A STUDY ON A REGULAR EVALUATION METHODOLOGY OF STREAMFLOW DATA

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Abstract: A system for regularly appraising the reliability of streamflow data, KORSAS (KOwaco's Regular Streamflow Appraising System) was developed on PC based Windows for hydrological specialists and engineers working in the Korea Water Resources Corporation (KOWACO). The reliability of streamflow rates can be evaluated with KORSAS in various aspects according to the evaluation duration and method. The former being selected as short term (event based) or long term (continuous based), and the latter being classified into comparison methods of flow measurement, other stations results, and simulation. Rainfall-runoff models can be used together with KORSAS in order to evaluate the reliability of observed flow data by comparing with simulated flow data. The objective of this study is to develop a systematic methodology in various aspects to evaluate the reliability of streamflow data regularly.

Keywords: hydrologic observation, streamflow evaluation, regular reliability analysis

1. INTRODUCTION

Streamflow data plays a basic role in water resources planning and operation. However, the analysis results may generally give a variety of uncertainties to water resources projects due to a low level of streamflow data reliability. Water levels in streams and rainfall are observed hourly, in a basin through a telemetry data collection system, and recorded on real time basis in a database (DB). Flow rates at observation sites along streams are calculated, in general, from observed water levels by applying the rating relationship between water levels and flow rates.

The reasons for unreliable streamflow rates may be reviewed as follows; a disagreement between the measured water levels and the real water levels, inaccurate results of measured flow rates, the complex relationship between water levels and flow rates, the transformation of stream cross sections, the changes in water surface profiles due to sedimented or scoured stream beds, etc. Data managers have difficulties in correcting data because the causes of errors are not easily found when using time elapsed historic data. Therefore, inaccurate hydrological data has to be corrected regularly as data is observed in real time, and the causes of error have to be reviewed and recorded.

Water levels in streams are recorded in real time and the rating relationships between water levels and flow rates are prepared using historic streamflow measurement data. From this, flow rates are calculated continuously. Reservoir inflows can be calculated considering differences

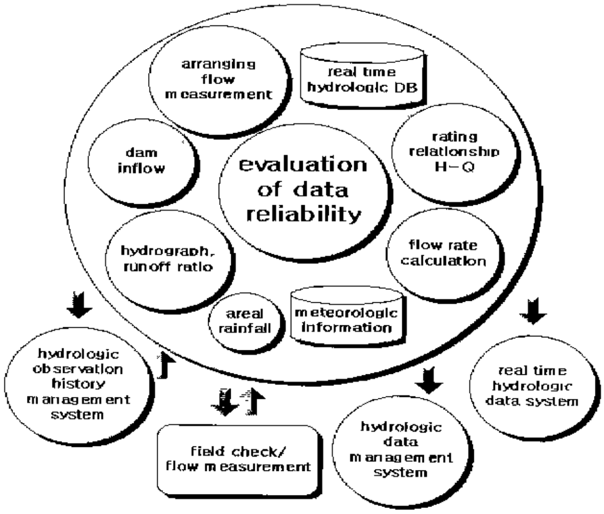

Fig. 1. System Configuration of the KORSAS

in reservoir water levels, and the amount of water used and releases obtained from reservoir operation. The calculated flow data from observatory sites within dam watersheds are compared concurrently and the reliability of the data is evaluated. The reliability of streamflow data is enhanced through prompt evaluation and the management of the calculated flow data as soon as water levels are observed. The evaluation of streamflow rates is performed on a daily, weekly, monthly, and a seasonal basis. Using this procedure, the reliability of data is certainly increased.

A variety of PC-based hydrological data processing and analysis systems have been developed, some examples include HYMOS (1998), KOWACO-HYMOS (1998), HYDATA (2000), HYDRON (2000), and HYDROTECH (2000). Contrary to these systems, KORSAS (1999, 2000) was developed to evaluate streamflow data promptly, as soon as rainfall and water levels are affected.

Using the KORSAS program, a methodology is shown to evaluate the reliability of streamflow data regularly.

