Section 7-8

Effect of Sacramento Model Parameters on Model Response

Introduction

It is critical to understand the most important function of each of the model parameters when per forming interactive trial and error calibration. It is also essential to know what to examine to fi nd the periods when the effect of each parameter can be isolated. This understanding allows th e person doing calibration to make educated decisions regarding which parameters should be alte red as opposed to random guesses. Without this knowledge, interactive calibration becomes an exercise in futility.

This section describes the most important function of each of the Sacramento model parameters and how to determine which periods to examine to isolate the effects of each parameter on model response. Besides their major function, many of the Sacramento model parameters also influe nce other aspects of the model computations. This is especially true with all the parameters that are involved in the percolation computations. The percolation equation in the model involves 8 parameters, ZPERC, REXP, LZFSM, LZFPM, LZSK, LZPK, LZTWM, and UZFWM. Two of these parameters are unique to the percolation computations, ZPERC and REXP, while all of t he others are involved in other aspects of the model's algorithms. Thus, while these other para meters have a major function of their own, they also affect the percolation computations. Beca use of this, when the values of these parameters are changed, there are multiple effects. The us er needs to anticipate these effects, but should concentrate on the major function of each paramet er when performing interactive calibration.

The major function of each Sacramento model parameter is illustrated in this section by using me an daily flow hydrograph plots showing the response of two different values of the parameter for a period when the effects of the parameter can be isolated. The plots are generated by running the model with everything exactly the same except for the values of the parameter being consid ered. Under such conditions the unique effect of each parameter can clearly be shown. The act ual problem of deciding on which parameters to change becomes much more difficult during cali bration because of noise in the data and the fact that generally multiple parameters, perhaps invol ving several models, need to be adjusted. To have any hope of making the proper changes duri ng calibration, one must know what periods to examine and what to look for to isolate the effects of each parameter. It is also helpful to have a strategy for checking parameters for possible ch anges. Such a strategy for the Sacramento model is outlined in Section 7-1.

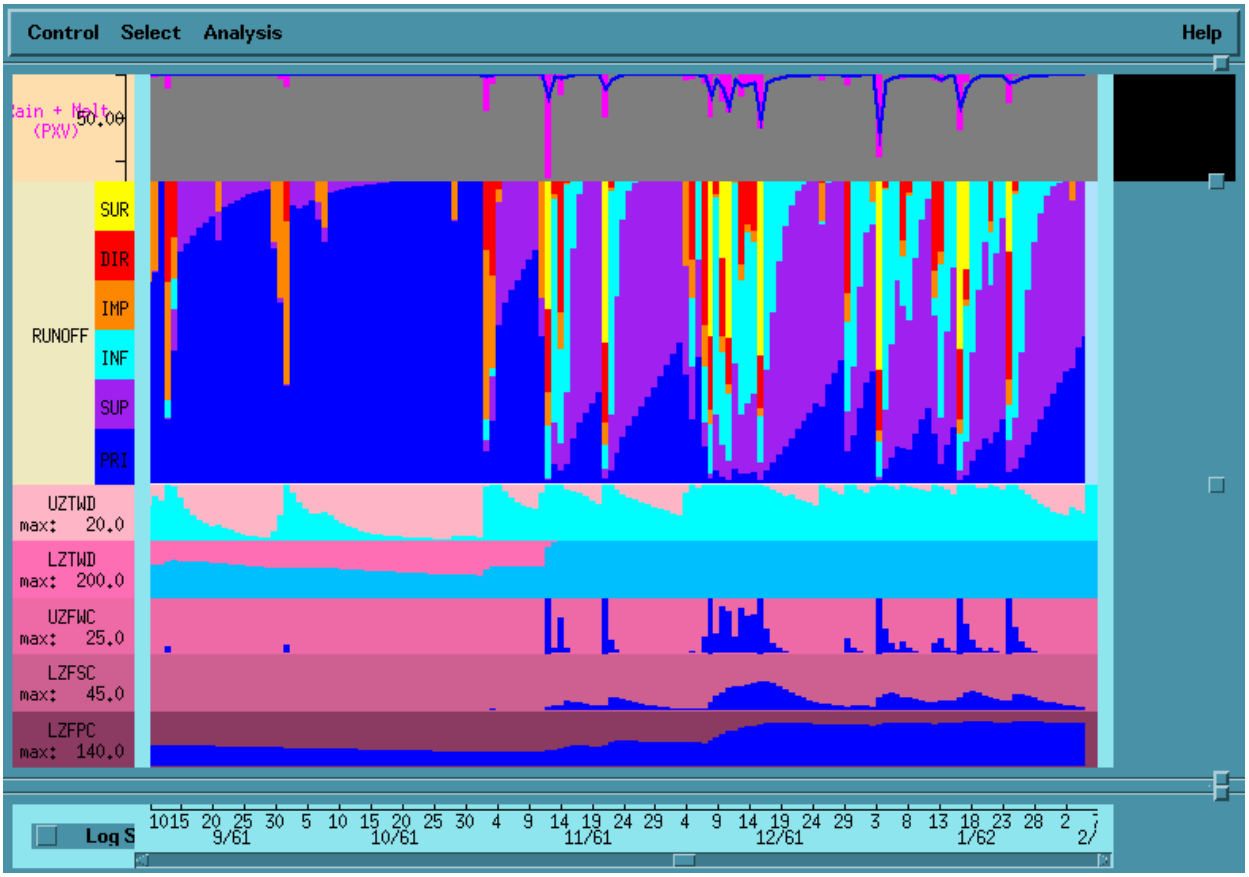
Most of the parameters are discussed individually, however, the percolation curve and the param eters that primarily affect it are lumped together. When making changes to the percolation rate it is important to think in terms of the entire curve as opposed to the individual parameters that in fluence the curve. In addition to the hydrograph plots, panels that show how the model states ar e changing and other results of the model computations are included in each of the figures. The se panels are extremely helpful in determining when the conditions occur that are needed to isola

te the effects of each parameter. Even though two hydrograph plots are included on each figure , the panels showing the model states and computations can only be included for one of the para meter values. This value is specified next to the panels on each figure.

Explanation of Panels Showing Model States and Computations

Figure 7-8-1 illustrates the panels which are part of the ICP WY-PLOT display for the SAC-SM A operation. The plots on these panels are for a daily time interval. Instantaneous values such as zone contents are for the end of each day.

Figure 7-8-1. Sample ICP display for the SAC-SMA operation.



Top Panel - This panel shows the total amount of water coming into the Sacramento model f or each day as a bar value in magenta with the scale on the left. These can be rain+melt val ues from the snow model or the direct input of rainfall when snow computations are not inclu ded. The dark blue line in this panel is the total amount of channel inflow, i.e. runoff, gener ated by the model for each day. This is the sum of all the runoff components. The scale is the same as for the precipitation input.

Middle Panel - This panel shows a breakdown of the runoff into components for each day.

The total height of the panel is divided in proportion to the fraction of each runoff component that occurs on any day. Surface runoff is displayed in yellow, direct runoff (i.e. from the additional impervious area) in red, constant impervious runoff in orange, interflow in light blue, supplemental baseflow in purple, and primary baseflow in dark blue. This panel allows the user to see relatively how much runoff is being generated by each of the components on a daily basis.

Bottom Panel - This panel shows the states of each of the upper and lower zone moisture storages at the end of each day. The capacities of each zone are labeled on the left. The blueish tones represent contents and the pinkish tones deficits (i.e. capacity minus contents). If for a given day a zone is all blue, it indicates that the zone is completely full of water. Vice versa if the a zone is all pink, it indicates that the zone is empty. Generally when viewing this panel, the tension water storages are being thought of in terms of deficits, i.e. how much water is needed to fill the storage, while the free water storages are being thought of in terms of contents, i.e. how much water is available for runoff, or in the case of the upper zone free water storage, both for interflow and percolation.

Sacramento Model Parameters

On the remaining pages in this section the major function of each parameter is described, as well as how to isolate the effect of the parameter. The order that the parameters are discussed is based on the strategy for examining the parameters during a calibration as suggested in Section 7-1. The parameters that primarily affect baseflow are described first, followed by tension water storages and PCTIM, storm runoff parameters, and lastly those that primarily affect evapotranspiration. Table 7-8-1, at the very end of the section, summarizes the primary function of each of the Sacramento model parameters.

Besides this material, the portions of Section 7-5 that describe how to derive estimates of parameter values from an analysis of the hydrograph provide considerable information that should assist in determining how to isolate the effect of each model parameter. That material should be reviewed even if one is not going to derive initial parameter values.

LZPK

The primary function of the LZPK parameter is to specify the slope of the primary baseflow recession. LZPK is not to be used to correct for problems with the magnitude of primary baseflow. As long as the simulated slope of the recession during periods when only primary baseflow is contributing to runoff is parallel to the observed recession, LZPK shouldn't be modified even if though the amount of primary baseflow is considerably high or low. Figure 7-8-2 illustrates how changing the value of LZPK alters the slope of the recession. For this illustration the percolation term PBASE was kept the same for both values of LZPK.

The value of LZPK is checked by examining periods when primary baseflow is basically the only source of runoff. Small amounts of constant impervious runoff may occur during such periods from rain that is not sufficient to fill the upper zone tension water storage, but no other runoff components should contribute significant amounts. Complications that can affect periods when primary baseflow dominates are discussed under the 'Assigning Runoff Components' portion of Section 7-5. Periods with riparian vegetation evaporation should be avoided when determining whether the value of LZPK should be changed. Also, during periods with a snow cover it should be recognized that ground melt may cause the primary recession to be slower than during snow free periods. Thus, it is best to use snow free periods whenever possible.

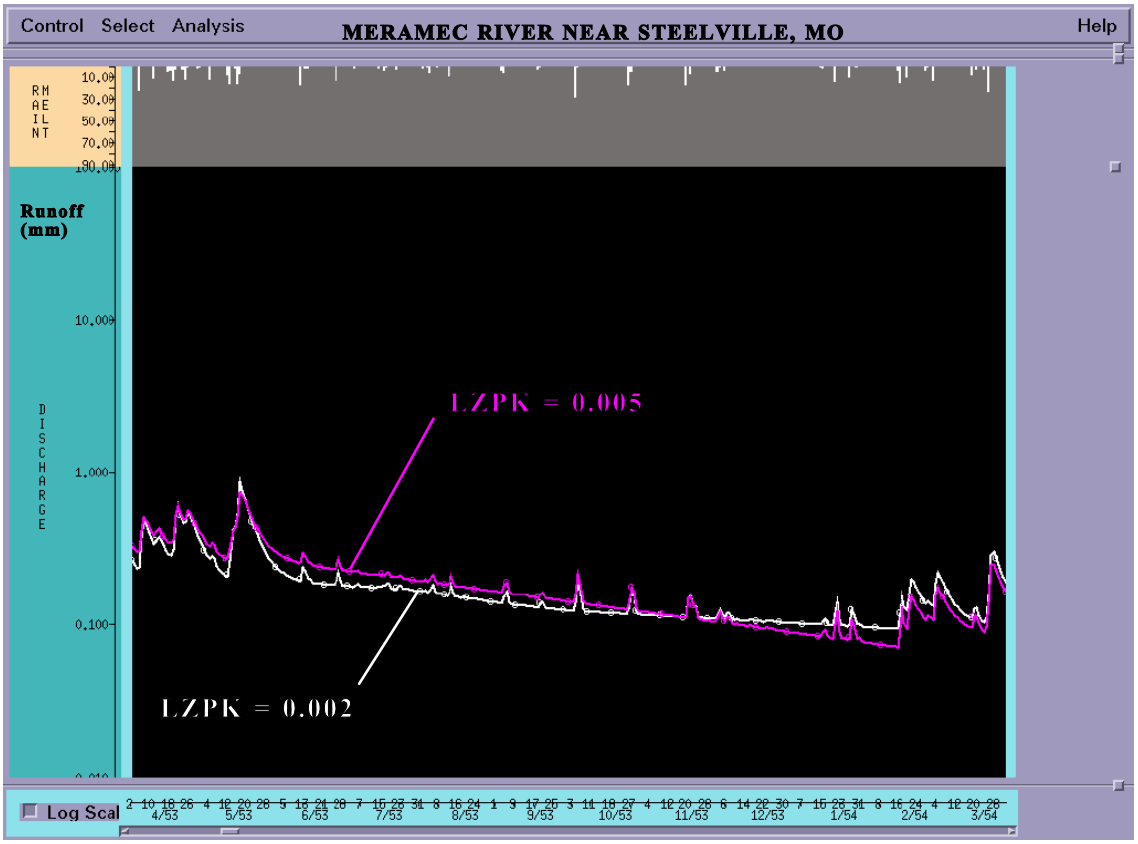


Figure 7-8-2. Effect of changing LZPK on model response.

