Chapter 2 – Calibration Overview

Introduction

The calibration of a conceptual model to a large region, such as the entire area of responsibility of a RFC, is a major undertaking. This effort must be carefully planned and monitored in order complete the process within a reasonable time frame and end up with consistent, quality results. In order to keep the overall task manageable, it is recommended that the region be broken down into individual river basins or portions of basins involving in the order of 75-200 precipitation stations, 25-100 temperature stations, and 20-50 river locations. The steps and procedures in this manual can then be applied to each river basin until the complete area is calibrated.

General Calibration Requirements

There are a number of factors that are important in order to be able to complete a large scale calibration effort in a reasonably efficient manner and end up with quality results. Some of the most important requirements are knowledge, experience, teamwork, and leadership for the people involved, computerized tools to aid in doing the work, and following proven procedures and strategies.

- Knowledge and Experience – Calibration of a conceptual model is not a skill that one becomes proficient at by merely taking a course or studying a report. True expertise in the calibration process can take years. Even after being involved with model calibration for many years, one still learns something new from almost every river basin that they work on. Thus, it is important when starting a calibration effort or when a person first begins to work on model calibration, that sufficient time be allocated to learn about the process and gain experience. Those that have gained a reasonable level of experience should be assigned to mentor those that are beginning their first calibration. Usually by the time that someone finishes their first calibration they know enough to realize that they should go back and redo what they have just done. If a person receives the proper training, the right guidance, and a reasonable period to gain some experience (in the order of 6 months), they should be able to become a productive member of a calibration team. It should also be noted that the knowledge and experience gained during calibration should pay large dividends in how well the person is able to use the models and procedures to produce operational forecasts.

- Teamwork – There are many aspects to the total model calibration and implementation process. The overall process involves having people with skills in areas such as data analysis, calibration of snow and soil moisture models, development of parameters for routing models, reservoir operations, operational procedures, and the application of geographical information systems (GIS). It is nearly impossible for one person to have the necessary expertise in all these areas, thus calibration becomes a team effort. In building a calibration team it is important to assess the skills and aptitudes of each member. Not everyone has the background and propensity to become proficient at calibrating headwater models, plus those that are good at calibrating snow and soil moisture models may not have the ability to do the best job at a nalyzing data or calibrating routing models. Thus, it is important to the successful completion of a major calibration effort to have people with a variety of skills involved and to make maximum use of the abilities of each team member to accomplish the final goal.

• <u>Leadership</u> – Even though a major calibration project requires a team effort, it is also very important that the team has the proper leadership and that the results of the project are carefully monitored and evaluated. Leadership is generally best provided by someone with experience in and a good knowledge of all aspects of the calibration process. This person must also have the necessary leadership skills to work with the other team members and be able to clearly communicate goals, progress, and resource needs to those in charge of the office and others interested in the results. The leader, possibly with the help of others in the office, should carefully review the results of each step of the process to make sure that the results meet performance standards adopted by the office concerning such factors as model selection and basin splitting and that parameter and data values are consistent with nearby watersheds and river basins.

• <u>Computerized Tools</u> – In order for the overall calibration process to be done in an efficient manner, computer tools must be available and used properly to perform many of the necessary tasks. These tools range from number crunching programs to process data and perform data analysis or model computations to GIS applications to display information and generate new data fields to interactive, graphic interface programs that allow the user to better understand the inner workings of models and to interact with the models and data . Without a complete set of tools, portions of the calibration process will become very labor intensive and severely affect the time required to complete the process. In addition such tools assist the user in gaining the knowledge and experience to better calibrate and operationally apply the models and procedures. Tools that exist in NWSRFS or are needed in order to efficiently do calibration in all types of situations include:

- Programs to access historical data bases, inventory the data, and convert the needed data to the proper form for subsequent processing,
- Data processing programs to analyze gage data and compute areal time series of precipitation, temperature, and evaporation,
- Programs that perform the computations for all of the operations necessary to simulate streamflow and other hydrologic variables,
- Calibration Assistance Program (CAP) to perform computations necessary to prepare the input to the data analysis and model calibration programs and to use GIS features to display and generate various data fields, and
- Interactive, graphical interface programs that allow the user to easily view results, make changes, and rerun computations for portions of the process such as model calibration and data consistency analysis.

Many of these tools exist. Others are in the process of being developed. Throughout this manual further details will be given regarding the tools needed.

- Follow Proven Procedures and Strategies – Innovation is periodically required during the calibration process, but there is much that has already been tried and learned. Many procedures and strategies have been developed, tested, and proven that can make the process efficient and more likely to end up with consistent, quality results. It is much better to follow these procedures and benefit from this experience than to try to invent new methods for doing things. If some of the procedures and strategies clearly don't work properly in a given situation, then alternative techniques can be tried. This manual tries to cover the recommended calibration procedures and strategies that have been proven effective.

