Section 7-5

Initial Parameter Values for the Sacramento Model

Introduction

In most cases initial parameter values for the Sacramento Model are obtained from a nearby previously calibrated watershed. This can be a watershed within the river basin being worked on or one in an adjacent river basin that has previously been calibrated. However, when calibrating the initial headwater area in a river basin where no nearby watersheds, or at least none with physiographic features at all similar to the current area, have been previously calibrated, initial parameter estimates should be derived. Procedures are available for obtaining initial parameter estimates from an analysis of the observed daily flow hydrograph and from soils information.

Besides providing recommendations for deriving initial parameter values, this section also contains information on the physical basis for some of the parameters. This information should help in better understanding of how the model works and provide a basis for possibly altering parameters from one area to another based on physical characteristics. The portions of the section that describe how to determine parameter values from a hydrograph analysis should also help in understanding what to look for in order to isolate the effects of many of the parameters. Section 7-8 focuses on how to isolate the effect of each parameter, but the material in this section should provide some added emphasis to understanding this critical aspect of interactive calibration of a conceptual model. This section doesn't attempt to describe the structure and algorithms of the Sacramento model. For that information the reader is referred to Part II.3-SAC-SMA of the NWSRFS Users Manual.

Before describing the techniques for deriving initial parameter estimates, we first need to talk about how the various runoff components of the Sacramento model are going to be used to reproduce the hydrograph for the watershed. It is very important to take some time prior to starting the calibration to examine the various runoff time delay segments that are represented in the hydrograph and decide which runoff component is to be assigned to each segment. This effort should provide the best chance for obtaining good results in the least amount of time. If the runoff components are not assigned properly at the beginning, considerable time can be wasted modifying the parameter values once one realizes that the runoff components are not being used correctly.

Assigning Runoff Components

The Sacramento model contains 4 basic runoff components with various time delays that can be used to represent the various portions of the hydrograph. These are primary baseflow, supplemental baseflow, interflow, and surface runoff. The model is designed so that the longest time delay, usually in terms of months or years, is assigned to primary baseflow. Supplemental baseflow generally has a time delay in terms of weeks or months and interflow typically has a time delay in terms of days. Surface runoff has no time delay in the Sacramento model, i.e. it becomes inflow to the channel during the same time interval as the rain or melt that produced it. The Sac ramento model can also generate constant and variable impervious area runoff components. Both of these respond immediately just like surface runoff. Variable impervious runoff can be produced from low intensity rain or melt when the watershed is quite saturated. Constant impervious runoff can occur whenever there is rain or melt no matter what the soil moisture conditions. An analysis of the hydrograph may determine if these two additional components will be needed, but primarily at this stage of the calibration we are trying to decide which portions of the hydrograph will be assigned to each of the 4 main runoff components.

The first step in this process is to identify when primary baseflow is the only or at least the dominant source of runoff. Primary baseflow typically sustains flow in the channel long after any events that produced storm runoff have occurred and after perched, or supplemental, aquifers have been drained. Primary baseflow is used to represent the flow segment with the longest time delay. It is critical to properly identify what portion of the hydrograph represents primary baseflow because the time delays for the other runoff components are all going to be based on this determination. The segment of the hydrograph with the next slowest time delay will be assigned to be modeled with supplemental baseflow and then the next slowest with interflow. Surface runoff can only be used to produce immediate storm runoff from high intensity events. Periods of surface runoff can usually be identified by comparing the immediate amount of storm runoff to the amount of rain plus melt (the period for determining the amount of immediate storm runoff is dependent on the response time of the channel system as represented by the unit hydrograph -- initial snow model parameters are used to get an idea as to the amount of melt). If the amount of immediate storm runoff is around 50% or more of the rain plus melt, then it is likely that surface runoff needs to be generated for these events. Identifying what runoff component will be used to represent each portion of the hydrograph prior to beginning the calibration should insure that all the components are used properly and that the various time delays that occur can each be modeled.

In some regions it is quite easy to identify which runoff component will be used to model each portion of the hydrograph. If the time delays for each runoff component are close to typical values, there are sufficiently long dry periods after major events to allow for a clear identification of interflow and supplemental baseflow recessions, and there are also some even longer dry periods when primary baseflow becomes the only component with no distortions of the flow during these periods, the runoff components can be fairly easily identified. However, in many regions, probably the majority, there are complications that make it more difficult to clearly identify what portion of the hydrograph represents each component of runoff, especially to properly identify primary baseflow. Primary baseflow becomes more difficult to identify in very wet regions, when frequent small rains occur during low flow periods, when the supplemental baseflow recession is very slow, and when riparian vegetation evaporation draws down the flow during dry periods.

