Section 7-2

Calibration of Other Headwaters and Locals with Minimal Complications

Introduction

This section describes procedures and strategies to follow when calibrating other drainages within a river basin for which a good definition of the local flow contribution can be determined. The calibration for these areas will be closely tied to the results from the initial headwater area after taking into account information determined earlier about the spatial variations of physical, climatic, and hydrologic conditions over the basin. In order to determine if a drainage area falls into this category, it is necessary to examine the hydrograph produced from the area. In order to obtain this hydrograph it may only be necessary to look at the observed streamflow data or it may be that some computations must first be performed to remove the effect of control structures or upstream flows. Once the local drainage area hydrograph is established, an evaluation can be made as to whether model parameters can be reliably determined or whether there is so much noise in the hydrograph that a full calibration is not possible. This decision is subjective, but guidelines for making the choice include:

- Compare the hydrograph to the streamflow record for the initial headwater area or other headwaters that have no complications caused by such things as reservoirs, large lakes, diversions, or irrigation. Determine whether the general pattern is similar or, at least any differences are reasonable. For instance see if the hydrographs go up and down at the same time though the time to peak and amount of attenuation may vary, and if the magnitude and timing of snowmelt runoff makes sense.

- Examine baseflow periods to assess whether the general magnitude of the flow and the recession rate can be reasonably determined most of the time at these flow levels. A semi-log scale should be used when making this determination. Considerable scatter might occur at times when looking at low flow periods, but if such periods are few or the effects minor enough so that the baseflow pattern can be reasonably ascertained, a calibration of low flow parameters is possible.

Derivation of the Hydrograph for the Drainage Area

As mentioned previously for many headwater areas the observed mean daily flow data defines the hydrograph for the drainage area. In other cases computations may be necessary in order to determine the hydrograph that can possibly be used for calibration. This includes situations where the flow data need to be adjusted to natural flow conditions by adding or subtracting diversions, the inflow to an upstream reservoir is computed from outflow and storage data, and downstream local area contribution is derived by subtracting routed upstream flows from the observed flow at the gaging station. In a few cases the computations may involve a combination of these situations, e.g. a downstream local area may contain some diversions.

Adjustment to Natural Flow

In order to determine natural flow conditions to use for calibrating the snow, soil moisture, and channel models, the streamflow data need to be adjusted for man-made effects. Primarily this includes adjustments for diversions into or out of the drainage area. It could also include adjustments for the effects of reservoirs within the area, a large spring, or flood overflows across drainage divides. Section 6-6 discusses adjustments to mean daily flow records. Once the adjustments are completed, an evaluation can be made as to whether the resulting hydrograph can be used for calibration or whether too much noise exists.

<u>Computation of Reservoir Inflows</u>

The inflow hydrograph for a reservoir can be computed, if sufficient data are available, and possibly used to calibrate the models to the drainage area. Inflow hydrographs to any reservoir can be calculated though it is highly unlikely that the derived flows can be used for calibration other than the case of a headwater reservoir, i.e. a dam with no upstream calibration points. The water balance equation for a reservoir, as was shown in Section 6-6 (Eq. 6-6-1), is:

$$I - O + P \cdot A - E \cdot A + D = \Delta S \qquad (7\text{-}2\text{-}1)$$

where: I = Inflow,
- O = Outflow,
- P = Precipitation on water surface,
- E = Evaporation from the water surface,
- A= Water surface area,
- D = Diversions into or out of the pool other than at the main outlet, and
- ΔS = Change in Storage (each term is in volume units).

In order to compute the inflow, the outflow and the other terms must be known. At a minimum the outflow and change in storage terms are required. The change in storage can be computed from reservoir storage data using the DELTA-TS operation. If pool elevation measurements, rather than storage, are available, then they must first be converted to storage using the elevation-storage curve for the reservoir with the LOOKUP operation. Precipitation and evaporation could possibly be ignored if the water surface area of the reservoir is very small as compared to the drainage area above the reservoir, i.e. if the volume of water transferred at the water surface is small compared to the inflow. If precipitation and evaporation are included, the computations are relatively straight forward when the water surface area can be assumed to be a constant (LOOKUP operation used to convert depth of precipitation or evaporation to a volume based on the surface area). If the water surface area changes substantially over the range of pool elevations that occur, then this needs to be accounted for in the computations. In that case the volume of water transferred is a function of both the amount of precipitation and evaporation and the amount of storage or the pool elevation. Unfortunately the 3 variable relationship operation in NWSRFS, LOOKUP3, is currently only programed to solve for depth as a function of discharge and depth or 2 discharge variables and is not in a gene ral form for any 3 variables (this application would require solving for volume as a function of depth and volume or 2 depth variables).