Basic Steps in the Calibration Process

When calibrating hydrologic models to a river basin there are six steps that are recommended to be followed.

- Gather Information and Data -- The first step is to gather all the information and data necessary for the calibration of the river basin. This includes all available historical data, plus a determination of what real time data are available. It includes gathering maps and data sets that describe physiographic features such as topography, vegetation, and soils, as well as past analyses of the variability of quantities such as precipitation, temperature, evaporation, and snow cover. It also includes information about control structures and their effect on streamflow, plus data on diversions into or out of the basin or between watersheds within the basin and any irrigation effects. Information is also needed on current and possible future forecast requirements. After all this information and data are gathered, the pertinent values need to be accessed and put into the form needed for further processing.

- Assess Spatial Variability of Hydrologic Factors – Before proceeding further with the calibration process it is necessary to take the gathered information and data and get an idea of how various hydrologic factors vary over the river basin. This includes such variables as precipitation, temperature, evaporation, and snow cover, as well as features such as topography, vegetation, soils, and geology. Hydrographs from headwater drainages and local areas can be used to get an idea of how different portions of the river basin respond to the integrated effects of these factors. A knowledge of the spatial variability of hydrologic factors is important in determining how the basin should be divided for modeling purposes and which procedures should be used to analyze the data.

- Select Flow-points and Period of Record for Calibration – The determination of where streamflow is to be simulated during the calibration process is dependent on a number of factors. These include availability of historical streamflow and reservoir data, location of current and future forecast points including those needed to meet all user requirements, location of diversions, irrigation, and control structures, and the variability of hydrologic factors over the basin. The period of record to be used for calibration is dependent on the period of record of the historical data, especially streamflow, and information on changes that have occurred within the basin over time such as the building of control structures or diversions, increase or decrease in irrigated acreage, and vegetation and land use changes.

- Analyze Historical Data and Put in Form Needed by Models – This step involves the generation of areal average values of precipitation, temperature, and evaporation for the local drainage above each simulation point. In mountainous areas it also involves first determining which drainages must be subdivided into elevation zones and what elevation bands are appropriate. Other areas may also be subdivided if the hydrograph shape varies significantly depending on where the runoff occurs and if there is sufficient gage data to adequately define the input for each subarea. This step also includes the checking of discharge data and the adjustment of these data, if needed, to account for diversions and other factors. Regional water balance computations are an important part of this step especially in mountainous areas to insure that the precipitation, evaporation, and runoff estimates are physically reasonable and consistent.

- Calibrate Hydrologic Models (Snow, Soil Moisture, River, and Reservoir) – Finally after completing all the previous steps it is time to calibrate the hydrologic models to the individual headwater drainages and local areas. The recommended procedure involves the calibration of the headwater with the best data and least complications first and then proceeding to other drainages. Parameters from previously calibrated points are used as initial values for the subsequent areas and only those parameters that clearly need to be changed are altered. Areas that can’t be calibrated due to the effect of control structures or because the local contribution is small compared to the total flow are assigned parameter values from the most similar calibrated watershed.

- Implement Calibration Results for Operational Use – The final step in the process takes the results of the data analysis and the model calibration and implements them into the operational systems. This includes the NWSRFS Operational Forecast System (OFS) used for maintaining state variables and producing short term river forecasts and the ESP system used to make extended predictions. The most important factor in the operational implementation of the results is to not produce any bias between the operational application and the historical simulations produced during calibration while still trying to reduce random variations to a minimum through the use of new data sources, dynamic data analysis methods, and real time model adjustment techniques. Bias can occur due to differences in data networks, data types and processing methods, and operational modifications made to state variables.

The subsequent chapters of this manual will describe in detail the recommended procedures to follow for each of these steps in the calibration process.

Extension of Historical Records and Recalibration

Besides the initial calibration of the models to each river basin in an RFC area, it will generally be necessary at times to extend the historical record and to recalibrate at least portions of the area. Reasons for extending the historical record include:

- To have more years of data to use for ensemble streamflow predictions, especially extended predictions. Extending the length of record should improve the confidence of the probabilistic statements that are generated by providing a greater assortment of climatological conditions that might occur in the future. Extensions might be done on a regular 5 or 10 year interval when extended streamflow predictions are being generated for the basin.

- The occurrence of events that were not included in the previous model calibration, such as a new record flood, prolonged dry spell, record snow cover, or surface runoff occurring for the first time. The additional data record can then be used to check the extrapolation capabilities of the models and to make any necessary parameter adjustments (doesn’t typically require redoing the calibration).

- Changes occurring within portions of the river basin, such as new control structures, changes in how reservoirs or diversions are operated, changes in agricultural practices, large forest fires, or land use changes. When such changes occur, some of the models being used and/or model parameters for the part of the basin affected typically will need to be modified which may require a recalibration of those watersheds.

