Han River Flood Control Office (Ministry of Land, Infrastructure and Transport)

Korea Institute of Civil Engineering and Building Technology (KICT)



DWAT (Dynamic Water resources Assessment Tool) – User's Manual 1.0

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For Software version 1.0 Beta

Han River Flood Control Office (HRFCO)



Ministry of Land, Infrastructure and Transport Han River Flood Control Office

Korea Institute of Civil Engineering and Building Technology (KICT)



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Foreword

DWAT is a software to analyze water cycle for a watershed or water management unit with runoff, evapotranspiration, water use and water supply in aspect of space and time. DWAT uses a distributed conceptual scheme for water cycle analysis and can be used with or without observed data. As the system is linked to an open GIS tool, physical input parameters can be searched and optimized conveniently. DWAT has been developed since 2008 as a part of WMO (World Meteorological Organization) RA (Regional Association) II WGHS (Working Group on Hydrological Services) activities, and it has been supported by the Han River Flood Control Office, Ministry of Land Infrastructure and Transport, Republic of Korea.

The global analysis of a hydrologic-hydraulic network is essential in numerous decision-making situations such as the management or planning of water resources. DWAT makes such analyses accessible to a broad public through its user-friendly interface and its valuable possibilities.

DWAT contains sub-algorithms such as evapotranspiration, infiltration, watershed runoff, groundwater movement and channel routing. The model is under verification through applications to various rural and forest catchments and new urban development regions in Korea. The model reliability will be strongly enhanced through the further model applications to global area.

The DWAT was developed in a "node-link type" that enables objective considerations of runoff characteristics resulting from different geomorphological factors by dividing ranges into subcatchments judged to be hydrologically homogenous. The user interface of the model was developed for easy access and operation of the model and it will help how to use the model to effectively simulate and analyze many scenarios simultaneously. The purpose of this user guide gives instruction on how to use the DWAT. When using the program, please check the content of this user guide.

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For any further information on this program including technical issues and questions regarding to the use of the program, please contact researchers and development team.

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Index

Foreword	3
Chapter 1: Introduction	8
1.1 System Requirements	8
1.2 Installation procedure	9
Chapter 2: Model Interface	12
2.1 Main Menu	14
2.1.1 File	15
2.1.2 Edit	17
2.1.3 View	17
2.1.4 GIS Preprocessor	18
2.1.5 Model	29
2.1.6 Help	31
2.2 Icons	31
2.3 Property view	31

Chapter 3: Model Input Data	32
3.1 Subject Catchment	36
3.1.1 Background Image	36
3.2 Climate	37
3.2.1 Climate Data Import	38
3.2.2 Climate Data Checking	40
3.2.3 Climate Node Entry	42
3.3 Ground Surface	49
3.3.1 Catchment Node Entry	50
3.3.2 Parameter Entry	50
3.4 Soil	52
3.4.1 Parameter Entry	53
3.5 River	56
3.6 Groundwater Aquifer	56
3.6.1 Aquifer Specification Entry	57
3.6.2 Groundwater Movement Parameter Entry	58
3.7 Reservoir	59

3.8 Wetland	63
3.9 Recycle	65
3.10 Import	67
3.11 Channel Routing (Link)	69
3.12 Junction and Outlet	72
3.12.1 Junction	72
3.12.2 Outlet	73
Chapter 4: Model Running	75
4.1 Analysis Condition Setting	75
4.2 Model Execution	76
Chapter 5: Analysis of Results	77
5.1 Water Balance	79
5.2 Chart	81
5.3 Table	84
References	85

Chapter 1: Introduction

This user guide provides instruction on how to use DWAT and assists water resources engineers and researchers to easily understand the program and to increase the ability to apply the program to fields.

This chapter includes introduction to program installation and its interface. In addition, all the processes to create, extract and correct input data are explained in detail and the methods to execute the model and analyze various figures and graphs are explained.

However, the configurations of the model described in this user guide are those for the current version and they may be changed with further development. Characteristics of DWAT are summarized as follows:

- Physical parameter-based link-node type model
- Separate runoff simulations for pervious and impervious zones
- Analysis of infiltration, evaporation, groundwater flows relative to soil layers and groundwater aquifers and simulations of channel routing
- · Simple, practical and easily accessible
- Guaranteed satisfactory results with minimal data and efforts
- Easy user convenience system (GUI)
- Provision of results through diverse tables and figures

1.1 System Requirements

In order to use the DWAT program, at least 100Mb are required as the minimum available disk space. The minimum requirements for a PC system are summarized in the following table.

System	Minimum	Recommended		
Operation systems	Windows 98, Windows ME, Windows XP, Windows 2000 Windows Vista, Windows 7, Windows 8, Windows 10			
Memory	512MB	1GB		
CPU	P-4, 1.5Hz processor	P-4, 3.0Hz processor Core2 2.0 processor		
Hard disk capacity	100Mb extra space	500Mb extra space		

1.2 Installation procedure



You install the DWAT by double-clicking on the **DWATSetup.msi** file in the installation directory.



When the 'DWAT Setup screen' appears, click Next.

😌 CAT Setup	
Choose Install Location Choose the folder in which to install CAT.	
Setup will install CAT in the following folder. To install in a different folder, click Brows select another folder. Click Next to continue.	e and
Destination Folder	
C:\Program Files\CAT\ Browse	
Space required: 8.8MB Space available: 207.2GB	
Korea Institute of Construction Technology	Cancel

The DWAT install defaults to installing the program in C:\Program Files\DWAT and users can create their own directory structure. Once you've designated the directory to which the program will be installed, click **Next**.

🕫 CAT Setup		
Choose Start Menu Folder Choose a Start Menu folder for the CAT shortcuts.		
Select the Start Menu folder in which you would like to create the program's short can also enter a name to create a new folder.	uts. You	
CAT		
Administrative Tools A1/99/E@140CARE@ Chart FX Client Server DAEMON Tools Lite Games Intel PROSet Wireless Microsoft .NET Framework SDK v2.0 Microsoft Office Microsoft SQL Server 2005 Microsoft Visual Studio 2005 Spread 6 Startup		
Korea Institute of Construction Technology	Cancel	(교체)

In the 'installation confirmation screen', click Next.

🗑 CAT Setup	
Installing Please wait while CAT is being installed.	(internet)
Execute: msiexec /i vcredist.msi /qn	
Korea Institute of Construction Technology	Next > Cancel (교체)

The 'Program installation screen' will appear. If you click the cancel button, the program installation will not be completed. Please wait until the 'Installation completion screen' appears.



When the 'Installation completion screen' has appeared, click Finish.

The DWAT program has been successfully installed.

You may check the installation in the 'Program Start Menu'.

Windows start menu > program > DWAT > DWAT

Chapter 2: Model Interface

The interface of the model has been developed so that it can be easily applied and managed by users and so that various scenarios can be easily applied. The user interface has been designed so that all input/output data are linked with Microsoft Excel. All data sets are easily managed in each project. The environment used in developing the user convenience system (Graphic User Interface, GUI) is Microsoft Visual Studio and the system was developed for Windows.

Figure 2.2-1 shows the basic configuration screen of the DWAT. The main screen of the DWAT is primarily divided into the Main Interface, Parameters and Node. The tools are used in analysis and include the Main Menu and Toolbar, Node, etc. The Parameters window indicates the attributes of nodes and the variables of selected nodes.



<Figure 2.2-1> Basic configuration screen of the CAT

2.1 Main Menu

The DWAT has six main menu items and they are shown in Figure 2.2-2. The main menu provides overall operation functions, including project file management, model executions and input/output result checking.





The functions of each menu are reviewed in the following sections.

2.1.1 File

<u>New Project</u>: This is a menu to create new projects. This menu clears all data in memory and interface fields and opens an empty project.

Open Project: This is a menu to display the standard file open dialog. It allows users to open existing projects stored in the certain directory and is mainly used to revise existing data in the project. The extension of the project files of the DWAT is ***.dpr** and only project files (*.dpr) can be opened.



Save: It allows you to save the current .cpr file (including all screens, attribute information and data of the open project).

Save as: It allows users to save the current project under another name.

Save reslult: It allows users to save simulation result of the current project under another name.

Background: Background images (*.bmp or *.jpg) can be imported. This may be useful for configuring each source node and link on the background (e.g. the watershed boundaries and rivers).



<u>Create Series</u>: This menu creates time series (e.g. rainfall, meteorological data and observed discharges) into input data files (*.dat) in the DWAT.

Create series					X
Create series Time step ● Hour ● Month ● User define 2007/01/01 00:00 2 3 4 5 6 7 8 9 10 11 12 13 14	O Day O Year (min)	Period Field	2007-01-01 Rainfall Date Rainfall Evaporation Humidity Solar Wind Temperature(Min) Temperature(Min) User defined Observed data	2010-1	2-31 V Add
15 16 17					>
File header Series file					
	Sav		Close		

2.1.2 Edit

Edit menu has various functions. These are briefly described below.

<u>Undo</u>: a function to undo after editing <u>Cut</u>: a function to remove attribute tables, links and nodes <u>Copy</u>: a function to reproduce attribute tables, links and nodes <u>Paste</u>: a function to paste attribute tables, links and nodes <u>Delete</u>: a function to delete attribute tables, links and nodes

2.1.3 View

View menu has various functions. These are briefly described below.

Toolbar: a function to show or hide the tool bar on the bottom of the main menu



Status bar: a function to show or hide the display window on the bottom of the CAT program window



<u>Pan</u>: a function to pan the entire configuration screen

Zoom in: expanding function (interlocked with mouse scrolls)

Zoom out: reducing function (interlocked with mouse scrolls)

<u>Series</u>: functions to display the time series input data recreated in the DWAT; check, edit and save data files from model outputs; export the files as text (*.txt) files (since all files created in the DWAT are

stored in the form of data files, *.dat (binary type format), this is a function to facilitate users' checking.).