In many cases when calculating the flow from the drainage area above a reservoir, errors in t
he various terms used to compute the inflow will result in considerable variability in the resul
ting time series. This is especially true at low flow levels and when the reservoir surface ar
ea is quite large. Also noise can result from problems caused by wind effects on the measur
ement of storage or pool elevation. High winds will tend to pile water up on the downwind edge of the lake resulting in inaccurate values of the change in storage term when the wind s
peed and direction differ greatly from one day to the next. For these reasons, in many cases it is not possible to derive a reservoir inflow time series that is of good enough quality to be used for model calibration.

<u>Computation of Local Flows for Downstream Locations</u>

The typical sequence for a downstream location is to route the upstream flows to the downstr
eam gage and then subtract the routed flow from the total downstream flow to get the local ar
ea contribution. The resulting local area hydrograph can be examined to determine if a sepa
rate calibration can be done for this drainage or whether there is so much noise that it will mi
nimize the chance of obtaining model parameter values with any degree of confidence. The flow to be routed downstream should be the adjusted instantaneous discharge, as discussed i
n Chapter 7, so that simulation volume errors from upstream locations are not carried downst
ream. In some cases, primarily based on where the local drainage network enters the main c
hannel, it may be more realistic to add all or a part of the local area contribution to the upstre
am flow before routing. This situation is illustrated in Figure 7-2-1. In this case it would be most realistic to add the flow from Areas 1 and 2 to the flow at point A before routing sinc
e these areas enter the main channel at the very upstream

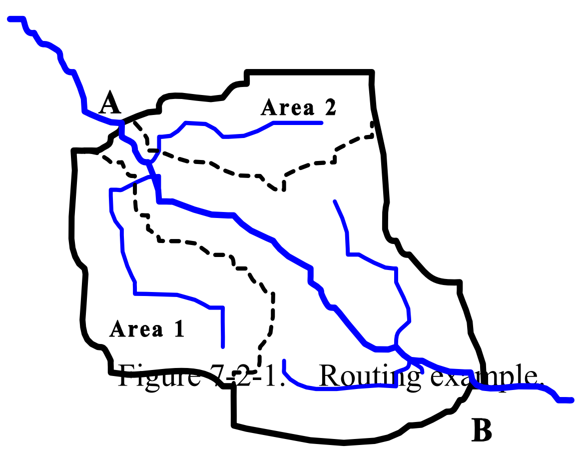


Figure 7-2-1. Routing example.

end of the local drainage. In this situation a separate local area hydrograph is not obtained a nd a full calibration of the local area is not possible.

NWSRFS contains a number of routing models that can be used to move upstream flows to a downstream location. Generally the parameters of these routing models can best be determined from instantaneous discharge data for a number of storm events with different magnitudes of flow. In some cases routing model parameters can be adequately determined using mean daily flow data. This occurs mainly when the response time of the watersheds is relatively slow and there is a considerable amount of lag and attenuation in the river reach. The verification of the routing model parameters can be accomplished by using a long continuous record with a wide variety of flow conditions. An evaluation of the resulting local area hydrograph is one of the best methods of determining whether any further refinement of the routing model parameters is necessary. The steps in this process are as follows:

1. Generate adjusted instantaneous discharge hydrographs at each upstream location. If simulated instantaneous flows are not available at an upstream point, i.e. the area above that location has not been modeled, then adjusted instantaneous flows can be derived from just observed mean daily discharge data, rather than using the ADJUST-Q operation with both observed daily and simulated instantaneous flows. An option within the CHANGE-T operation allows for the generation of an instantaneous discharge time series from mean daily flow data. The shape of the resulting hydrograph should be quite realistic for areas with a slow response time, i.e. peaks in terms of days, but cannot be guaranteed for fast responding streams.