Figure 7-5-1 illustrates the case of assigning runoff components in a very wet region. In such a region rainfall or snowmelt occurs frequently and soil moisture conditions remain quite wet. Dry periods that exist for a long enough time so that primary baseflow predominates only occur on

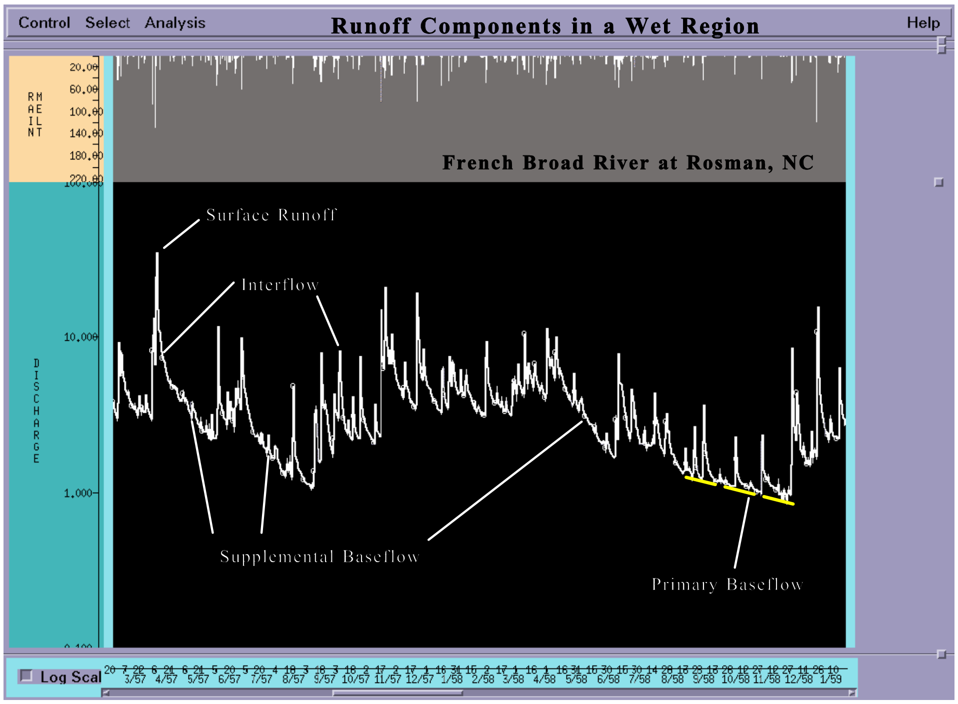
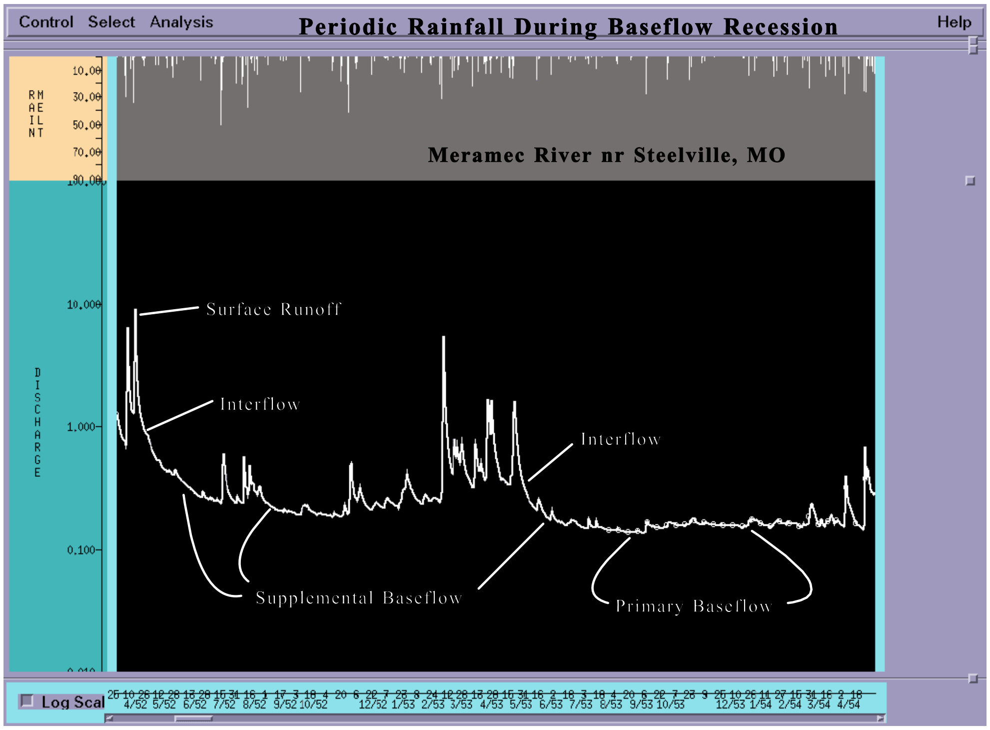


Figure 7-5-1. Assigning runoff components in a wet region.

the average about once every 5 to 10 years. Even then there are frequent small rain events that occur during these periods. Thus one must look very carefully at a long period of record to pro



perly determine the appropriate primary baseflow recession. Once primary baseflow is identified, generally the times when the other components can be isolated fall into place. In regions with high percolation rates such as the one in this figure, surface runoff seldom occurs, if at all. If surface runoff does occur, it is associated with only the largest flood events. Interflow produces most of the rises from rain or melt periods, as well as the early part of the recession for the flood events that generate surface runoff.

Figure 7-5-2 illustrates the case when there are frequent small rain events during the low flow periods when primary baseflow dominates. In such regions, periods when primary baseflow dominates occur during the majority of the years, but the recession doesn't show up as a nice straight line on a semi-log plot due to the frequency of constant impervious runoff produced by small rain storms. One must again determine the primary recession rate by the general slope of the semi-log plot during periods when no recharge occurs, i.e. there is no other runoff than that from constant impervious areas. As with most cases, once primary baseflow is identified, the other runoff components fall into place.

Figure 7-5-3 illustrates the case where the supplemental baseflow recession is very slow. In

Figure 7-5-2.   Runoff components in regions with frequent small events during baseflow period s.