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ab			×	Decim	a. 0.00000			
	Date	В	С	D	E	F		^
1	98/01/01 00	0.00000	0.50000	0.20000	86.00000	0.00000		
2	98/01/01 01	0.00000	0.50000	1.20000	86.00000	0.00000		
3	98/01/01 02	0.00000	0.50000	0.00000	86.00000	0.00000		
4	98/01/01 03	0.00000	0.50000	0.30000	86.00000	0.00000		
5	98/01/01 04	0.00000	0.50000	0.80000	86.00000	0.00000		
6	98/01/01 05	0.00000	0.50000	0.70000	86.00000	0.00000		
7	98/01/01 06	0.00000	0.50000	0.50000	86.00000	0.00000		
8	98/01/01 07	0.00000	0.50000	0.80000	86.00000	0.00000		
9	98/01/01 08	0.10000	0.80000	0.20000	95.00000	0.00000		
10	98/01/01 09	0.00000	0.80000	0.80000	95.00000	0.00000		
11	98/01/01 10	0.00000	0.80000	1.70000	95.00000	0.00000		
12	98/01/01 11	0.40000	3.40000	2.50000	92.00000	0.00000		
13	98/01/01 12	0.00000	3.40000	2.00000	92.00000	0.90000		
14	98/01/01 13	0.00000	3.40000	1.50000	92.00000	0.20000		
15	98/01/01 14	0.00000	5.50000	2.30000	76.00000	0.00000		
16	98/01/01 15	0.00000	5.50000	1.20000	76.00000	0.00000		
17	98/01/01 16	0.00000	5.50000	0.20000	76.00000	0.00000		
18	98/01/01 17	0.10000	4.20000	1.00000	88.00000	0.00000		
19	98/01/01 18	0.00000	4.20000	1.70000	88.00000	0.00000		
20	98/01/01 19	0.00000	4.20000	1.20000	88.00000	0.00000		
21	98/01/01 20	0.00000	1.50000	1.30000	97.00000	0.00000		
22	98/01/01 21	0.00000	1.50000	0.50000	97.00000	0.00000		
23	98/01/01 22	0.00000	1.50000	0.30000	97.00000	0.00000		
24	98/01/01 23	0.00000	-1.20000	0.00000	97.00000	0.00000		
25	98/01/02 00	0.00000	-1.30000	0.50000	97.00000	0.00000		
26	98/01/02/01	0.00000	-1.30000	0.00000	97.00000	0.00000		
27	98/01/02 02	0.00000	-1.30000	1.00000	97.00000	0.00000		
28	98/01/02/03	0.00000	-1.30000	1.00000	97.00000	0.00000		~
29	98/111/112/114	0.00000	4.30000		97.00000			

2.1.4 GIS Preprocessor

Hydrologic models like DWAT require land use and soil data to determine the area and the hydrologic parameters of each land-soil category simulated within each sub-watershed.

The physical parameters of the system can be searched and optimized conveniently using GIS Preprocessor menu. This tool allows users to load land use and soil themes into the current project and determine the land use/soil class combinations and distributions for the delineated watershed and each respective sub-watershed.

Watershed delineation is one of the most commonly performed activities in hydrologic analyses. Digital elevation models (DEMs) provide good terrain representation from which watersheds can be derived automatically using GIS technology.

The complete process of watershed delineation and input parameters using GIS Preprocessor involves a sequence of steps

It is important to use a DEM with no depressions or sinks, so we first have to "fill" the DEM.
 To create an accurate representation of flow direction and, therefore, accumulated flow, it is best to use a dataset that is free of sinks. A digital elevation model (DEM) that has been processed to remove all sinks is called a depressionless DEM. The identification and removal of sinks, when creating a depressionless DEM, is an iterative process. When a sink is filled, the boundaries of the filled area may create new sinks that need to be filled.

- 2. Determining the slope direction at each pixel, i.e. the "aspect" of the terrain.
- 3. Determining the "flow accumulation", that is, the number of up gradient pixels that slope toward each point in the DEM grid.
- 4. Calculation of preliminary stream network raster using a flow accumulation.
- 5. Add a point that represents the outlet of watershed. You need to add and load a "shape file" that has the outlet for the watershed.
- 6. Determining watershed area using channel threshold value.

• Set the channel formation threshold value to something like 100 or 1000 or 5000 depending on the size of your watershed and goals of your analysis. There is no standard threshold value.

7. Overlay Soil map.

• In this model, the concept of surface soil indicates the depth (range) where pores exist to temporarily store intermediate runoff. In the DWAT, infiltration and evapotranspiration into/from soil are analyzed based on the physical characteristics of soil, and thus surface soil parameters should be established. The physical characteristics of soil (including soil depth, saturated hydraulic conductivity, horizontal hydraulic conductivity, saturated moisture contents, residual moisture contents and Mualem's n) are used in this model. The information on the surface soil depths and parameters is used after being classified by soil texture based on the 1:25,000 precise soil map.

8. Overlay Land use map

• Input data for land use conditions includes ground surface slopes, impervious area ratios and depression storage. The information on topological parameters is based on land use map from the National Geographic Information System (NGIS).

First go to Main Menu and select GIS Preprocessor.

2 2016107.hd - DWAT			x
Fiel/F) Edx(1) View(0) GG5 Preprocessor Model/M) Help/H			
desdet v 3 X	Property		×
	Property		٠
silet attiment GIS Preprocessor	20: 24 🔟 🗲		-
CIC I Teplocessol	Name	Catchment 1	
	Descript		1
	Area	2.7117	
Import Wedand Climate 2	Impervious	13	
	Renious	87	

GIS Preprocess				×
DEM	🏐 SOIL	LANDUSE	NOUTLET	
Layers Load DEM				
DEM				
Subbasin				
🗖 Stream				
🔲 Soil				
Landuse				
L Outer				
			6487500.00 / -12	95000.00/ -9999.00

DEM: A browser will be displayed allowing the user to select the DEM grid (Raster file: hdr.adf).

This file format (*.adf) is the internal binary format for Arc/GIS Grid, and takes the form of a coverage level directory in an Arc/GIS database. To open the coverage select the coverage directory, or hdr.adf from within it.

ntale 1	A 971					
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	92	이플(N) hdradf			- Fastar fileschar	e,*st*stfhdra •

Click Open to proceed. When this step is complete, DEM and flow accumulation theme is added to the GIS Preprocessor view.





OUTLET: It allows users to add an outlet point.

Once you have zoomed in, go to the Select outlet browser. Make sure to select which folder to use whichever one has the newly created shape file for the outlet point. Click "Add point", directly user placed from add point using left-clicking on a stream pixel.

If you are off the stream channel by so much as one pixel you will not delineate the correct drainage area. Your outlet point must be in a flow channel pixel.



Click OK to proceed. You are ready to delineate watershed area.

Stream Sof		tream c	drop statisti	6		T			12		đ		
Dutlet			Threshold	Dran Den	No First Ord	No High Ord	Mean D First Ord	Mean D High Ord	Std Dev High Ord	Std Dev High Ord	T	-	
		1	5.000000	3.970252e-003	106	53	35.403225	38.849056	41.126354	43.677311	-0.530713		
		2	8.340503	2.844119e-003	107	32	35.168224	37.218750	39.712288	40.023167	-0.255817		
		3	13.912798	2.216164e-003	70	17	33.320571	44.117645	40.151062	53.609566	-0.927001		
	1.	4	23.207947	1.714755e-003	39	9	35.820515	42.888889	35.614063	45.087261	-0.510604		
		5	38.713192	1.311410e-003	24	7	31.791666	29.571428	43.206261	20.173061	0.130663		
	7	6	64.577499	9.794905e-004	9	3	40.222221	29.666666	46.542397	12.503335	0.376960		
	<u> </u>	7	107.721756	8.596037e-004	6	2	53.000000	27.500000	50.600395	4.949748	0.675472		
	1	8	179.690720	6.788122e-004	4	2	50.750000	6.000000	47.310146	8.485281	1.254473		
	the second	Input #	rreshold	150 14	i Z		×_	Cancel	Ž	£		•	

BASIN: It allows you to delineate watershed area using channel threshold value.

Click OK to proceed. You have delineated a watershed.



<u>SOIL</u>: It allows you to overlay soil type theme to the watershed boundaries.

DWAT require land use and soil data to determine the area and the hydrologic parameters of each landsoil category simulated within each sub-watershed. If the soil and land use is defined in the same projection as the DEM, select shape file (*.shp) in file browser. If soil map is not projected as the DEM, This will stop map processing.

When this step is complete, a dialog box will pop up listing database files from which soil type can be selected. User need to define DWAT soil type associated with soil type theme categories. Select the attribute field containing the codes/category values to be reclassified: SO_TYPE.



Click OK to proceed.



LANDUSE: It allows you to overlay land use theme to the watershed boundaries. Select land use theme (*.shp).



When this step is complete, a dialog box will pop up listing database files from which soil type can be selected. Select the attribute field containing the codes/category values to be reclassified: UCB.





Click OK to proceed. Land use theme is added to the watershed boundaries.

<u>RUN</u>: It allows you to determine the area and the hydrologic parameters of each land-soil category simulated within each sub-watershed. When this step is complete, land use attributes box will appear stating that the land use theme has been processed to the watershed boundaries. The attributes box also remind the user to edit a look-up table or manually define the land use classes for the theme.



You can manually assign a land use NAME and TYPE.

- To manually assign land use NAME, double-click in the NAME fields.

	Index	Name	Type		٠
1	1120	7555	Plant	-	
2	1210	Upland	Plant		
3	2110	Grassland	Pervious		
4	2120	Grassland	Pervious	+	
5	2210	Conifer	Pervicus	-	
6	2220	Hardwood	Pervious		
7	2230	Coniter-Hardwood	Pervious		
8	2310	Golf	Pervious	+	
9	2320	Park	Pervious	-	
10	2330	Park	Pervious	-	
11		e 14.944	· · · · ·		ň

- To manually assign land use TYPE (Pervious, Impervious and Plant), highlight the desired database item by clicking on it.

16 3310			
1990 B	Indutinal	Impervious	-
17 3320	Industrial	Impervious	-
18 3410	Public	Impervious	*
19 3420	Public	Impervious	-
20 343	Public	Impervious	
21 3440	Public	Impervious	
22 3530	Livestock	Impervious	•
23 3550	Livestock.	Impervious	•
24 4210	Stream	Pervicus	
··· 4310	Lakes	Flant	-
23 3550 24 4210 26 4310) Livestock) Stream) Lakes	Pervicus Pervicus Repeivous	•

Click OK to proceed. This will return you to the definition of soil attributes box.

DEM Layers	SOIL LAND	JSE 🕅 C	OUTLE	T BAS	in C	RUN			-		
P DEM				B.S.L	1.16	1		2			
Accum				00							
Stream	A PHOT	Martin			X			B			
⊽ Sol	Station of the second				ALL.	- 1-		1			
Landuse	Antes	÷			1	-A	2	200			
T outlet	1400.000					5 an	S.	1.44			
								-	÷.,		
	1 A . W	Soil							*		
	1 N	6.000		C Market and						217	
	200	(* Prop	Aprey .	 Match sacks 	direction (0.00011	2000	100 mm		2	
		1	Index 1	Clav	depin 50	0.475	1_per 0.090	FL_per 0.38	-		
		2	2	Clay loam	50	0.464	0.075	0.25			
	* *	3	3	Sand	20	0.437	0.020	0.09		2. S	
	2.7.7	4	4	Sandy clay loam	50	0.398	0.068	0.33			
	1997 A.	5	5	Sandy loam	20	0.453	0.041	0.21			
	1 N 100	6	6	Silly clay	50	0.479	0.056	0.34		A	
	1. 200-	7	- 0	Silly clary loam	20	0.4/1	0.040	0.32	- 1		
	R. Com	8	•	Sitty Kodim	50	0.901	0.015	0.30	11		
			-							11	
	and the second	<u> </u>		1	-	2001				1	
				L	OK	Cancel				1 3 4	
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	and the second	1.4			1	1		1.5	1		
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	Sec. 1	No.	1.5	Mar Contract	1.1	L . 3	Sec.			2010	
	18.00			1 A A	- A.		2	100		100	

The attributes box also remind the user to edit a look-up table or manually define the soil classes for the theme.

You can manually assign a soil NAME, TYPE and Properties.