LZSK

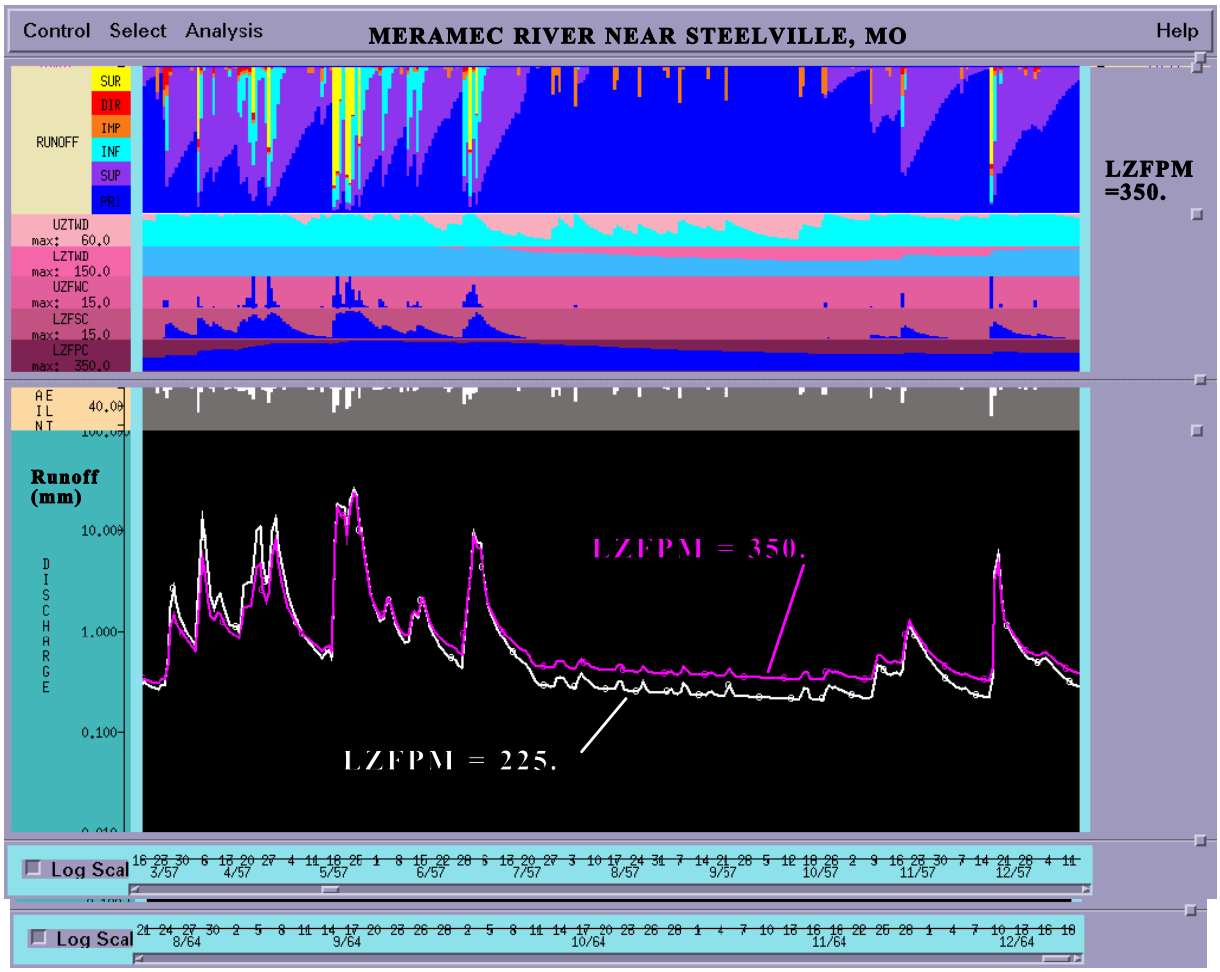
The primary function of LZSK is the timing of supplemental baseflow runoff. This can be evaluated in terms of the slope of the supplemental recession or in terms of how long significant supplemental baseflow exists after the storage is recharged. The longer that supplemental baseflow exists, the slower the withdrawal rate. LZSK shouldn't be used in an attempt to change the amount of supplemental baseflow, but only the timing. The periods to use for determining if the value of LZSK should be changed are recessions after significant groundwater recharge has occurred. There should be no major runoff producing events during the recession in order to best evaluate LZSK. Such an ideal case may be difficult to find for watersheds with a very slow supplemental recession rate (see Section 7-5 for further information).

Figure 7-8-3 illustrates the how changing the value of LZSK alters the timing of the supplementa l recession. The value of PBASE in the percolation equation is kept the same for both values of LZSK. The panel at the top is for LZSK=0.20. It shows for the October 1964 recession peri od that the supplemental baseflow contribution is essential gone by the end of the month. For t he LZSK value of 0.10, supplemental baseflow lasts until the middle of November.

Figure 7-8-3. Effect of changing LZSK on model response.

LZFPM

The primary function of LZFPM is to control the amount of primary baseflow runoff. Whereas LZPK controls the withdrawal rate, i.e. the slope of the recession, LZFPM controls the magnitud e. The greater the value of LZFPM the more water that can be stored in the primary storage, th us a greater overall contribution from primary baseflow. If the total amount of baseflow from b oth primary and supplemental contributions is too great or too small, the percolation rate will nee d to be decreased or increased to correct the problem. Once the total amount of baseflow is rea sonable, then LZFPM can be changed so that the proper proportion is assigned to primary basefl



ow runoff.

The periods to examine for LZFPM are the same as were used to evaluate LZPK, i.e. periods wh en primary baseflow is the major source of runoff. Figure 7-8-4 illustrates how changing the va lue of LZFPM alters the magnitude of primary baseflow runoff. When LZFPM is altered, very little change occurs during periods when other runoff components dominate.

Figure 7-8-4. Effect of changing LZFPM on model response.

LZFSM

The LZFSM parameter is unusual in that it has 2 primary functions. The first, which is described on this page, is to control the amount of supplemental baseflow. The other is its effect on the percolation rate. This function is discussed, along with the role of other parameters on percolation, in the 'Percolation Rate' portion of this section.

Analogous to primary baseflow, LZSK controls the timing of supplemental baseflow and LZFSM controls the magnitude. The greater the value of LZFSM, the more water can go into supplemental storage. The periods to examine to isolate this effect of LZFSM are the same periods used to evaluate the LZSK parameter, i.e. recession periods after significant recharge when there is considerable supplemental baseflow contribution and very little storm runoff. It is especially important to examine recession periods after major events when the maximum amount of supplemental baseflow should occur. Figure 7-8-5 illustrates the effect of changing the value of LZFSM. It can be seen that besides affecting the magnitude of supplemental baseflow, altering LZFSM also changes the response during and immediately after the storm events. This change is due to the effect of LZFSM on the percolation rate. The larger the value of LZFSM, the greater the percolation rate and thus less storm runoff (i.e. surface runoff and interflow).

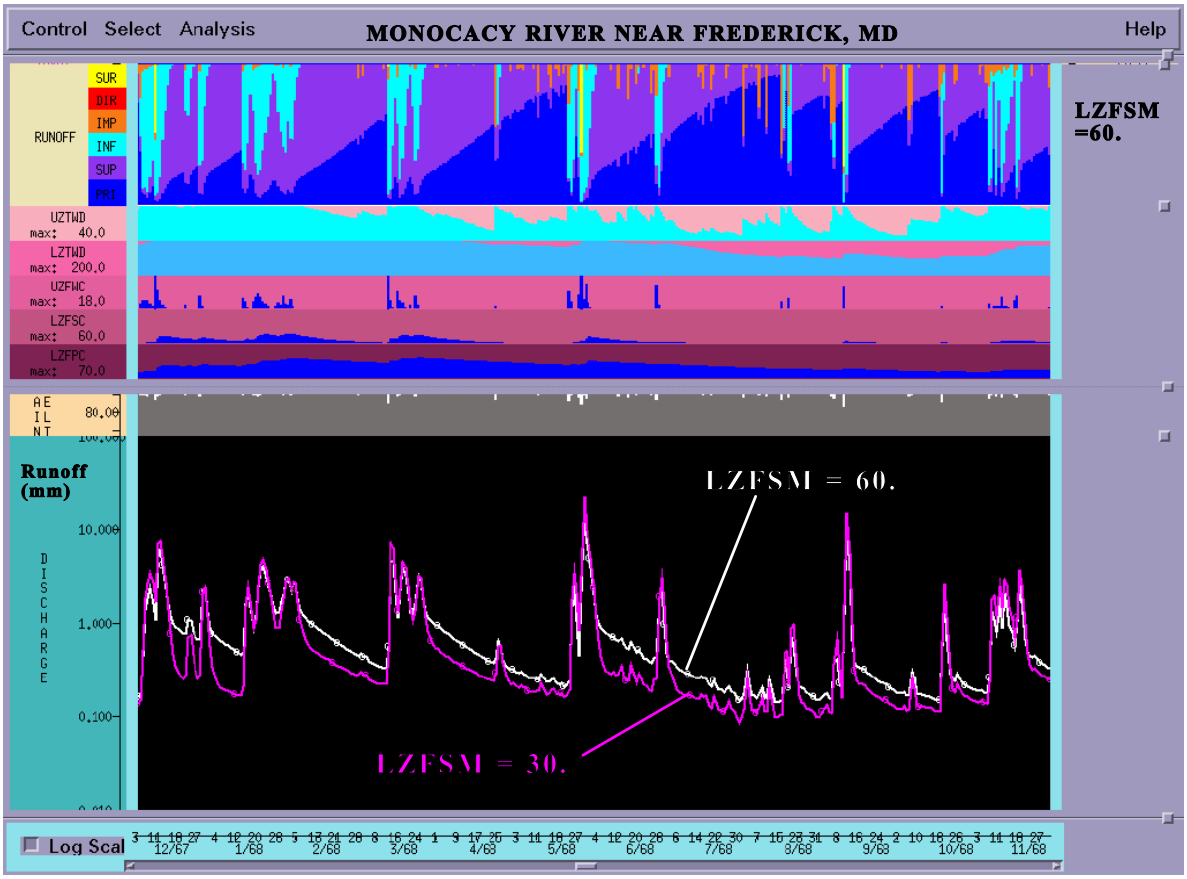


Figure 7-8-5. Effect of changing LZFSM on the magnitude of supplemental baseflow.

PFREE

The function of PFREE is to determine what fraction of the percolation goes directly to free water storages, i.e. how much baseflow recharge occurs, when there is a lower zone tension water deficit, i.e. LZTWC is less than LZTWM. Thus the only periods to examine when evaluating the value of PFREE are those when there is a lower zone tension deficit. Whenever lower zone tension water is full, PFREE has no affect. The amount of recharge is determined by how much the baseflow increases after an event that produces storm runoff (the upper zone tension water must fill in order to have any percolation or storm runoff). When there is a lower zone tension deficit, the relative amount of recharge will likely vary depending on the size of the deficit as in reality PFREE should be function of the dryness of the lower zone as discussed in Section 7-5. Generally it is preferable to use a PFREE value that works well during extended periods with a substantial lower zone tension deficit than to set the value of PFREE based on the shorter transition periods when the deficit first appears or dissipates, though this decision is left up to the user. Figure 7-8-6 illustrates how PFREE affects baseflow recharge after storm events when there is a lower zone tension deficit. Note that PFREE has essentially no effect when the lower zone tension water is full. In very wet regions lower zone deficits seldom occur. In such areas it may not be possible to determine the value of PFREE. Even though PFREE has little effect in such areas, spatial consistency in the parameter value should be maintained.