2. DEVELOPMENT OF THE KORSAS COMPUTER PROGRAM

The KORSAS program was developed by Noh (1999, 2000) to evaluate streamflows and to check suspicious or uncertain data on a regular basis. The objective of the KORSAS program is to improve the reliability of streamflow data. KORSAS was designed, and is comprised, of a variety of modules, including DB access and data management, flow measurement arranging, H-Q relation deriving, area rainfall calculating, flow calculating, and flow evaluating modules. KORSAS is configured with the above modules and related to other hydrological systems as shown in Fig. 1. The real time hydrological data and meteorological information are managed by the Oracle Database management system, and are accessed through the local intranet.

The system is operated on PC based Windows operating system and was programmed using Visual Basic 6 computer programming language. Menus, command buttons, and labels in KOR-

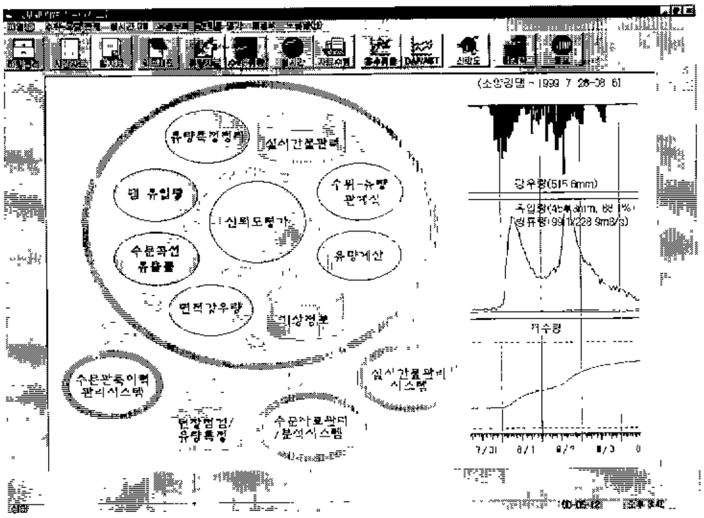

Fig. 2. Main Menus and Screen of the KORSAS

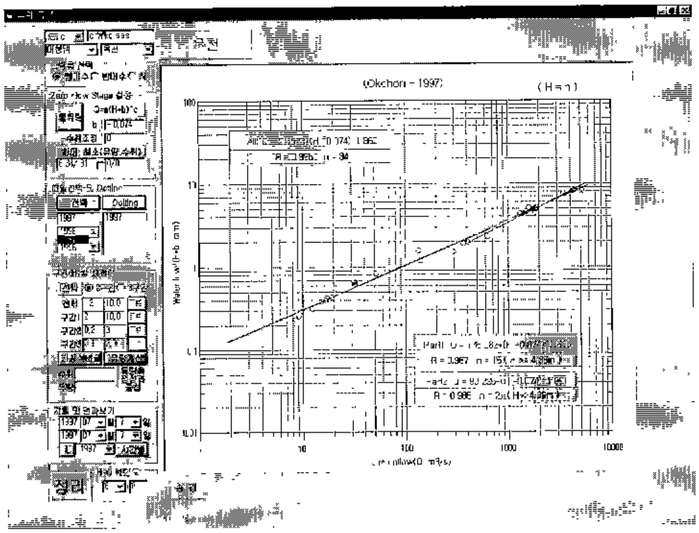

Fig. 3. An Example of a Derived Rating Relationship Between H and Q

SAS were written in Korean for ease of understanding for Korean practitioners and incorporate a user-friendly GUI. Simply by selecting menus and pressing buttons can practitioners do all work necessary, including data loading, calculating, and evaluating, etc. Fig. 2 shows the main screen that is designed for easy access to desired modules via menus and toolbars. Fig. 3 shows an example of a derived rating relationship between water levels and flow rates. Fig. 4 shows an example of a hydrograph obtained from area rainfall and flow rates. Fig. 5 shows an example of the hourly reservoir operation results in real time.

