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Development of a Decision Support System for Reservoir Sizing

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Abstract □ A decision support system for determining reservoir capacity, named as KORESI DSS (KOwaco's REservoir SIzing Decision Support System), was developed. The system is composed of three subsystems; a database/information subsystem, a model subsystem, and an output subsystem. This system is operated using MS-Windows with a GUI (Graphic User Interface) system developed using Visual Basic 5.0. As a continuous runoff model, the DAWAST model (DAily WAtershed STreamflow model) developed by Noh(1991) was adopted and incorporated into the system. A reservoir water balance model was incorporated and its analysis module was developed. This system was applied to a newly-planned dam, the Cheongyang Dam, which will be located in Cheongyang-Gun, Chungcheongnam-Do and it was proved to be applicable in determining reservoir storage.

Keywords □ reservoir capacity, decision support system, reservoir water balance, continuous runoff model

I. Introduction

Reservoir size (or dam capacity) should be determined by satisfying both water demand and flood control in the downstream areas. Several analysis are required to determine the optimal reservoir size. They include design storm runoff simulations, continuous reservoir operations, and sedimentation within the reservoir, by using available meteorological data, events and continuous runoff data, topology, soil and land use data, reservoir volume by elevation, channel section surveying data etc..

These procedures are so complex and time consuming to obtain required results for the decision maker. A computer-aided decision support system, which has modules of data control and management, hydrological analysis, output display and product management for reservoir sizing, can be a helpful tool to decide the proper size of reservoirs.

The purpose of this study was to develop a PC-based decision support system for engineers to conveniently determine reservoir capacity, and to evaluate the applicability of the system on the Cheogyang Dam (located in Cheongyang-Gun and Buyeo-Gun) under construction planning.

Ⅱ. DSS Design and Implementation

The system components necessary to develop a decision support system as considered in this study are shown in Fig. 1. User judgement includes dam site, sub-watershed division and the reservoir operation criteria. Database includes meteorological, hydrological, sociocultural and planning related data. GIS information includes topology, soil and land use data. Models include continuous runoff models, reservoir water balance models, storm runoff models and reservoir flood routing models. Output includes monitor and printer output generation as graphic or text based for input and results.

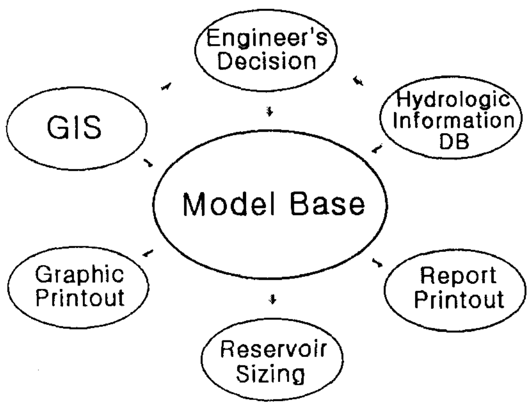


Fig. 1. System configuration for reservoir sizing

1. Database and GIS information subsystem

The database was designed to have functions of data input and update, query and search, and display by user request. Meteorological data (e.g., rainfall and evaporation), hydrological data (e.g., observed runoff) and planning data (e.g., municipal, industrial, agricultural and environmental water demand) are included.

GIS data was prepared to extract some model parameters, including time of concentration, SCS-CN, the slope and length of the channel, etc.. Table 1 shows the contents of the GIS data used in this study.

Table 1. Type of geographic information in DSS

Item	Name of layer	Property	Data type
Base map	DEM	-	raster
	stream	line	vector
	administration boundary	area	vector
Thematic map	watershed boundary	area	vector
	soil map	area	vector
	land use	-	raster
	observation site	point	vector

2. Model subsystem

(1) Reservoir operation model

A reservoir operation model, accomplished using a daily water balance, was included to obtain proper reservoir storage size, and the schematic diagram is shown in Fig. 2. Water balance components, such as reservoir inflow, water demands, sedimentation to the reservoir, daily rainfall and reservoir evaporation are considered. To get reservoir inflows, a daily runoff model DAWAST was adopted.

This model simulates scores of long-term reservoir water levels in order to take into account the carryover effect. The user interprets the water level changes subjectively, based on whether the reservoir capacity is acceptable or not. If it is not, then the user changes the reservoir size, and re-runs the model to get reasonable results.