- To manually assign soil NAME, double-click in the NAME fields.

Soil				×	
C Pro	perty 📀	Match table			
	Index	Name	Туре		
1	1	AnC	Clay	•	
2	2	AnD	Clay loam	•	
3	3	ArB	Sand	•	
4	4	ArC	Sandy clay loam	•	
5	5	ArD	Sandy loam	•	
6	6	AsC2	Silty clay	•	
7	7	AsD2	Silty clary loam	•	
8	8	AsE2	Silty loam	•	
9	9	BcB	Clay	• •	L
4				•	
	-	(OK Cancel		

- To manually assign soil TYPE, highlight the desired database item by clicking on it.

oil					X
O Pro	perty 📀 I	Match table			
	Index	Name	Туре		_
1	1	AnC	Clay	•	_
2	2	AnD	Clay loam	-	
3	3	ArB	Sand	-	
4	4	ArC	Sandy clay loam	-	
5	5	ArD	Sandy loam	-	
6	6	AsC2	Silty clay	-	
7	7	AsD2	Silty clary loam	-	
8	8	AsE2	Clay loam	^	
9	9	BcB	Sand Sandu clau loam		_
•			Sandy loam Silty clay		• •
			OK Cancer	-	

- To manually assign soil Properties, double-click in each fields.

	Index	Name	depth	s_per	r_per	FC_per	-
1	1	Clay	50	0.475	0.090	0.38	
2	2	Clay loam	50	0.464	0.075	0.25	
3	3	Sand	20	0.437	0.020	0.09	
4	4	Sandy clay loam	50	0.398	0.068	0.33	
5	5	Sandy loam	20	0.453	0.041	0.21	
6	6	Silty clay	50	0.479	0.056	0.34	
7	7	Silty clary loam	20	0.471	0.040	0.32	
8	8	Silty loam	50	0.501	0.015	0.30	
c I							

Once the joining attribute codes have been assigned to all map categories, the file browser will be appeared. It allows the current file to save in text file format (attribute information and data of the watershed).



Click SAVE to proceed. Hydrologic model is created.



Click OK to proceed. When you close the GIS Preprocessor window, Delineated watershed is appear.



2.1.5 Model

Table: The results for hydrologic component at each source node can be displayed at tal	ble
---	-----

	Seri	ies											l	x
	File							Load						
	Interv	al Iday		Start time 2	002/01/01	00:00	Count	2191						
	Table			-	Ded	mal 0.00	T							
	Catch	nment 1												
1		Date	Inflow(§©)	Bainfall(mm)	Actual	Potential	Flow Surface(mm)	Flow Inter(mm)	Flow Groundwater	Flow Total(mm)	Infiltrate(mm)	Recharge(mm)	Groundwater	
	562	03/07/16 00	0.00	0.00	0.00	6.39	0.00	0.00	1.09	1.09	0.00	0.00	0.00	
I L	563	03/07/17 00	0.00	0.10	0.00	4.52	0.00	0.00	1.05	1.05	0.07	0.00	0.00	
	564	03/07/18 00	0.00	48.50	0.01	2.37	6.04	22.04	1.01	29.10	32.49	10.52	0.00	
	565	03/07/19 00	0.00	13.50	0.26	4.33	1.49	7.89	1.37	10.76	9.05	1.15	0.00	
	566	03/07/20 00	0.00	6.50	0.24	2.69	0.60	0.00	1.36	1.96	4.36	0.00	0.00	
	567	03/07/21 00	0.00	0.10	1.78	3.24	0.00	0.00	1.31	1.31	0.07	0.00	0.00	
	568	03/07/22 00	0.00	121.50	0.01	2.32	15.53	73.79	1.26	90.59	81.40	10.52	0.00	
	569	03/07/23 00	0.00	4.50	0.24	2.68	0.34	0.00	1.61	1.96	3.02	0.00	0.00	
	570	03/07/24 00	0.00	1.00	0.26	4.24	0.00	0.00	1.55	1.55	0.67	0.00	0.00	
	571	03/07/25 00	0.00	9.50	0.13	3.83	0.97	7.64	1.49	10.10	6.37	2.41	0.00	
	572 •	03/07/26 00	0.00	0.00	0.26	4 85	0.00	0.00	1 53	1 53	0.00	0.00	0.00	



<u>Chart</u>: Graphs of the simulation results after running the model will appear on screen.

Model Setup: It allows users to set up environments for running the model (e.g. simulation time and period)

Title Term 1/ 1/2002 ▼ ~ 12/31/2007 ▼ Interva 85400 ↔ (cerc) ↓ 000 ↓ 0
Term 1/ 1/2002 ▼ ~ 12/31/2007 ▼
Interva 85400 - (sec) Loop 10
OK Cancel

Run : It allows users to execute model simulation

Run model
Complete calculation
Run Close

2.1.6 Help

Manual: It is a view menu for the DWAT user manual

Support: It allows users to link to the DWAT's website

About CAT: It is a menu to identify the copyright and version information of the DWAT



2.2 Icon

The user interface of the DWAT basically includes 10 icons. There are: Three basic nodes (i.e. Catchment, Reservoir, Wetland); and four functions for catchment configurations (i.e. Links, Junctions, Recycle, Import and Outlets to connect between nodes). In addition, Select and Climate icons are included to check attributes.



2.3 Property View

The Property View displays the attribute information of each node, link and junction. That is, an attribute information screen automatically appears on the left when a node, link or junction is individually selected on the main screen. Information on parameter values can be identified and corrected.



Chapter 3: Model Input Data

The DWAT requires various input data to reflect watershed characteristics, such as topology, geological features, hydrologic and hydraulic features, artificial systems for water use and drainage, in the analysis of water cycle.

In the analysis, the DWAT uses physical parameters based on physiographic factors, soil and groundwater as shown in Table 3.1. Physical parameter values can be established using land use data, soil diagrams and river data, etc. Table 3.1 ~ Table 3.3 contain a list of input data at source nodes (i.e. urban, forest, paddy and water cycle improving facilities) and links. In this chapter, the processes to create, extract and process these input data are explained in detail.

Division	Input variable	Description of variable	Unit
Subject watershed	Area	Area	km²
Meteorological	Latitude, Elevation, Height	the location, elevation and height of the observatory	m
condition	Climate data	rainfall, wind velocity, sunshine hours, lowest/highest temperatures, relative humidity	-
	Slope	catchment average slope	-
	Aratio_imp	impervious area ratio	%
Ground surface	Aratio_per	pervious area ratio	%
condition	Aratio_per_plant	Vegetation area ration in pervious zone	%
	DepC_imp	depression capacity in impervious zone	mm
	DepC_per	depression capacity in pervious zone	mm
	theta_per	current soil moisture content	-
	soil_th_per	soil thickness	m
	s_per	Saturated soil moisture content	-
	r_per	residual soil moisture content	-
	FC_per	SMC at field capacity	-
	W_per	SMC at wilting point	-
	ks_per	saturated hydraulic conductivity	mm/s
Surface soil	ksi_per	Saturated horizontal hydraulic conductivity	mm/s
	Mualem	Index for Mualem Eq.	-
	PSI	wetting front soil suction head	mm
	f _o	maximum or initial value of infiltration capacity into soil	mm/hr
	f _c	maximum or ultimate value of infiltration capacity into soil	mm/hr
	k	decay coefficient	hr ⁻¹
	rivE	riverbed elevation	m
River	Area_riv	area of riverbed	km²
	riv_th	thickness of riverbed	m
	ku_riv	riverbed material permeability coefficient	mm/s
	gwE	current groundwater level	m
Groundwater	aqf_S	storage coefficient of aquifer	-
aquifer	aqf_Top	top elevation of aquifer	m
	aqf_Bot	bottom elevation of aquifer	m

<Table 3.1> Model parameter (Catchment nodes)

aquifer slope	average slope of aquifer	-
node length	average node length	m
conj. length	conjugated length between nodes	m
Kgw	saturated hydraulic conductivity of aquifer	mm/s
GW_pump_rate	groundwater pumping rate	m³ /day
 leakage_rate	leakage rate of water supply networks	-

<Table 3.2> Model parameters (Other node)

Division	Input variable	Description of variable	Unit
	vol_init	initial storage	m³
	vol_eff	effective storage	m³
	intake_vol	intake volume	m³/day
	Kgw	saturated hydraulic conductivity of aquifer	mm/s
	spill_ht	Height of spillway	m
	spill_length	Length of spillway	m
Reservoir	spill_coef	overflow coefficient of spillway	-
(online/offline)	pipe_ht	Height of outlet pipe	m
	pipe_area	Area of outlet pipe	m²
	pipe_coef	runoff coefficient of outlet pipe	
	offline_max	Maximum inflow into offline pond	m ³ /sec
	offline_ratio	Control ratio for offline inflow	-
	offline_out	downstream outflow from offline pond	m ³ /sec
	H-V-A	stage-storage-area relationship	m-m ³ -m ²
	vol_init	initial storage	m ³
	vol_max	maximum storage	m ³
	flood_bypass	High flow bypass during flood	m³/sec
\/(atland	Kgw	saturated hydraulic conductivity of aquifer	mm/s
welland	pipe_ht	Height of outlet pipe	m
	pipe_area	Area of outlet pipe	m²
	pipe_coef	runoff coefficient of outlet pipe	-
	H-V-A	stage-storage-area relationship	m-m ³ -m ²
Pocyclo	rec_intake	Total intake volume	m³/day
Recycle	rec_cond	Restriction for intake rate according to streamflow	%

external water	import_water	Constant volume or time series data of imported from outside	m³/day
	Leakage	leakage rate	%

<Table 3.3> Model parameter (link, channel routing)

	Division	Input variable	Description of variable	Unit
		DT	time step for calculation	unit time
	Muskingum	Х	routing factor (0.0 $~$ 0.5)	-
		К	wave travel time	hr
		Channel length	length of channel	m
		Channel slope	bed slope of channel	-
Channel	Muskingum Cunge	Manning N	Manning roughness coefficient	-
		Top width	top width of channel	Unit unit time - hr m - - m - m - m m m m
routing				
	Kinematic wave	Manning N	Manning roughness coefficient	-
		Channel slope	bed slope of channel	-
		Channel length	length of channel	m
		Bottom width	bottom width of channel	m
		Top width	top width of channel	m
		Channel depth	channel depth	m

3.1 Subject Catchment

The range of water cycle assessment primarily consists of watershed systems, including stream network. In the stage of composing a watershed system, catchment information is required and information on water level stations is needed to compare simulation results to observed data. The user can import images of watershed systems including catchment information as the background. It allows users to configure links and source nodes easily.

3.1.1 Background Image



Load: It allows users to insert background images

Open					? 🔀	
Look in:	🚞 test		~	G 👂 🖻 🖽	•	
My Recent Documents	Pangyo_Back.t	mp				
Desktop						
My Documents						
My Computer						
	File name:	Pangyo_Back.bmp		~	Open	
My Network	Files of type:	BMP files(*.bmp)		~	Cancel	<u>ت</u>)

)
<u>Adjust</u>: It allows users to adjust the location and size of imported background images **<u>Delete</u>**: It allows users to delete background images

When a background image has been loaded, a screen as shown below is created.