Reasons for recalibrating include:

- The people doing the calibrations have gained considerable experience and realize that they can now do a much better job at improving all of the calibration objectives.

- Operational use has uncovered problems and situations that were overlooked or modeled improperly during the original calibration.

- Significant changes have occurred in one or more watersheds within the basin as a result of new agricultural practices, large forest fires, or modifications to land use.

- There is a need to establish some new forecast points at locations with historical streamflow data that were not included in the original calibration. This typically doesn’t require a recalibration of all models. Generally it involves subdividing the area between original calibration locations so that simulations are produced at the new forecast points. This requires producing new data input and parameters for channel models, but usually only slight modifications to soil moisture and snow model parameters.

- New methods of determining input data, such as precipitation computed from a combination of gage, radar, and other data, become available which cannot be made totally consistent with the data used for the original calibration.

- It is decided to change the way that the historical data were analyzed and processed, such as switching to mountainous area procedures when non-mountainous techniques were originally used.

- New models become available which will replace existing models or simulate situations that were not modeled in the original calibration.

- Climatic changes have occurred which could alter climatological average estimates of ET-Demand or other model parameters.

It is very important when extending the existing historical data record to make sure that the new data are consistent and unbiased compared to the data used to determine the current model parameters. This requires that station and areal means used in the computation of the areal estimates of precipitation, temperature, and evaporation for the new period must be the same as those used to generate the data on which the current calibration is based. For example, if the current calibration is based on data from the period 1949 to 1990 and the record is now being extended for the period 1991 to 2000, the station and areal means established for the 1949 to 1990 period must be used in the processing programs when generating data input for the 1991 to 2000 period. Likewise, if the data are further extended in the future, e.g. for the period 2001 to 2010, the station and areal means for the 1949 to 1990 period must continue to be used so that the additional data remain consistent and unbiased with the period on which the calibration is based. If new stations are included when generating the extensions, the means for these stations should be determined by using ratios (precipitation) or differences (temperature) with long established stations that have well defined mean values for the period used for the calibrations.

Recalibrations can be based on the initially processed period of record plus any consistent and unbiased extensions to it or the entire data period can be regenerated prior to a recalibration. If the entire historical record is regenerated involving new types of data or different processing methods, then the models used for the entire area must be recalibrated unless somehow one can guarantee that the new data values are consistent and unbiased compared to the data previously used for calibration. As examples we can related these statements to the reasons for recalibration listed previously in this section.

- If new data types, such as radar estimates of precipitation, or new processing methods, such as switching from non mountainous to mountainous area procedures, are being used to generate the input data, then the data for the entire data period (may not be the same as the original data period due to the length of record for the new data types) needs to be regenerated and the entire area recalibrated.

- When new models are being implemented, calibrations are being redone based on increased experience, or operational problems indicate a need to reexamine the calibrations, it may or may not be necessary to regenerate the input data. As long as the new models can use the existing data (though additional data types may be needed depending on model requirements) or the simulation problems are not related to the data record, there is no need to regenerate the input for the models. If the new models are being implemented or the existing models recalibrated over just a portion of the river basin, then the possibility of regenerating the input data only needs to be considered for this part of the area.

- Land use changes, new agricultural practices, large forest fires, and climatic changes typically do not require regenerating the historical data record. Generally this situation involves extending the data to cover the period after the action took place and then using this period to modify the model parameters.

- The need to establish new forecast points involves subdividing existing drainages and thus the creation of new areal data estimates. This typically requires that a complete new data record be generated for each new subarea. This only needs to be done for the affected drainage areas. Whenever generating new data input for only a portion of the area it must be remembered that many of the same stations will be used for these areas as are used for surrounding drainages and thus, the station means used to compute the new data input records should be those used when the data were processed for the latest full calibration of the river basin.

When extending the period of historical record or recalibrating all or part of a river basin, the same general principles and recommendations apply as when doing an initial calibration except that certain of the basic steps may not be necessary or require less attention. The gathering of information and data definitely will be a part of an extension of the data record or a regeneration of the model input involving new data types and likely needed when changing processing methods, but, for the most part, will not needed when the existing historical record is sufficient for any modifications to the model parameters. Analyzing the spatial variability of hydrologic factors typically would not be necessary unless completely new data types are now involved though a review of this step could be beneficial in many cases. The considerations regarding the selection of flow-points and the period to be used for calibration should definitely be examined whenever a recalibration, especially a complete recalibration of the entire river basin, is being done. The recommendations regarding the analysis of historical data and the generation of model input applies whenever a new historical data record is being produced. Special considerations apply to the extension of existing records and these will be discussed further in the chapter covering this step. Likewise, the recommendations regarding the calibration of the hydrologic models apply whenever model parameters are being calibrated or modified and the chapter covering this step will include a discussion of items that need emphasis when doing a recalibration. The chapter on the operational implementation of calibration results will also include a discussion of operational changes that may be needed after completing a historical record extension or a recalibration.