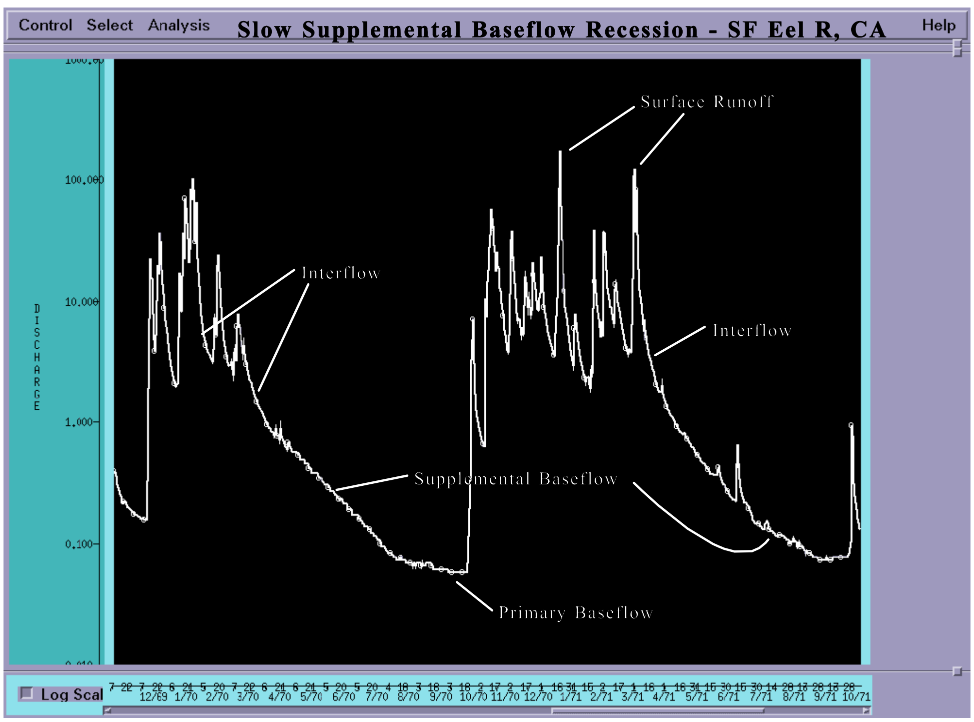


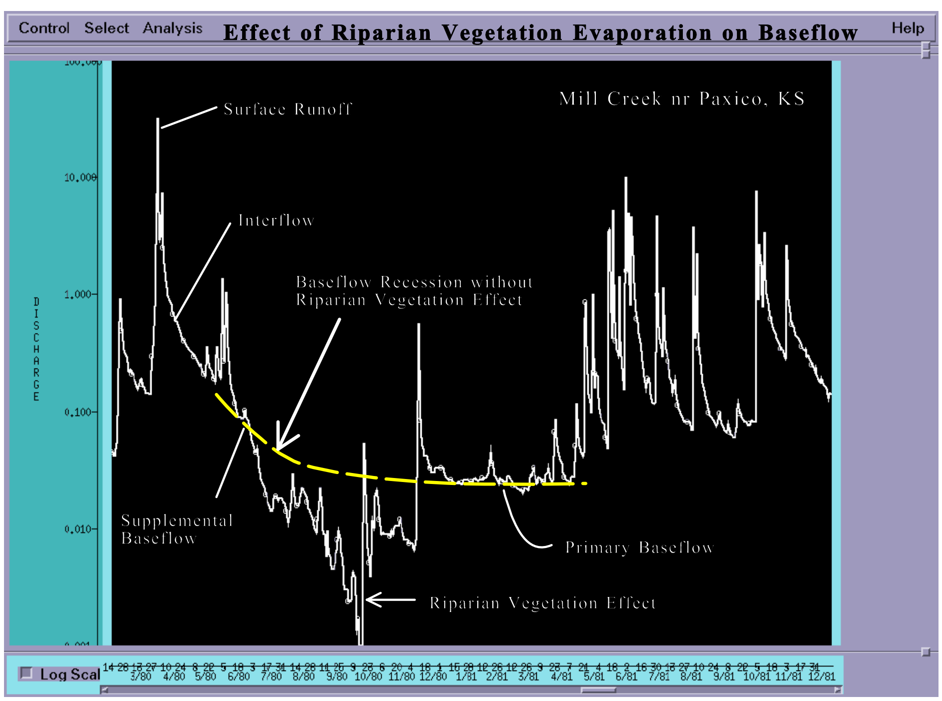
Figure 7-5-3. Watershed with a very slow supplemental baseflow recession.

these situations it may take many months for the supplemental aquifers to drain, thus requiring quite a long dry period before there are situations when primary baseflow predominates. Periods with only primary baseflow may only occur once every 10 years or more, especially if this is in a region with year around rainfall. This is probably the most difficult case for determining how to allocate the runoff components. There is a tendency to not look carefully at a sufficiently long record to find the few cases when primary baseflow dominates. Instead the periods labeled as supplemental baseflow are modeled as primary causing simulated baseflow to drop off too rapidly when primary baseflow actually predominates. When this is done, it is likely that supplemental baseflow and interflow will end up with similar withdrawal rates.