3.2 Climate

The DWAT requires the meteorological time series such as the highest/lowest temperatures, wind velocities, sunshine hours, humidity, etc. the model was designed to enable loading not only text files but also Microsoft Excel files. When inputting meteorological data in Excel or text files, the model has also been designed to enable users to freely load time series data defined by the users without standardized file formats. It facilitates the easy usage and management of the program. In addition, the user can not only choose weather stations but also can allocate weighted values from the Thissen networks at each node. The location of each weather station, the height from the ground of each observing device and the latitudes should also be collected. They are necessary to calculate potential evapotranspiration by the Penman-Monteith method.

3.2.1 Climate Data Import



<u>**Create series**</u>: It allows users to create Excel (*.xls), text (*.txt), and DBF (*.dbf) formats of meteorological data into the DWAT input data file (*.dat) format. The following window will pop up.

<u>Time step</u>: time step for climate data (min, hour, day month, year)

<u>Period</u>: time of start and finish

Field: specify the type of field for input (to calculate the evapotranspiration, temperature, wind, humidity

and sunshine hours selected. After select the field name and click the Add), the user can prepare his/her own data with format of *.xls or *.txt and Copy & Paste can be carried on.

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3	1998-01-	01 1:00	0	0.5	1.2		86	0	
4	1998-01-	01 2:00	0	0.5	0		86	0	
5	1998-01-	01 3:00	0	0.5	0.3		86	0	
6	1998-01-	01 4:00	0	0.5	0.8		86	0	
0	1998-01-	01 5:00	0	0.5	0.7		80	0	
9	1998-01-	01 7:00	0	0.5	0.5		86	0	
10	1998-01-	01 8:00	0.1	0.8	0.2		95	0	
11	1998-01-	01 9:00	0	0.8	0.8		95	0	
12	1998-01-0	1 10:00	0	0.8	1.7		95	0	
13	1998-01-0	1 11:00	0.4	3.4	2.5		92	0	
14	1998-01-0	1 12:00	0	3.4	2		92	0.9	
15	1008-01-0	1 14:00	0	3.4	1.5		92	0.2	
17	1998-01-0	1 15:00	0	5.5	2.3		76	0	
18	1998-01-0	1 16:00	0	5.5	0.2		76	0	
19	1998-01-0	1 17:00	0.1	4.2	1		88	0	
20	1998-01-0	1 18:00	0	4.2	1.7		88	0	
21	1998-01-0	1 19:00	0	4.2	1.2		88	0	
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Series file D:\CAT-U_jang\penman_0202\climate_0228.dat

Click and enter the saving directory and file name.

File header Climate data Enter the file description.

Save: The file will be saved as DWAT time series input data by pressing the 'Save' button. When the saving has been completed, press the 'Confirm' button.

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Month	🔿 Yea	r		ndi	· · ·	Add
OUser define	(min)		Clear	Remove]
	Rainfall	Temperatur	Wind	Humidity	Solar	^
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2	0.00	-0.90	1.50	82.00	0.00	
3	0.00	-0.70	0.60	83.00	0.00	
4	0.00	Droto	1	88.00	0.00	
5	0.00	Proto		88.00	0.00	
6	0.00			89.00	0.00	
7	0.00		Comple	ete 90.00	0.00	
8	0.00	<u> </u>		90.00	0.00	
9	0.00		화이	87.00	0.00	
10	0.00		<u> </u>	80.00	0.00	
11	0.00			73.00	0.00	
12	0.00	6.70	1.20	60.00	0.10	
13	0.00	9.10	2.30	52.00	0.40	
14	0.00	10.10	2.70	49.00	1.00	
15	0.00	10.40	4.90	49.00	1.00	
16	0.00	9.90	6.10	54.00	1.00	~
· 1/		8 /11	570	6210	11511	>
header climat	e_data					
ries file D:₩2	011_sim₩c	limate.dat				

3.2.2 Climate Data Checking

To check whether data have been properly saved or not, the following process should be performed:



Series: It allows users to display all data files created in the DWAT in the screen. View > Series gives the following window. 🗔 Pressing this button to display meteorological data previously saved, and then to load the time series data in the spread sheet of the window as shown in pressing this button Open

the following figure.

ile	D:₩2011_sim	n₩climate.d	at				Open	
nter	val 1hour	C Start	time 200	0/01/01 00	:00	Count	17544	
īab	le climate_date	1	~ C	Decimal	0.00000	*		
clim	ate data							
C.I.I.I	ano_aana							
	Date	В	С	D	E	F	~	
1	00/01/01 00:00	0.00000	-0.40000	0.50000	78.00000	0.00000		
2	00/01/01 01:00	0.00000	-0.90000	1.50000	82.00000	0.00000		
3	00/01/01 02:00	0.00000	-0.70000	0.60000	83.00000	0.00000		
4	00/01/01 03:00	0.00000	-0.80000	0.90000	88.00000	0.00000		
5	00/01/01 04:00	0.00000	-1.30000	0.30000	88.00000	0.00000		
6	00/01/01 05:00	0.00000	-1.30000	1.30000	89.00000	0.00000		
7	00/01/01 06:00	0.00000	-1.50000	0.90000	90.00000	0.00000		
8	00/01/01 07:00	0.00000	-1.40000	0.80000	90.00000	0.00000		
9	00/01/01 08:00	0.00000	-0.80000	1.40000	87.00000	0.00000		
10	00/01/01 09:00	0.00000	1.10000	0.10000	80.00000	0.00000		
11	00/01/01 10:00	0.00000	3.40000	1.20000	73.00000	0.00000		
12	00/01/01 11:00	0.00000	6.70000	1.20000	60.00000	0.10000		
13	00/01/01 12:00	0.00000	9.10000	2.30000	52.00000	0.40000		
14	00/01/01 13:00	0.00000	10.10000	2.70000	49.00000	1.00000		
15	00/01/01 14:00	0.00000	10.40000	4.90000	49.00000	1.00000		
16	00/01/01 15:00	0.00000	9.90000	6.10000	54.00000	1.00000		
17	00/01/01 16:00	0.00000	8.20000	5.70000	62.00000	0.50000		
18	00/01/01 17:00	0.00000	7.70000	5.80000	66.00000	0.00000		
19	00/01/01 18:00	0.00000	7.40000	6.40000	70.00000	0.00000		
20	00/01/01 19:00	0.00000	7.30000	5.40000	72.00000	0.00000		
21	00/01/01 20:00	0.00000	6.90000	6.20000	75.00000	0.00000		
22	00/01/01 21:00	0.00000	6.40000	5.90000	78.00000	0.00000		
23	00/01/01 22:00	0.00000	6.80000	4.50000	77.00000	0.00000		
24	00/01/01 23:00	0.00000	6.30000	6.00000	79.00000	0.00000		
25	00/01/02 00:00	0.00000	5.00000	2.30000	85.00000	0.00000		
26	00/01/02 01:00	0.00000	4.20000	1.20000	89.00000	0.00000		
27	00/01/02 02:00	0.00000	3.00000	0.90000	91.00000	0.00000		
~~	00/01/02 03:00	0.00000	3 10000	1 80000	92 00000	0.00000	×	

The following figure appears on the upper part of the 'Series View' window. It shows information of the data file: the time interval (one hour), the number of data rows (17,544) and the data start time (2000/01/01 00:00).

File D:₩2011_sim₩climate.dat	Open
Interval 1hour C Start time 2000/01/01 00:00	Count 17544
Table climate_data. Climate_data	₩

^CThis is a function to modify the time interval for input data. Once it has been selected, the current time interval appears. The process is: change the time interval in the 'NEW' tab; select whether to show the sum, average, maximum or minimum in the 'Method' tab; and then press 'OK'. The changed time interval will be displayed.

Change in	nterval	
Currnet	60	ОК
New	60	Cancel
Method	Sum 💌	 (記:

Export : If meteorological data imported by the DWAT have been checked, these data may be exported in text file format (*.txt). These text format data may be opened and checked in general text editors.

Open					? 🗙
Look in:	🗀 test		✓ G	🏚 📂 🛄-	
My Recent Documents	 calculate orde export.txt import.txt 	r.txt			
Desktop					
My Documents					
My Computer					
	File name:	climate_export		~	Open
My Network	Files of type:	Text Files(*.txt)		~	Cancel

Save In addition, meteorological data imported into the 'Series View' may be revised and the revised data may be saved under another name.

3.2.3 Climate Node Entry

After completing the processes of setting the catchment system and importing meteorological data, the user will reach the stage to enter meteorological nodes. As mentioned earlier, the DWAT is a node-link model and the user can select icons (e.g. link, source and junction) with a mouse to easily configure

체)

catchment information. A climate node will be created by clicking the left mouse button on the appropriate position in the 'Main Interface' after selecting the Weather icon in the meau. The same process is required to configure multiple weather stations.



When meteorological data is used in the DWAT, the user not only can choose climate stations having meteorological data but also may allocate weighted values from the Thissen network at each node. Although meteorological data had to be separately established to use the Thissen network, data were fixed as meteorological data to be used for one node in existing urban water cycle models. In the DWAT, weighted values as shown in the following Figure were configured for usage.[H1]

To back to meteorological node inputs, the user should enter weather station information and conditions for simulations. After left-clicking on a meteorological node, the following window will appear on 'Property View'.



Property: This is a menu to import meteorological data and enter weather station information. .

Pro	perty	×
Pro	operty	•
0	∎ <u>⊉</u> ↓ 🔲 🗲	
	Climate node	•
	Name	Climate 1
	Descript	
	Climate	C:\Program Files (x86)\
	Create evaporation	
	Calculate	True
	Latitude	38
	Elevation	20
	Height	20
		•
Cli	mate	
Se	lect import series data	

Climate station names may be modified in the 'Name' column and a brief description is to be entered into the 'Descript' column. After that, press a button under 'Climate' to import meteorological data.



<u>Calculate</u>: By selecting 'True', parameters to calculate Penpan-Monteith potential evapotranspiration can be brought from meteorological data. If 'false' is selected, the program will use the potential evapotranspiration entered by users.

Latitude, Elevation and Height: This a dialog box to enter the location of the climate station (latitude, elevation and height). This function is used when the 'True' option has been selected.

When all information of the meteorological nodes have been defined, press the 'OK' button.

<u>**Table</u>**: This is a menu to identify rainfall and calculated evapotranspiration in a table. This function may be used once the model has been executed. That is, this menu is used to view results after running the model. Meteorological data can be identified at the View > Series menu.</u>



<u>Chart</u>: This is a menu to view graphs from the model runs. This function is provided in not only a meteorological node but also all links, nodes and junctions. No matter which of them is selected, an identical window will appear (i.e. no matter which source node, link or junction is selected, graphs at all points can be identified). This menu will be explained in the 'Result Analysis' chapter in detail.



Following graph shows the result of Potential evapotranspiration (ET_p) and actual evapotranspiration at source node.



