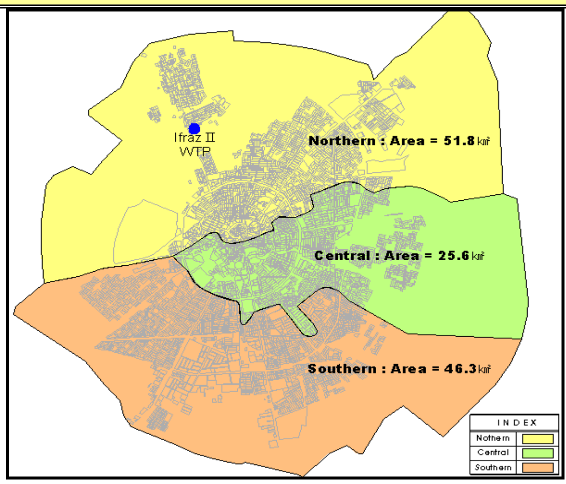


Figure1. Map of Sangdang-gu Chongju and Erbil

The selected 2 computer applications were applied to analyze hydrology and hydraulics of sewer lines in the Sangdang-gu treatment district in Chongju, Korea and 3 treatment districts in Erbil, Iraq. In the Sangdang-gu district, branch sewer lines are connected to the intercepting pipes laid along the stream of Mushimchon. This type of sewer structure can be commonly seen throughout the country. The sewers of the district consist of 220.3km underground pipes including 184.4km circular and 35.9km box pipes.

One of unique characteristics of Erbil's sewers is intercepting sewers functioning as trunk sewers. The total length of sewers is 247.0km including 169.6km circular and 77.3km box pipes. The maps of the Sandang-gu Chongju and Erbil treatment districts are shown in Figure 1.

2. Principles

The main purpose of hydraulic modeling of sewers is in optimizing the sewer networks through identifying potential or existing problems such as low capacity, reversed slope, low flowrate, and high flowrate in the planning stage. Well-designed and properly rehabilitated sewer networks can transport sewage more efficiently. In this study, MAKESW and MOUSE were selected as the tools for sewer modeling after reviewing multiple computer-aided modeling programs.

2.1 Overview of Software

Conventionally, for hydraulic modeling of sewers, static modeling was conducted using MAKESW or Microsoft Excel. Recently developed computer software such as MOUSE and SWMM is designed to support dynamic modeling of wide factors such as pollution load caused by surface runoff, sediment accumulation inside sewer systems, and water quality change due to microbial activities. These highly-sophisticated computer programs are applied in turnkey and BTL projects funded by private sectors.

Table 1. Comparison of hydraulic modeling software

Classification	MAKESW	MOUSE	XP-SWMM	ILLUDAS
Principles	▪ Generally used for planning new sewer systems or maintenance of old sewer networks	▪ Hydraulic modeling based on various time-series rainfall event ▪ Modeling of surface runoff, water quality, and sedimentation	▪ Hydraulic modeling of sewage and storm water, and the diffusion and fate of pollutants	▪ Hydrologic modeling and design of urban storm sewer
Company	A Korean engineer	DHI, Denmark	XP Software, USA	Illinois State Water Survey, USA
Surface runoff model	▪ Application of runoff coefficient to accumulated watershed area	▪ Rainfall loss model ▪ Time-area method ▪ Linear and nonlinear reservoir model	▪ Rainfall loss model ▪ Nonlinear reservoir model	▪ Uniform height method ▪ Horton penetration equation
Pipe flow model	▪ Uniform formula - Manning & Kutter ▪ Non-uniform formula - Standard step method	▪ Saint Venant method ▪ 6-point Abott-scheme ▪ Implicit method ▪ Diffusive and dynamic wave	▪ Saint Venant method ▪ Gauss-Seidel method ▪ Implicit method, diffusive and dynamic wave ▪ Nonlinear reservoir model	▪ Storage equation (flow tracking) ▪ Trial and error
Water quality modeling	▪ N/A*	▪ Movement and fate of various pollutants	▪ Process of pollution including sedimentation	▪ N/A*

