HYDROLOGY PROJECT

Technical Assistance

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Training module # SWDP - 32

How to carry out secondary validation of stage-discharge data

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1. Module context

While designing a training course, the relationship between this module and the others, would be maintained by keeping them close together in the syllabus and place them in a logical sequence. The actual selection of the topics and the depth of training would, of course, depend on the training needs of the participants, i.e. their knowledge level and skills performance upon the start of the course.

2. Module profile

Title	:	How to carry out secondary validation of stage-discharge data
Target group	:	Assistant Hydrologists, Hydrologists, Data Processing Centre Managers
Duration	:	One session of 60 minutes
Objectives	:	After the training the participants will be able to*:* • Carry out secondary validation of stage-discharge data
Key concepts	:	• Balancing of flows at adjoining stations • Review of stage-discharge data in extrapolated range
Training methods	:	Lecture, software
Training tools required	:	Board, OHS, Computer
Handouts	:	As provided in this module
Further reading and references	:	

3. Session plan

No	Activities	Time	Tools
1	***General*** • Overhead – Secondary validation of stage-discharge data	5 min	
2	***Review of rating curve on the basis of balances*** • Overhead – Water level time series • Overhead – Rating curve Khed, 1997 • Overhead – Rating curve Chaskman, 1997 • Overhead – Discharge time series (hourly) • Overhead – Discharge time series (detail) • Overhead – Water balance	5 min	
3	***Review of rating curve on the basis of double mass analysis***	5 min	
4	***Review of rating curve on the basis of relation curve relation curves between stages at adjacent station*** • Overhead – Consistency check of rating curve (1) • Overhead – Consistency check of rating curve (2)	5 min	

4. Overhead/flipchart master

5. Handout

Add copy of Main text in chapter 8, for all participants.

6. Additional handout

These handouts are distributed during delivery and contain test questions, answers to questions, special worksheets, optional information, and other matters you would not like to be seen in the regular handouts.

It is a good practice to pre-punch these additional handouts, so the participants can easily insert them in the main handout folder.

7. Main text

Contents

How to carry out secondary validation of stage-discharge data

1. General

Rating curves are normally developed and validated with respect to current metering observations at an individual station. It is often necessary to extrapolate the relationship beyond the measured range.

One means of providing a further check on the reliability of the extrapolated rating curve is to make comparisons of discharges computed using the stage discharge relationships between neighbouring stations. The secondary validation of discharge, as will be described in Modules 36 and 37, thus also provides a basis for secondary validation of stage discharge relationships. If there is an inconsistency or an abrupt change in the relationship between discharge time series at sequential stations on a river or around a confluence, then the most likely source is the stage discharge relationship at one or more of the compared stations. Where such inconsistencies are observed, rating curves and their extrapolations must be reviewed.

2. Review of rating curve on the basis of balances

After finalising rating curves, observed stage time series are converted to discharge. Discharge time series are then aggregated and compiled to successively longer time intervals - from hourly to daily to ten-daily and monthly. Discharge time series at consecutive stations on a river should then show a consistent pattern of relationship and water balance, taking into consideration the intervening catchment area, major tributary inflows and abstractions. The balance of flows can be checked using the average discharge or flow volumes during a time interval. Generally better and less variable relationships are obtained using longer time intervals. Comparison plots of discharge time series provide a helpful means of identifying anomalies.

In addition a residual series can be plotted (Fig. 2.1a-h) alongside the comparison plots as the difference between discharges at the two stations.

Residual series generally provide a better means of detecting anomalies. Where inconsistencies occur, the station at fault may not be immediately evident. A potential source, which should be investigated, are periods when rating curve extrapolation has been used at one or both stations.

