RAINFALL AND PET
MANUAL CALIBRATION

• Description of EF5/CREST parameters
• Description of EF5/KW parameters
• Manual calibration strategies
• Distributed vs. lumped parameters
• Calibrate EF5 for Okavango River

AUTOMATIC CALIBRATION
INTERPRETING AND USING MODEL OUTPUT
What is calibration?

Calibration is the process of adjusting model parameters so that the model more accurately simulates stream flow (as compared to observed stream flow)

We adjust each parameter and see how the model evaluation indices (NSCE, CC, and bias) change

This can be a lengthy and complex process – there is no one right answer when it comes to calibration
EF5 Parameters

First, let’s review what we know about EF5’s parameters

There are a total of 13 of them
They’re divided into 2 categories
- The CREST parameters, which affect the water balance (how water is partitioned and accounted for in each cell)
- The kinematic wave parameters, which affect how water is routed from cell to cell

Some parameters affect the model results more than others

WM, B, ALPHA, BETA, and ALPHA0 are generally the most important, but others can be too
The CrestParamSet block contains the six water balance parameters:

- **WM**: Maximum soil water capacity
- **PB**: The exponent of the variable infiltration curve
- **IM**: Impervious area ratio
- **KE**: Conversion factor from PET to actual ET
- **FC**: Soil saturated hydraulic conductivity
- **IWU**: Initial value of soil water, a % of WM
WM is the maximum soil water capacity (depth integrated pore space) of the soil layer in the model, in millimeters

This is how much water the soil layer can store

Physically, this a function of several soil properties

If I increase WM, that means there’s more space in the soil for water, which means less runoff will be produced

WM will generally be between 5.0 and 250.0 mm
B is the exponent of the variable infiltration curve (VIC)

Remember the VIC governs how much water enters the soil layer and how much remains at the surface as runoff.

If I increase B, I tend to produce more runoff.

B can range between 0.1 and 20.0
IM is the impervious area ratio

You can think of this as the percentage area of your modeled domain covered in roofs, concrete, rocky soils and other impervious materials.

If I increase IM, my runoff increases.

IM can range from nearly 0 to 0.5

You generally do NOT want to calibrate IM, because it is fairly easy to observe from surveys or remote sensing.

So if you know 10% of a basin is covered in rocks or concrete, your IM should be about 0.10.
KE is the multiplier to convert between input PET and local actual ET

This is essentially an adjustment to the monthly global PET grid to make it more accurately reflect conditions over the modeled basin.

The PET forcing provided in this training course tends to be a little too “hot”

In other words, too much water gets evaporated when the original PET grid values are used.

KE can range from 0.001 (one one-thousandth of the PET grid) to 1.0 (the entire PET grid)

You can use values over 1.0, but this worsens the already “hot” tendency of the provided PET grids.
FC is the soil saturated hydraulic conductivity ($K_{\text{sat}}$) in mm/hr

This describes how easily water moves through saturated soil
The higher the value, the more easily water can travel through saturated soils
Higher values tend to decrease runoff
FC can be determined from soil properties and field measurements, which can help reduce the possible range of values in the calibration process

FC can range from 0.0 to 150.0
IWU is the initial value of soil water

It is a percentage of WM
If you have a long enough warm-up period in your simulation, the value of this parameter is unimportant
Even if you don’t have a warm up period, IWU can be safely estimated around 25.0
This is because the soil isn’t bone-dry (0.0) but it’s also a safe bet that it’s probably not totally saturated either
To summarize:

WM and B are important to the accuracy of the simulation, so focus your attention here when calibrating.

FC and IM can be measured or estimated for a basin via other means, so pick values for these and leave them alone.

IWU is not important if you use a warm-up period.

KE should generally be less than 1.0 when using the PET grids provided with this training.
The KWParamSet block contains the seven routing parameters in EF5:

- **TH**
  Number of grid cells needed to flow into a cell for it to be part of a channel

- **UNDER**
  The interflow flow speed multiplier

- **LEAKI**
  Amount of water leaked from interflow reservoir in each time step

- **ISU**
  Initial value of the interflow reservoir

- **ALPHA and BETA**
  Used in the equation $\text{Streamflow} = \alpha \times (\text{cross-sectional channel area})^\beta$

- **ALPHA0**
  The alpha value used for overland, not channel, routing
TH is the threshold for how many cells must drain into a cell for it to become part of a river in the model

- Determined from the FAC grid
- Dependent on resolution of the topographical files
- As the FAC resolution increases, the value of TH should also increase

If you convert from grid cells to actual area (in km$^2$), TH should be between 30 and 300 km$^2$
UNDER is the interflow flow speed multiplier

• Higher values of this mean water moves faster through the soil layer, which can result in faster peaks in a hydrograph

• This only affects the timing of the flood wave, not the volume of water making it into the river channel

This parameter can range between 0.0001 and 3.0
LEAKI is the amount of water leaking out of the interflow reservoir at each time step

- This is expressed as a percentage of the total water in the interflow reservoir
- The water that leaks out moves on to the next downstream cell’s interflow reservoir
- Increasing this parameter will result in faster peaks

This can range between 0.01 and 1.0
ISU is the initial value of the interflow reservoir

- If you use a warm-up period this parameter is unnecessary
- Setting this parameter to something other than zero will result in an unrealistic peak in the hydrograph at the very beginning of the simulation time

This parameter should usually be set to 0
ALPHA is the multiplier in the equation $Q = \alpha A^\beta$

This governs routing.