3. EVALUATION METHOD OF STREAMFLOW DATA

The evaluation of the calculated streamflow

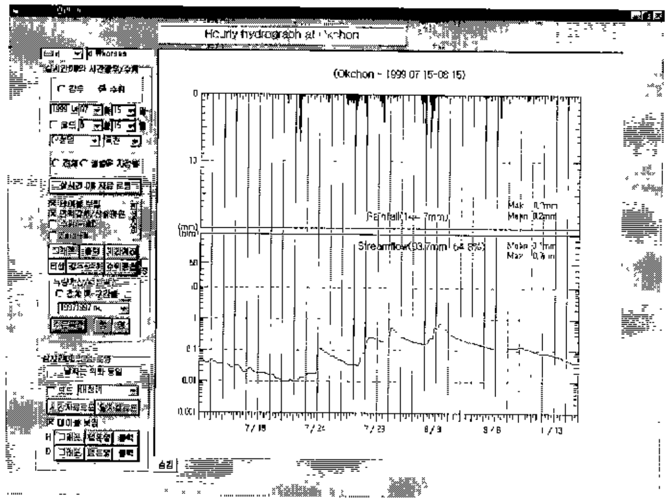

Fig. 4. An Example of Real Time Hydrograph in Hour from DB

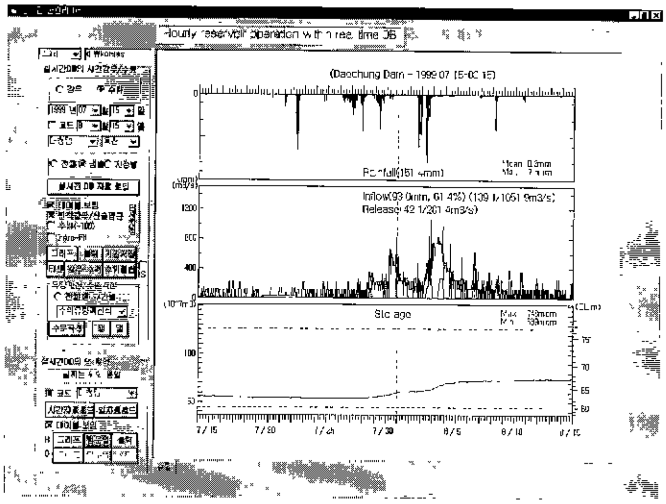

Fig. 5. An Example of Hourly Reservoir Operation Data in Real Time DB

rate is performed in various aspects according to evaluation duration and method. Evaluation duration is determined either as short term (event based) or long term (continuous based).

The process for producing reliable streamflow data in KOWACO is shown as Fig. 6. Hourly streamflow data is calculated indirectly from water level data stored in the DB server by applying the rating relationship. Hourly areal rainfall data is calculated from point rainfall data stored in the DB server by applying Thiessen networks. Hydrographs are drawn and are compared to the inflow hydrographs of multi-purpose dams and the hydrographs of water level observation sites located within the same stream basin, as well as hydrographs derived from simulated results using models.

If the reliability of calculated streamflow data is at a low level, field checkups may be done and streamflow measurements can be done as necessary. Thus, the quality of rating relationship between water levels and flow rates may be increased, and streamflow data can be more reliable. If the reliability of streamflow data is high, it is stored in the DB and will be utilized for various water resources projects.

3.1 The Comparison Method of Flow Measurement

This method is to compare streamflow data calculated from the existing rating relationship with streamflow rates directly measured in a stream.

The procedure is shown as Fig. 7 in which the measured streamflow at a gauging station, is marked on a hydrograph drawn using the existing rating curve equation, overlaying the measured streamflow volume on the past rating relationship.

First, streamflow measurement data is prepared as shown in Fig. 8 and then streamflow rates are calculated as shown in Fig. 9.

Second, the calculated flow rates are overlayed on the hydrograph. The existing rating equation is selected to bring the smallest difference between the measured flow data and the flow data on the hydrograph as shown in Fig. 10. The measured streamflow rate is 8.201 m^3/s, and the calculated streamflow rate is 11.352 m^3/s as shown on the hydrograph. The selected rating equation was derived using flow data measured during the 8 years from 1991 to 1998.