Features	▪ Easy to create and edit database ▪ Simultaneous manipulation of cross-sectional and vertical data ▪ Output of bill of quantities	▪ Hydraulic modeling using time-series rainfall and dry season flow pattern ▪ Estimation of quality change and pollution loads	▪ Easy to enter specifications of structures such as shape and dimension ▪ Estimation of limited quality change	▪ Suggestion of pipe diameter in designing ▪ Suggestion of additional capacity through capacity assessment
Application	●	●		

*Not applicable

The most popular software used in Korea includes MAKESW, MOUSE, XP-SWMM, and ILLUDAS. As its strong merits in hydrologic modeling ILLUDAS was used widely for designing rain pump stations. However, in the sewer rehabilitation field, ILLUDAS is widely used. Instead MOUSE and XP-SWMM have been verified and used popularly in sewer rehabilitation projects. Among 2 programs, MOUSE is preferred because it is compatible with GIS and is capable of modeling of pollutant diffusion and transportation.

So far, in applying modeling software, sewage treatment facilities have been considered as separate sewer parameters from sewer networks. However, the influent quality at a sewage treatment facility is highly influenced by the condition of sewer networks. Considering this factor, the application of MOUSE for sewer modeling is estimated to be appropriate. Using MOUSE, the information on underground features prepared by local governments can be utilized efficiently. Description and features of mentioned software are summarized in Table 1.

In applying surface runoff model, MAKESW conducts modeling by simply using specified runoff coefficient and rainfall intensity formula without considerations on detention. This program is widely used in designing processes.

Time-series rainfall data, which incorporate site-specific factors such as detention and retention, is used in MOUSE. Due to the time factor, the peak flow of MOUSE is smaller than that of MAKESW. The peak flow difference between MOUSE and MAKESW increases with the increase in the area of target modeling sites.

In this study, the modeling results of MAKESW and MOUSE of the target sites are compared under the same condition.

2.2 MAKESW

MAKESW is a computer application created on a DOS platform by a Korean engineer. A user can modify input data on a graphic screen. Including hydraulic calculation results, cross sectional and vertical views, and bill of quantities, various formats of outputs can be printed. Though not as popular as MOUSE, MAKESW is used at some engineering companies for modeling. Features of MAKESW are summarized in Table 2. Exemplary screens are provided in Figure 2.

Table 2. Features of MAKESW

Classification	Contents
Overview	▪ Easy data input: Automatic connection of the starting and the end point ▪ Compatibility: Highly compatible with SWER, a computer sewer software developed through a project coordinated by Seoul City ▪ Automatic CAD map drawing and detail data on target rehabilitation pipes

Easy data input	▪ Automatic recognition of data input order and connections: No need to specify connection numbers and inflow pipe number. By specifying the following pipe, the software automatically recognizes the shape of the sewer networks. ▪ Unlimited column and input length: Reduced errors during the process of data input because the data can be separated simply with space, tab, or enter keys.
Compatibility	▪ Creation of input data in existing Seoul sewer networks program (swer.exe)
Flexibility in hydraulic condition	▪ Calculation of dry and wet seasons and storm sewer ▪ Conversion of factors such as allowable water level and flow rate standards for each project ▪ Standard step method ▪ Calculation of new and branch pipes
Automatic determination of improved data	▪ Automatic determination of the pipes to be replaced ▪ Automatic determination of estimated results ▪ Improved data of minimum and maximum flow rate ▪ Provision of low capacity range and slope adjustment range

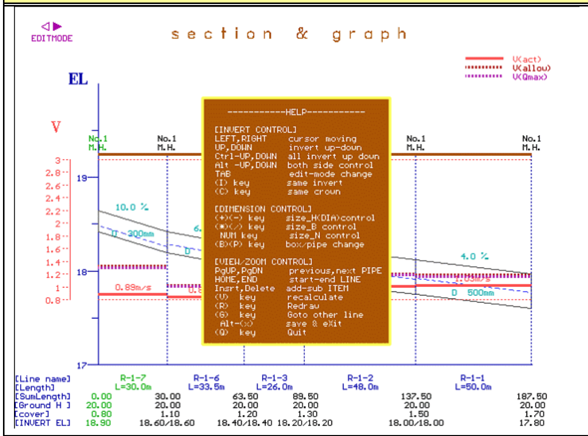
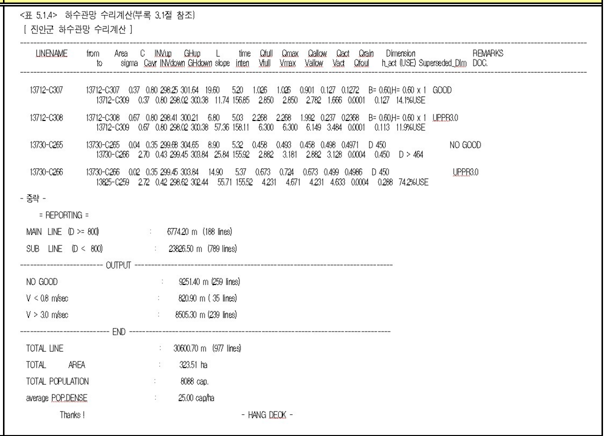
Computation	Output
	