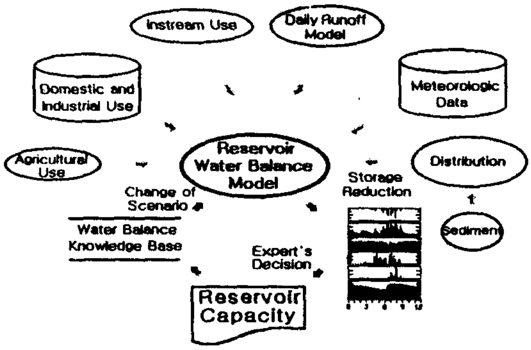


Fig. 2. Schematic diagram of reservoir water balance model

(2) Reservoir flood routing model

A reservoir flood routing model was included to determine the flood control volume and proper spillway size. Fig. 3 shows the schematic diagram of the model. As a first step, the relationship between reservoir storage and reservoir release from the graphs using reservoir release versus elevation and reservoir storage versus elevation should be prepared.

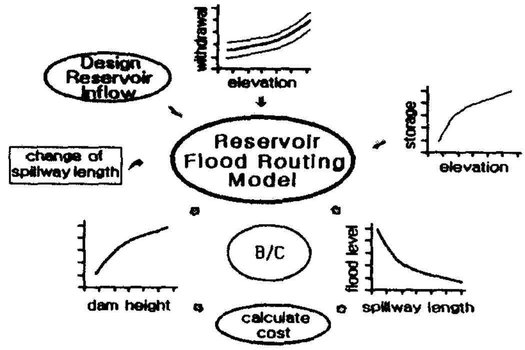
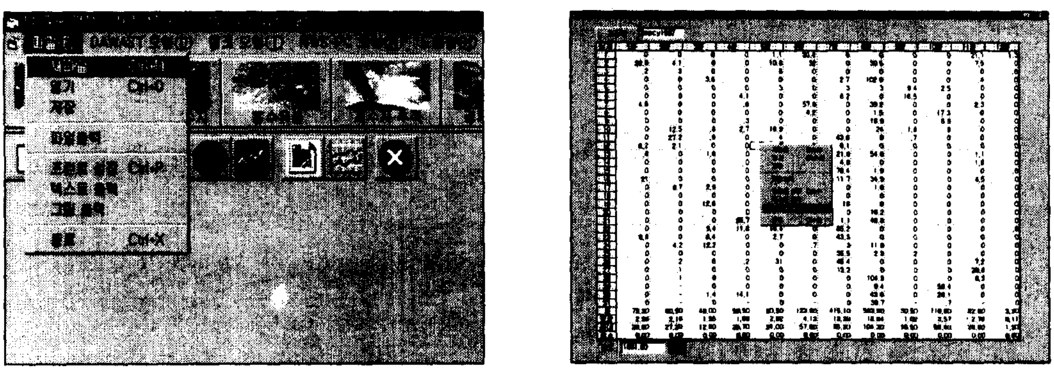


Fig. 3. Reservoir flood routing model

After that, flood routing is accomplished by using design hydrograph of reservoir inflow. As a design rainfall, PMP (Probable Maximum Precipitation) and probability rainfall by frequency analysis were included. To get the design hydrograph, SCS unit hydrograph, Nakayasu and Clark method were used.

3. Output subsystem

Output was designed to have functions to display the input data and the analyzed results on screen and print out as a hard copy with various options. There is also a function to store selected information from the analysis and to print this data as a summarized report.



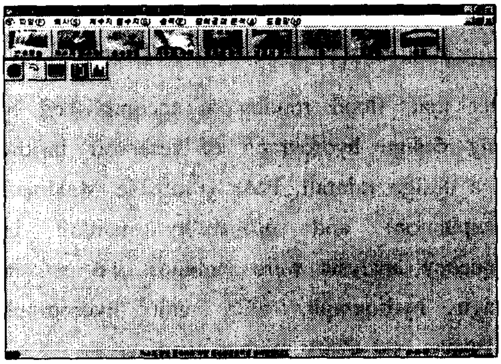
(a) menu for data management

(b) spreadsheet for data handling

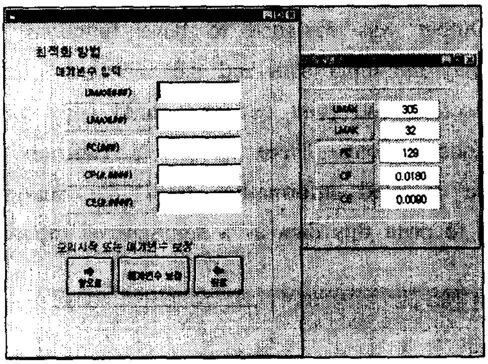
Fig. 4. Example screen of data input and handling

4. DSS Implementation

The system was implemented using Visual Basic MDI (Multiple Document Interfaee) and it was named as KORESI DSS (KOwaco's REservoir SIzing Decision Support System). Fig. 4 and Fig. 5 show an sample screen from data handling and model input, respectively.