Third, the measured flow rates are overlayed on the existing rating curve, as shown in Fig. 11,

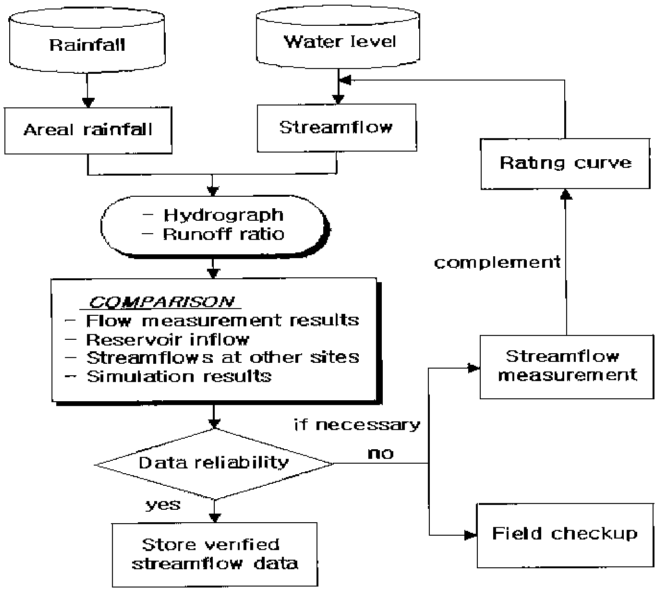

Fig. 6. Process of Reliable Streamflow Data Production

Fig. 7. Process of Comparing with Flow Measurement Result

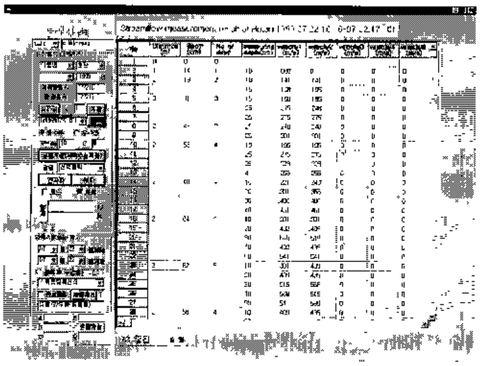

Fig. 8. An Example of Arranging the Flow Measurement Results in a Stream

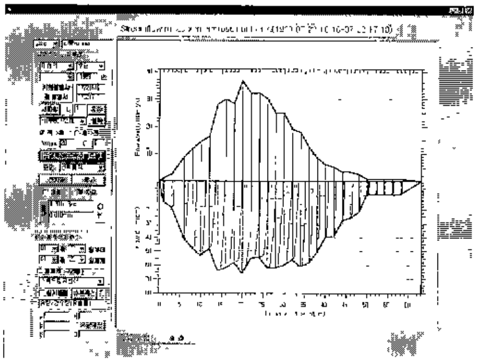

Fig. 9. The Calculation Result of Accurate Streamflow Measurement(Hotan, 1999.7.22)

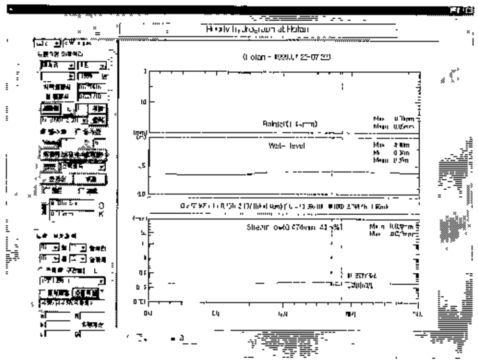

Fig. 10. Overlay of the Measured flow on Hydrograph by the Existing Rating Equation