DWAT can use the rainfall gauges in network. The Thiessen weight coefficient can be specified to each source node. Also it can specify different stations for climate data and stations for rainfall data considering the climate measuring stations are rare compare to rainfall measurement. The maximum gauging stations to apply climate and rainfall are five.



<u>ET method</u>: It allows users to select actual evapotranspiration calculation methods

🗆 Cli	imate	
Ξ	Evapotranspiration	
	Method	Monthly Coefficient
	Jan	Monthly Coefficient
	Feb	Leaf Area Index
	Mar	FA056
	Apr	0.7
	May	0.7
	Jun	0.7
	Jul	0.7
	Aug	0.7
	Sep	0.7
	Oct	0.7
	Nov	0.7
	Dec	0.7

Monthly Coefficient: A method to calculate actual evapotranspiration by multiplying the potential evapotranspiration with monthly coefficients.

Leaf Area Index: A method to calculate actual evapotranspiration considering monthly leaf area indexes (LAI, Leaf Area Index) and soil moisture contents (the same method used in the SWAT, Soil and Water Assessment Tool)

FAO 56: The actual evapotranspiration is calculated by the Penman-Monteith method in FAO56 using climate data (Max. & Min. air temperature, sunshine hours, humidity and wind speed).

	🗆 Cli	mate	
	-	Evaporate	
		Method	Monthly Coefficient 🔹
		Jan	0.7
		Feb	0.7
		Mar	0.7
		Apr	0.7
		May	0.7
		Jun	0.7
		Jul	0.7
		Aug	0.7
		Sep	0.7
		Oct	0.7
		Nov	0.7
		Dec	0.7

The above figure shows how to enter monthly coefficients. Monthly evapotranspiration correction coefficients and monthly leaf area indexes (LAI) are entered in the monthly method and the AETSWAT, respectively. The types of vegetation used in the model are divided into four groups: forests, grasslands, urban trees and crops (Jia, Y., 2002). The leaf area indexes are values from a previous study (A study on the development of watershed diagnosis methods for establishing healthy water cycle systems, 2005). The following figure shows the leaf area indexes (LAI) applied to the model.



3.3 Ground Surface

Once entries of the meteorological nodes have been completed, information on the source nodes, links and junctions configured about sub-catchments is to be entered one by one. Input data for ground surface conditions includes ground surface slopes, impervious area ratios and depression storage as shown in Table 3.1. In general, depression storage in impervious zones is undertsood as 2mm. Examples of impervious area ratios by land use are shown in the Table 3.4.

Classification	Class 1	Class 2	Ratio Impervious area * (%)
1		residential	65
2		industrial	72
3	Urban -	commercial	85
4		recreation	50
5		road	100
6		public	60
7		paddy	-
8	Agriculture	upland	-
9		Green house	-
10		orchid	-
11		Etc.	-
12		decidious	-
13	Forest	coniferous	-
14		mixed	-
15		natural	-
16	Grass	golf course	-
17		Etc.	-
18	Wetland	inland	-
19	Welland	coastal	-
20	Bare soil	mines	-
21		etc	-
22	Water	inland	-
23	Water	sea	-

<table 3.4=""></table>	Classification	of	land	cover
------------------------	----------------	----	------	-------

* Ratio of impervious area (Guideline for river planning, KWRA, 2009)

In this chapter, entry processes for the basic ground surface condition of the Catchment node will be explained in detail.

3.3.1 Catchment Node Entry

Catchment node will be located by placing each of the Catchment node icons at an appropriate position on the Main Interface and left-clicking the mouse after selecting each node icon.



3.3.2 Parameter Entry

In the following Figure, the 'Property View' will show the information on the catchment node. The 'Property View' is used to enter or revise all catchment node data (ground surface, soil, groundwater aquifer, etc). Basic ground surface conditions are to be entered under the node.

Pro	perty	×			
Property					
	Catchment node	_			
	Name	Catchment 1			
	Descript				
	Area	2.7117			
	Impervious	13			
	Pervious	87			
	Plant ratio	21			
	Slope	0.05			
	depC_per	5			
	depC_imp	2			

Name: This indicates source node (sub-catchment) names.

Descript: Information of a source node (sub-catchment) may be entered.

Area: source node (sub-catchment) area.

Slope: watersheds' average slope.

Impervious: impervious area ratio.

<u>Pervious</u>: pervious area ratio.

<u>Plant ratio</u>: vegetation area ratio in pervious zone (This parameter is an evapotranspiration-related variable that is divided into four types, including forests, grasslands, urban trees and crops, and the range of the variable and these values are shown in the following figure (Jia, Y., 2002)).



<u>DepC_imp</u>: depression capacity in impervious zone (generally 2 mm) **<u>DepC_per</u>**: depression capacity in pervious zone

3.4 Soil

In this model, the concept of surface soil indicates the depth (range) where pores exist to temporarily store intermediate runoff. In the DWAT, infiltration and evapotranspiration into/from soil are analyzed based on the physical characteristics of soil, and thus surface soil parameters should be established. The physical characteristics of soil (including soil depth, saturated hydraulic conductivity, horizontal hydraulic conductivity, saturated moisture contents, residual moisture contents and Mualem's n) are used. The information on the surface soil depths and parameters is used after being classified by soil texture based on the 1:25,000 precise soil map. The following table is utilized based on the study (A study on the development of watershed diagnosis methods for establishing healthy water cycle systems, 2005). In Table 3.5, the horizontal hydraulic conductivity is determined by giving 10 times the values of the saturated hydraulic conductivity.

Soil texture	saturated moisture content ratio s_per	residual moisture content ratio r_per	SMC, field capacity FC_per	SMC, wilting point W_per	saturated hydraulic conductivity Ks_per (mm/s)	Horizontal hydraulic conductivity Ksi_per (mm/s)	Mualem's n
Sand	0.437	0.020	0.091	0.033	6.5E-02	6.5E-01	3.37
Loamy Sand	0.437	0.035	0.125	0.055	1.7E-02	1.7E-01	3.64
Sandy Loam	0.453	0.041	0.207	0.095	6.1E-03	6.1E-02	3.91
Loam	0.463	0.027	0.27	0.117	3.7E-03	3.7E-02	4.17
Silty Loam	0.501	0.015	0.3	0.133	1.9E-03	1.9E-02	4.20
Sandy Clay Loam	0.398	0.068	0.33	0.148	8.3E-04	8.3E-03	4.23
Clay Loam	0.464	0.075	0.255	0.197	5.6E-04	5.6E-03	4.26
Silty Clay Loam	0.471	0.040	0.318	0.208	5.6E-04	5.6E-03	4.29
Sandy Clay	0.430	0.109	0.366	0.239	3.3E-04	3.3E-03	4.32
Silty Clay	0.479	0.056	0.339	0.250	2.8E-04	2.8E-03	4.35
Clay	0.475	0.090	0.384	0.272	1.7E-04	1.7E-03	4.38

<Table 3.5> Surface soil input parameters by soil texture

* Rawls & Brakensiek Soil parameter estimates (1985).

3.4.1 Parameter entry

-	Soil	
	theta_per	0.25
	soil thick	47.6402
	Saturate	0.455007
	Residual	0.0664587
	Field capacity	0.285145
	Wilting point	0.189706
	ks	0.00181713
	ksi	0.0181713
	Mualem	7
	Inf method	Rainfall Excess
	PSI	13.9638
	k	4.14
	Fc	9.5
	Fo	80.7998

The 'Property' window is opened by left-clicking on each source node.

theta_per: This is the current moisture content of the soil. 0.25 is a default value and this value may change at each time step. It is a computated value between saturated moisture content ratios and residual moisture content ratios.

soil_thick: This is the soil thickness generally in a range of 1 - 5.

Saturate: This is the saturated soil moisture content ratio in a range of 0.4 - 0.6 (refer to Table 3.5).

<u>Residual</u>: This is the residual soil moisture content ratio in a range of 0.02 - 0.2 (refer to Table 3.5).

Field capacity: This is the soil moisture content at field capacity in a range of 0.1 - 0.5 (refer to Table 3.5).

Wilting point: This is the soil moisture content at wilting point in a range of 0.03 - 0.3 (refer to Table 3.5).

<u>ks</u>: This is the saturated hydraulic conductivity in a range of $0.1 \times 10^{-4} - 0.7 \times 10^{-1}$ (refer to Table 3.5).

ksi: This is the horizontal hydraulic conductivity in a range of 0.1×10^{-3} - 0.7 (refer to Table 3.5).

<u>Mualem</u>: When calculating vertical and horizontal infiltration, this model uses the Mualem equation, which utilizes unsaturated hydraulic conductivity. This shows the n (index) value of the Mualem equation, which is the input parameter. This value is in a range of 3 - 5 (refer to Table 3.5).

Inf_method : Selection for infiltration method, Rainfall Excess, Green & Ampt, Horton method are provided.

-	Soil					
	theta_per	0.25				
	soil thick	47.6402				
	Saturate	0.455007				
	Residual	0.0664587				
	Field capacity	0.285145				
	Wilting point	0.189706				
	ks	0.00181713				
	ksi	0.0181713				
	Mualem	7				
	Inf method	Rainfall Excess 🔹				
	PSI	Rainfall Excess				
	k	Green&Ampt				
	Fc	Horton				
	Fo	80.7998				

PSI: Capillary suction head for Green & Ampt method. Table 3.6 shows the typical values of PSI

Soil type	PSI (mm)	
Sand	49.5	
Loamy Sand	61.3	
Sandy Loam	110.1	
Loam	88.9	
Silt	130.7	
Silty Loam	166.8	
Sandy Clay Loam	218.5	
Clay Loam	208.8	
Silty Clay Loam	273.0	
Sandy Clay	239.0	
Silty Clay	292.2	
Clay	316.3	

<Table 3.6> Typical value of PSI

* Rawls & Brakensiek Soil parameter estimates (1985)

 $\underline{\mathbf{k}}$: decay constant for soil used by Horton method.

 $\underline{\mathbf{fc}}$: Minimum infiltration capacity for Horton method. See Table 3.6

<u>fo</u> : Maximum infiltration capacity by Horton method. It affected by the type of soil, initial soil moisture and the surface condition. See Table 3.7

Soil drainage Classes	Minimum Infiltration (fc) (mm/hr)		
A (Excessively drained)	11.43 ~ 7.62		
B (Well drained)	7.62 ~ 3.81		
C (Poorly drained)	3.81 ~ 1.27		
D (Very Poorly drained)	1.27 ~ 0.0		

<Table 3.6> Typical minimum infiltration capacity (fc)

* XP-SWMM User's Manual (2007)

Soil type	Maximum Infiltration (fo) (mm/hr)	
A. Dry soils ((with little or no vegetat	tion)
Sandy soil		127.0
Loam soil		76.2
Clay soil		25.4
B. DRY soil	Is (with dense vegetation	on)
Sandy soil		254.0
Loam soil	152.4	
Clay soil		50.8
(C. MOIST soils	
Soils which have drained but not dried out	Sandy soil	84.7
Soils close to saturation	Loam soil	Choose value close to minimum infiltration rate
Soils which have partially dried out	Clay soil	33.9

<Table 3.7> Typical maximum infiltration capacity (fo)

* XP-SWMM User's Manual (2007)

3.5 River

Since the parameters related to channels in the DWAT are closely related with groundwater aquifers, the model was designed to enter the parameters in the 'Property View' window. It is shown in the following figure. Channel specifications can be entered using the existing report or field survey. In this section, channel specification related variables will be explained and groundwater aquifer input parameters will be addressed in the next section.