2. Route these adjusted instantaneous upstream flows, either separately or in some combination, to the downstream point.

3. Use the MEAN-Q operation to produce a mean daily routed time series.

4. Subtract the routed mean daily flow from the observed mean daily flow at the downstream location to generate a mean daily hydrograph for the local area. This also can be done for instantaneous discharges for periods when observed instantaneous flow data are available at the downstream point.

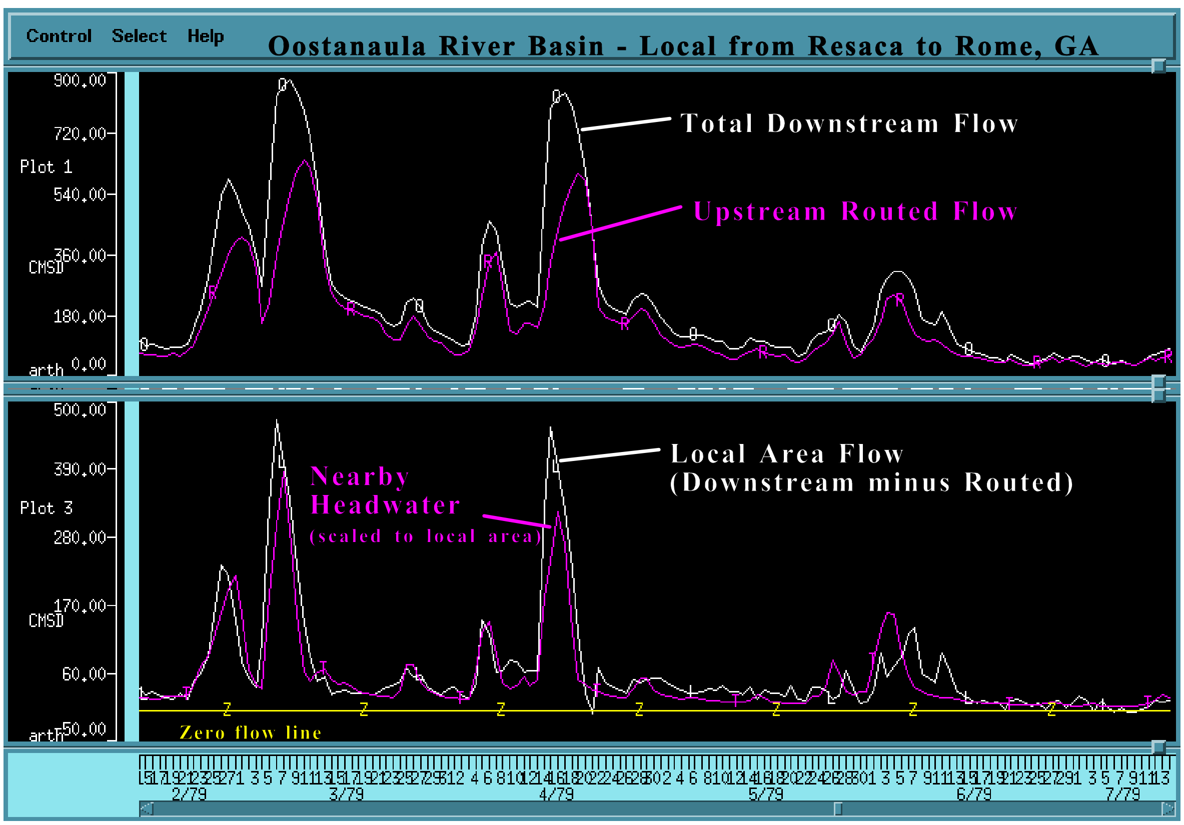
5. Produce two daily flow plots to evaluate the results. One plot should contain the total routed and downstream observed discharges. It can also contain the local area flow, upstream inflows (before routing), and individual routed flows. The second plot would contain the local area hydrograph and discharges from one or more nearby headwater areas with minimal complications. The hydrographs for the nearby headwaters should be scaled to the local drainage area before plotting. These plots can be produced using two WY-PLOT operations or a single PLOT-TS operation. Using PLOT-TS has two advantages. First, both plots can be viewed at the same time and second, negative values can be seen (generated when routed flow is greater than the downstream total flow - a zero flow line can be shown by having a time series included for which all values have been set to zero using the CLEAR-TS operation). The results are evaluated by seeing if the local

area flow plot looks like it should by comparing it to the hydrographs for nearby headwat
er areas. Peaks should occur at the same time and the recessions should be smooth with
out any sudden dips caused by the routed flow being close to or exceeding the total down
stream discharge.