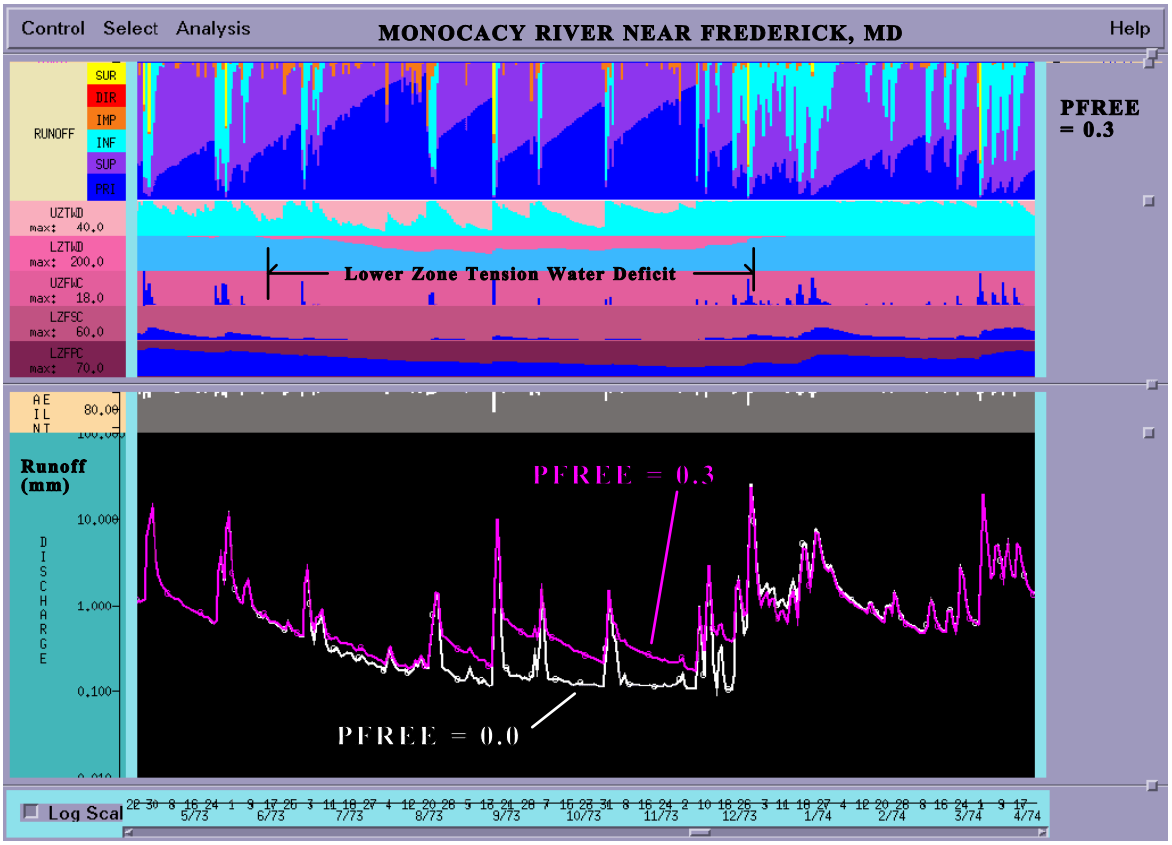


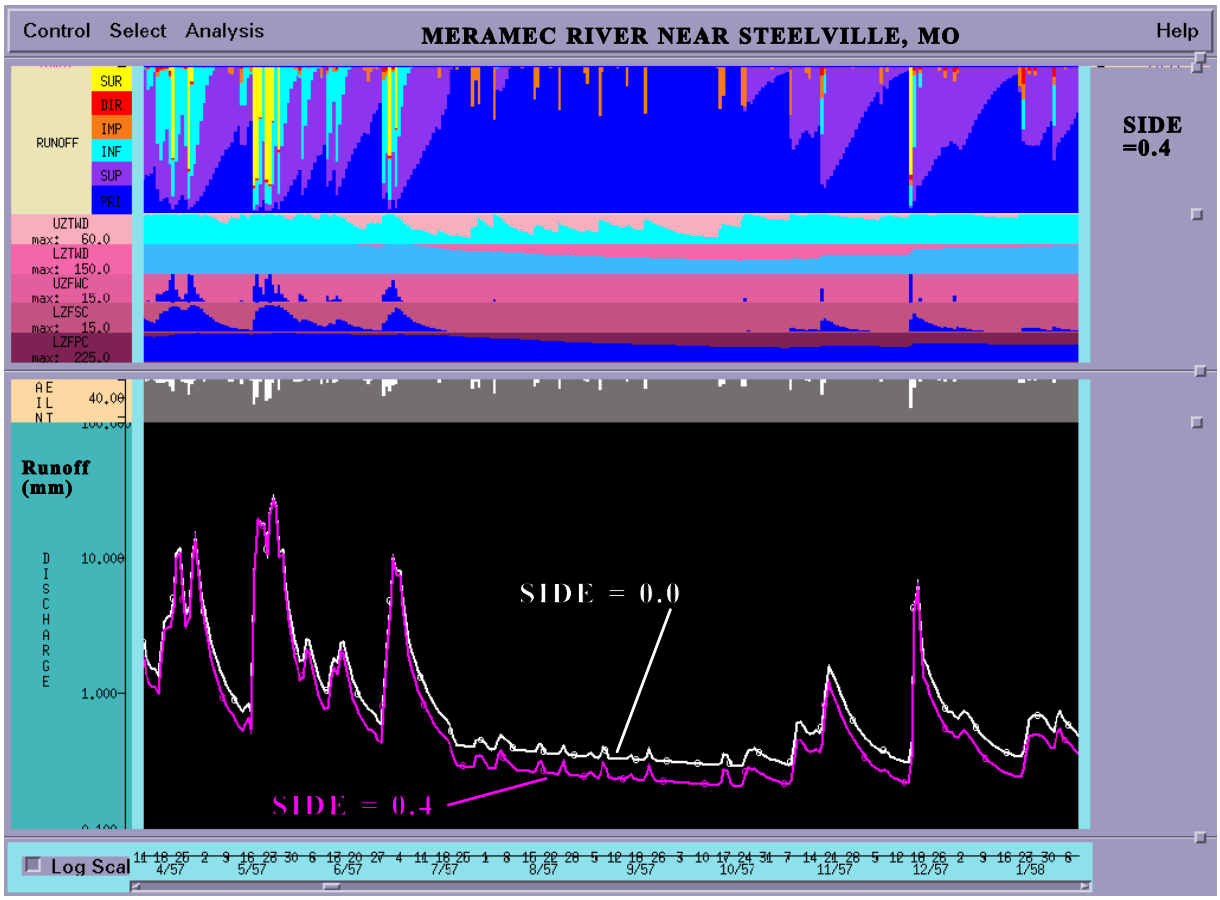
Figure 7-8-6. Effect of changing PFREE on model response.

SIDE

The function of the SIDE parameter is to have a portion of the withdrawal from baseflow storage s go to deep groundwater recharge rather than appearing in the stream. The SIDE parameter all ows the user to get rid of water by removing it from baseflow when storm runoff is being reprod uced in a reasonable fashion and increasing the amount of evaporation or decreasing the precipit ation seems physically unrealistic. The SIDE parameter should only be used when there is som e collaborating evidence that significant deep groundwater recharge is an important part of the w ater balance.

Figure 7-8-7 illustrates the effect of using a non zero value for SIDE. The same fraction of the withdrawal from lower zone free water storages is removed every day from the water balance. Since the amount of withdrawal varies with the contents of the primary and supplemental storage s, the amount of deep recharge is greatest when the amount of water in these storages is the great est.

Figure 7-8-7. Effect of using SIDE on model response.



UZTWM

The primary function of UZTWM is to control the maximum upper zone tension water deficit th at can be created. Remember no storm runoff, other than that from constant impervious areas, c an occur when the upper zone tension water is not full. The value of UZTWM controls the time when the other storm runoff components (surface, interflow, and direct runoff) are suppressed d uring a dry period. Typically dry periods after a storm event during the summer are used to det ermine if changes are needed to UZTWM. Such periods allow for a sizeable upper zone tensio n deficit to develop. An evaluation can then be made as to whether the deficit is too large or no t large enough based on the response from moderately large rain events that occur when the mag nitude of the deficit approaches the value of UZTWM. Figure 7-8-98 illustrates the effect of ch anging UZTWM on the amount of storm runoff produced after a large upper zone tension deficit is generated. The deficits that exist prior to two storm events are noted on the figure. The firs t event had a much larger hydrograph response when UZTWM was equal to 40 partly due to mor e rainfall, but also the intensity was sufficient to generate surface runoff.

In very wet regions a significant upper zone tension deficit may never develop, thus it is impossi ble to determine the value of UZTWM. In such areas it is important to maintain a realistic spati al consistency in the values of UZTWM. Soil based estimates as discussed in Section 7-5 can p rovide this consistency in such regions.

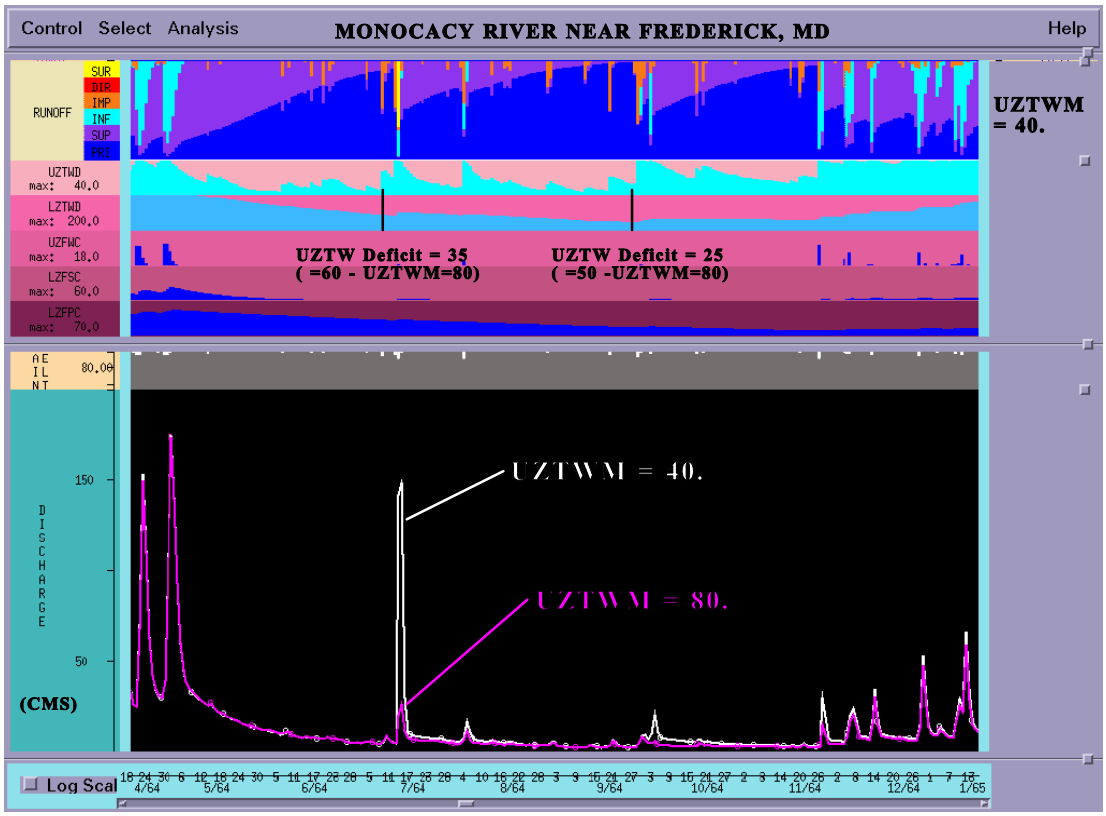


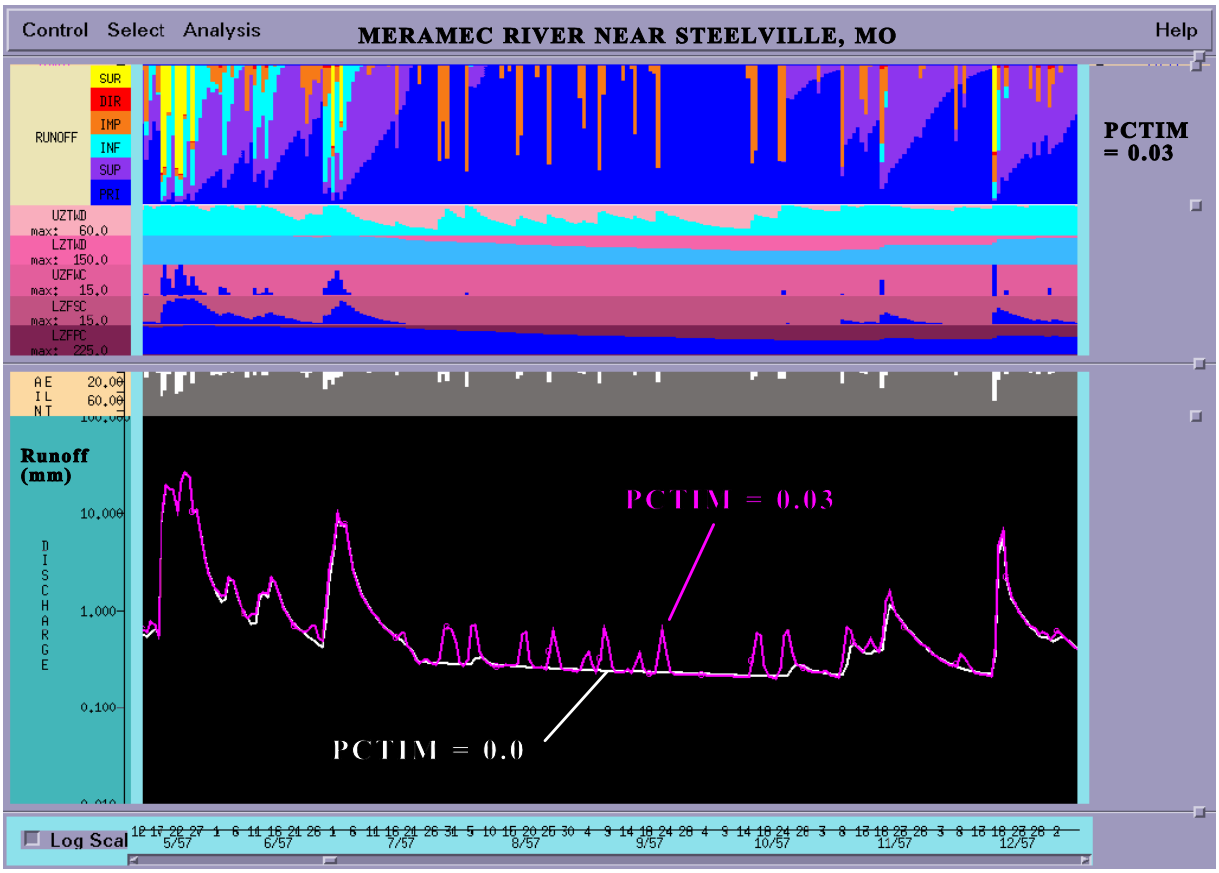
Figure 7-8-8. Effect of changing UZTWM on model response.

PCTIM

The PCTIM parameter is evaluated at the same time as UZTWM since the only source of new runoff during periods when an upper zone tension deficit exists is from constant impervious areas. During periods when there is a substantial upper zone tension deficit, the response from small to moderate rain events is examined to determine if the value of PCTIM should be changed. As with any parameter, changes should be based on the trend over many events. The periods used to evaluate PCTIM are typically in the warm season when convective rainfall is predominate, especially for smaller events. Since the MAP values from such events are quite uncertain, it is even more important in the case of PCTIM to base any decision on the response of many events. Figure 7-8-9 illustrates how changing the value of PCTIM affects the watershed response during periods when a upper zone tension deficit exists. PCTIM has only a small effect on the hydrograph during other periods unless the value of PCTIM is very large.

In very wet regions where significant upper zone tension deficits seldom exist, it may be very dif ficult to determine a unique value for PCTIM. In many cases in such regions it is best to set P CTIM to zero if constant impervious runoff can't clearly be shown to exist..

Figure 7-8-9. Effect of changing PCTIM on model response.



LZTWM

The primary function of LZTWM is to specify the maximum lower zone tension water deficit tha t can occur. The maximum possible deficit will occur after a long dry period when the vegetati on withdraws all the moisture from the soil that the roots can reach. If the absolute maximum d eficit occurred, all of the vegetation in the watershed would be wilted. Since such a situation se ldom exists in nature, the lower zone tension water should never dry out completely. To deter mine if the value of LZTWM should be changed, the hydrograph response after long dry periods when the lower zone tension deficit approaches the value of LZTWM should be examined. The amount of runoff that occurs as the deficit is filled will indicate if the deficit was allowed to be t oo large or not big enough. In most areas, a large deficit that is built up over a very dry summe r will be filled by fall rains, however, in watersheds where snowmelt dominates, such as in the in termountain west, the deficit is usually not filled until the spring melt season. In these cases the response in the early part of the melt season should be examined. Several factors can affect th e model response at the beginning of the snowmelt season as discussed in the last part of Section 7-7. The value of LZTWM should only affect the response during years when a large deficit is carried through the winter. Figure 7-8-10 illustrates the type of period to use and the effect of c hanging LZTWM for the case when the deficit built up during the summer is filled by fall rains. Figure 7-8-11 illustrates the effect of LZTWM when a deficit is carried through the winter and not filled until the early part of the melt season.