-	Aquifer		
	gwE	35	
Γ	rivE	34	
	Bed thick	1	
	ku_riv	0.004	
	Area	0.03	
	aqf_S	0.1	
	Тор	36	
	Bottom	26	
	Pumping	0	
	Leackage	0.15	

<u>rivE</u>: riverbed elevation

Bed thick: riverbed material thickness (1.0 is a default value and this value is in a range of 0.1 - 1.0 depending on river elevation) **ku_riv**: hydraulic conductivity of riverbed material (the range of 1.0×10^{-4} - 1.0×10^{-6} is generally used)

Area: riverbed area

3.6 Groundwater Aquifer

In the DWAT, groundwater and river runoff are simulated using the relationship between groundwater and river levels. That is, if the groundwater level is higher than the river level, water will flow into the river depending on soil hydraulic conductivity. Conversely, if the river level is higher than the groundwater level, water will percolate into the aquifer. The model was designed to consider groundwater pumping and leakage from water supply networks. The leakage is simulated to flow into soil layer. In addition, moisture content movements between aquifers are considered. That is, level changes in groundwater by moisture content movements between aquifers in each sub-catchment can be analyzed. As shown in the following figure, parameters related to aquifer specification may be entered under the 'Aquifer' tab while comparing with channel specifications in order to determine the mutual relationship between groundwater and river levels. Each parameter will be reviewed in detail in the following section.

Aquifer	Aquifer			
gwE	35			
rivE	34			
Bed thick	1			
ku_riv	0.004			
Area	0.03			
aqf_S	0.1			
Тор	36			
Bottom	26			
Pumping	0			
Leackage	0.15			

3.6.1 Aquifer Specification Entry

 \underline{gwE} : This indicates the initial groundwater level. This value will vary through the year if there is no initial groundwater level in each modeling period. Thus it is necessary to start the calculation from approximately one year before the analysis period in order to minimize the effect of uncertainty from the initial groundwater values during simulation.

<u>aqf</u> S: This indicates storage coefficient of aquifer. If there are records, a value in a range of 1.0×10^{-1} - 1.0×10^{-2} is recommended.

<u>Top</u>: The elevation of aquifer shall be determined by deducting the surface soil thickness from the ground surface elevation.

Bottom: The bottom elevation of aquifer shall be determined by referring to existing examinations. When there are no field surveyed data, this value is generally assumed to be $20m \sim 30m$ below the top elevation of the aquifer. For existing records, groundwater survey reports for sub-catchment or field data can be used.

<u>Pumping</u>: This indicates the groundwater pumping rate

leakage: This indicates the leakage rate from water supply networks. 15% is generally recommended and 0.15 is a default value.

3.6.2 Groundwater Movement Parameter Entry

Parameters related to groundwater movement between adjacent sub-catchments are entered through a separated 'Property View'. It is shown in the figure below.

Ξ	GW Move				
	Co	nnect	Not use		
		Use Auifer slop			
		Use slope	False		
		Auifer slope	0.05		
	Node length		1000		
	Conj. length		3000		
	Kgw		5e-007 🔹		

<u>Connect</u>: This is a window for selecting adjacent sub-catchment nodes to consider groundwater movement.

-	G١	V Move		
	Connect		Not use	-
		Use Auifer slop	Catchment 1	
		Use slope	Catchment 2	
		Auifer slope	Catchment 9 Catchment 7	
	No	de length	Catchment 3	
	Conj. length		Catchment 11	
	Kg	w	Catchment 5	-
Connect		ect	Catchment 10 Catchment 8	
			Catchment 6	

<u>Use_slope</u>: This indicates groundwater hydraulic gradient. It can be obtained by calculation when the groundwater level is known for a catchment. However, if there is no information, it is generally recommended to use values smaller than ground surface slope.

Node_length: This indicates a average distance between adjacent sub-catchments

<u>Conj.</u> length: This indicates a conjuncted length between adjacent sub-catchments

<u>Kgw</u>: This indicates hydraulic conductivity of aquifer. A value in a range of $1.0 \times 10^{-4} \sim 1.0 \times 10^{-6}$ is recommended.

3.7 Reservoir

Ponds can be divided into two types: online and offline reservoirs. For offline reservoirs, the ratio of maximum inflows from the stream to the offline reservoirs to the mainstream discharge are predefined. It is used to calculate inflows into the offline reservoirs. Then, the mainstream discharge that will be a condition for discharge from the offline reservoirs to the mainstream is to be established in order to determine the outflow to downstream.[H2] Offline reservoirs are simulated[H3] to be emptied after a flood. In the case of online reservoirs, evaporation from water surface is considered. The reservoir storage, water level and discharge are calculated using the initial storage, effective storage, intake (here, water is taken only when the storage is at least 20% of the effective storage volume), the specifications of spillways and discharge outlet in the reservoir.

Storage and water levels for both of the types are renewed by inflows based on the relationships of stagestorage-area.

The reservoir nodes are entered by selecting the 'Reservoir' icon and placing it in an appropriate position in the 'Main Interface' with clicking the left button on a mouse.



If the pond node is right-clicked, a window to set the parameters related to ponds will appear.

Property X							
Property 💌							
	8∎ 2↓ 🔳 🗲						
	Pond no	de					
	Name			Res	ervoir 1		
	Descript						
	Climate						
	Rainfall						
	Climate						
	Base						
	Туре			On	line		
	vol_init			1e+	-006		
	vol_eff			1e+	-006		
	Kgw			0.0	005		
	Recharg	e to					
	Pipe						
	pipe_ht			5			
	pipe_are	a		1			
	pipe_coe	ef		0.5			
	Spillway						
	spill_ht			15			
	spill_len	gth		30			
	spill_coe	f		0.8			
-	Offline						
	offline_n	nax		0.5			
	offline_r	atio		0.5			
	offline_o	out		1			
	Intake						
	Туре			Constant			
	Supply t	0		None			
	Intake			100	00		
	Series fil	e					
	Table						
_	Field						
S WE-Volume-Area Relationship							
	1 2				3	4	5
	WL(m)						
V	VOL(m3)						
A	REA(m2)						
•							

Name: This indicates reservoir name.

Descript: Information of the reservoir may be entered.

<u>Rainfall</u>: rainfall station for the rainfall on the surface of reservoir. It uses the selected adjacent rainfall station.

<u>**Climate</u>**: climate station for evapotranspiration from the surface of reservoir. It uses the selected adjacent weather station.</u>

Type (Base tab): This is to select the type of the reservoir (online/offline).

vol_init: Initial storage

vol_eff: Effective storage

<u>Kgw</u>: This indicates reservoir's bottom saturated hydraulic conductivity. This parameter is used to calculate the amount of loss in the bottom of reservoir. The value is in a range of $1.0 \times 10^{-3} - 1.0 \times 10^{-5}$.

<u>Recharge to</u>: The loss from the bed of reservoir can be calculated by hydraulic conductivity (Kgw). If "Recaharge to" is selected, the recharged water can be transferred to catchment node to recharge groundwater.

Ξ	Base	
	Туре	Online
	vol_init	1e+006
	vol_eff	1e+006
	Kgw	0.0005
	Recharge to	· · · · · · · · · · · · · · · · · · ·
	Pipe	Catchment 1
	pipe_ht	Catchment 2
	pipe_area	Catchment 9
	pipe_coef	Catchment 3
⊡	Spillway	Catchment 11
	spill_ht	Catchment 5
	spill_length	Catchment 4
	spill_coef	Catchment 8
	Offline	Catchment 6

pipe_ht: Pond's outlet height

<u>pipe_area</u>: Pond's outlet area

pipe_coef: Pond's outlet runoff coefficients in a range of 0.5 - 1.0

<u>spill_ht</u>: Height of spillway

spill_length: Length of spillway

spill_coef: Overflow coefficient of spillway in a range of 0.3 - 1.7

Type (Intake tab): This is to select the type of the intake type (Constant/Time series).

	Intake	
	Туре	Constant 🔹
	Supply to	Constant
	Intake	Series
	Series file	
	Table	
	Field	

<u>Supply to</u>: The intake from the reservoir can be transferred to selected node. To use this function the Recycle node must be located at the downstream of the reservoir node..

intake: This is intake volume from the reservoir. Water is taken only when the storage is at least 20% of the effective storage

The online reservoir input parameters are described above. The following description is for offline reservoir input parameters.

	Offline		
	offline_max	0.5	
	offline_ratio	0.5	
	offline_out	1	

offline_max: This indicates maximum inflow into offline reservoirs. The streamflow discharge that does not flow into offline reservoirs is added to downstream links.

offline_ratio: This indicates ratio for inflow into offline reservoirs to the streamflow discharge.

offline_out: This indicates the stream discharge as a condition for discharge into the river.

WL-Volume-Area Relationship					
	1	2	3	4	5
WL(m)					
VOL(m3)					
AREA(m2)					
•					

As shown in the above Figure, the amount of storage and the storage water level relative to the amount of inflows are based on the relationships among water levels-storage amounts-areas.

3.8 Wetland

The storage of wetlands was assumed to be the initial condition. It was also assumed that the excess flow is to be sent to the downstream node when inflow is larger than the high flow bypass during flood. After calculating the volume of the remaining inflow, all of the volume will be overflowed when the volume is larger than the maximum storage. The module was designed to calculate water level, area, evaporation from the water surface and discharge through the outlet based on the final remaining storage volume.

The wetlands node is entered by selecting the icon shown in the following figure, placing it on an appropriate position in the 'Main Interface' with clicking the left button on a mouse.



If the wetland node is left-clicked, a window to set the parameters related to wetlands will appear.

Pro	Property X						
Pro	Property 💌						
	?≣ 2↓ ■ 🖌						
	WetLan	d node					
	Name			We	tLand 1		
	Descript						
	Climate						
	Rainfall			Clir	nate 1		
	Evaporat	tion		Clir	nate 1		
	Base						
	Init volume		100	00			
	Maximum storage		100000				
	Flood by	pass		1			
	Kgw		0.0005				
	Recharg	e to					
	Pipe						
	Pipe height		1				
	Pipe area		0.5				
	Pipe coe	Pipe coefficient		0.5			
	WL-Volun	ne-Area Re	lations	ship			
1 2			3	4	Ę		
WL(m)							
V	/OL(m3)						
A	REA(m2)						
•	<						

Name: This indicates wetland name.

Descript: Information of wetland overview may be entered.

<u>Rainfall</u>: rainfall station for the rainfall on the surface of wetland. It uses the selected adjacent rainfall station.

<u>**Climate</u>**: weather station for evapotranspiration from the surface of wetland. It uses the selected adjacent weather station.</u>

Init Volume: Initial storage

Maximum storage: Maximum storage

Flood_bypass: High flow bypass during flood

<u>Kgw</u>: This indicates pond's bottom saturated hydraulic conductivity. This parameter is used to calculate the amount of loss in the bottom of ponds. The value is in a range of $1.0 \times 10^{-3} - 1.0 \times 10^{-5}$.