In the Figures 2.1a to 2.1h an application of the technique is outlined. In Figure 2.1a the hourly water level time series of the stations Chaskman and Khed in the Bhima basin are show. Both stations are located along the same river, Khed d/s of Chaskman. The rating equations fitted to the stage-discharge data available for 1997 are shown in Figures 2.1b and c. Next, the hourly water level time series have been transformed into hourly discharge time series using the rating curves presented in Figures 2.1b and c. The results are shown in Figures 2.1d and e, where the latter is a detail. Since Chaskman is upstream of Khed, and lateral inflow may occur, one should expect that the discharge at Khed exceeds the discharge at Chaskman. From the comparison of the two series it is observed that this is generally the case, except for a short duration prior to the second peak. The differences are far better exposed if the difference between the series are plotted, see Figure 2.1f. It is noted that particularly with sharp rises of the hydrograph and little inflow in between the stations the peak at the upstream station advances the downstream one, hence creating negative values in the balance, which is apparent from the first peak. Large positive values as is observed for the second peak is likely due to lateral inflow (provided that timing errors in the water level hydrograph do not exist).

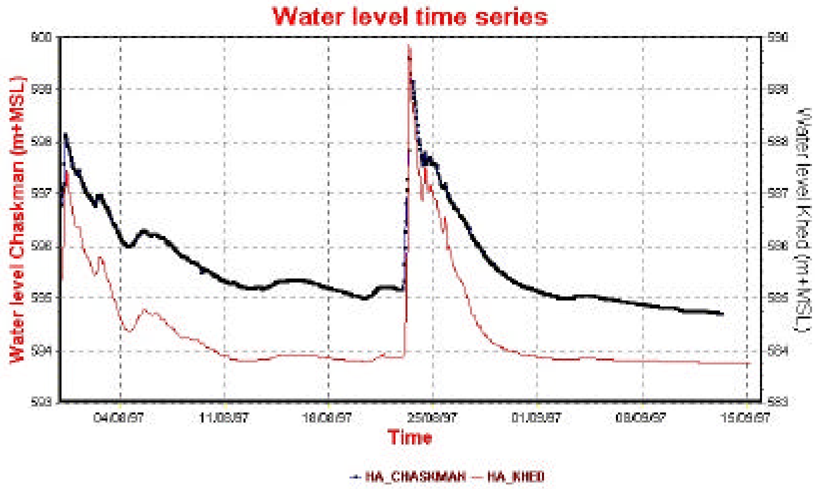


Figure 2.1a Hourly water level time series

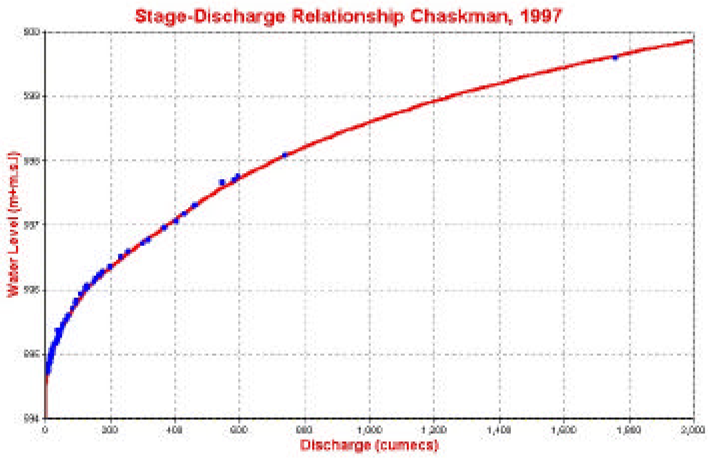


Figure 2.1b Stage-discharge rating curve Chaskman, 1997

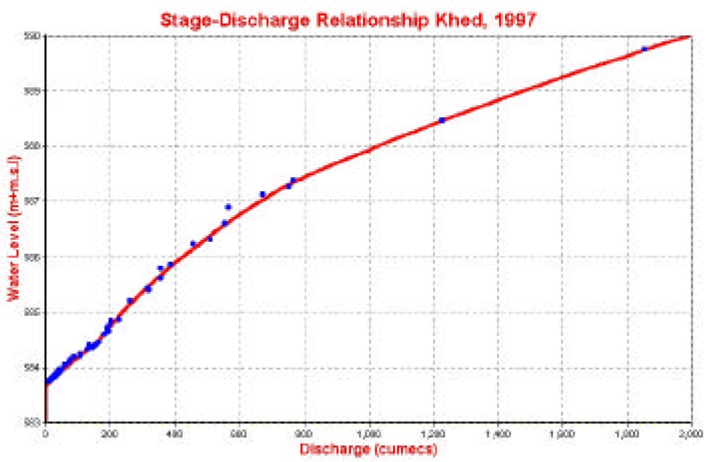


Figure 2.1c Stage-discharge rating curve Khed, 1997

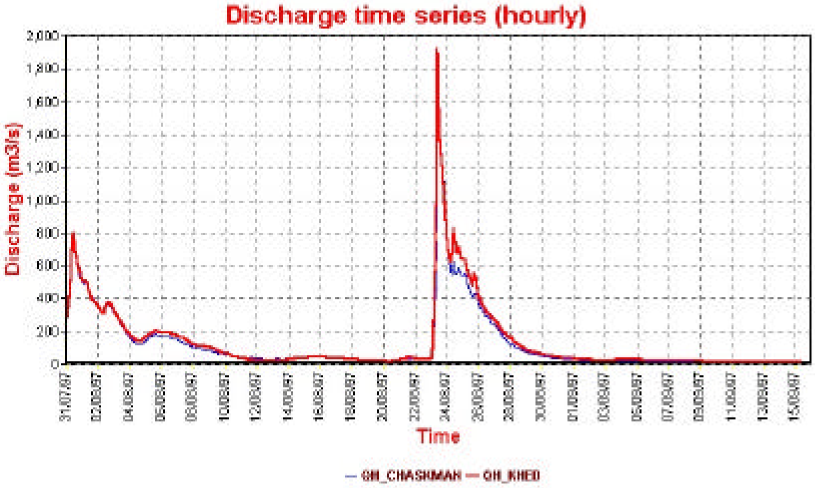


Figure 2.1d Hourly discharge time series Chaskman and Khed

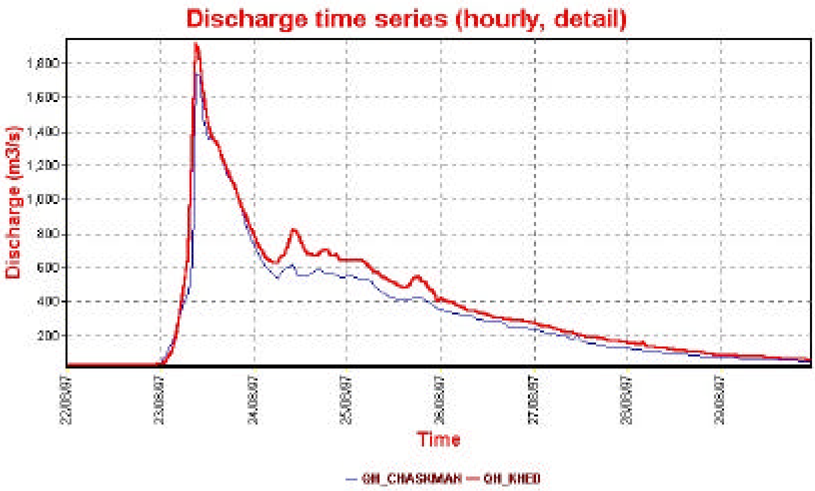


Figure 2.1e Hourly discharge time series Chaskman and Khed (detail)