Figure 7-5-4 illustrates the case when there is a large amount of evaporation from riparian vegetation during summer and early fall dry periods. These are also the periods when primary baseflow predominates. The evaporation from the riparian vegetation draws down the water table near the stream causing a rapid decrease in baseflow. In such regions if dry conditions persist into the late fall and winter, the baseflow level will increase with no recharge occurring due to the reduction in riparian vegetation effects caused by a decrease in evaporation and the vegetation becoming dormant. It is these late fall and winter periods that must be used to determine the proper primary recession rate. When modeling such a watershed, the simulated baseflow should follow the dashed line shown in the figure when the RIVA parameter is set to zero, i.e. evaporation from riparian vegetation is not being included. It is important to be able to recognize when riparian vegetation affects baseflow and ignore these periods when deriving baseflow recession rates.

Figure 7-5-4. Assigning runoff components in a region with riparian vegetation.

It is very important to understand these complications when determining how the runoff compon
ents of the model are going to be used to simulate the various time delay segments of the hydrogr



aph. It is also critical to take the time to do a careful analysis of the observed hydrograph over a long period in order to understand how the runoff components of the model should be used.

Doing this should simplify the calibration and produce the best possible results in the least amount of time.

<u>Deriving Initial Parameter Values</u>

The Sacramento model was designed so that each model parameter serves a particular function and the effect of the parameter controls the hydrograph response under a specific set of circumstances. In most cases this effect can be isolated when the proper situation occurs and thus, the appropriate value of the parameter can be estimated by analyzing the observed hydrograph over a period of many years. Thus, hydrograph analysis is the most direct method of deriving initial estimates for most parameters of the model. For some parameters a numerical derivation is not possible, but an analysis of the hydrograph contains information that suggests the general range of values. In other cases the specific set of circumstances needed to derive the parameter value doesn't occur during the period of available record. In some of these cases a lower limit for the parameter can be computed based on less than ideal circumstances and in other cases the initial value must be assigned using general guidelines or another method.

Procedures have been developed to derive *a priori* estimates of the model parameters based on physiographic information. The procedures proposed up to this point in time have relied solely on soils information to estimate the values for most of the Sacramento model parameters. The most recent of these procedures [*Koren*, 2000] is included in CAP. This procedure utilizes STATSGO soil texture data in 11 soil layers to derive 11 of the 16 Sacramento model parameters. In reality many of the Sacramento model parameters are related to factors in addition to soils information, including vegetation, geology, terrain, and man-made features such as farm ponds and agricultural drain tiles. This means that methods using only soils data typically have to rely on assumptions that may not be valid for all regions or even for all watersheds in a given region.

One of the possible uses of *a priori* parameter estimates is as a source of initial values for model calibration. More importantly, if such a procedure can be shown to produce good results in a given region, it could be used to determine how parameter values should vary from one watershed to another, to obtain parameter estimates for ungaged areas, and to specify how parameter values vary within the boundaries of a watershed. Such estimates would be helpful when applying the models to a large region, when trying to apply models to small ungaged watersheds for flash flood forecasting, and for distributed applications of a conceptual model. An *a priori* method could be used to directly obtain parameter values or it could be used to determine differences in parameters from one watershed to another or within the drainage boundaries. In the second case a calibration would be used to determine the appropriate parameter values for a watershed and then the parameter variations within the drainage or with adjacent watersheds would be obtained by adjusting the calibrated values by the relationships between *a priori* estimates for these areas.

Model calibration involves determining appropriate model parameter values based on data sets that contain noise, both in the input and output data. When the amount of noise becomes excessive, it becomes very difficult to determine the values of many of the parameters. As discussed previously in this manual, a sufficiently long period of record is generally needed to filter out the e ffect of the noise during individual events. Since the amount of noise will vary from watershed to watershed, primarily based on the number and location of precipitation gages, differences in calibrated parameter values from one watershed to another may not be totally reflective of physical differences between the areas, but could be influenced by differences in the amount of noise in the data. This is why the procedure recommended in this manual stresses only changing those parameters that can be clearly justified when moving from the initial headwater area to other watersheds in the river basin. If an *a priori* parameter estimation procedure can be shown to produce realistic values for a given region, it could be a useful tool to achieve spatial consistency in model parameters. Given the noise in the data, it is important to have physically realistic variations in parameter values across the river basin even if it means less accurate overall fit statistics.

An evaluation of any *a priori* parameter estimation procedure for a conceptual model like the Sacramento model should examine how each derived parameter behaves during times when the effect of the parameter can be isolated. Comparisons of overall 'goodness of fit' statistics for simulations based on *a priori* parameter estimates to those based on calibrated values don't reveal whether the procedure results in physically realistic parameter values. It is suggested that before an *a priori* parameter estimation procedure is used in a given region that comparisons be made between simulations using the *a priori* estimates and observed hydrographs for gaged headwater areas. These comparisons should concentrate on those portions of the hydrograph where each of the parameters can be best isolated to determine if the *a priori* estimation procedure is deriving realistic parameter values. Comparisons should ideally be made for several watersheds in the region, especially cases where the spatial analysis conducted in step 2 (see Chapter 4) suggests that some of the model parameters are quite different. In order to take full advantage of an *a priori* parameter estimation procedure, the method should be able to detect these differences. Section 7-9 illustrates such an evaluation for the Koren *a priori* parameter estimation procedure for several regions scattered around the country.