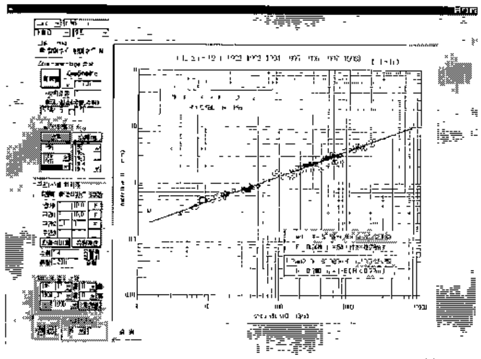

Fig. 11. Overlay of the Measured Streamflow on the Existing Rating Curve

in which the measured flow rates are displayed in large circle. The analysts are able to identify the degree of uncertainty from the extent of deviation from the rating curve.

From this procedure, we will be able to decide if the measured flow rates are incorrect or if the existing rating curve was derived incorrectly.

3.2 The Comparison Method of Reservoir Inflow and Station Flow Rate

It is now assumed that reservoir inflow data might be the most reliable in comparison to other hydrological data due to its regular evaluation. Of course, reservoir inflow data may have some errors because it is calculated from

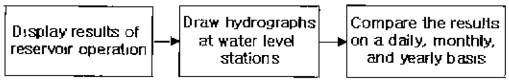

Fig. 12. Process of Comparing with Reservoir Inflow and Station Flow Rates

the water level difference, and water budget analysis. In spite of that, it can be stated unequivocately that the reservoir inflow is more reliable than the measured streamflow data. The procedure for comparing streamflow data with reservoir inflow and station flow rate is shown as Fig. 12, and consists of displaying the results of reservoir operation for wanted periods, drawing hydrographs at several water level stations within the same dam watershed, and comparing the calculated streamflow data mutually among

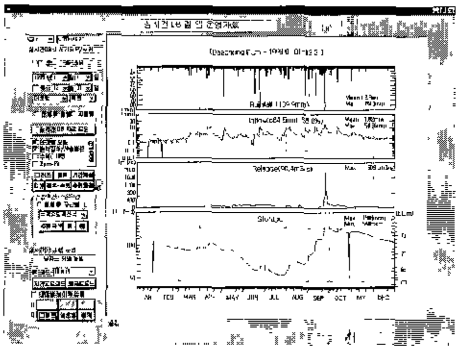

Fig. 13. An example of Displaying Data on Daily Dam Operation in Real Time DB

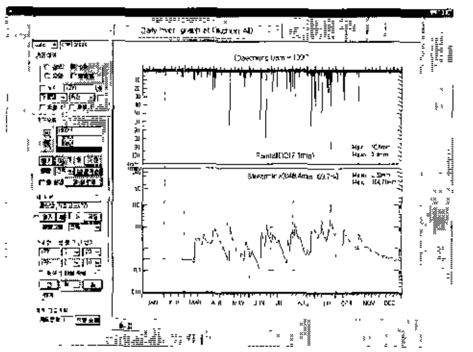

Fig. 14. An example of a Daily Hydrograph at a Water Level Station(Okchon, 1997)

stations on a daily, monthly, and yearly basis.

Fig. 13 shows an example of displaying the Daechung dam daily operation results in 1999 in a real time DB. Fig. 14 shows an example of a daily hydrograph from the Okchon station, in which the areal rainfall is calculated using Thiessen networks and streamflow rates are calculated from the existing rating equation. Fig. 15 shows an example of comparing the flow rates at observatory sites located within the Daechung dam basin. The horizontal axis expresses watershed area in km^2. As watershed area is increased, flow volumes are increasing and runoff ratios are decreasing, generally. The flow unit of the upper graph is expressed in mm and that of the lower graph is expressed in 10^6 m^3. Data reliability is determined easily from trends of flow volumes and runoff ratios with the increase of watershed area.

Comparing the results of Fig. 14 and Fig. 15, the Daechung dam has a total rainfall of 1189.9 mm, an inflow of 664.5 mm in depth, and a runoff ratio of 55.8% for the period but the Okchon station has a total rainfall of 1217.1 mm, a streamflow of 848.4 mm in depth, and a runoff ratio of 69.7%. It can be concluded that the flows are over-observed at the Okchon station.