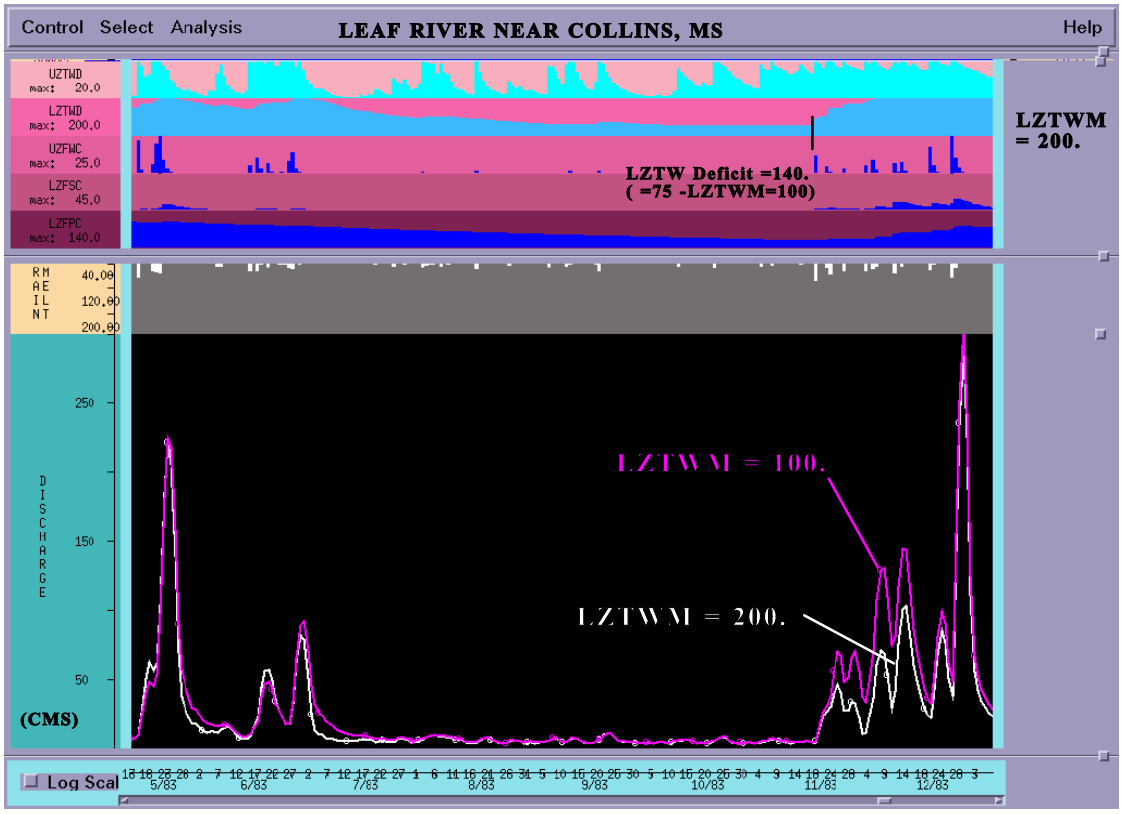
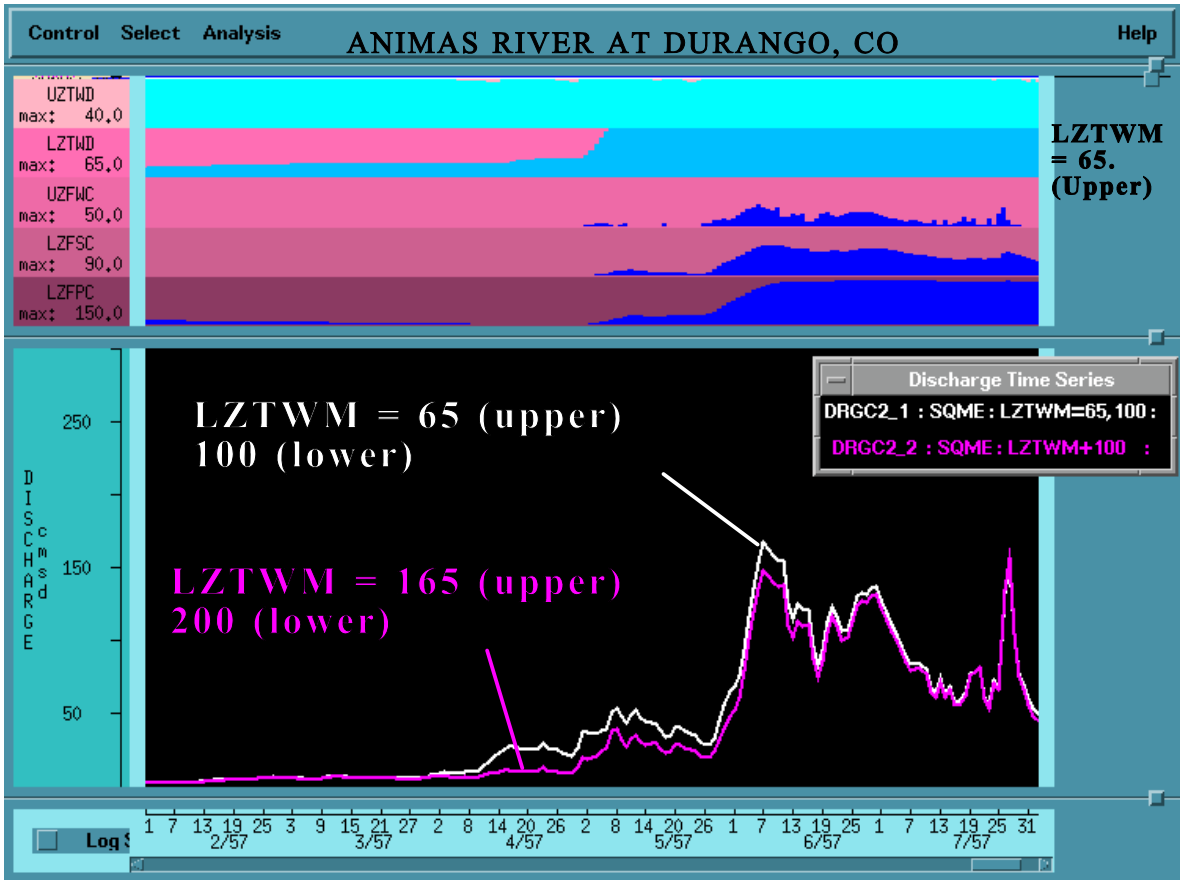


Figure 7-8-10. Effect of changing LZTWM for an area with fall rains.


Control
Select
Analysis
ANIMAS RIVER AT DURANGO, CO
Help
UZTWD max: 40.0
LZTWD max: 65.0
UZFWC max: 50.0
LZFSC max: 90.0
LZFPC max: 150.0
LZTWM = 65. (Upper)
Discharge Time Series
DRGC2_1 : SQME : LZTWM=65,100 :
DRGC2_2 : SQME : LZTWM+100 :
LZTWM = 65 (upper)
100 (lower)
LZTWM = 165 (upper)
200 (lower)
DISCHARGE cmsd
250
150
50
Log S
2/57
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4/57
5/57
6/57
7/57

Figure 7-8-11. Effect of changing LZTWM on a predominately snowmelt basin.

If the size of the lower zone tension deficit never approaches the value of LZTWM for watershed s where long dry periods periodically occur from late spring into the fall resulting in hydrologic drought conditions, the value of LZTWM should likely be reduced so that the maximum deficit i s closer to the value of LZTWM. During extreme dry periods it is physically realistic for the de ficit to approach its limiting value. In wet regions where significant lower zone tension deficits never occur, a true value for LZTWM can't be determined by calibration. In these regions cha nging LZTWM will alter the amount of computed ET since the LZTWM is part of the equation u sed to calculate evaporation from the lower zone tension water, however, LZTWM must be chan ge by quite a bit to produce a significant change in ET (i.e. the parameter is not very sensitive in this situation). In wet regions it is probably best to use the soil based estimates of LZTWM to maintain spatial consistency though it would be better if the estimates were based on vegetation, as well as soils data. In very dry regions it may also be impossible to reliably determine the val ue of LZTWM since the lower zone tension deficit may seldom be filled. Simulation results usi ng a lumped application of a conceptual model are generally poor such regions as shown in Figur e 1-1.

Percolation Rate (ZPERC, REXP, LZFSM)

It is best to evaluate the entire percolation curve when determining whether changes are needed t o the parameters that control amount of percolation. This is especially true in the case of ZPER C and REXP. Since LZFSM has two primary functions, changes can be made to alter the magn itude of supplemental baseflow without doing a full evaluation of its affect on the percolation cur ve. The thought process recommended when evaluating the percolation curve is to first determi ne how the curve needs to be changed at different levels of lower zone wetness and then decide o n the combination of parameter values that will produce the desired curve. It is important to ev aluate the whole curve before deciding on any parameter changes since percolation rates may be too high under some moisture conditions and too low under others. Only an examination of eve nts that occur at various lower zone moisture conditions will indicate how the curve should be m odified.

As indicated ZPERC, REXP, and LZFSM are the 3 parameters whose primary function is to cont rol the percolation curve (LZFSM also affects the amount of supplemental baseflow). REXP de termines the shape of the curve, ZPERC the percolation rate when the soil is completely dry, and LZFSM dominates the rate when the soil is saturated). Other parameters also affect the percol ation rate, but that is not their primary function. This includes UZFWM, LZFPM, LZTWM, L ZSK, and LZPK. The PBASE term in the percolation equation, which specifies the rate when t he lower zone is saturated, is calculated based on the fact that water can't enter the lower zone u nder saturated conditions faster than the lower zone free water storages can drain. PBASE is co mputed as:

PBASE = LZFSM • LZSK + LZFPM • LZPK.
(7-8-1)

The withdrawal rates, LZSK and LZPK, should never be changed in order to modify PBASE. Their only function is to specify the slope of the two baseflow recessions. Changes to LZFPM will alter the value of PBASE, however, generally the LZFSM • LZSK term of the equation is an order of magnitude greater than the primary baseflow term, thus LZFSM becomes the dominate parameter when changing the saturated percolation rate. When the division between suppleme ntal and primary baseflow is correct, but changes to PBASE are indicated, both LZFSM and LZF PM can be changed in a manner that keeps their ratio the same.

Before evaluating the percolation curve, it is important to first know what to look for to decide w hether a change in the percolation rate is needed. Figure 7-8-12 illustrates the model response t hat indicates there is an error in the percolation rate. When LZTWC is equal to LZTWM, i.e. lo wer zone tension storage is full, none of the percolated water can be stored in tension water. In that case the percolation curve controls the division between storm runoff, surface plus interflow, and baseflow, supplemental plus primary. A decrease in the percolation rate at any given low er zone moisture level will produce more storm runoff and less baseflow recharge. An increase in the percolation rate will do the opposite. When LZTWC is less than LZTWM, then much of the percolated water will go into tension water storage, thus reducing the amount of recharge (all

of the percolated water will go into lower zone tension storage when PFREE is zero - some recharge will occur if PFREE is greater than zero). Thus, in this case, changing the percolation rate primarily alters the amount of storm runoff with only a minimal effect on recharge depending on the value of PFREE.

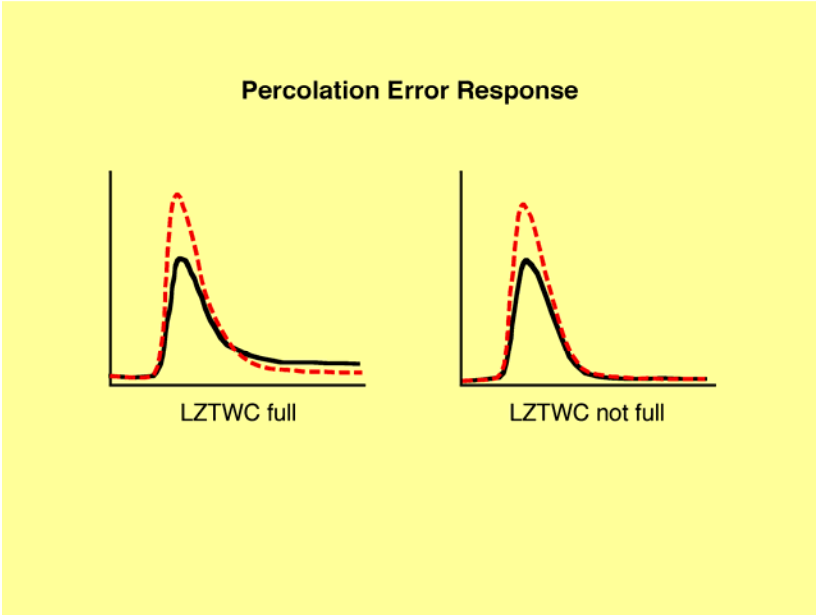


Figure 7-8-12. Illustration of model response to changes in the percolation rate.

The ICP has a percolation analysis feature built into the WY-PLOT display. This tool allows the user to go through many events, hopefully over a wide range of lower zone moisture conditions, and indicate the relative magnitude that the percolation curve should be altered to improve the simulation. If this analysis shows any trends in how the overall shape of the curve should be modified, then the parameters can be changed by trial and error until the desired curve is obtained. The steps to follow to perform a percolation analysis are:

1. In the main ICP window select 'Water Year Plot' under the 'Display' menu. Then choose 'SAC-SMA' under the 'Select' menu of the WY-PLOT display (the Sacramento model zone contents and runoff component breakdown must be included on the WY-PLOT display for the percolation analysis option to be active). Then choose 'Percolation' under the 'Analysis' menu. This will cause the current percolation curve to be displayed in one window and the current values of ZPERC, REXP, LZFSM and LZFPM to be displayed in another window.