On the following pages recommendations are given for deriving the initial value of each of the Sacramento model parameters for use in model calibration. The recommendations are primarily based on deriving the values from a hydrograph analysis, but also utilize estimates from *a priori* parameter estimation procedures in certain situations. Also for a few of the parameters, this author's opinion as to what the parameter physically represents is included. As mentioned in the introduction to this section, all this information should be helpful in understanding the structure of the model and how to isolate the effects of the various parameters even if it is seldom used to derive initial values.

LZPK

The LZPK parameter reflects the slowest baseflow recession rate which occurs after there has been no groundwater recharge for a period that is typically in terms of months. The only method for obtaining a reasonable value for LZPK is from a hydrograph analysis. The identification of periods when primary baseflow dominates the hydrograph is discussed in the section "Assigning Runoff Components" in this section. It is critical to properly identify when primary baseflow is dominate before deriving the value of LZPK. Once the proper periods are found, the values needed to compute LZPK are obtained as shown in Figure 7-5-5 from the straight line portion of a semi-log plot. The straight line segment will have to be estimated when complications such as riparian evaporation, small power plants, and diversions cause fluctuations in the flow.

Figure 7-5-5. Hydrograph values needed for deriving LZPK.

Using time, t, in days, the primary recession rate, K_p, can be computed as:

(7-5-1)

and the withdrawal rate (1.0 minus the recession rate), i.e. the LZPK parameter value, is:

(7-5-2)

During winter periods when there is snow on the ground, the computed withdrawal rate could be less than the value of LZPK due to small amounts of melt at the snow-soil interface which can be providing a steady slow recharge to the lower zone storages.

LZSK

LZSK is the withdrawal rate from the supplemental baseflow aquifers. As with LZPK, the only method for obtaining reasonable values for LZSK is by analyzing the observed daily flow hydrograph. The effect of this parameter can be isolated by finding relatively dry periods when no recharge is occurring beginning several days after intervals of significant runoff and recharge. During such periods both supplemental and primary baseflow are being generated. Thus, in order to determine the supplemental recession, the primary baseflow component must first be removed. When primary baseflow is subtracted from the total flow, periods of supplemental baseflow should plot as a straight line on a semi-log plot. This is illustrated in Figure 7-5-6.

Figure 7-5-6. Hydrograph values needed for deriving LZSK.

Two points can then be picked off this straight line and by using time, t, in days, the supplementa l recession rate can be computed as:

(7-5-3)

and the withdrawal rate, i.e. the LZSK parameter value is:

(7-5-4)

As one gains experience, the two runoff values needed to compute the supplemental recession ca n be obtained by subtracting primary baseflow from total flow for two days during the suppleme ntal recession without having to generate a plot of total flow minus primary baseflow.

LZFPM

There are two ways of computing an estimate of LZFPM from a hydrograph analysis. The first is to find a nice recession period following several months of significant runoff and recharge during which the primary baseflow aquifer has a chance to accumulate a substantial amount of storage. The largest primary contents will typically occur during the very wettest years. If the recession period is of sufficient length to reach the point where only primary baseflow remains, then the primary recession can be extrapolated backwards to find the amount of primary baseflow at the end of the recharge period, Q_x, as shown in Figure 7-5-7.

Figure 7-5-7. Back extrapolation to estimate maximum LZFPC.

The initial estimate of LZFPM can then be computed from:

(7-5-4)

where ε is a decimal fraction typically in the range of 0.1 to 0.25. The ε term is needed since the contents of the lower zone primary storage never actually become completely full. Generally the greater the withdrawal rate, LZPK, the larger the value of ε since it is harder to fill a storage the faster it drains.

If a backwards extrapolation is not possible during any of the wet years to get an estimate of Q_x, then the second way to estimate Q_x and then LZFPM is to attempt to sketch on a semi-log plot the primary baseflow component during some of the wettest years. This can be done if periods when primary baseflow is dominant exist prior to and after a prolong period of recharge. With these tie in points and having an estimate of LZPK, one can sketch the primary baseflow contribution and come up with a value of Q_x to use in Equation 7-5-4.

LZFSM

An estimate of LZFSM can also be derived by back extrapolation. This can be done when the baseflow recession can clearly be determined after a very large storm event. If the supplemental withdrawal rate, LZSK, is relatively slow, then a recession period after a series of storms is likely needed to have as much water as possible in supplemental storage. Figure 7-5-8 illustrates how to estimate the maximum amount of supplemental runoff, Q_x, by extrapolating the supplemental recession back to when the contents of this storage are at their fullest. It is best to subtract primary baseflow from total flow in order to clearly find the supplemental recession, though with experience the plotting of the total minus primary line is not needed to estimate a reasonable value for Q_x

Figure 7-5-8. Back extrapolation to estimate maximum LZFSC.

Once Q_x is determined an estimate of LZFSM can be computed from:

(7-5-5)

where ε in this case typically varies from about 0.5 to 1.0. Larger values of ε are needed for supplemental baseflow than for primary since the supplemental storage drains faster, thus the supplemental contents seldom get close to capacity. Also the value of ε should be greater for larger values of LZSK.

PCTIM

The PCTIM parameter represents the part of the area that always produces some runoff no matter what soil moisture conditions exist. The value is generally not the same as the portion of the area covered by surfaces such as pavement, roofs, and rock outcrops since runoff from many of these surfaces encounter areas of soil before reaching the stream channel. PCTIM represents impervious areas that are directly connected to the channel system.