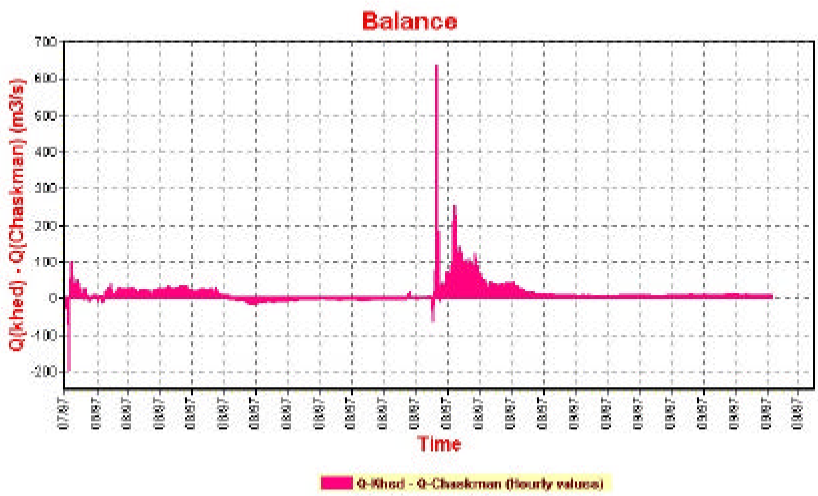


Figure 2.1f Q(Khed) – Q(Chaskman) hourly discharge series

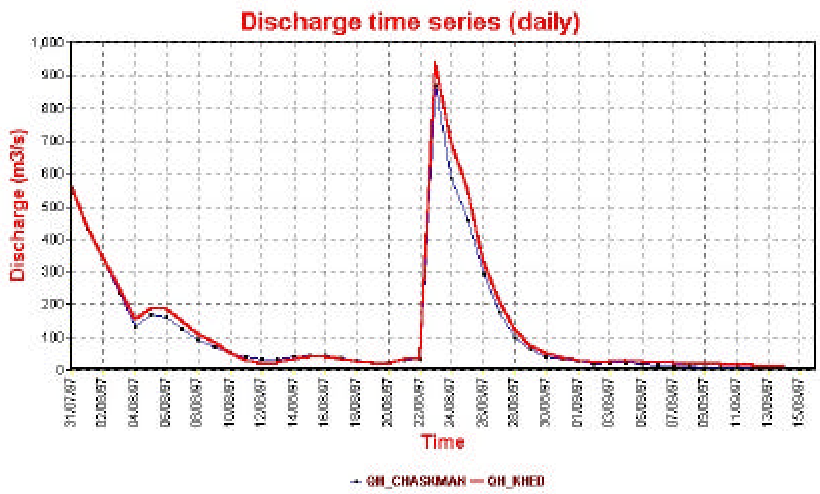


Figure 2.1g Daily discharge time series Chaskman and Khed

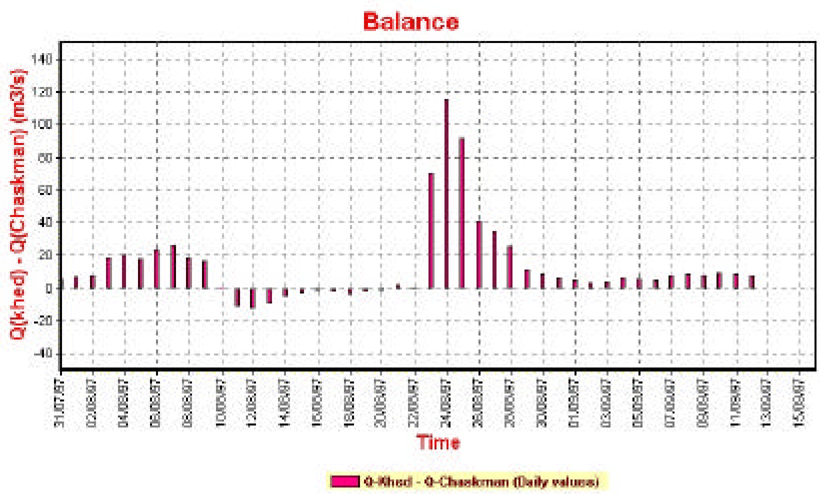


Figure 2.1h Q(Khed) – Q(Chaskman) daily discharge series

The eliminate these travel time problems in the water balance the water balance for the discharge time series should be executed at a higher aggregation level. In view of the travel time of the flood wave between Chaskman and Khed of approximately 1 hour an aggregation up to daily intervals will do. For larger rivers with larger distances between the stations a higher aggregation level may be more appropriate. The daily discharge time series and the water balance are shown in Figures 2.1g and h. It is observed that between 10 and 20 August 1997 the daily discharges as computed for Chaskman are exceeding those of Khed. Provided that no water is being abstracted from the river, the reasons could be:

- Either the water series at one or at both sites are erroneous, or
- The rating curves established for one or both sites are biased for that period, or
- Both water level series and rating curves are incorrect.