6. Modify the routing model parameters if needed to try to improve the resulting local are
a hydrograph and rerun the computations. Once the best possible results are obtained, d
ecide whether the local area hydrograph is of sufficient quality to use for a full calibratio
n. If a full calibration can be done, the local area daily flows can be saved to a file for u
se while calibrating (routing operations would not be included while working on the local
area) or the local area flows can be recomputed on each run, rather than being read from
a file, by including the routing computations. During calibration the simulated and "ob
served" (total minus routed) local flows would be used to determine and evaluate change
s to model parameters. At the end, both the local and total area flows should be examin
ed before finalizing the parameter values.

Figure 7-2-2. Sample PLOT-TS display for deriving a local area hydrograph.

Figures 7-2-2 and 7-2-3 show examples of the types of plots used to evaluate the routing mod



el parameters. Figure 7-2-2 is a PLOT-TS display that has two daily flow plots. The top p
lot shows the routed and total downstream flows. The bottom plot includes the local flow

(total downstream minus routed), the hydrograph from a nearby headwater that is scaled to the local drainage area, and a time series of all zeros. In general the derived local area flow looks fairly reasonable though there are times when the local flow dips to zero or below due to the routed flow being equal or exceeding the downstream discharge. There also appears to be more variability in the derived local flow than in the hydrograph for the nearby headwater at lower flows.

Figure 7-2-3. Sample WY-PLOT semi-log display for deriving a local area hydrograph.

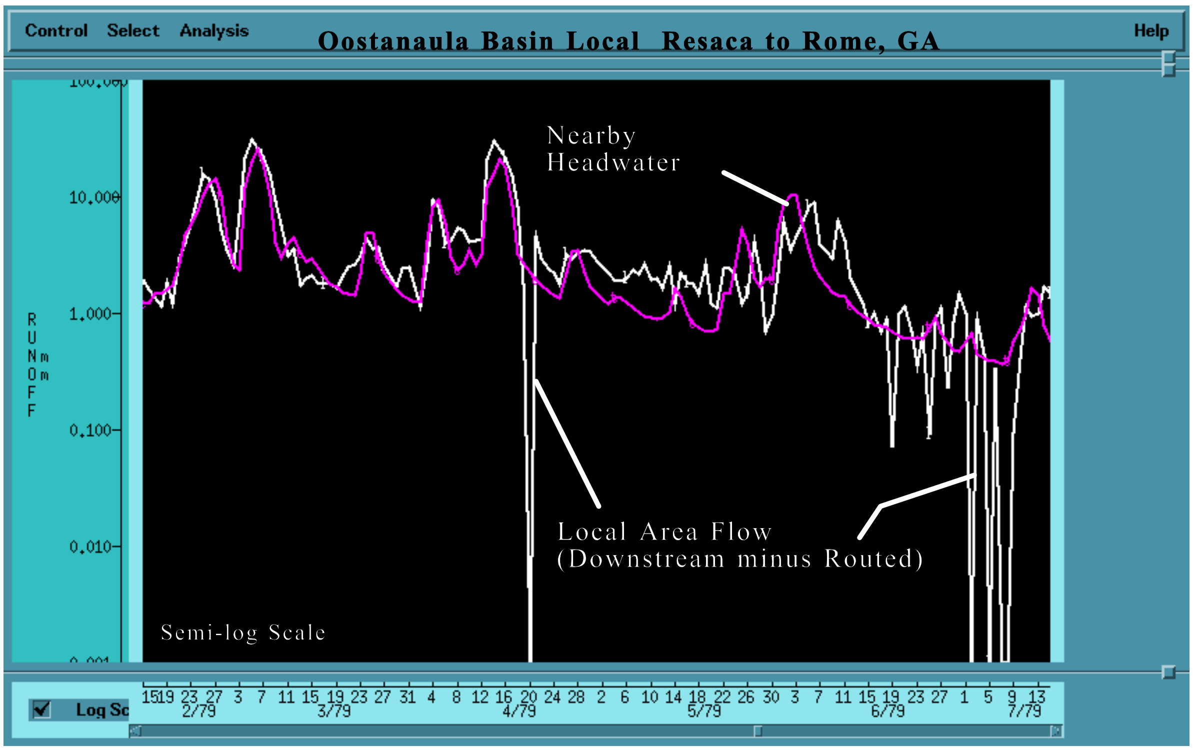


Figure 7-2-3 shows a semi-log display of the lower panel of the previous figure using the WY-PLOT operation display. This plot accentuates the dips and the flow variations in the local area flow. While this derived local area hydrograph is probably of sufficient quality to make some limited parameter adjustments, it is not good enough for a full calibration.