Data editing	Output in a text format

Figure 2. Exemplary MAKESW screens

2.3 MOUSE

Since its development in 1985 by DHI, a Danish company, MOUSE has been widely used in fields of highly sophisticated modeling of discharge systems in urban areas, surface runoffs from sewers, flowrate and movement of pollutants can be performed using this application. There is a graphic user interface (GUI)-supported environment for the analysis on hydraulic and fluid dynamic movement.

Because of highly sophisticated hydraulic features on rainfall, surface runoff, inflow and discharge of flow and movement and fate of pollutants, the demand for this software is increasing in many countries especially in Europe and North America.

The system can be used in conjunction with geographic information system (GIS) data. Considering numbers of on-going projects on digitization of sewer maps, MOUSE is estimated to be efficiently used for analyzing hydrodynamics and water quality of sewers in the country. The features of MOUSE are summarized in Table 3 and the exemplary screens are shown in Figure 2.

Table 3. Features of MOUSE

Classification	Contents
Development	▪ DHI, a Danish company in 1985 ▪ Development of a simulation application MOUSE TRAP in 1994
Purpose	▪ An application for sophisticated hydraulic and movement modeling of discharge systems in urban areas, surface runoffs from sewers, and pollutants ▪ Analysis of surface runoff and hydraulics based on time-series rainfall event
Applications	▪ Combined sewer overflows (CSOs) ▪ Sanitary sewer overflows (SSOs) ▪ Real-time control (RTC) ▪ Analysis and diagnosis of sewer and storm water systems
Features	▪ Wide range of applications ▪ Various simulations ▪ Easy to edit input data ▪ GUI

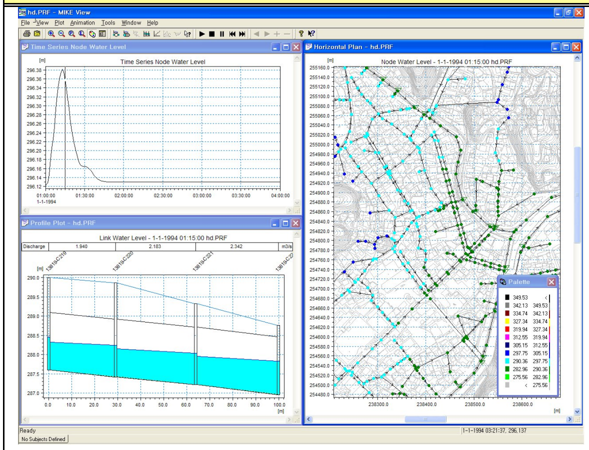
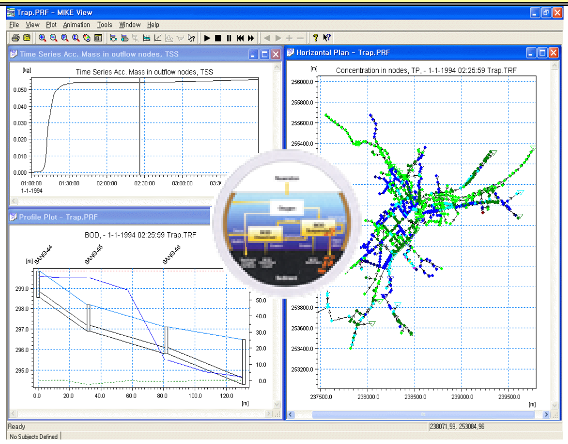
MOUSE HD (hydraulic modeling)	MOUSE TRAP (quality modeling)
	