These possibilities then have to be investigated in detail. If the anomaly is due to one or both rating curves, more segments have to be incorporated in the rating curves or the rating curves for shorter periods of time have to be developed.

It is noted here that for the peaks some negative values in the water balance may occur due to damping of the flood wave. The damping per unit length is approximately:

$$\frac{dQ_{\max}}{dx} \approx \frac{(3/5)^3}{2} \frac{(B_s / B_r)^2}{K_m^2 h_{\max}^{1/3} S_0^2} \frac{\partial^2 Q}{\partial t^2}$$

where : B_s = total width of river and flood plain
B_r = width of the main river
K_m = K-Manning (=1/n)
h_{max} = flow depth for the flood peak
S_0 = slope of the river bed

To get an impression of the magnitude assume that the shape of the flood wave can be approximated by the following cosinus function:

$$Q(t) = Q_0 + a_0 (1 - \cos(\frac{2pt}{T})) \qquad hence: \left(\frac{\partial^2 Q}{\partial t^2}\right)_{Q\max} = \frac{-a_0 4p^2}{T^2}$$

With the above, the damping per unit of length becomes:

$$\frac{dQ_{\max}}{dx} \approx -\frac{(3/5)^3 4p^2}{2} \frac{(B_s / B_r)^2}{K_m^2 h_{\max}^{1/3} S_0^2} \frac{a_0}{T^2}$$

The equation shows that the damping is large if:

- B_s/B_r is large, i.e if the a wide flood plain is present
- K_m is small, i.e. Manning's n is large that is a hydraulically rough river bed
- S_0 is small; in steep rivers the attenuation is small
- The amplitude a_0 of the wave is large and its period T (duration) is short, i.e. rapidly rising and falling hydrographs.

Using this for the second flood peak of the example with:

- Q_0 = 400 m^3/s, a_0 = 750 m^3/s and T = 36 hrs
- B_s/B_r = 1 (no flood plain), K_m = 40, h_{max} = 5 m and $S_0 = 8x10^{-4}$

Then $dQ_{max}/dx = 1.1x10^{-4}$ $m^3/s/m$ and the damping over a distance of 11 km is approximately 1.2 m^3/s, which is negligible. For a bed slope of 10^{-4}, the damping would have been 64 times as large, whereas a flood plain would have increased the damping further.

3. Review of rating curve on the basis of double mass analysis

Double mass curve analysis has already been described in the secondary validation of rainfall (Module 9) and climate (Module 17). It can also be used to show trends or inhomogeneities between (a) flow records at neighbouring stations or (b) observed flow records and flows computed on the basis of regression relationships with rainfall and is normally used with aggregated series (usually monthly). It can again be used to identify potential problems in the rating curve of one or more stations.

A distinct break of slope in the double mass curve between neighbouring stations suggests inhomogeneity in one of the records. Inspection for rating changes at the time of the break of slope will help to identify the source. It should be noted however that inhomogeneities also arise from artificial changes in the catchment, for example the commencement of abstraction for an irrigation scheme.

4. Review of rating curve on the basis of relation curves between stages at adjacent stations

Relationship between stages at adjoining stations for steady state conditions can be established. At both such stations relation between stages and corresponding discharges would have been also established. It can then be possible to combine these three relationships together in the following way. Consider the stations Cheskman and Khed, which are two adjoining stations on a river reach. Figure 4.1 shows the relationship between stages h-Chaskman and h-Khed. Figures 2.1b and c show the rating curves for stations Chaskman and Khed (i.e. relation between discharge $Q_{Chaskman}$ & $h_{Chaskman}$ and Q_{Khed} & h_{Khed}) respectively.