<u>Strategy to Follow</u>

The recommended strategy to follow when calibrating these other headwater and local areas with minimal complications and for which a good definition of the hydrograph can be determined is:

1. First calibrate the other headwater areas with minimal complications. These headwaters should not contain any large discharge adjustments or be reservoir inflow points. These should be the next best drainages for determining parameter values. Start with a watershed that is close to the initial headwater and then move across the river basin. The steps to follow for each of these watersheds are:

a. Determine the calibration period – It is best to use the same period to calibrate the remaining watersheds as was used to calibrate the initial headwater area. In some cases this is not possible because the other headwater areas may not have observed streamflow data for this period or there may have been changes within the drainage area over time that dictate that another period be used for calibration.

b. Assign initial parameter values – Initial values for the snow and Sacramento models should be those determined for the most hydrologically similar area that has been previously calibrated. Different values could be used for some of the minor snow model parameters if there are significant differences in the typical amount of snow from one area to the next. Differences in soils and vegetation could be used to alter some of the Sacramento model parameters if there is sufficient confidence in the relationship between a given parameter and the physiographic information. Also, the ET-Demand curves could vary based on elevation and vegetation cover as described in Section 6-5. A unique channel response function should be derived for each new watershed as drainage areas and the channel network will vary from one watershed to the next.

c. Determine parameter adjustments -- Follow the strategy described in Section 7-1 for the initial headwater area with the exception of *only changing those parameters that clearly should be altered*. Possible changes to parameters that affect certain components of the models may be suggested based on the assessment of spatial variability that was described in Chapter 4, but parameter values should not be actually altered until closely examining the simulation results in a step by step manner. Modifications for large errors should involve changing as few parameters as possible. Then as you go through the various groups of parameters, i.e. starting with parameters that control low flows, then major snow model parameters, then tension water capacities, then storm runoff parameters, and at last the final adjustments, locate those portions of the hydrograph where the effects of each parameter can be isolated and then only change the parameter value when there is clear evidence that a change is justified. The magnitude of the parameter change doesn't have to be large, but there must be no doubt that the change is needed based on looking at multiple situations when the parameter's effects can be isolated. The statistics mentioned in Chapter 7 should be monitored during the calibration and may assist in determining which parameters may need to be modified. Also additional data, such as instantaneous and peak flows and snow observations should be used when available just like for the initial headwater area.

Making only those parameter changes that are clearly justified, will result in a consistent and realistic variation in parameter values across the river basin. It is important to base any changes on a consistent pattern involving a large number of cases when the effect of a given parameter can be isolated. Parameter changes shouldn't be based on one or two events or a sight improvement in some 'goodness of fit' statistic. It is more important to achieve spatial consistency in the parameter values than to change values merely to improve some statistical value. By starting with parameters from a previously calibrated wa tershed and then looking at each parameter in an organized manner should also result in significantly reducing the time needed for calibrating the remaining drainages within the river basin, thus making the whole calibration process much more efficient.

2. Calibrate the remaining drainages in this category for which it has been determined that the hydrograph is of sufficient quality to support a full calibration. This includes locations with large flow adjustments, headwater reservoir inflow points, and downstream local areas. The sequence of steps and the strategy for making parameter changes should be the same as was just described for the other headwater areas. Many of these drainages will contain somewhat more noise in the “observed” discharge hydrograph. The more noise that exists, the harder it generally is to justify parameter changes, thus these drainages will typically have fewer parameter modifications than the main headwater areas. The time needed to calibrate these locations is largely dependent on the time needed to make flow adjustments or derive the hydrograph for the drainage area. The time needed for making snow and soil moisture model parameter adjustments shouldn’t take very long if done in an organized manner.