In Fig. 15, runoff volumes at Okchon and Ho-

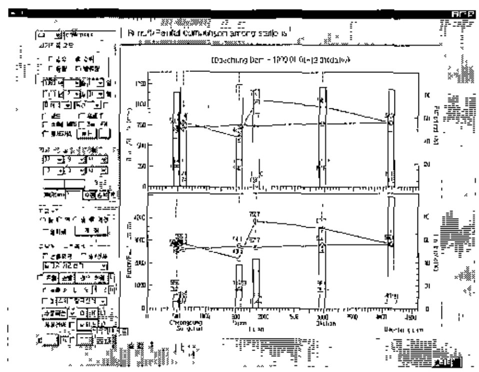

Fig. 15. Flowrate Comparision of Dam Inflow and Outflows at Water Level Stations

tan are larger than the inflow volume of the Daechung dam. On the contrary, the situation is reversed at Sutong station.

Table 1 expresses the results of flow evaluation in analysis terms of year, month and day. In the yearly result, the runoff volumes at Okchon and Hotan are larger than the Daechung dam inflow volumes, on the contrary, the reverse is true at Sutong station. In the monthly result, the runoff volumes at Sutong and Chongsung were suspiciously low. In the daily result, runoff volumes at Okchon and Hotan were too high, and runoff volumes at Sutong and Chongsung were too low.

In an integrated conclusion, it can be decided that the reliability of data is at an intermediate level of reliability at Okchon, Hotan, and Songchon station, and at a low level of reliability at Sutong and Chongsung station. As the most likely cause of error, the difference between the measured water level and stream water level was identified, which reduced the quality and reliability of data.

3.3 The Comparison Method of Flow Simulation

The reliability of flow rates in stream can be analyzed using continuous rainfall-runoff models or event-based flood runoff models. The procedure for comparing with model simulation is as shown in Fig. 16. This procedures calculates streamflows at water level stations during desired periods, runs rainfall-runoff models on a event or continuous basis, and compares the calculated streamflows with modeling results.

In this study, only a continuous model was suggested to analyze the reliability of streamflow data and the DAWAST runoff model (Noh, 1999) was adopted. This analysis was performed for 2 years.

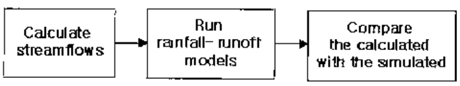

Fig. 16. Process of Comparing with Model Runs

Fig. 17 shows the comparison between observed flows using rating equations and simulated flows from the DAWAST model. The amount of rainfall is 1,217.1 mm, the observed flow rate is 848.7 mm, and the simulated flow is 719.2 mm in depth. Runoff ratios of the observed and the simulated flows are 69.7% and 59.1% respectively. The larger the difference between observed and simulated ratio, the poorer the reliability of the flow data observed.

Fig. 18 shows an example of overlaying observed runoff ratios marked in a square to equal value lines of runoff ratio equations functioned with watershed area (km^2) and rainfall amount (mm). The observed runoff ratio is 69.7% and deviates far from the equal value line. On the other hand, the runoff ratio by equation is 52.2% in Fig. 18 and this results in a poor comparison with the simulated result of 59.1% in Fig. 17.

Conversely, a good example of an adequate comparison is shown in Fig. 19-20. In Fig. 19, the amount of rainfall is 1,321.6 mm, the ob served flow is 754.5 mm, and the simulated flow is 704.5 mm in depth. The runoff ratios of the observed and simulated flows show 57.1% and 53.3% respectively. In Fig. 20, the observed

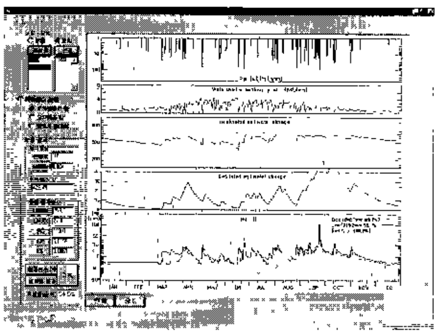

Fig. 17. An Example of Daily Hydrograph Simulated by the DAWAST Model (1999, Okchon)