2. In the window that shows a plot of the percolation curve choose 'Points' under the 'Select' menu and then choose 'Build'. After this is done, whenever the right mouse button is clicked within the hydrograph plot portion of the WY-PLOT display, a dotted, red vertical line will appear on the percolation curve plot to indicate the lower zone deficiency ratio, LZDEFR, at that time and thus where you are on the percolation curve.
3. Go through the calibration period and select those events when the model response indicat

es a percolation error as shown on Figure 7-8-12. Events where other types of errors predo minate, such as volume or timing errors, should be ignored. The SAC-SMA display is used to determine whether a lower zone tension deficit exists. Then determine where you are on the percolation curve during the event as described in step 2. You can determine where y ou are just prior to the event or can get the average percolation rate by checking on days just before and after the event. The main consideration is to be consistent in what you do from o ne event to another. For each event selected, click on the percolation curve plot where the v ertical line appears to indicate whether the percolation rate should be higher, lower, or remai n about the same. This will put a small red 'x' on the plot to indicate the relative change in the percolation rate that is needed to improve the simulation of that event (e.g. increase the ra te significantly, decrease the rate slightly, or keep the rate the same). The amount that the c urve needs to be changed is subjective. Over time you will become more skilled at anticipat ing the amount of change needed.

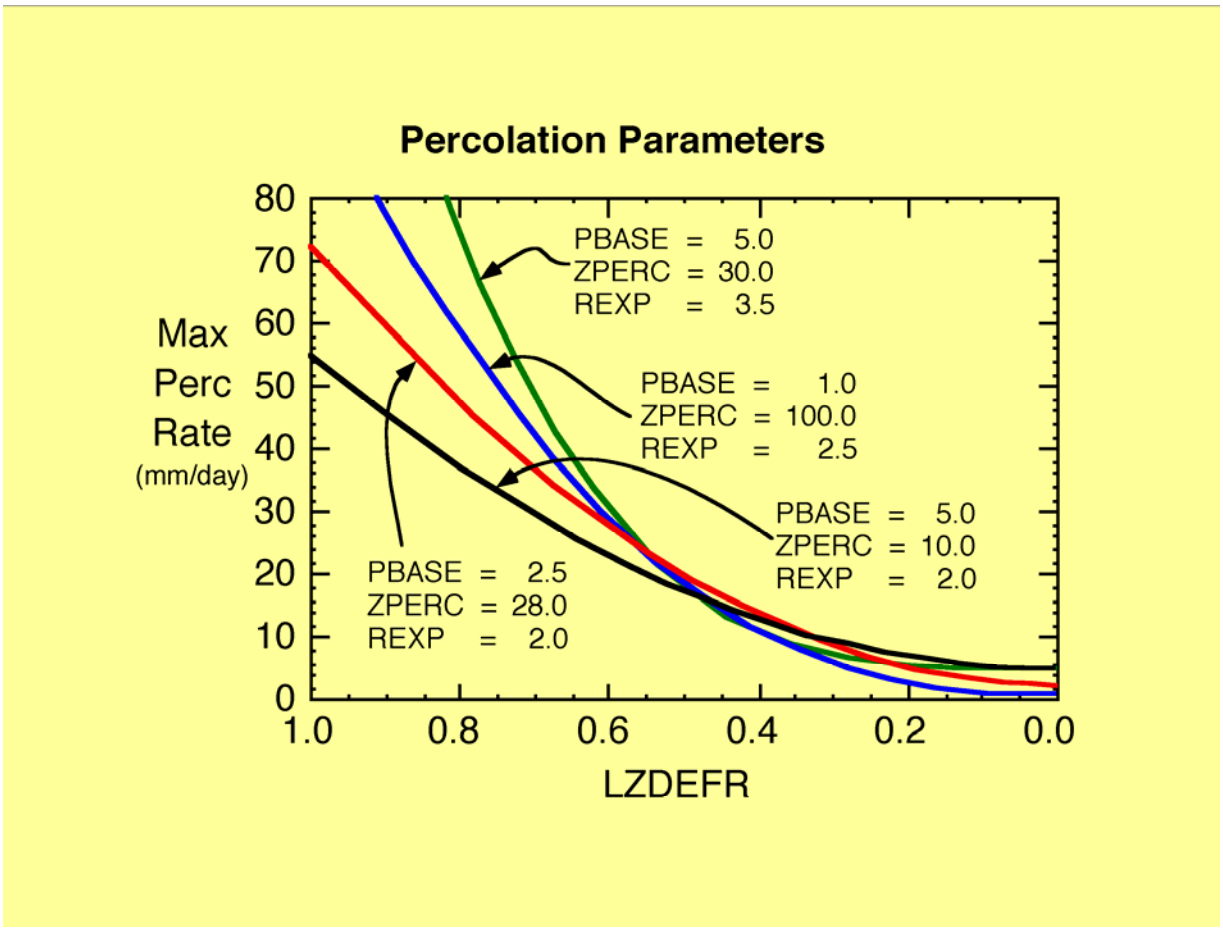
4. After going through the entire calibration period there should be many red x's on the perco lation curve plot. If there is a trend in the suggested changes, it indicates that a new percola tion curve is likely needed. If the points are scattered around the plotted curve, it indicates t hat no changes are needed to the current parameter values. If a new curve is suggested, the idea is to select changes to the parameter values to produce a curve that best fits the points. This is done by trial and error. Under the 'Select' menu of the percolation curve plot windo w choose 'Parameters'. This will bring up a new window that lists the current value of the 4 parameters. Make changes to the parameters and then click on 'Compute'. A new curve will be drawn on the percolation plot. Keep doing this until you get a curve that fits the po ints to your satisfaction. Then use those parameter values for the next calibration run. The re is also a 'Solve' option under the 'Points' option of the 'Select' menu that will automatical ly fit a curve to the points. It is not recommended that this option be used.

In many situations going through the steps in the percolation analysis will not result in significan t changes in the simulation results. By the time that a percolation analysis is performed, adjust ments typically have been made to get a reasonable baseflow simulation and an overall water bal ance that is within a few percent. In order to for this to be the case, the overall amount of storm runoff should be realistic. Thus, most events will already have a reasonable percolation rate. The percolation analysis is primarily helpful in determining if the percolation curve adequately handles the full range of soil moisture conditions. Thus it is very important when doing the ana lysis to include as wide of range of LZDEFR values as possible. This is because over a certain range of LZDEFR values there are many combinations of PBASE, ZPERC, and REXP that will produce very similar curves. This is illustrated in Figure 7-8-13. For LZDEFR values from a bout 0.3 to 0.6 all of the curves on this figure look very much alike. For this example it would be very important to have events that occur under very wet conditions and especially cases when significant rain occurs when the soil is very dry in order to adequately define the percolation cur ve. In wet areas there may not be a wide range of LZDEFR values and thus it is impossible to g et unique values for ZPERC and REXP. In these situations it is best to follow the guidelines in Section 7-5 and maintain spatial consistency. In some watersheds even though a wide range of LZDEFR values occur, the rain events that take place when the soil is dry are not of sufficient si

ze to produce enough runoff to determine if the percolation curve needs to be modified. In thes e cases, if a good evaluation of the percolation curve can be achieved for some watersheds in the region, the values of ZPERC and REXP for those watersheds should be applied throughout the re gion with some possible modification for changes in soils.

Figure 7-8-13. Illustration of how various parameter values produce similar percolation curves.

Figures 7-8-14 through 7-8-18 illustrate how changes to PBASE, ZPERC, and REXP affect mod



el response. These figures should also reinforce what you are looking for when determining wh ether the percolation rate needs to be changed. In most of these figures the percolation analysis window that shows the percolation curves is included along with the main WY-PLOT display.

Figures 7-8-14 and 7-8-15 show the effect of PBASE on the model response. An arithmetic sca le is used for the first figure to emphasize the high flow response and a semi-log scale is used for the second figure to accentuate the effect on baseflow recharge. When PBASE is 7.3, there is

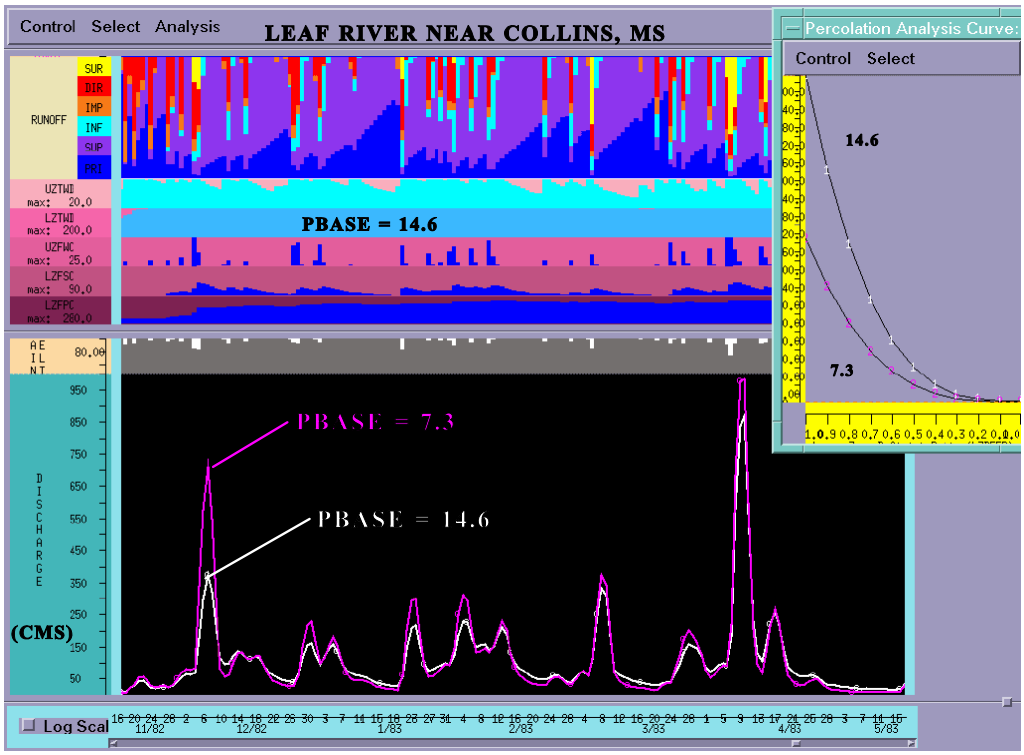


Figure 7-8-14. Effect of changing PBASE on model response (arithmetic scale).

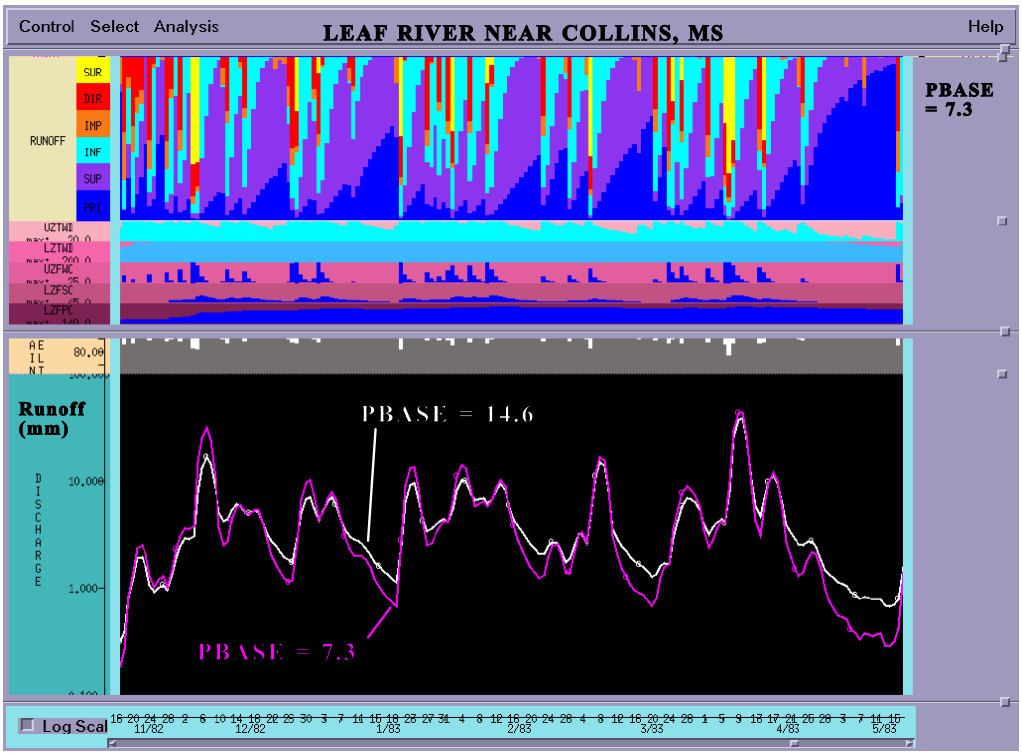


Figure 7-8-15. Effect of changing PBASE on model response (semi-log scale).