Produces highly sophisticated modeling results by integrating time-series rainfall data and runoff model	Analysis of sewer system through estimation of influent quality and pollution load at the discharging river through computation of surface runoff, transport of sediment, and water quality change in sewer pipes

Figure 3. Mouse interface

3. Methodology

In addition to the rainfall intensity equation and sewage unit factors needed for modeling by MAKESW, MOUSE requires additional input data including GIS information, time-series data based on rainfall data. This section focuses on the input data required for modeling using MOUSE as summarized in Table 4.

Table 4. Input data required by MOUSE and MAKESW

Classification	MOUSE	MAKESW

Basic iformation	▪ Extraction of pipe specifications through GIS works -Specification of pipe connections -Automatic extraction through ArcView after mapping sewer networks ▪ Extraction of pipe number and depth using ArcInfo -Rearrangement of pipe order in consideration of direction	▪ Manual works required -Data acquisition directly from CAD files or sewer inventory -Text file format
Rainfall data	▪ Time-series rainfall data of specific rainfall event -Derivation of rainfall intensity equation and rainfall distribution in the function of time -Reproduction of probability rainfall and determination of critical duration -Establishment of time-series rainfall data ▪ Manual input of runoff coefficient for each catchment	▪ Manual input of rainfall intensity equation -Derivation of rainfall intensity equation -Specification of required coefficients ▪ Manual input of runoff coefficients for each catchment
Sewage data	▪ Unit sewage data of dry season flow pattern -Measurement of dry season flow -Distribution of hourly weight factors after the determination of dry season pattern ▪ Incorporated population density factor	▪ Specification of hourly maximum unit flow -Application of unit values for all cases ▪ Incorporated population density factor

3.1 Establishment of Basic Data

GIS data of Chongju and Erbil pipelines were extracted using ArcView GIS and Arc Info after the pretreatment of data using CAD. GIS information such as X, Y, Z coordinates, elevation, and diameter of manholes were entered. The link data were completed with diameter, type, length, and depth of pipes. Node and link data including population data of each catchment were summed to acquire information of the entire basin. For the selected basin, runoff coefficient was estimated. The GIS sewer maps were produced over 220.4km and 247.0km long sewer lines in Sangdang-gu Chongju, Korea and Erbil, Iraq as shown in Table 5 and Figure 4.

Table 5. Sewer pipes of Sangdang-gu Chongju and Erbil

Treatment district	Sum	Cylindrical pipe		Box pipe		Remarks
		Length(m)	Ratio(%)	Length(m)	Ratio(%)	
Sangdang-gu	319,188	220,385	69.0	98,803	31.0	
Erbil	247,015	169,697	68.7	77,318	31.3	

MOUSE HD (hydraulic modeling)	MOUSE TRAP (quality modeling)