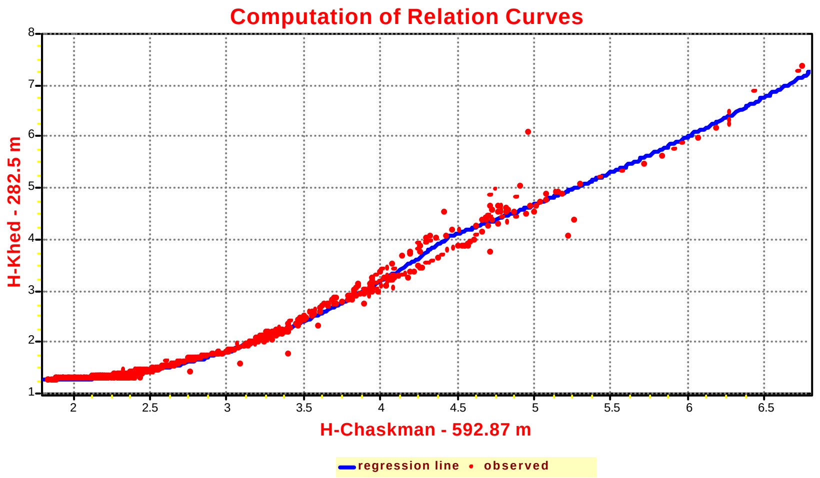
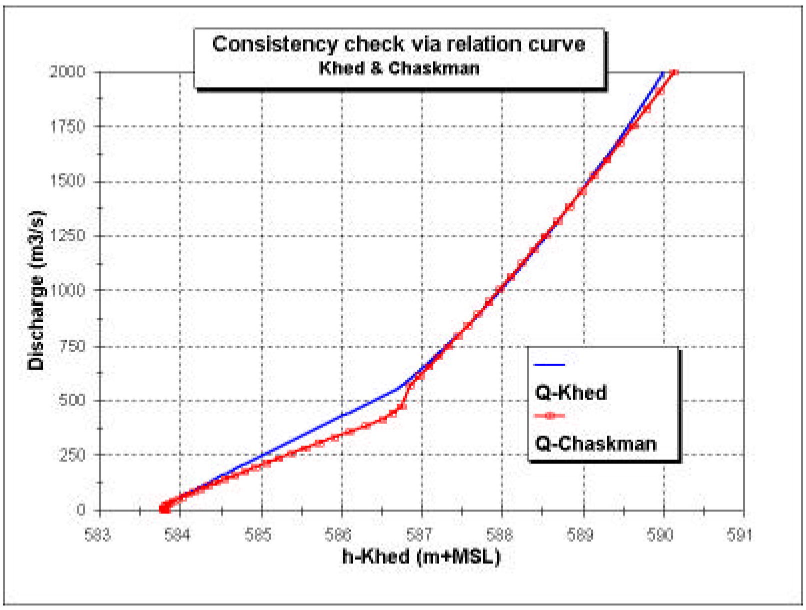


Figure 4.1 Stage-relation curve h(Khed) = f(h(Chaskman))



Now, using Fig. 4.1 and Fig. 2.1b the relationship between $Q_{Chaskman}$ & $h_{Chaskman}$ can be translated into relationship between $Q_{Chaskman}$ & h_{Khed}. Relationship between Q_{Khed} & h_{Khed} is also superimposed on the same plot depicting relationship between $Q_{Chaskman}$ & h_{Khed}. These superposed relationships are depicted in Fig. 4.2.

Figure 4.2
Discharge at Chaskman and Khed displayed versus h-Khed

Now a comparison can be made for $Q_{Chaskman}$ & Q_{Khed} for the same h_{Khed}. The range of discharge variation for the same stage in this plot depends upon whether the condition of flow is steady state or if it unsteady with or without lateral contributions from the intervening catchment between the two stations. It is observed from Figure 4.2 that for the same stage at Khed the flow in Chaskman is less than at Khed, which confirms the consistency of thye two curves.