An good estimate of the amount of constant impervious area can normally be derived from a hydrograph analysis. The conditions needed to derive a value of PCTIM are a week or two of dry weather during late spring or summer that produce a significant upper zone tension water deficit, followed by a moderate rain event (typically 0.25 to 0.75 inches) which is not sufficient to fill this deficit (no recharge occurs). The amount of runoff produced during such events is then computed as shown in Figure 7-5-9.

Figure 7-5-9. Runoff volume from the constant impervious area.

Then an estimate of the PCTIM parameter is computed by dividing the runoff volume, R_{imp}, by t
he amount of precipitation, P, as shown in Equation 7-5-6.

(7-5-6)

It is best to compute PCTIM for a number of events since rainfall under such conditions can be
more uncertain since it is often from convective events with considerable spatial variability. Th
en take the average of these events after throwing out any with a significantly greater runoff perc
entage than the majority of the cases. The upper zone tension water may have filled during suc
h events and thus, they could contain some interflow, or even variable impervious runoff, in addi
tion to runoff from areas that always act as impervious.

UZTWM

The UZTWM parameter indicates the amount of rain that must fall after a long dry period before
any runoff, other than that from constant impervious areas, is produced. The upper zone tensi
on water comprises water held in the pervious surface soil, plus interception (by vegetation and f
orest litter) and depression storage. In agricultural regions with many farm ponds, the effect of
these ponds is typically implicitly absorbed by the UZTWM parameter.

If the right conditions occur, a good estimate of UZTWM can be computed from an analysis of t
he hydrograph. The conditions needed are several weeks or more of quite dry weather in the lat
e spring or summer, followed by a significant rain event that generates a small amount of recharg
e and more runoff than specified by PCTIM to indicate that the upper zone tension water deficit
has been filled. Such an event is shown in Figure 7-5-10.

Figure 7-5-10. Runoff from event that just fills UZTW storage.

The amount of rain that falls during such an event can be used as an estimate of UZTWM. Rainfall amounts that produce no additional runoff after a summer dry period can also be used as a lower limit for UZTWM. A number of events should be examined.

In regions where such situations don’t occur, typically wet regions with frequent summer precipi tation, it would probably be best to use the soil based value of UZTWM as an initial value. This should produce spatial consistency in UZTWM values over such a region. It should be verified that the soil based value is greater than any rainfall amounts that produce little or no recharge or additional runoff after the limited dry periods that may occur in these regions.

LZTWM

The LZTWM parameter indicates the maximum moisture deficit that can occur in the lower soil layers. Tension water is only removed from the lower zone by evapotranspiration via the vegetation in the watershed. Thus, this parameter is primarily a function of the depth of the root zone and not of the depth of the soil layer, though in shallow soils, the root zone may be controlled by the depth to bedrock. This was clear when modeling a watershed that had been transformed from a rural, forested landscape to a mostly suburban area with the primary vegetation being grass. The main parameter change needed to account for the effects of this transformation was to significantly reduce LZTWM. The grass cover produced runoff much earlier in the fall after a dry summer than when the watershed was forested.

The LZTWM parameter can be derived from a hydrograph analysis when the right conditions occur. The conditions needed are very dry conditions from late spring to late fall followed by a 2 to 3 week period with sufficient rain to fill the soil moisture deficit that has been generated. The water balance equation can then be used on the period from just after UZTW fills to just after LZTW fills (can be detected by a large increase in recharge) to compute the lower zone deficit that existed prior to the rain. Such a period is illustrated in Figure 7-5-11.

Figure 7-5-11. Period for computing LZTW deficit via water balance.

By assuming UZTW is full and UZFW is empty at the beginning and end of the period, that LZFSC=0.0 at the start, and that deep recharge equals zero, the LZTW deficit is computed as:

$$\mathbf{\Delta LZTWC = P - R - ET - QS_2/LZSK - (QP_2 - QP_1)/LZPK} \qquad (7\text{-}5\text{-}7)$$

LZTWM (Continued)

where: P = precipitation, R = runoff, and ET = evapotranspiration. The ET for each day during the period should be close to the ET-Demand rate since UZTW should remain full or nearly full due to the periodic rainfall that generally occurs and the fact that evaporation rates are low at this time of year. The initial estimate of the LZTWM parameter should be somewhat greater than the maximum deficit that occurs after such a long dry period. If the LZTW deficit was ever equal to LZTWM it would indicate that the wilting point was reached throughout the watershed which is an unlikely situation.

In regions where a sufficiently long dry period never occurs and thus the LZTW deficit never approaches its maximum, the initial value of LZTWM should probably be obtained from the soil based derivation. It would be an improvement if this derivation also took vegetation type and coverage into account, however, the use of the current soil based value would insure some spatial consistency in wetter regions. When large lower zone deficits never occur, the effect of this parameter is difficult to isolate during calibration and fairly large variations in its value can be compensated for in many cases by reasonable changes to other parameters and the ET-Demand curve.

UZK

The withdrawal rate from upper zone free water, i.e. the UZK parameter, cannot be derived like the lower zone withdrawal rates, LZPK and LZSK, because water percolates from this zone in addition to draining out as interflow. It is possible in many cases when doing a recession analysis for a major storm event to compute the overall recession rate for the upper zone free water. The steps in a recession analysis are described in Section 7-6 as part of the procedure for deriving a unit hydrograph for use with the Sacramento Model. This overall recession rate is based on both the interflow withdrawal rate and the percolation rate. The percolation rate of course varies with soil moisture conditions. If the recession analysis is being done for a storm during a time when soil moisture conditions are close to saturation and the watershed has a very low percolation rate under these conditions, the upper zone free water recession rate derived from the analysis should be only slightly greater than the interflow withdrawal rate and can be used to estimate the initial value of UZK. In a case with such low percolation rates, the watershed should produce very little baseflow in general and almost all the storm runoff from the event should be surface runoff. The combination of all these conditions is quite rare, thus normally it is not possible to derive an good initial value for UZK from a hydrograph analysis.