(a) menu for model management



(b) menu for model handling

Fig. 5. Example screen of model input and handling

Ⅲ. DSS Application

This system was tested for the Cheongyang Dam, under planning. The watershed area is 193.5km^2. Fig. 6 shows the DEM of the Cheongyang Dam watershed.

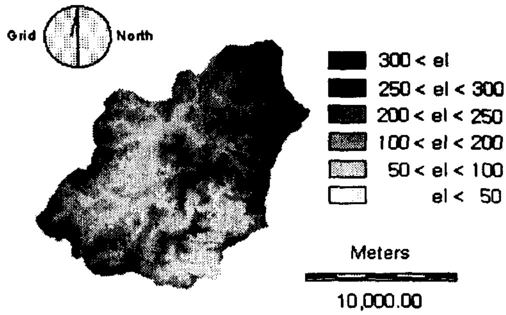


Fig. 6. DEM of CheongyangDam watershed

1. The estimation of reservoir inflows

The DAWAST model was calibrated at the Guryong site which is 4km downstream from the Cheongyang Dam site. We used observed runoff data at the site in 1989, with a rainfall of 1,386.0mm and an observed runoff of 793.7mm. Model parameters were obtained using the Simplex method. The optimal parameters are UMAX 322mm, LMAX 29mm, FC 128mm, CP 0.0184, and CE 0.0066. Fig. 7 shows an agreeable result with 797.9mm of simulated runoff.

By using these calibrated parameters, the

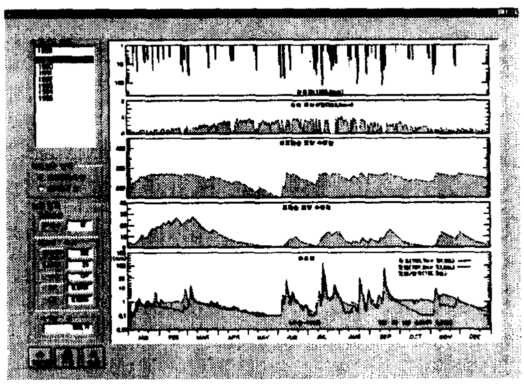
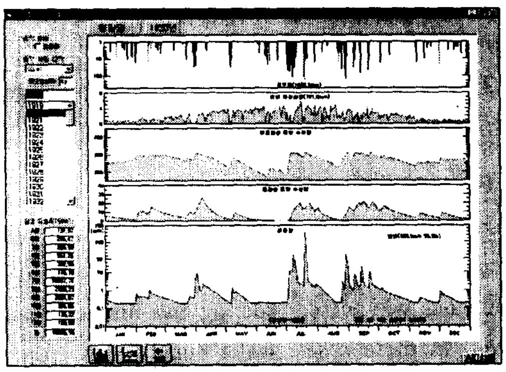
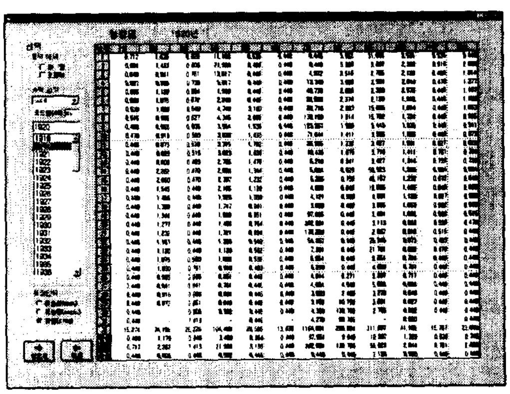


Fig. 7. Calibrated result of DAWAST model by optimization technique (Guryong site, 1989)

DAWAST model estimated the inflows, with long-term daily rainfall and evaporation, for the Cheongyang Dam. Meteorological data for this was supplied by Jeonju station and used records from 1919 to 1996. Fig. 8 shows an example of reservoir inflow estimation result using the DAWAST model. For the period of 1919 to 1996, the average rainfall was 1,260.9mm/yr, evaporation and runoff was simulated as 1.152.8mm and 659.5mm (runoff ratio 52.3%), respectively.



(a) graphic result



(b) text result

Fig. 8. Example of dam inflow simulation(1920)

2. Reservoir operation

As operating conditions, water levels (full; EL.63m, limiting; EL.62m, low; EL.40m, dead; EL.30m, initial for simulation; EL.63m) and water demands (municipal; 190,000m^3/day, industrial; 76,000m^3/day, agricultural; area - 1,100ha, infiltration - 5mm/day, facility and cultivation management water demand ratio - 15% and 20%, respectively, ponding depth - 60mm, river maintenance - 0.5m^3/sec) were assigned. The volume of reservoir sedimentation during the fifty years was calculated using the Saemaeul formula, and the reservoir capacity was recalculated by using the area reduction method. Fig. 9 shows the setup screen of initial values for reservoir operation. The model was operated with data cumulated for 78 years (1919-1996) with a drought frequency of 10 years for agricultural water demand and 20 years for municipal and industrial water demand.