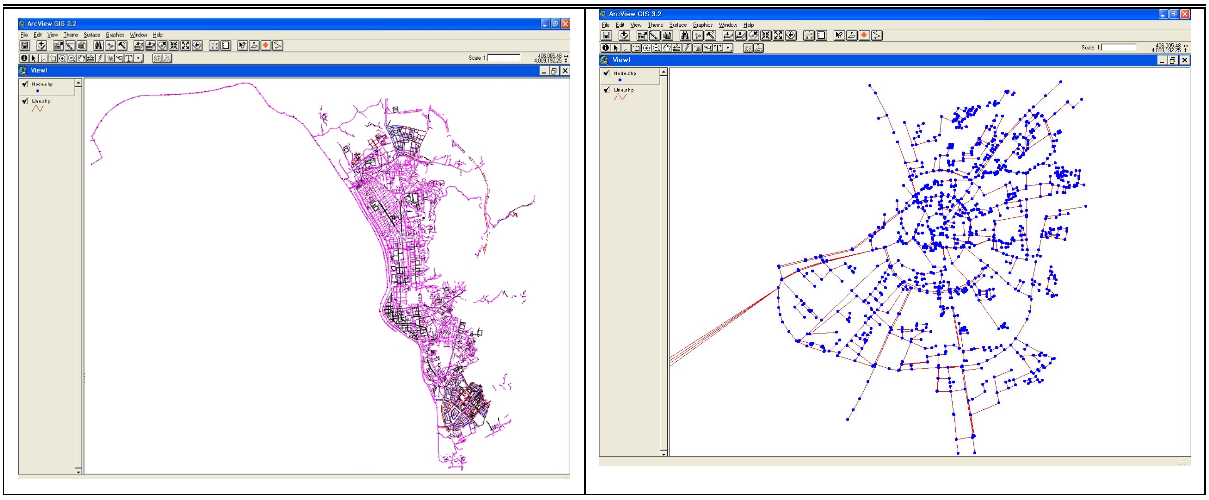
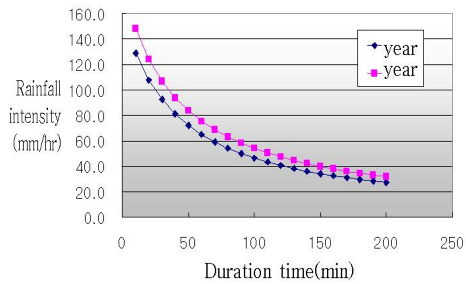
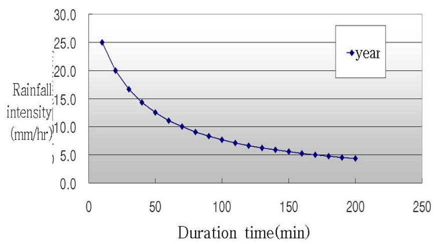


Figure 4. GIS sewer map

3.2 Rainfall Data

In case of Chongju, a Rainfall intensity equation was derived based on the data on Report on Urban Streams (Ministry of Construction and Transportation), Plan on Sewer Maintenance (Chongju), and BTL Plan on Sewer Maintenance. However, as there was not sufficient Iraqi weather data, intensity equation developed by JHIC was used.

Table 6. Derivation of rainfall intensity equation using rainfall data

<table>
<tr><th>Location</th><th colspan="2">Classification</th><th colspan="4">Analysis</th></tr>
<tr><td rowspan="3">Sangdang-gu, Choungju</td><td colspan="2">Rainfall data</td><td colspan="2">Urban rive report(KWA, 1978)
Master plan for sewer in Chongju (Chongju, 2001.3)
BTL for sewer (Chongju, 2005.8)</td><td rowspan="3">IDF curve</td><td rowspan="3">
</td></tr>
<tr><td rowspan="2">Rainfall intensity</td><td>5yr</td><td>$I_5 = \frac{6,570}{t + 41}$</td><td>t30min = 92.54</td></tr>
<tr><td>10yr</td><td>$I_{10} = \frac{7,700}{t + 42}$</td><td>t30min = 106.94</td></tr>
<tr><td rowspan="2">Erbil, Iraq</td><td colspan="2">Rainfall data</td><td colspan="2">UN project service department</td><td rowspan="2">IDF curve</td><td rowspan="2">
</td></tr>
<tr><td>Rainfall intensity</td><td>5yr</td><td>$I = \frac{1,000}{t + 30}$</td><td>t30min = 16.67</td></tr>
</table>

Among Yen and Chow method, Huff method, Keifer and Chu method, and Pilgrim and Cordery method discussed in Temporal Distribution of Regional Design Rainfall (Korea Institute of Constructing Technology, 2000), Huff's quartile method was adopted. The 2nd quartile value was used to determine temporal distribution of design rainfall because the 2nd quartile value was the lowest. Based on the non-dimensional accumulative rainfall curve equation for each quartile, accumulative rainfall during the given time and temporal hyetograph were deduced. Rainfall duration ranged from 30 to 300 minutes. The critical rainfall duration was determined to be 180 minutes, where the maximum runoff was observed through modeling.