When UZK cannot be derived from a hydrograph analysis, it is recommended to start with a nominal value of UZK = 0.3. The soil based derivation of UZK assumes that the interflow withdrawal rate is related to soil texture, with the more clay particles, the slower the withdrawal rate. Texture is indexed by the ratio of field capacity to porosity with the more clay, the higher the ratio. This seems logical, however, for the watersheds used by the author to test the soil based parameter derivations, the empirical equation used to compute UZK from this ratio produced unrealistically high UZK values in most cases. For this reason it is suggested that the nominal value of 0.3 be used as an initial estimate of UZK.

UZFWM

When a reasonable initial estimate of the UZK parameter can be derived from a hydrograph stor m recession analysis as mentioned on the previous page, then an estimate of the capacity of the UZFW storage can also be computed. The maximum amount of interflow runoff can be determ ined by extrapolating the total minus baseflow line segment back to the time when the hydrograp h peak occurred to obtain Q_i in depth units. Since surface runoff must be generated from such a n event in order to determine a reasonable value for UZK, the UZFWC must be completely full a t this point. Thus, UZFWM can be computed as:

(7-5-8)

If UZFWM cannot be derived from a hydrograph analysis, which is the most common case, the i nitial value of the parameter can be based on some general guidelines depending on how frequen tly surface runoff occurs. Surface runoff can be detected prior to running the model by compari ng the amount of immediate storm runoff to the amount of rain+melt for a given event. When t he immediate storm runoff exceeds about 50% of the rain+melt, it is likely that surface runoff oc curred. The guidelines are given in Table 7-5-1. Estimates of UZFWM derived from soil dat a could also possibly be used as initial estimates. The soil based UZFWM values from the eval uation by this author were generally in the same ballpark as the calibrated values for most waters heds, though most of the watersheds examined generated surface runoff infrequently. For the o ne watershed that had frequent surface runoff (woon3 - 6-10 times/year), the soil based value of UZFWM was over twice as large as the calibrated value.

Table 7-5-1. Guidelines for initial estimate of UZFWM.

Frequency of Surface Runoff	Suggested Initial Value of UZFWM
Every moderate to heavy rainfall event (i.e. very frequently)	10 - 20 mm
Every large rainfall event	15 - 30 mm
Only during the largest flood events	30 - 60 mm (upper end of range for very wet regions)
Never or only during a record flood event	40 - 100 mm (upper end of range for very wet regions)

ADIMP

The ADIMP parameter indicates the maximum amount of variable impervious area within the watershed. These are portions of the watershed that become completely saturated and thus act as impervious areas as the soil moisture increases. The variable impervious area portion of the model is related to the variable contributing area concept that has been described in hydrology literature. The portions of the watershed that can be modeled using this feature are areas adjacent to the stream channels and areas along ravines that drain directly into the channel system. If such areas generate fast response runoff when the soil is wet no matter what is the rainfall intensity, then the ADIMP parameter is needed.

Generally it is recommended to initially set ADIMP to 0.0 and then determine during the calibration if a non-zero value is needed. However, in some cases the need for ADIMP and the computation of an initial estimate can be determined from a hydrograph analysis. What is required is a watershed with a quick response time for the channel system (i.e. unitgraph peaks in 6-12 hours). In this case an estimate of ADIMP can be made by examining moderate intensity rainfall events that occur when the soil is very wet (generally use moderate intensity storms that occur within a few days after a major event). Such a case is shown in Figure 7-5-12.

Figure 7-5-12. Determination of variable impervious area runoff volume.

An estimate of ADIMP can be computed from the runoff volume, R_v, and the precipitation, P, for this event as:

(7-5-9)

PFREE

The PFREE parameter specifies what decimal fraction of the percolated water goes directly to lower zone free water storages when the lower zone tension water is not full. While this parameter would not be required if one were modeling a column of soil, it is needed when the model is being applied to a watershed. Over an entire drainage area the capacity of the lower zone tension water varies due to variations in soil properties and the depth of the root zone. This results in the tension water storage filling in some parts of the watershed before the capacity is reach over the whole area. In reality the fraction of percolation going to free water should not be a single value, but should be a curve with no percolation going to free water storages when LZTWC=0.0 and nearly all the percolation recharging baseflow as LZTWC approaches LZTWM. However, the developers of the model decided that given the simplified nature of the algorithms that a single value was adequate.

A general idea of the initial value of PFREE can be obtained by examining the hydrograph when moderate rains occur during otherwise dry periods or when the baseflow is first being recharged after a long dry summer. The amount of recharge that occurs during these periods is an indication of the magnitude of PFREE. This is illustrated in Figure 7-5-13.

Figure 7-5-13. Evaluation of baseflow recharge during dry periods to estimate PFREE.

No baseflow recharge occurs in case A indicating that either UZTW never filled during the event
or that PFREE should be 0.0. Case B shows some recharge occurring and would suggest usin
g an initial value of PFREE in the range of 0.1 to 0.25, while case C has more recharge and woul
d indicate setting PFREE to a value in the range of 0.3 to 0.5.