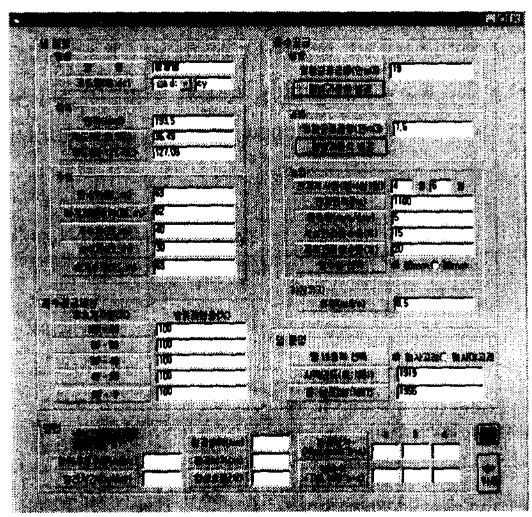
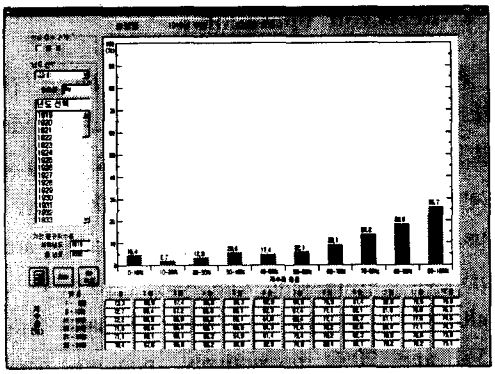
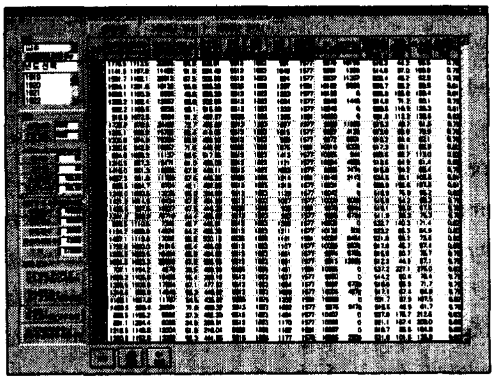


Fig. 9. Set up screen of initial values for reservoir operation



(a) grading by reservoir water ratio



(b) year summary of reservoir operation

Fig. 10. Decision support example menus to determine the reservoir size

To evaluate complex results of long-term reservoir operation, several useful menus were developed. "Daily reservoir water ratio for full analyzing period" can identify the frequency of empty and full reservoir storage. "The reservoir water ratio of the end of each year" can estimate the proper water supply capacity. "The exhausted period of the reservoir" can evaluate the amount and days of missing water supply. "The grading by reservoir water ratio" can be used to evaluate water supply capacity. "The year summary of reservoir operation result" can be used as water supply index. Fig. 10 shows an example of developed menus to determine the reservoir size.

3. Example of reservoir sizing and water supply

By using the KORESI DSS, four cases of reservoir operation were evaluated. Two cases were operated by fixing the full water level with and without considering the limiting water level. In these cases, water supply were adjusted. Another two cases are operated by fixing the amount of water supply with and without considering the limiting water level. In these cases, reservoir size was evaluated. Table 2 shows the summary of the four cases of res-

Table 2. Summary with four cases of reservoir operation

Case		Full water level (EL.m)	Water supply			
			Municipal (m^3/day)	Industrial (m^3/day)	Agricultural(ha)	River maintenance(m^3/s)
Fixing full water level	with limiting water level	63.0	105,000	50,000	1,100	0.5
	w/o limiting water level	63.0	130,000	50,000	1,100	0.5
Fixing water supply	with limiting water level	68.0	150,000	50,000	1,100	0.5
	w/o limiting water level	66.0	150,000	50,000	1,100	0.5

ervoir operation.

Ⅳ. Conclusions

A decision support system for determining the reservoir capacity, named as KORESI DSS (KOwaco's REservoir SIzing Decision Support System), was developed, and tested for the Cheongyang Dam, which is under planning. The DAWAST model was successfully calibrated at the Guryong site, which is 4km downstream from the Cheongyang Dam site. By changing various conditions for reservoir operation, the KORESI provided acceptable results for reservoir sizing and water supply limits. Based on the results of this study, we believe that the system (KORESI DSS) is an applicable tool for determining reservoir storage.

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