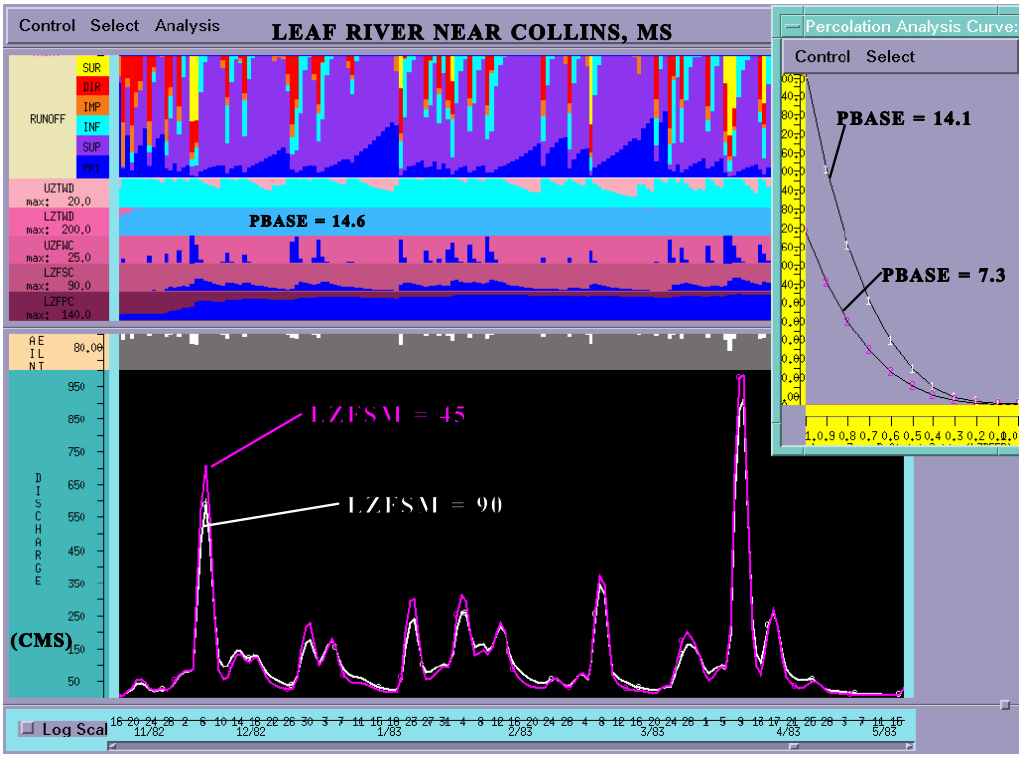
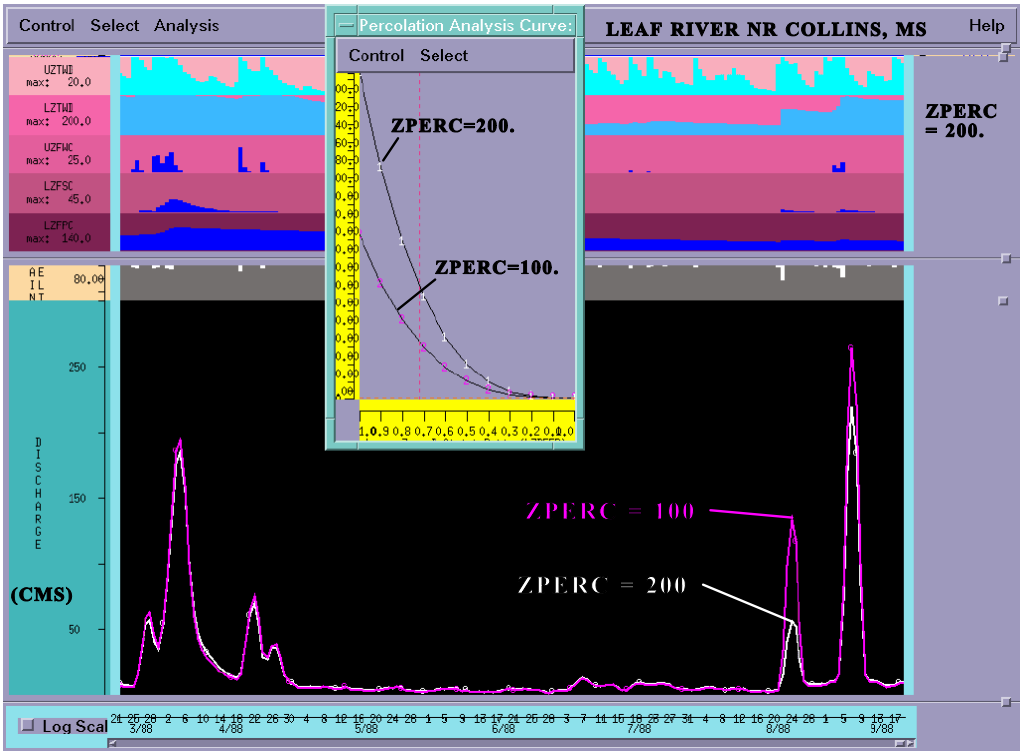


Figure 7-8-16. Effect of changing LZFSM on the percolation rate.

Figure 7-8-17. Effect of changing ZPERC on model response.



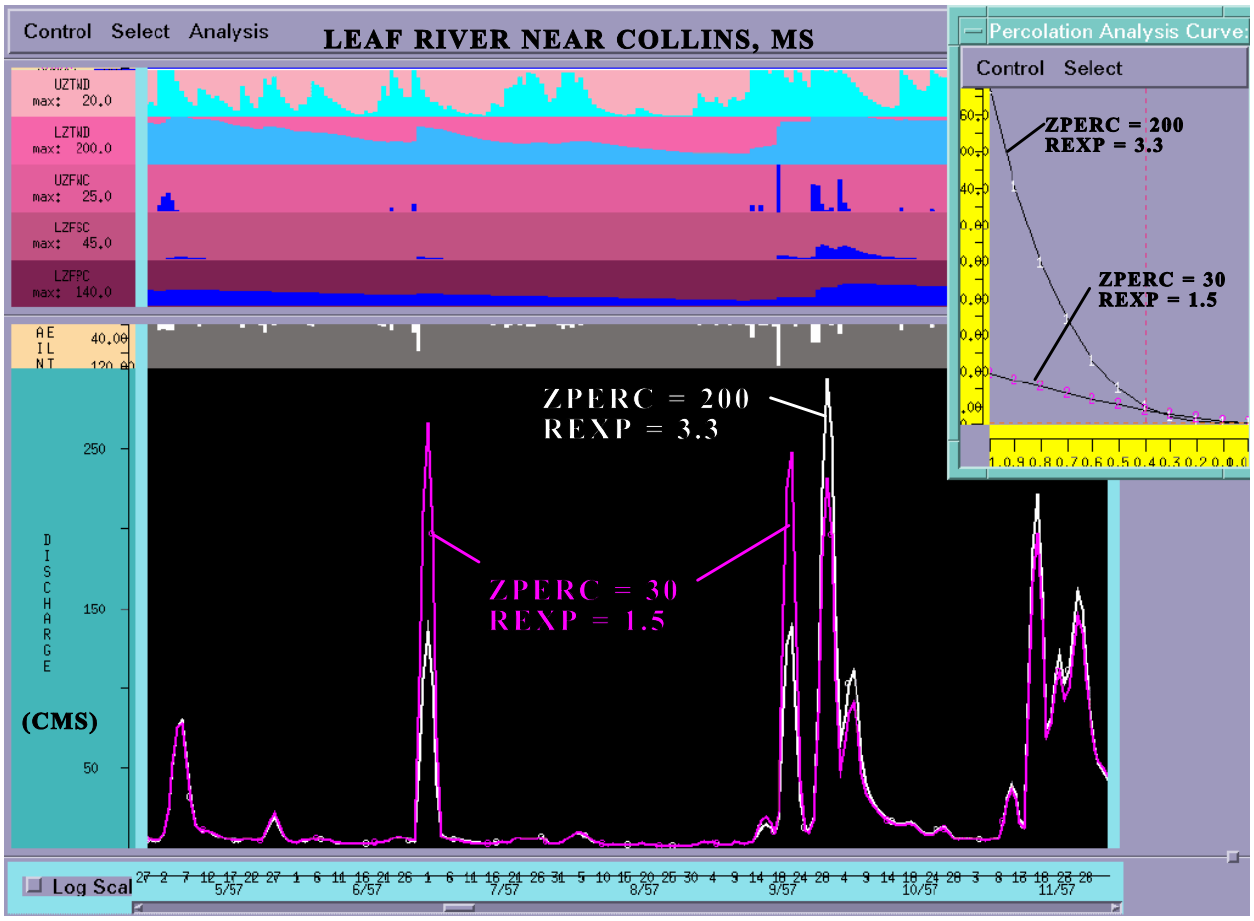


Figure 7-8-18. Effect of changing ZPERC and REXP on model response.

more storm runoff and less baseflow. This occurs for all events because a change in PBASE causes the entire percolation curve to increase or decrease by the ratio of the new PBASE to the previous value. Figure 7-8-16 is the same as Figure 7-8-14 except that only LZFSM is changed (in the previous 2 figures both LZFSM and LZFPM were altered by the same ratio in order to change PBASE). Doubling LZFSM from 45 to 90 mm causes PBASE to change from 7.3 to 14.1, thus showing how LZFSM dominates the PBASE value (doubling both LZFSM and LZFPM resulted in a PBASE of 14.6). The effect on percolation of doubling LZFSM is almost the same as the effect when both lower zone free water storages are doubled.

Figure 7-8-17 illustrates the effect of changing only ZPERC. Doubling ZPERC results in the maximum percolation rate under dry conditions to almost double while the rate under saturated conditions is not changed. Thus, the events in August and September, when the LZDEFR is quite large (i.e. dry soil due to a substantial lower zone tension deficit and little water in free water storages), are significantly more affected by changing ZPERC than the events in March and April when the soil is wet.

Figure 7-8-18 illustrates how events can be affected in different ways when the percolation curve

is modified. In this case the two curves cross at a LZDEFR value of about 0.4. The maximum percolation rate is lower for the ZPERC=200, REXP=3.3 curve when the soil is wet, but greater when the soil is dry. This causes the model response to change as the soil becomes more saturated during the period shown. During the summer, the soil is quite dry, thus the ZPERC=30, REXP=1.5 curve produces much more storm runoff for the early July and mid September events. Right after the mid September event the LZDEFR value drops below 0.4, therefore the response of the remaining events is the opposite, i.e. the 30,1.5 curve produces the least amount of storm runoff. This example emphasizes why it is important to work with the entire percolation curve and to analyze the rate over a wide range of moisture conditions.

UZFWM

The primary function of the UZFWM parameter is to control when surface runoff occurs. Surface runoff can only occur when the intensity rate of the rainfall or rain+melt is sufficient to fill the upper zone free water storage. It is much easier to fill this storage when the percolation rate is low. This implies that surface runoff most frequently occurs under wet conditions and in regions where the soils have low permeability (baseflow amounts are low). Thus, the events to examine to determine if a change is needed to the value of UZFWM are those where surface runoff is already taking place with the current value of the parameter and those with large amounts of precipitation and near saturated soil conditions. Surface runoff can also occur for very high intensity events under dry conditions for watersheds with low permeability. The immediate response from these events is evaluated to determine whether more or less surface runoff is needed. The most important events to analyze are those that are just producing a little surface runoff and those that are currently not generating any, but the upper zone free water is close to being filled. An analysis of these events should suggest whether UZFWM should be increased or decreased. It should be noted that the UZFWC values shown on the ICP Sacramento display cannot always be used as an indication of how close an event was to producing surface runoff since the value shown is for the end of the day and free water contents can change quite rapidly for the upper zone.

Figures 7-8-19 and 7-8-20 illustrate how the model response is affected by changing the amount of surface runoff that is generated as the value of UZFWM is modified. The hydrograph plots on these two figures are exactly the same. The difference in the figures is the panel showing the runoff components. On Figure 7-8-19 the components are shown for the case when UZFWM=15. Figure 7-8-20 shows the components when UZFWM=30. When UZFWM=15 there are 4 events generating surface runoff. The first 3 produce quite a bit of surface runoff, while the early May event only generates a little. When UZFWM is changed to 30, the May event doesn't generate any surface runoff and the other events produce much less. As UZFWM is increased and surface runoff decreases, the amount of interflow increases since there is more room to storage potential interflow runoff in the upper zone free water. Thus an effect of altering UZFWM is to change the relative division of storm runoff into surface and interflow. When less surface runoff occurs as in the case of UZFWM=30, not only is the immediate response reduced, but the timing is also modified. When there is more interflow, the peak occurs later because surface runoff enters the channel immediately while interflow is released from storage over some period of time.

For regions with highly permeable soils and those that never experience high intensity precipitation, at least at the spatial and temporal scales being used, surface runoff will never occur. In these cases it is impossible to determine the value of UZFWM. If UZFWM can be reasonably determined for a couple watersheds in such regions, these values could be used throughout the region. If not, a value great enough to surpress surface runoff should be selected and spatial consistency should be maintained.

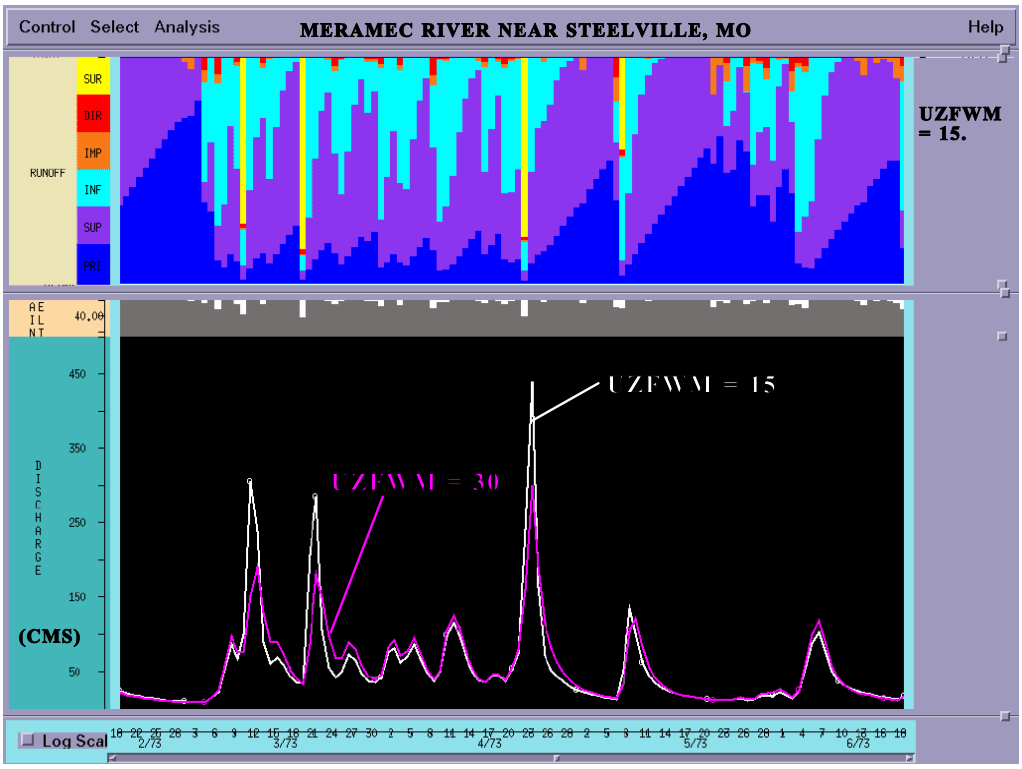


Figure 7-8-19. Effect of changing UZFWM on model response (UZFWM=15 components).