ZPERC and REXP

When considering the variation in percolation rates from dry to wet conditions, one should be thinking in terms of what the curve should look like instead of dealing with ZPERC and REXP as individual parameters. The shape of the percolation curve should be based on the type of soil that exists over the area. For example, a predominately sandy soil would have a large permeability when wet, but the ratio of dry to wet percolation rates would be relatively small and there wouldn’t be much curvature to the relationship, whereas a clay soil would have a much larger permeability when dry than the low percolation rate that would exist when the soil was wet and there would be much more curvature to the relationship. This is illustrated in Figure 7-5-14.

Figure 7-5-14. Sample percolation curves for sand and clay soils.

Hydrograph characteristics, as well as soils information, can indicate the general soil type and its permeability and thus can be used to obtain an initial estimate of the ZPERC and REXP parameters. Guidelines for estimating these parameters are given in Table 7-5-2. These guidelines are based primarily on logic considerations and not on actual calibration results. The relationship between ZPERC and REXP values from calibrations and soil types or hydrograph characteristics is not well defined. This is because for most watersheds the range of lower zone deficiency ratios for most significant runoff events is quite small (generally in the order of 0.2 to 0.3). Over such a small range, various values of ZPERC and REXP can produce similar percolation rates. When using real data with most of the significant events occurring at similar moisture levels, the ZPERC and REXP parameters are not very sensitive, thus the calibrations end up with a variety of values.

ZPERC and REXP (Continued)

The value of REXP derived from soil properties using the Koren method should give similar values for REXP as shown in the table. Soil based values of ZPERC may not be as useful due to questions concerning the assumption that the maximum daily percolation rate is equal to the combined capacity of all the lower zones, both tension and free water, as well as uncertainty in the capacity of these zones derived from soil data. From a physical standpoint, the value of REXP should always be greater than 1.0 as the shape of a percolation curve should always be concave.

General soil type	Hydrograph characteristics	Initial ZPERC and REXP
Clay	Frequent surface runoff, Little baseflow (max of 1 mm/day), PBASE: 2 - 4 mm/day	ZPERC: 150 - 300 REXP: 2.5 - 3.5
Silt	Some surface runoff - especially during larger storms, Moderate amount of baseflow (max of around 2 mm/day), PBASE: 4 - 8 mm/day	ZPERC: 40 - 150 REXP: 1.8 - 2.5
Sandy	No surface runoff or only during the very largest storm events, Considerable baseflow (max greater than 2.5 mm/day), PBASE: greater than 8 mm/day	ZPERC: 20 - 40 REXP: 1.4 - 1.8

Table 7-5-2. Guidelines for initial values of ZPERC and REXP.

OTHER PARAMETERS

Suggestions for initial values of the other Sacramento model parameters are as follows:

• RIVA – the need for RIVA should be determined when examining the hydrographs to deci
de how to assign runoff components as discussed earlier in this section, but the initial value s
hould be set to 0.0. The final value of RIVA will be determined near the end of the calibrati
on as discussed in Section 7-1.

• RSERV – this is a very insensitive parameter and in almost all cases a value of 0.3 is reaso
nable.

• SIDE – the initial value of SIDE should be set to 0.0.

• Seasonal PE adjustment or ET-Demand curve – recommendations and guidelines for these
curves are given in Section 6-5.

• EFC – this parameter is only used when the snow model is included and an areal extent of s
now cover time series is passed from the snow model to the Sacramento model. In that case
the ET-Demand is modified when snow is present using the equation:

(7-5-10)

where: D_s is the ET-Demand with snow, D_{ns} is the ET-Demand without snow, and S_c is the d
ecimal fraction areal extent of the snow cover. The initial value of EFC should be the porti
on of the area covered by conifer trees times the average cover density of the conifers expres
sed as a decimal fraction.

• Preliminary (Frost Index) frozen ground model – based on limited use of these algorithms t
he following initial values are suggested:

° CSOIL - 0.1 for open areas and 0.05 for forested areas
° CSNOW - 0.08
° GHC - 0.1
° RTHAW - 0.0 (don't use unless clearly needed)
° FRTEMP - -3.0
° SATR - 0.0 (with SATR=0.0 the frost index will have no effect on interflow withdrawal
and percolation rates – start with SATR=0.4 once it is determined that the use of the fro
zen ground model may be helpful)
° FREXP - 8.0

Typical Range for Parameter Values

Based on experience with the Sacramento model over a wide range of physiographic conditions, Table 7-5-3 gives the typical range of values for each of parameters. In some cases the value co uld fall outside this range, but if so, there needs to be clear evidence that such a value is required. For example, in some watersheds the value of LZPK may be greater than the upper limit show n in the table, but in most cases when LZPK is greater than this limit, it is very likely that what s hould be modeled as supplemental baseflow is being treated as primary baseflow.

Parameter	Lower Limit	Upper Limit
LZPK	0.001	0.015
LZSK	0.03	0.20
LZFPM	40.	600.
LZFSM	15.	300. (highest values associated with low values of LZSK)
UZTWM	25.	125.
LZTWM	75.	300.
UZK	0.2	0.5
UZFWM	10.	75.
PFREE	0.0	0.5
PCTIM	0.0	0.05
ADIMP	0.0	0.20
ZPERC	20.	300.
REXP	1.4	3.5
RIVA	0.0	0.20

Table 7-5-3. Typical range of values for the Sacramento model parameters.