Table 7. Determination of critical rainfall duration Sangdang-gu Chongju

Outlet \ Duration(min)	30	60	90	120	150	180	240	300
OUTLET 1	0.882	1.773	2.311	2.604	2.759	2.806	2.798	2.786
OUTLET 23	0.12	0.257	0.328	0.349	0.355	0.356	0.348	0.337
OUTLET 30	0.607	1.037	1.231	1.398	1.480	1.491	1.478	1.456

Because of the limited rainfall data of Erbil, Mononobe's method was used instead of Huff's method. By setting the peak rainfall duration at the center of the rainfall duration ranging from 60 to 360 minutes, probable rainfall was calculated. To determine the critical rainfall duration, the method used for the Chongju case was used. By referencing rainfall data of 6 locations with the highest 6 runoffs, the duration was determined to be 120 minutes.

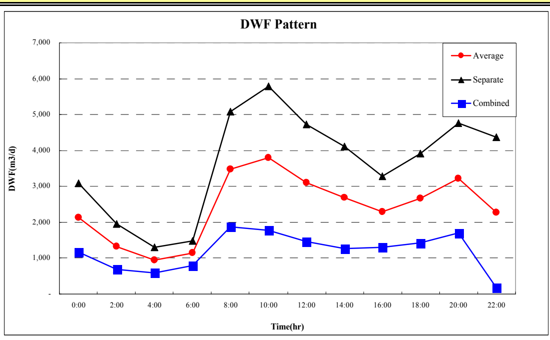
Table 8. Determination of critical rainfall duration of Erbil

Outlet \ Duration(min)	60	90	110	120	150	180	240	360
OUTLET C-1	8.621	9.333	9.342	9.351	9.309	9.301	9.115	8.4
OUTLET C-2	8.621	9.333	9.342	9.351	9.309	9.301	9.115	8.4
OUTLET C-3	8.621	9.333	9.342	9.351	9.309	9.301	9.115	8.4
OUTLET C-4	8.621	9.333	9.342	9.351	9.309	9.301	9.115	8.4
OUTLET S-2	3.813	3.856	3.98	3.981	3.767	3.72	3.347	2.77
OUTLET S-3	1.771	1.788	1.801	1.804	1.711	1.593	1.324	0.956

3.3 Establishment of Sewage Data

At the locations at downstream of separated and combined sewers, sewage data was collected during dry season for 1 month. The flow pattern of dry season was converted into the time-series non-dimensional values. Based on the surveyed data, the unit hourly maximum flowrate was determined to be 0.536m3/cap/day. At the selected 2 points on intercepting pipes, sewage data was collected at Erbil to acquire the dry season flow pattern. The maximum hourly flowrate was determined to be 0.270m^3/cap/day.

Sangdang-gu Chongju, Korea



Erbil, Iraq

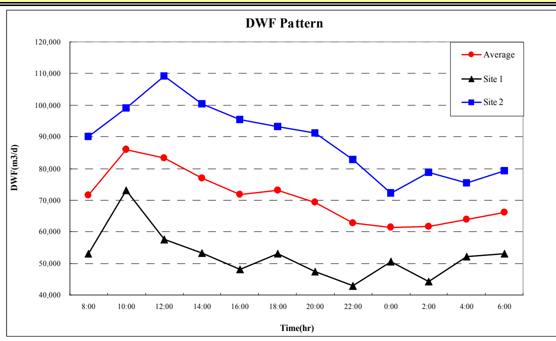


Figure 5. Sewage flow patterns of Chongju and Erbil in dry season

4. Results and Discussion

As MOUSE conducted runoff modeling for the data of relatively short period of time, time-area method, Model A, was applied without additional consideration on retention and diffusion. In case of pipe flow, dynamic wave model, which incorporated gravity and friction factors, was applied. The time interval of modeling was synchronized with the time interval of time-series rainfall data.

MAKESW produced static results including pipes of low capacity, pipes of low flowrate, and pipes of high flowrate, on the basis of peak flow. On the other hand, the hourly maximum and minimum values were allocated for each pipe and manhole in the dynamic modeling results of MOUSE.

For unbiased comparison of the modeling results produced by MAKESW and MOUSE, the pipes of low flowrate were determined by dividing the maximum sewage flow (Qmax) by the maximum carrying capacity (Qfull).

4.1 MOUSE and MAKESW Results Comparison: Sangdang-gu Chongju

The modeling results of Sangdang-gu Chongju are summarized in Table 9.