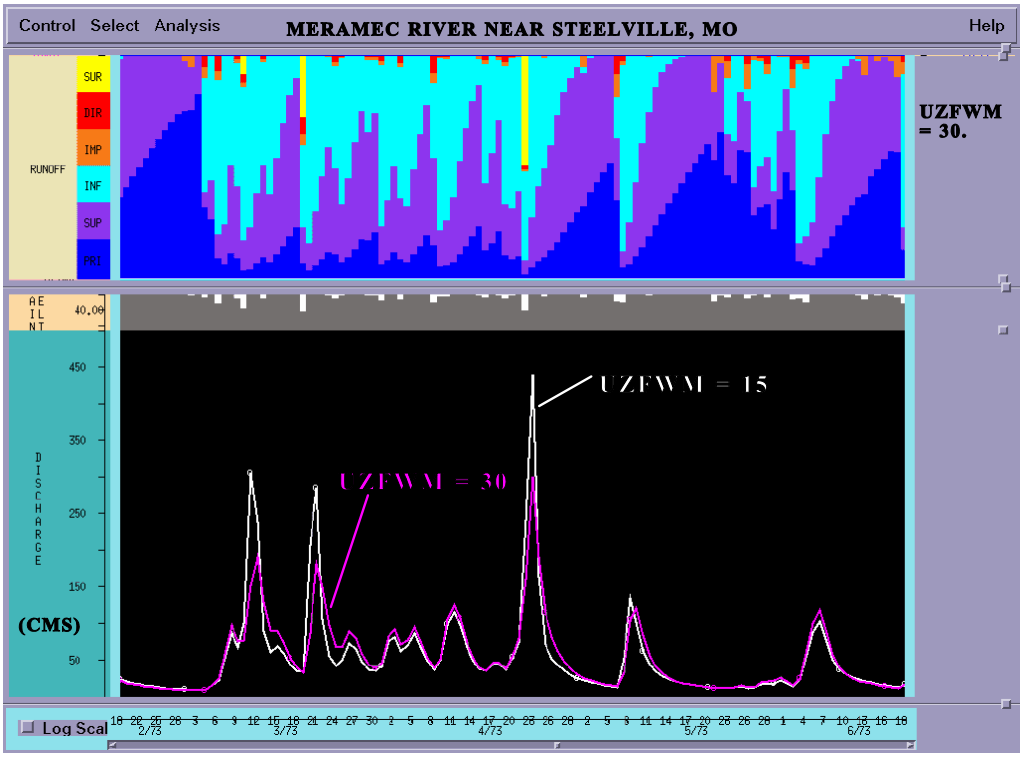


Figure 7-8-20. Effect of changing UZFWM on model response (UZFWM=30 components).

UZK

The primary function of the UZK parameter is to control the timing of interflow runoff. For mo st watersheds, interflow dominates small to moderate rises in the hydrograph. These are the ev ents to examine to determine if the value of UZK should be modified. For watersheds with hig hly permeable soils and little or no surface runoff, interflow will dominate the response from all storm events. In these cases the timing sometimes appears to vary with the magnitude of the ev ent, i.e. a greater UZK is indicated for large events than for small rises. Since only a single val ue can be used, it is generally best to try to match the response of the larger events when this situ ation occurs, though sometimes ADIMP can be used to produce a faster response from the larger events without affecting the smaller events very much.

Figure 7-8-21 illustrates the effect of changing UZK on model response. Changing UZK prima rily affects the smaller rises where interflow is basically the only source of storm runoff. When surface runoff is significant, modifying UZK doesn't have much affect on the response. It sho uld be noted that there is a large difference in the two UZK values used in this figure. This indi cates that UZK is not as sensitive as some of the other model parameters. The effect of small c hanges in the value of UZK may be difficult to see.

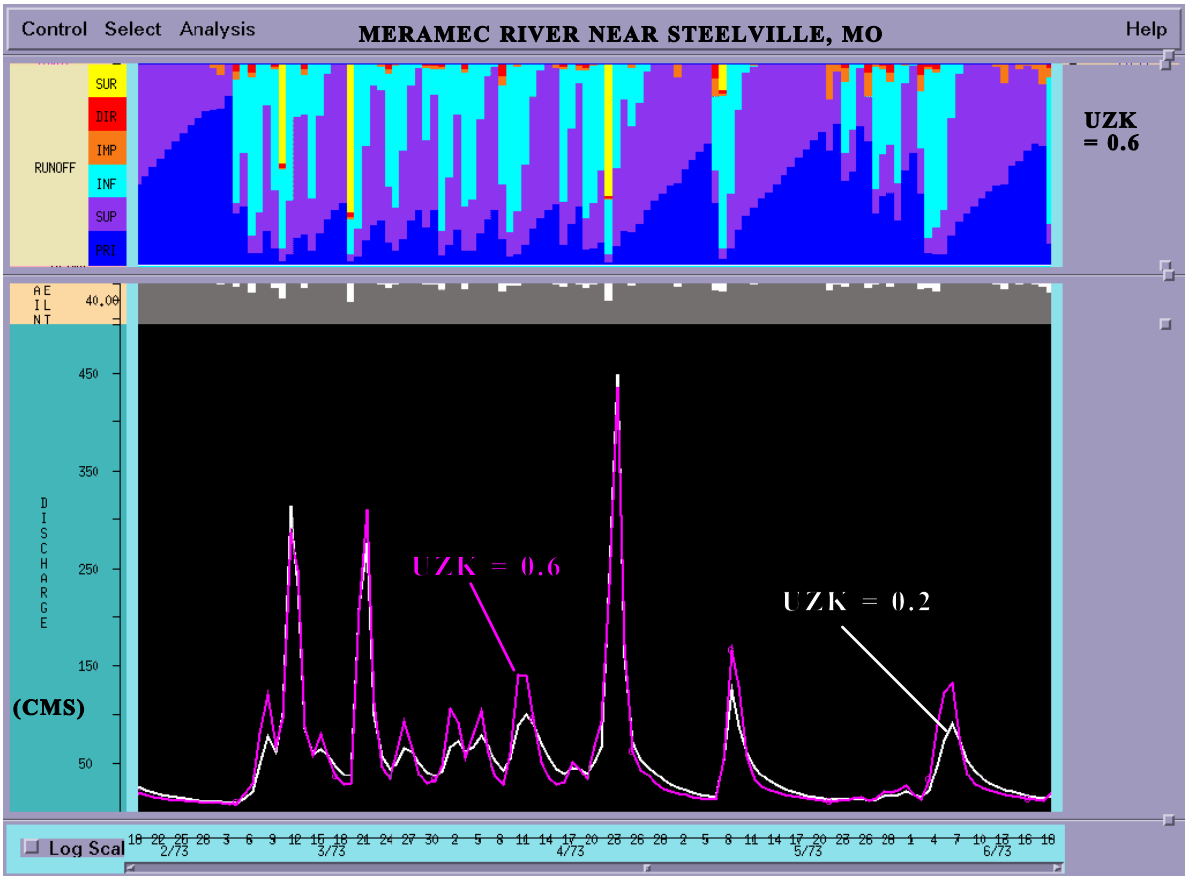


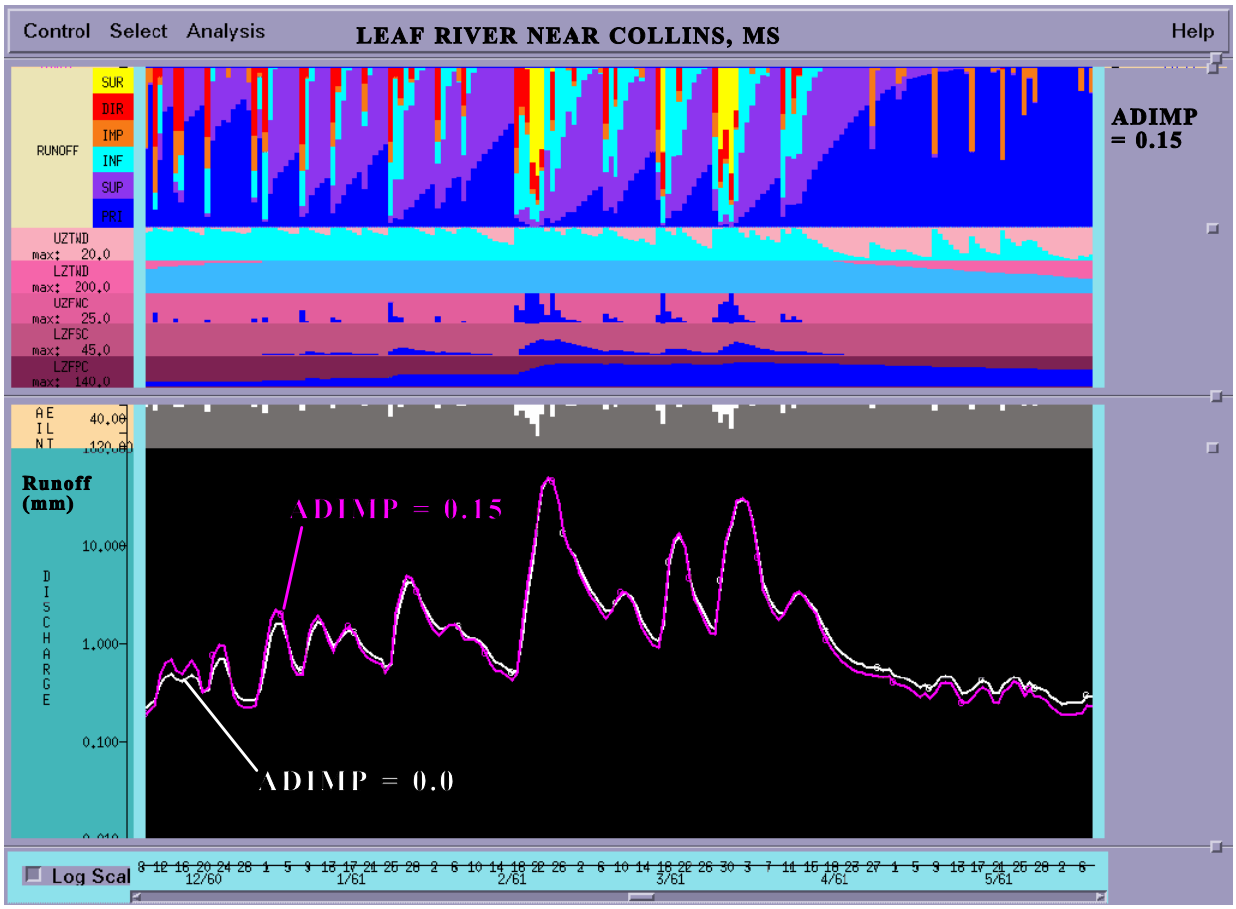
Figure 7-8-21. Effect of changing UZK on model response.

ADIMP

The primary function of the ADIMP parameter is to produce some immediate response runoff (direct runoff) in cases when precipitation intensities are relatively low or the soils are very permeable. These are events when interflow dominates and there is little or no surface runoff. This suggests that for watersheds where surface runoff occurs frequently ADIMP may not be needed and that ADIMP will have the most noticeable effect on watersheds where surface runoff seldom or never occurs. It should be remembered that direct runoff can only occur when upper zone tension water is full, i.e. during events that produce some storm runoff.

Figure 7-8-22 illustrates the effect of ADIMP on a watershed that generates surface runoff from most large rain events. For the large events where surface runoff predominates, adding direct runoff by using some ADIMP produces little difference in model response. For smaller events where there is no surface runoff, the use of ADIMP generates a more rapid response though the semi-log scale masks some of the effect. Figure 7-8-23 illustrates the effect of ADIMP on a watershed that seldom produces any surface runoff. In this case adding some direct runoff produces a more rapid response from all the storm events.

Figure 7-8-22. Effect of adding ADIMP on a watershed with periodic surface runoff.