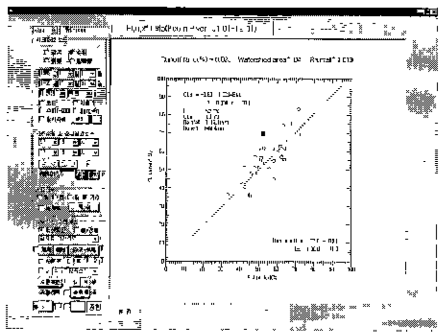

Fig. 18. An example of Overlaying Runoff Ratio on the Equal Value Line (1999, Okchon)

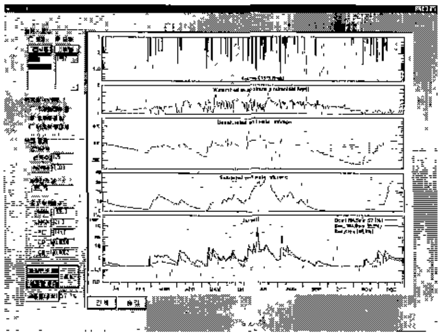

Fig. 19. An example of Daily Hydrograph Simulated by the DAWAST Model (1997, Okchon)

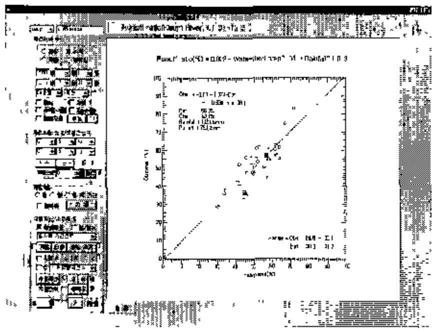

Fig. 20. An Example of Overlaying Runoff Ratio on the equal value line (1997, Okchon)

runoff ratio is 57.0% and it just fits along the equal value line. The runoff ratio by equation also shows 56.7% and this results in a good comparison with the simulated result, 53.3% in Fig. 19.

Using KORSAS, according to the above mentioned successive processes, the reliability of streamflow data can be assessed easily and promptly and the uncertainties are removed using a variety of reasonable methods. Table 1 shows an example of the results of evaluation on the recent data.

4. CONCLUSION

The PC based KORSAS program was developed to analyze and evaluate in real time, concurrent to hydrological data observation. This study's purpose was to review and apply the evaluation methodology of streamflow data in a real world setting using the developed system. KORSAS helps hydrological practitioners within KOWACO to do hydrological work such as streamflow measurement, calculation, analysis, and evaluation, etc. Using the various methods within KORSAS, suspicious or uncertain data is checked regularly and the reliability of streamflow data is improved using continuous data verification practices. But, to achieve the objectives completely, continuous concerns and interest is required and these are the most important objectives when compared to other duties.

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Table 1. Flow Calculation and Evaluation at Measuring Stations Upstream to the Daechung Dam

Station	Year(1999)			Month(2000.4.1-26)			Day(2000.4.26)		Evaluation
	rainfall (mm)	runoff (mm)	ratio (%)	rainfall (mm)	runoff (mm)	ratio (%)	hourly (mm)	daily (mm)	
Daechung dam	1189.9	664 6	55.8	46.8	15.0	32.1	-	0.541	0
Okchon	1217.1	848.3	69.7	41 2	20.8	50.5	0.033	0.790	△
Hotan	1180.0	893.2	75.7	37.2	16.9	45.5	0.032	0.778	△
Sutong	1247.0	543.5	43.6	27 1	3 5	12.8	0.005	0.129	
Songchon	1212.7	675.2	55 7	44.9	13.2	29.4	0.018	0.432	△
Chongsung	1149.0	585.8	50.9	46.1	4.2	9 1	0.008	0.192	

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