Table 9. Comparison of Modeling results of MOUSE and MAKESW: Sangdang-gu Chongju

<table>
<tr><th rowspan="2">Classification</th><th rowspan="2">Pipe type</th><th rowspan="2">Diameter</th><th colspan="3">Length(m)</th><th rowspan="2">Remarks</th></tr>
<tr><th>MOUSE</th><th>MAKESW</th><th></th></tr>
<tr><td rowspan="3">Conveyance lack (Qact>Qfull)</td><td>Circular</td><td>D250 ~ D1200</td><td>9,778</td><td>32,905</td><td>337%</td><td rowspan="3">Rehabilitation</td></tr>
<tr><td>BOX</td><td>0.3 X 0.1 ~ 3.5 X 2.0</td><td>3,032</td><td>6,591</td><td>217%</td></tr>
<tr><td colspan="2">Total</td><td>12,810</td><td>39,496</td><td>308%</td></tr>
<tr><td rowspan="3">Less than min. velocity (V<0.8m/sec)</td><td>Circular</td><td>D250 ~ D1500</td><td>183,105</td><td>51,765</td><td>-72%</td><td rowspan="3">Maintenance</td></tr>
<tr><td>BOX</td><td>0.1 X 0.4 ~ 9.0 X 3.0</td><td>92,122</td><td>38,671</td><td>-58%</td></tr>
<tr><td colspan="2">Total</td><td>275,227</td><td>90,436</td><td>-67%</td></tr>
<tr><td rowspan="3">Upper than max. velocity (V>3.0m/sec)</td><td>Circular</td><td>D300 ~ D1500</td><td>1,758</td><td>33,940</td><td>1,931%</td><td rowspan="3">Maintenance & Rehabilitation</td></tr>
<tr><td>BOX</td><td>0.3 X 0.3 ~ 9.0 X 3.0</td><td>556</td><td>18,828</td><td>3,386%</td></tr>
<tr><td colspan="2">Total</td><td>2,314</td><td>52,768</td><td>2,280%</td></tr>
</table>

The length of pipes of low capacity estimated by MAKESW, 39,496m is 308% longer than the length of the same type of pipes estimated by MOUSE. The differences between the results produced by MOUSE and MAKESW are -67% and 2,280% for the pipes of low flowrate and high flowrate respectively. It is estimated that the difference has caused by the difference in modeling methods of MOUSE and MAKESW. Because the time difference between the rainfall event and the runoff in the time-series rainfall data required by MOUSE, the initial runoff is considerably small. However, MAKESW shows instantaneously high runoff because the application utilizes rational formula. Thus the length of the pipes of low flowrate is estimated to be longer while the length of the pipes of low capacity and high flowrate is predicted shorter in MOUSE.

To ensure accuracy and credibility of the modeling results of MOUSE, the rainfall data of over 30 years should be used.

4.2 MOUSE and MAKESW Results Comparison: Erbil

The modeling results of Erbil are summarized in Table 10.

Table 10. Comparison of Modeling results of MOUSE and MAKESW: Erbil

Classification	Pipe	Diameter	Length(m)	Remark

	type		MOUSE	MAKESW		
Conveyance lack (Qact>Qfull)	Circular	D200 ~ D1200	34,979	40,770	16 %	Rehabilitation
	BOX	0.3 X 0.5 ~ 2.5 X 2.0	8,166	6,294	-23 %	
		Total	43,145	47,064	9 %	
Less than min. velocity (V<0.8m/sec)	Circular	D200 ~ D1200	47,146	15,877	-67 %	Maintenance
	BOX	0.8 X 1.0 ~ 2.7 X 2.0	15,729	5,512	-65 %	
		Total	62,893	21,389	-66 %	
Upper than max. velocity (V>3.0m/sec)	Circular	D600 ~ D2600	25,580	16,837	-35 %	Maintenance & Rehabilitation
	BOX	1.0 X 1.2 ~ 2.5 X 2.0	1,462	16,956	1,159 %	
		Total	27,042	33,793	25 %	

The length of pipes of low capacity estimated by MAKESW, 47,064m, is 9% longer than the length of the same type of pipes estimated by MOUSE. The differences between the results produced by MOUSE and MAKESW are -66% and 25% for the pipes of the low flowrate and high flowrate respectively. As in the case of Sangdang-gu Chongju, rainfall runoffs are estimated lower in MOUSE because it utilizes time-series rainfall data reflecting the time difference between the rainfall event and the runoff. On the other hand, the rainfall estimation by MAKESW is relatively high because it utilizes the rational formula.