<u>Recharge to</u>: The loss from the bed of wetland can be calculated by hydraulic conductivity (Kgw). If "Recaharge to" is selected, the recharged water can be transferred to catchment node to recharge groundwater.

Ξ	Base				
	Init volume	10000			
	Maximum storage	100000			
	Flood bypass	1			
	Kgw	0.0005			
	Recharge to	Catchment 9 🔹			
Ξ	Pipe	Catchment 1			
	Pipe height	Catchment 2			
	Pipe area	Catchment 9			
	Pipe coefficient	Catchment /			
	- ipe coefficient	Catchment 11			
		Catchment 5			
		Catchment 4			
		Catchment 10			
		Catchment 8			
		Catchment 6			

pipe_height: Height of outlet pipe

pipe_area: Area of outlet pipe

<u>pipe</u> coefficient: Runoff coefficient of outlet pipe in a range of 0.5 ~ 1.0

WL-Volume-Area Relationship					
	1	2	3	4	5
WL(m)					
VOL(m3)					
AREA(m2)					
•					

Evaporation from water surfaces and the discharge in the wetland are calculated through a renewal of storage and water level of wetlands based on the stage-storage-area relationships. It is similar to the calculation process of reservoirs.

3.9 Recycle

In order to review the processes for designing recycle, the inflow is calculated and the daily used intake volume is then distributed to individual nodes. Water intake is restricted by defining intake restriction for intake rate determined by streamflow discharge rate.

That is, if the value obtained by considering the inlet inflow amount and the intake restriction ratios is larger than the intake amount, the recycling inflow amount will be the same as the intake amount and the

amount of runoff to the toe will become the value obtained by deducting the intake amount from the inlet inflow amount. If the inlet inflow amount, considering the intake restriction ratios, is lesser than the intake amount, the recycling inflow amount will be the same as the inlet inflow amount considering the intake restriction ratios. The amount of runoff to the toe is the value obtained by deducting the intake amount from the inlet inflow amount.

The Recycle node will be entered by selecting the icon shown in the following figure, placing it on an appropriate position in the 'Main Interface' with clicking the left button on a mouse.



If the Recycle node is right-clicked, a window to set the parameters related to the Recycle will appear.

Property							
Recycle node							
Na	ime	Recycle 1	_				
De	script						
🗉 Int	take						
int	ake	10000					
rec	_cond	5e+007					
Ξ Οι	Itput						
-	Node 1						
	Node	Catchment 2					
	amount	20					
	Node 2						
	Node	Catchment 3					
	amount	20					
	Node 3						
	Node	Catchment 4					
	amount	20					
-	Node 4						
	Node	Catchment 6					
	amount	20					
	Node 5						
	Node	Catchment 5					
	amount	20					

Name: This indicates Recycle node name.

<u>Descript</u>: Information of Recycle node may be entered.

Intake: Total intake volume

<u>rec_cond</u>: Restriction for intake rate according to mainstream flow rate. The DWAT has a function to send the determined discharge to many catchment nodes (maximum five nodes) using Recycle.

3.10 Import

Parameters related to the water use from outside of catchments are used to design the Import function. A constant amount on a daily basis is used, and time series data for water supply data can be loaded.

• The Import node may be entered by selecting the icon shown in the following figure, placing it on an appropriate position with clicking the left button on a mouse.



If the Import node is left-clicked, a window to set the parameters related to the Import will appear.



Name: This indicates a node name

Descript: Information of the node may be entered.

<u>Type</u>: This is to select the type of data to be imported: 'constant' for a constant daily amount; 'series data' for time series data for water supply.

Import water: This indicates imported water supply amounts. It is activated when the constant type is selected.

Leakage : Leakage from pipe network can be considered (The leaked water added to soil moisture in pervious area)

<u>Series file</u>: This is to load the time series data for water supply. This is activated when the series data type is selected. A screen to choose the file appears and the data can be loaded by pressing 'Time Series Data > Open'. The data file should be created using the 'File > Create series' menu as with the process to import meteorological data described in Section 3.2 (The 'Type' should be set as 'User defined').

3.11 Channel Routing (Link)

In the DWAT, the channel routing is a process to convert inflow hydrologic curves into runoff hydrologic curves in channel sections using the Muskingum, Muskingum-Cunge and Kinematic wave methods. In this section, the selections of methods of inputting data and routing methods in the Link are described in detail.



If the Link that connects nodes together is left-clicked, a window to set the parameters for the Link will appear.

Property		
∄ 2↓ 🔳 🗲		
∃ Link node		
Name	Link 7	
Descript		
Routing	No routing	-
Muskngum	No routing	
DT	Muskingum	
Х	Muskingum Cunge	
γ	Lis	
Muskingum Cunge		
Channel length	1000	
Channel slope	0.005	
Top width	15	
Manning	0.03	
Kinematic		
Channel length	1000	
Channel slope	0.005	
Top width	15	
Bottom width	10	
Manning N	0.03	
Channel depth	5	
	1	

Name: This indicates a link name.

Descript: Information of a link may be entered.

<u>Routing Method</u>s: This is to set channel routing methods. 'No routing' is a default value and any channel routing methods can be chosen by the user.

Muskingum: When the Muskingum method is selected. The user may enter various parameters to fit channel characteristics.

Link node				
Name	Link 19			
Descript				
Routing	Muskingum 🔹			
Muskngum				
DT	1			
Х	0.25			
γ	1.5			

<u>DT</u>: Time interval

 $\underline{\mathbf{X}}$: Dimensionless constant in a range of 0.0 - 0.5 that indicates the relative importance of the inflow and runoff contributed to the total storage

 $\underline{\mathbf{Y}}$: Storage constant in the dimension of time (hour) that indicates the ratio of the storage to the runoff in the routing section

<u>Muskingum Cunge</u>: The Muskingum Cunge method's attribute window appears and the user can enter each parameter to fit to channel characteristics.

-	Muskingum Cunge	
	Channel length	1000
	Channel slope	0.005
	Top width	15
	Manning	0.03

Channel length: Channel length

Channel slope: Riverbed slope (dimensionless)

Top width: Top width of channel

Manning N: Manning's roughness coefficient

<u>Kinematic wave</u>: The Kinematic wave method's attribute window appears and the user can enter each parameter to fit channel characteristics. Computational demanding in running the model is required in the Kinematic wave method due to the effect of iteration for channel routing.

	Kinematic			
	Channel length	1000		
	Channel slope	0.005		
	Top width	15		
	Bottom width	10		
	Manning N	0.03		
	Channel depth	5 🗸		

Channel length: Channel section length

Channel slope: Riverbed slope (dimensionless)

Top width: Top width of channel

Bottom width: Bottom width of channel

<u>Manning N</u>: Manning's roughness coefficient <u>Channel depth</u>: Channel depth

3.12 Junction and Outlet

3.12.1 Junction

The function of Junction in DWAT model have two aspect. The first one is a simple junction to combine the flow from upstream. The second one, combined sewer, is a unique in DWAT model.

The Junction node may be entered by selecting the icon shown in the following figure, placing it on an appropriate position in the 'Main Interface' with clicking the left button on a mouse.



If the Import node is left-clicked, a window to set the parameters related to the junction will appear.
Pro	operty		×							
Pro	Property									
	≣ ĝ↓ 🔳 🗲									
	Junction node		_							
	Name	Junc 5								
	Descript									
	Connect	Catchment 8	•							
	Maximum Q	0.1	-							
Co	onnect									

Name: Name of Junction

Descript: Information of a junction may be entered.

<u>Connect</u>: Select node to water transfer (for example, treatment plant), it is used for combined sewer networks. The flow less than specified rate can be moved to selected node. Water quality module will be added in next version.

Maximum Q: The maximum flow rate to using Connect.

3.12.2 Outlet

The Outlet is a final exit of the system. Basically the Outlet node is similar to Junction except combined sewer function. The Outlet can be multiple. The Outlet node may be entered by selecting the icon shown in the following figure, placing it on an appropriate position in the 'Main Interface' with clicking the left button on a mouse.



If click the left mouse button, a window to set the parameters related to the outlet will appear.

Pro	perty	×	ε								
Pro	Property										
	2↓ 🔳 🗲										
	Outlet node	_	•								
	Name	Outlet									
	Descript										
			1								

<u>Name</u>: Name of Outlet node

<u>Descript</u>: Information of an outlet may be entered.

Chapter 4: Model Running

If all input data have been completed, now you are ready to run the model. In the chapter, matters related to the model run will be explained.

4.1 Analysis Condition Setting

If the 'Model' menu is selected in the main menu, the 'Model Setup' menu for selecting analysis conditions and running the model will appear as follows:



If the 'Model' menu is selected, a window for setting analysis conditions before running the model will appear as follows:

Simulation setup
Title
Term 10/16/2016 • ~ 10/16/2016 •
Interva 86400 · (sec) Loop 10 ·
OK Cancel

<u>Title</u>: This indicates a simulation title.

<u>Term</u> A simulation period is needed to be selected. The total data period appears in the window and a user can define the simulation period. After clicking, the following date entry window will appear.



Interval: A user can revise a simulation time step for model run. The default unit is a second.

4.2 Model Execution

Once the analysis conditions have been set as above, the model is run by pressing 'OK' and selecting 'Run' in the 'Model' menu. Now, the model is ready to run. When 'Run' is pressed, the model will be executed.

Run model
Complete calculation
Run Close

Once 'Complete execute model' has appeared, press the 'Close' button.

Chapter 5: Analysis of Results

If all the executions have been completed, now you are ready to analyze the result. The DWAT enables users to freely compare outputs at each node, junction and link including hydrologic components. This configuration is very helpful to users in analyzing the results.

The DWAT basically has outputs of three types: water balance, graphs and tables. In this chapter, the methods to analyze the model results are explained in detail. The following Table 5.1 and Table 5.2 show summaries of the output parameters by source node that are created after executing the DWAT.