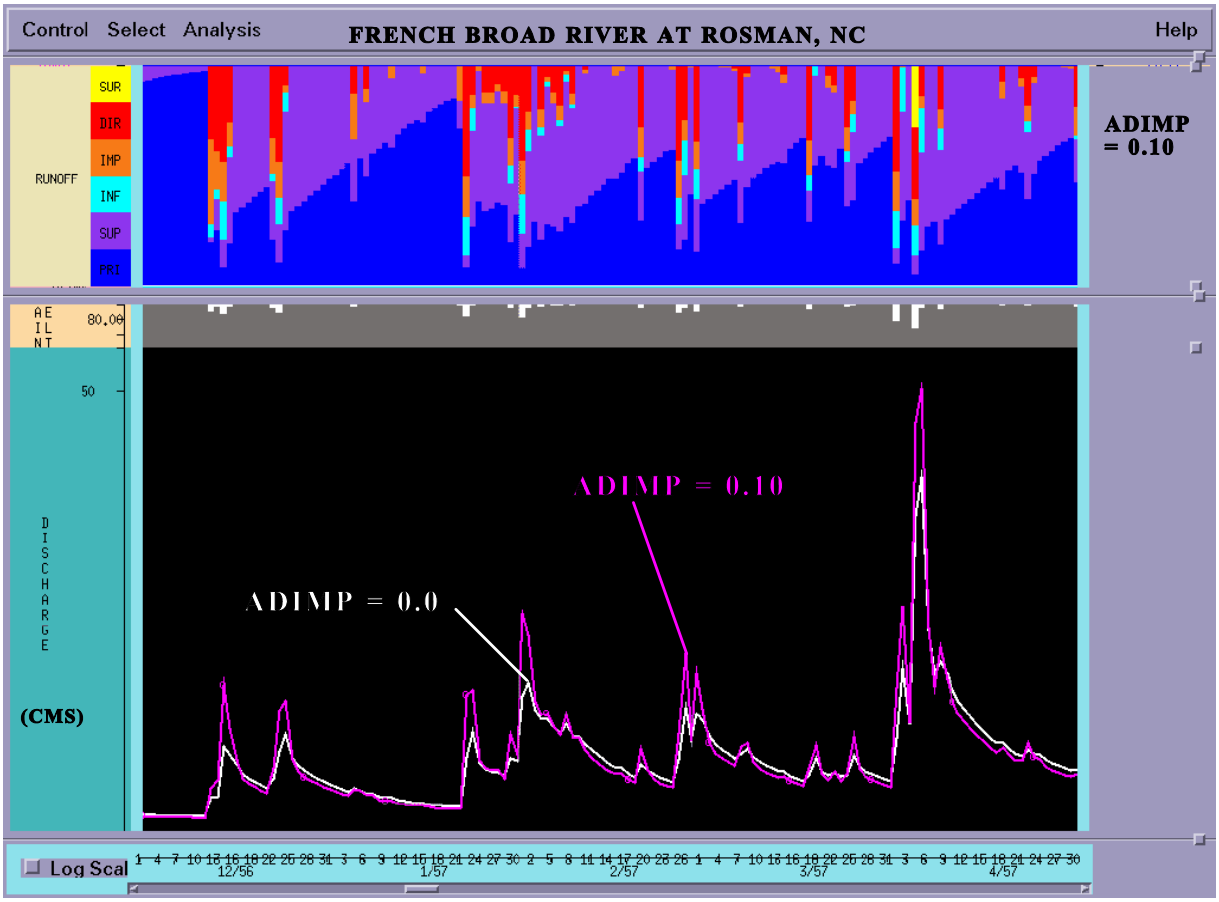


Figure 7-8-23. Effect of adding ADIMP for a watershed with little surface runoff.

As indicated in Section 7-5 it is best to start with ADIMP set to zero unless a value can easily be derived from a hydrograph analysis. Then during the calibration decide whether ADIMP is nee ded. There is no reason to add complexity to the model if it is not clearly needed.

RIVA

The primary function of the RIVA parameter is to draw down the baseflow during very dry perio ds when ET-Demand rates are significant. These are the periods when riparian vegetation does n't have adequate moisture near the surface to satisfy its needs so it withdraws water from groun dwater before it reaches the channel system. Thus, the periods to examine to determine if the v alue of RIVA needs to be changed are those when there is a substantial upper and lower zone ten sion water deficit during a time of the year when significant evaporation is occurring. Typicall y the most likely time for riparian vegetation evaporation to occur is in the later part of the summ er and early fall during a dry year. Figure 7-8-24 illustrates how adding RIVA will affect the m odel response during a dry period. In this case substantial tension water deficits exist from late May into October. The lower zone tension deficit doesn't fill until early January, but the ripari an vegetation effect is over by mid November primarily because of the reduction in the evaporati on rates and partly because of reduced upper zone tension water deficits.

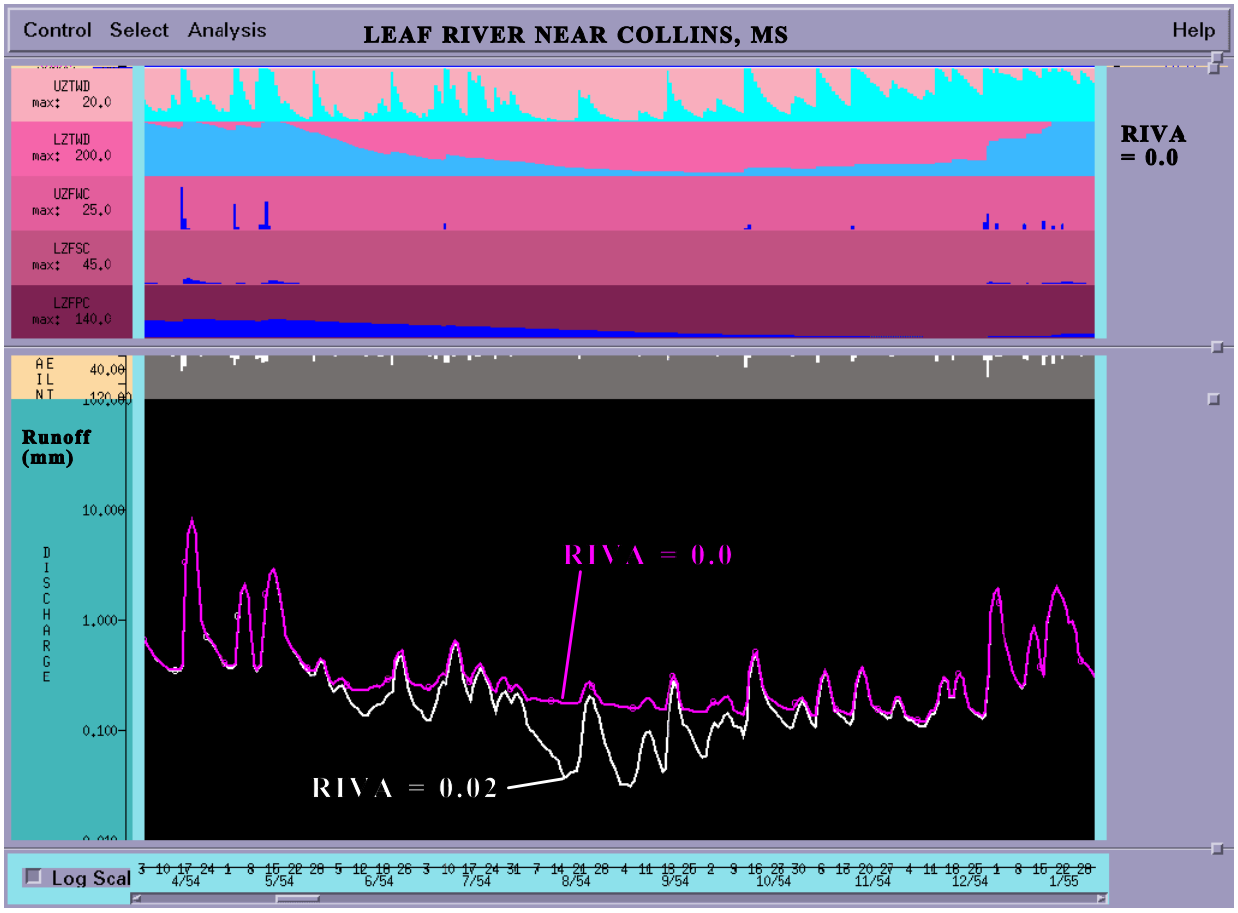


Figure 7-8-24. Effect of adding RIVA on model response.

PE Adjustment Curve

Changes to ET-Demand are indicated by a pattern in the seasonal, i.e. monthly, bias values on th e statistical summary. Since other processes can affect the seasonal bias, such as the division b etween storm runoff and baseflow, baseflow withdrawal rates, and snowmelt timing, one shouldn ’t look at possibly changing the ET-Demand until problems with these other processes have been corrected. Errors in ET-Demand could be the result of improper estimates of PE, but are most likely due to an erroneous estimate of the seasonal PE adjustment curve. Thus, it is best to chan ge the ET-Demand rate by modifying the PE adjustment curve. When using average monthly E T-Demand as input, the PE adjustment curve should be changed and then each months value mul tiplied by the average PE. This should insure that the shape of the PE adjustment curve remains physically realistic. Figure 7-8-25 illustrates how changes to the PE adjustment curve will aff ect the seasonal bias pattern. It should be noted that changes in the ET-Demand for a given mo nth may affect the bias in subsequent months since tension water deficits produced by evaporatio n don’t affect runoff until an event occurs.

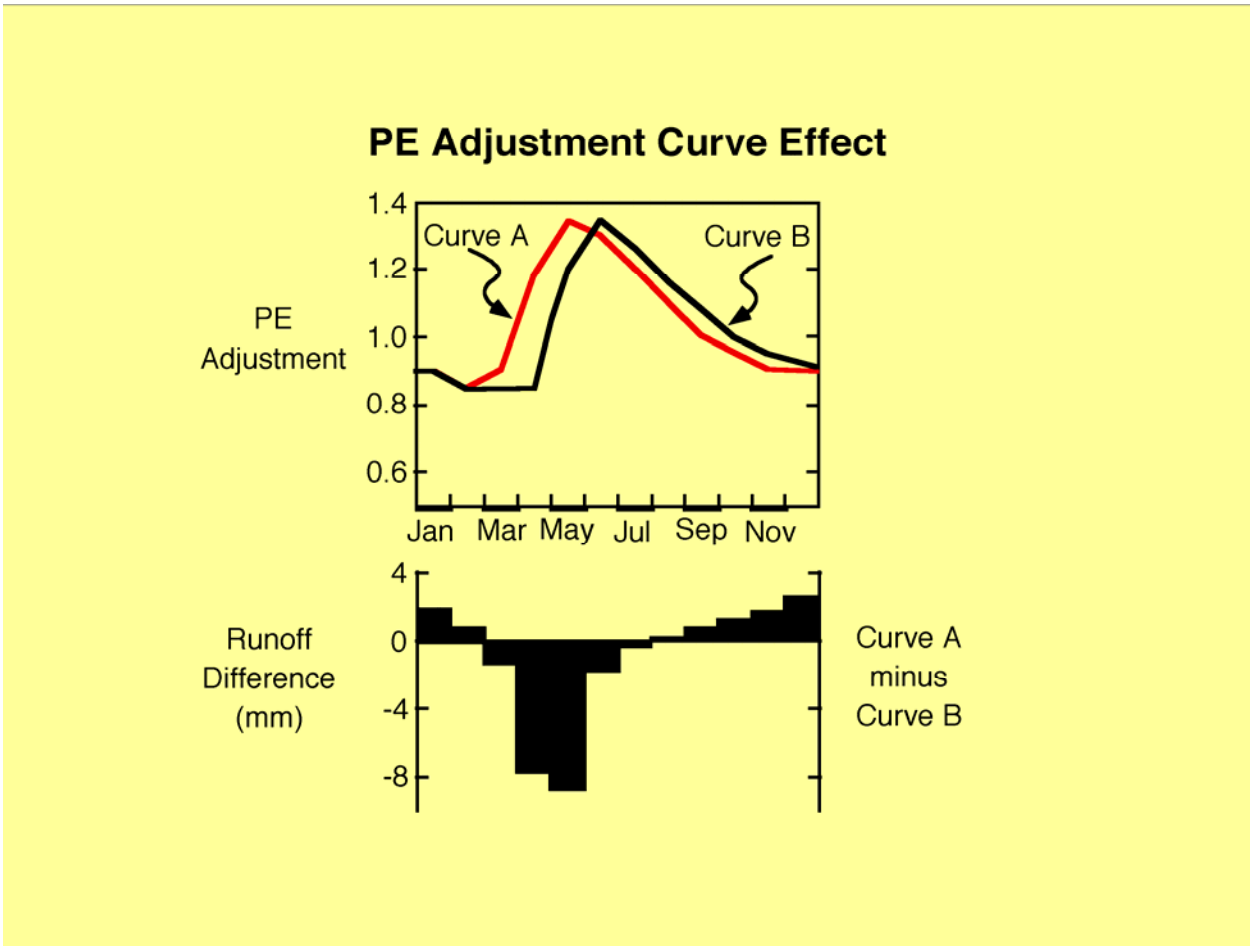


Figure 7-8-25. Effect of changing the PE adjustment curve on the seasonal bias pattern.

Parameter Effect Summary Table

Parameter	Primary Effect
LZPK	Controls slope of primary baseflow recession
LZSK	Controls timing of supplemental baseflow
LZFPM	Controls magnitude of primary baseflow
LZFSM	Controls magnitude of supplemental baseflow and percolation curve
PFREE	Controls baseflow recharge when lower zone tension deficit exists
SIDE	Determines if recharge to deep groundwater aquifers occurs
UZTWM	Controls maximum tension deficit that can occur in the upper zone (d etermines when storm and direct runoff and recharge will first occur after a dry period)
PCTIM	Controls the amount of fast response runoff when an upper zone tensi on deficit exists
LZTWM	Controls the maximum tension deficit that can occur in the lower zon e
Percolation Curve	Controls the division between storm runoff and baseflow • ZPERC determines percolation rate when soil is completely dry • REXP determines the shape of the percolation curve • LZFSM controls the saturated percolation rate
UZFWM	Controls when surface runoff occurs
UZK	Controls the timing of interflow
ADIMP	Determines whether direct runoff occurs from low intensity events w hen the soil is wet
RIVA	Determines whether evaporation from riparian vegetation occurs whe n the soil is dry and evaporation is significant
PE Adjustment Curve	Controls the seasonal ET-Demand pattern along with PE - effect refl ected in statistical seasonal bias pattern

Table 7-8-1. Summary of primary effect of each Sacramento model parameter.