4.3 Comparison of Modeling Results of Sangdang-gu Chongju and Erbil

The length of the pipes of low capacity in Sangdang-gu Chongju and Erbil are estimated to be 308% and 9% longer in MAKESW than MOUSE. The difference in these two percentage values is considered to be resulted from the difference in underground sewer pipes. The lengths of the pipes of low flowrate are estimated 67% and 66% shorter by MAKESW than MOUSE for Sangdang-gu Chongju and Erbil. In case of the pipes of high flowrate of Sangdang-gu Chongju and Erbil, the MAKESW modeling results showed 2,280% and 25% longer lengths. It is estimated that these differences are caused by topographic differences of these selected cities. In Sangdang-gu Chongju, relatively stiffly-sloped branch sewers are connected to the trunk and the intercepting sewers, laid along the Mushimchon. However, the increment ratio of Erbil is lower because the sewer pipes of the city are laid relatively flat terrain.

5. Conclusion

Hydraulic modeling utilizing MOUSE and MAKESW was conducted for the sewers of Sangdang-gu Chongju and Erbil. As mentioned previously, MOUSE utilizes several models based on time-series rainfall data. On the other hand, MAKESW conducts relatively simplified modeling based on the rational formula.

MOUSE was originally developed for various hydraulic modeling and simulation by integrating various factors such as hydraulic and hydrologic computations as well as on-site conditions. According to the requirements and criteria addressed on Standards for Sewers (ME, 2005), MAKESW was developed for relatively simplified modeling for the first-hand analysis of flows. Based on the simulation and the modeling results, following conclusion can be deduced.

1) The lengths of pipes of low capacity estimated by MAKESW are 308% and 9% longer than the lengths of the same type of pipes estimated by MOUSE in the cases of Sangdang-gu Chongju and Erbil respectively. Because of the time difference between the rainfall event and the runoff in the time-series rainfall data required by MOUSE, the initial runoff is considerably small. As MOUSE conducts modeling and simulation based on more specified and regional information such as delay of flow, detention, and rainfall distribution, it is considered that the results are close to the real conditions. However, MAKESW shows instantaneously high runoff because the application utilizes rational formula. The bigger the size of the modeled basin, the

bigger the magnitude of the estimated length of pipes will be. Consequently, using MOUSE, more accurate and efficient modeling results can be acquired.

2) The sewer systems of Sangdang-gu Chongju and Erbil are combined systems. The difference of the lengths of the pipes of low flowrate estimated by MAKESW and MOUSE are 67% and 66% shorter in case of Sangdang-gu Chongju and Erbil.

3) The lengths of the pipes of high flowrate estimated by MAKESW are 2,280% and 25% longer than the lengths of the same type of pipes estimated by MOUSE. It is assumed that these differences are caused by topographic differences of these selected cities. In Sangdang-gu Chongju, relatively stiffly-sloped branch sewers are connected to the trunk and the intercepting sewers, laid along the Mushimchon. However, the increment ratio of Erbil is lower than that of Sangdang-gu Chongju because the sewer pipes of the city are laid relatively flat terrain.

4) Because the modeling results of MOUSE show the condition of pipes as well as GIS information such as the location of potential flood, it is easy to establish hydraulic database as well as contingency plans. Setting up of hydraulic information using MOUSE is becoming easier because there are GIS data established through multiple sewer projects. Thus MOUSE can be efficiently utilized in the stage of planning, designing, and operation and maintenance of sewer networks.

References

1. Ministry of Environment (2005) Standards for Sewers

2. Korea Institute of Constructing Technology (2000) Temporal Distribution of Regional Design Rainfall

3. Ministry of Construction and Transportation (1978) Report on Urban Streams (Chongju)

4. Chongju (2001) Plan on Sewer Maintenance

5. Chongju (2005) Feasibility Study on BTL Projects and Plan on Sewer Systems

6. DHI Software (2004) MOUSE pipe flow – reference manual

7. DHI Software MOUSE surface runoff models – reference manual