Catchment node	Description of output variables
Inflow (m ³)	inflow volume
Rainfall (mm)	rainfall
Actual Evapotranspiration (mm)	actual evapotranspiration
Potential Evapotranspiration (mm)	potential evapotranspiration
Infiltrate (mm)	Infiltration
Soil moisture content (%)	current soil moisture content
Flow_surface (mm)	surface runoff
Flow_inter (mm)	interflow
Flow_groundwater (mm)	groundwater runoff
Recharge (mm)	groundwater recharge
Flow_total (mm)	total runoff
Groundwater Movement (mm)	groundwater movement
Groundwater Elevation (El. m)	groundwater level elevation

	Node	Description of output variables
	Inflow (m ³)	inflow volume
	Downstream Outflow (m ³)	mainstream discharge that did not flow into the pond
	Intake (m ²)	intake volume
	Evaporation Water surface (mm)	evaporation from water surface
Reservoir	Spillway Outflow (m ³)	overflow from spillway
	Pipe_Outflow (m ³)	discharge from outlet pipe
	Aquifer Loss (m ³)	loss from bottom of the pond
	Volume (m ³)	storage volume
	Water Level (m)	water level
	Inflow (m ³)	inflow volume
	Bypass Volume (m ³)	high flow bypass during flood season
	Evaporation Water surface (mm)	evaporation from water surface
\//atland	Spillway Outflow (m ³)	overflow from spillway
welland	Pipe Outflow (m ³)	discharge from outlet pipe
	Aquifer Loss (m ³)	loss from bottom of the pond
	Volume (m ³)	storage volume
	Water Level (m)	water level
	Inflow (m ³)	inflow volume
Pagyala	Intake (m ³)	intake volume
Recycle	Downstream Outflow (m ³)	downstream discharge after intake
	water supply node name	node name that receive supplied water
Import	Water Supply (m ³)	water supply from outside

<Table 2.5-2> Output variable (Other node)

5.1 Water Balance

The results of water balance in a watershed may be viewed based on two methods. The first is to view the results in the main menu and it is shown in the following figure. The second is to view the results at each sub-catchment node in the catchment node configuration screen of the 'Main Interface'.

Pressing 'Model' > 'Water-balance' menu in the main menu.



By year O B	ly node	Year 2	2002		Select Outlet						
	Average	Catchment 1	2002	Catchment 9	Catchment 7	Catchment 3	Catchment 11	Catchmen			
Rainfall	1231.7	1231	2003	1231.7	1231.7	1231.7	1231.7	12			
Inflow	0.0	d	2005	0.0	0.0	0.0	0.0				
ET	131.2	622	2007	93.9	51.3	237.0	56.9	1			
ET_imp	19.7	18.	7 1.4	53.1	18.7	0.0	33.0				
ET_per	111.4	43.	7 255.6	40.8	32.6	237.0	23.9				
Runoff	975.1	1022.	9 933.4	954.6	875.3	937.2	697.0	10			
Surface	176.6	141.4	4 126.1	402.5	141.4	118.0	250.2	1			
Interflow	271.2	536.	2 241.9	80.2	264.0	239.9	136.0	2			
Groundwater	527.3	345.	3 565.4	471.9	469.9	579.4	310.8	6			
Recharge	439.0	247.	7 474.6	372.8	369.9	479.7	210.9	5			
Soil	-2.46357	-2.3877	6 -3.42949	-1.01739	-1.47902	-2.92595	-1.25662	-3.03			
GW-Storage	-88.31232	-97.5605	5 -90.72383	-99.13438	-99.92149	-99.67852	-99.92617	-65.39			
MassBalance	216.18462	246.3801	6 135.49123	283.40039	406.49600	160.12206	578.97076	135.5			

By year: This is a tab to control output formats. Analysis results are displayed on an annual basis. As shown in the above figure, each hydrologic component is displayed on the left side and water balance is displayed by node on the right side along with average value.

By node: This is a tab to control output formats. Analysis results are displayed by sub-catchment. As shown in the following figure, each hydrologic component is displayed on the left side and resultant values are displayed on the right side on an annual basis.

By year 🔍 E	3y node	Node	Catchment 1 💌	Select Outlet						
	Average	2002	Catchment 1	2004	2005	2006	2007			
Rainfall	1346.5	1231	Catchment 9	1217.0	1427.7	1362.7	1325.0			
Inflow	0.0	d	Catchment 7 Catchment 3	0.0	0.0	0.0	0.0			
ET	54.4	62	Catchment 11	48.5	43.0	43.7	71.8			
ET_imp	20.0	180	Catchment 4	18.8	18.5	17.9	22.8			
ET_per	34.3	43	Catchment 10 Catchment 8	29.7	24.5	25.7	49.0			
Runoff	1039.3	1022	Catchment 6	916.4	1103.2	1045.5	990.1			
Surface	155.0	141.	4 173.5	139.4	167.1	159.2	149.5			
Interflow	581.9	536.	2 699.4	499.2	593.4	607.6	555.5			
Groundwater	302.4	345.	3 284.9	277.8	342.8	278.7	285.1			
Recharge	286.4	247.	7 284.5	284.5	338.1	283.5	280.2			
Soil	-0.46505	-2.3877	6 -2.39868	2.07700	0.66873	-3.81773	3.06816			
GW-Storage	-16.03515	-97.5605	5 -0.39688	6.68672	-4.76367	4.79805	-4.97461			
MassBalance	269.29692	246.3801	6 302.92104	243.40207	285.53765	272.53837	265.00221			

<u>Select</u>: This is to select the outlets of a catchment. If the catchment has many outlets, the results on the water balance may be identified for each catchment outlet.

In the second method for viewing water balance results, water balance may be viewed by rightclicking on each sub-catchment node as mentioned above. However, the water balance output from subcatchment nodes does not provide information on the entire water balance, but rather provides only the resultant water balance of the relevant sub-catchment. Right-clicking on the sub-catchment node and clicking the 'Water balance' menu.



The following window will appear.

Catchment 8								
Year	2002	•						
	Average		- I					
	2002	02						
Ra	2003	1231.	7					
Int	2005	0.	D					
E	2006	125.	В					
ET	_imp	34.	5					
ET	_per	91.	3					
R	unoff	940.3						
Su	rface	270.8						
Inte	rflow	199.8 469.6 666.7						
Grour	ndwater							
Infilt	ration							
Rec	harge	378.	1					
S	Soil	-1.	6					
GW-S	Storage	-91.	5					
GW	Move	0.	D					
Mass	Balance	258.73	D					
Close								

Year: The relevant year may be selected. As shown in the above figure, the water balance results at hydrologic component may be identified by clicking each relevant year.

5.2 Chart

Analysis results are shown in various forms of graphs in the DWAT. As with the above water balance results, there are two methods to view graphic results on the entire catchments. Graphic results for individual sub-catchments, links, junctions and outlets can be viewed by the setting tab of the left window, no matter which method the user selects to view the results. The method to check results in the main menu is as follows:

- Select 'Model' > 'Chart' in the main menu.
- Right-clicking on the sub-catchment node and clicking the 'Chart' menu.



A Chart result window will appear.

Current +	
Nodes	Result
Node	
Catchment 1	
Catchment 2	
Catchment 9	
Catchment 7	
Catchment 3	
Catchment 11	
Catchment 5	
Catchment 4	
Field	
Field A	
Inflow(m ³)	
Rainfall(mm)	
Actual Evapotranspiration(
Potential Evapotranspiratio	
Flow_Surface(mm)	
Flow_Inter(mm)	
Flow_Groundwater (min)	
4 III +	
Add Remove	
Field	
Tait Zaan All	

Current This is a project selection window. In 'Current', the results of the current project may be viewed. When the plus button is selected, the results of other projects are opened and displayed for comparison. That is, a function to compare the result of the current project with those of other projects is provided.



This attribute window shows the information of each node, junction, link and outlet of

the relevant project.



This is located below the node attribute window and shows the field attribute window.

They are the output parameters mentioned earlier in Tables 5.1 and 5.2. The user can select the relevant

sub-catchment or the link and junction through the node attribute window and then select output variables in the field attribute window to see graphic results.

The user may press the 'Add' button to display the graphic results when the sub-catchment and output variable have been selected. It is shown in the following figure.



currently output variables. The user may also select multiple nodes and output variables and display them simultaneously on the same screen. If the user wishes to delete some output items from the graph, the user may click on the item or right- click the button and select 'Remove'. If the user wishes to delete all items, the user may just select the 'init' button. In addition, the interested region in the graph may be expanded by using the dragging function of the mouse. Once expanded, the region may be moved using the scroll bar on the bottom of the graphic result. The user can go back to the entire view by pressing the 'Zoom

All' button. The form of an expended graph is as shown in the following figure.

5.3 Table

The DWAT contains a function to view result values in the form of tables at all nodes, junctions, links and outlets.

Unlike water balance and graphic results, table results can be viewed only through right mouse clicks on the nodes, links and junctions of the main screen. In addition, information on all nodes cannot be seen, and only the results for individual node are outputted. That is, the result field of tables is the output parameter and each output parameter is as shown in Tables 5.1 and 5.2.

The following window appears by right-clicking on a node in the configuration screen of the main interface.



When the 'Table' menu has been selected, the following table result window is displayed. As shown in the figure, the names of the output variable for each time series appear on the top and time series data are displayed.

🔳 Ser	ries													×
File							Load							
Inter	val Iday		Start time 20	02/01/01 00	.00	Count	2101							
	Var Iddy			02/01/01 00	.00	Count	2191							
Table			~	Decima	0.00	-								
Cate	hment 8													
, 	Data	[pf]ou(§@)	R ainfall(mm)	Actual	Potential	Flow Surfa	Flow Interf	Flow Group	Elow Totalí	Infiltrate(mm	Recharge(m	Groundwate	Soil	Groundwata 🔺
1	02/01/01 00	0.00	0.00	1.12	2.90	0.00	0.00	2.74	2.74	0.00	nechaigejii 0.00	0.00	0.21	34.97
2	02/01/02 00	0.00	0.00	1.13	2.93	0.00	0.00	2.67	2.67	0.00	0.00	0.00	0.16	34.95
3	02/01/03 00	0.00	0.00	0.00	1.60	0.00	0.00	2.59	2.59	0.00	0.00	0.00	0.16	34.92
4	02/01/04 00	0.00	0.00	0.00	1.94	0.00	0.00	2.52	2.52	0.00	0.00	0.00	0.16	34.89
5	02/01/05 00	0.00	0.00	0.00	2.89	0.00	0.00	2.45	2.45	0.00	0.00	0.00	0.16	34.87
6	02/01/06 00	0.00	0.00	0.00	2.13	0.00	0.00	2.39	2.39	0.00	0.00	0.00	0.16	34.85
7	02/01/07 00	0.00	2.60	0.00	2.53	0.14	0.00	2.32	2.46	1.43	0.00	0.00	0.22	34.82
8	02/01/08 00	0.00	0.00	1.48	2.68	0.00	0.00	2.26	2.26	0.00	0.00	0.00	0.18	34.80
9	02/01/09 00	0.00	0.00	0.03	1.72	0.00	0.00	2.19	2.19	0.00	0.00	0.00	0.18	34.78
10	02/01/10 00	0.00	0.00	0.00	1.35	0.00	0.00	2.13	2.13	0.00	0.00	0.00	0.18	34.76
11	02/01/11 00	0.00	0.00	0.00	1.91	0.00	0.00	2.08	2.08	0.00	0.00	0.00	0.18	34.74
12	02/01/12 00	0.00	0.00	0.00	1.54	0.00	0.00	2.02	2.02	0.00	0.00	0.00	0.18	34.72
13	02/01/13 00	0.00	0.00	0.00	2.00	0.00	0.00	1.96	1.96	0.00	0.00	0.00	0.18	34.70
14	02/01/14 00	0.00	0.70	0.00	2.11	0.00	0.00	1.91	1.91	0.39	0.00	0.00	0.19	34.68
15	02/01/15 00	0.00	8.80	0.46	0.84	1.66	1.01	1.86	4.53	4.84	2.02	0.00	0.25	34.68 💌

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