$Q$ is stream flow and $A$ is cross-sectional area of the stream channel.

For a constant $A$, $Q$, and $\beta$, increasing $\alpha$ slows down my flood wave (that is, the hydrograph peak is delayed).

ALPHA can vary between 0.01 and 3.0.
BETA is the exponent in the equation $Q = \alpha A^\beta$

For a constant $A$, $Q$, and $\text{ALPHA}$, as I increase $\text{BETA}$, my flood wave slows down.

$\text{BETA}$ can vary between 0.01 and 1.0.
ALPHA0 is the multiplier in the equation $Q = \alpha A^{0.6}$

This governs routing for overland cells.

It behaves the same as the channel ALPHA.

Note that in overland cells, the BETA value is set at 0.6; this value is found by solving Manning’s Equation.

ALPHA0 can vary between 0.01 and 5.0.
Routing Parameter Summary

In routing calibration, the ALPHA, BETA, and ALPHA0 parameters typically matter the most

- Keep ISU at zero and use a warm-up period
- Increase LEAKI and UNDER to speed up a flood wave
- Increase ALPHA, BETA, and ALPHA0 to slow it down
- Convert the 30-300 km\(^2\) to grid cells, based on your simulation’s resolution, and then try TH values in that range
So far we have only discussed “lumped parameters”

- With lumped parameters, the value of the parameters is the same over the *entire* model domain (that is, the entire river basin)
- But we know that soil properties, impervious area, channel cross-sectional area, and other properties of the land vary from place to place
- So EF5 contains the ability to use distributed parameter grids
- Think of these as a grid like a DEM, FDR, or FAC, but now instead of topographical information they contain the parameter values for every grid cell
Distributed Parameters

The advantage of this is it allows us to represent land variability

- The disadvantage is complexity

Parameter grids, when available, are stored in the params folder of a particular EF5 project

- Then regular lumped parameters can still be used, but would be interpreted by the model as multipliers applied to the distributed parameter grid

- So if FC were 0.3, the FC parameter grid would be multiplied by 0.3 at each location
To use distributed parameters, make sure the grid is of the exact same size, resolution, and extent as the topographical (DEM, FDR, FAC) files.

In `CrestParamSet` and `KWParamSet`, adding `_grid` to the end of each parameter name and then the file path to an `.asc` or `.tif` grid activates the gridded parameters.

- For example, `wm=150.0` might become this: `wm_grid=params\wm_namibia.tif`
- Then adding `wm=1.0` below would tell EF5 to use that exact grid with no multiplier (though you could scale the grid values up or down by specifying some other number than 1.0)
We have produced the necessary basic files and retrieved precipitation and PET forcing for the Okavango.

Let’s manually calibrate EF5 lumped parameters for this example and see if we can improve the results.
Open `control.txt` in `EF5_training/examples/okavango`.

We’ve successfully modified the Basic, PrecipForcing, PETForcing, Gauge, and Basin blocks in this control file.

Let’s tackle the parameter blocks and the Task and Execute blocks.
Let’s go ahead and keep the original Wang Chu parameters, since we’re going to be calibrating anyway.

But change the name of CrestParamSet to Okavango.

And kwparamset to Okavango.

Change the value of gauge in both blocks to Rundu.
In the task block,

- Change the name from RunWangchu to RunOkavango
- Change BASIN to Okavango
- Change PARAM_SET and ROUTING_PARAM_SET to Okavango
- Change TIMESTEP to 3h
- Our TIME_BEGIN should be 200701010300
- Delete TIME_WARMEND
- Set TIME_END to 200801010000

And change TASK to RunOkavango
Create a Batch File

Right-click in some blank space in your EF5_training/examples/okavango folder, and select “New” and “Text Document”

Name it RunEF5.txt

Open it and type

..\..\software\EF5.exe
Pause
Create a Batch File

Using the “File” menu, go to “Save As…” and then in the “Save as type:” dropdown box select “All Files (*.*)”

Save it as RunEF5.bat

Double-click RunEF5.bat
Visualize the Output

Load the model output into Microsoft Excel

This time, when you add a chart, you’ll need to use the “Select Data” button in the “Chart” and “Design” tabs of the Ribbon

Click “Hidden and Empty Cells” and select “Connect data points with line”
Visualize the Output

Then add “Legend Entries (Series)” one at a time, for discharge, observations, and precip.

In each, the first cell of the column (like B1) should be the “Series name:” and cells B2:B2920, for example, should be the “Series values”

Set the “Horizontal (Category) Axis Labels” to A2:A2920 and then click “OK”
Visualize the Output

Select the “Precip” series near the bottom of your new chart, right-click, and select “Format Data Series”

Plot it on the “Secondary Axis”
Visualize the Output

Invert the order of the values on the precipitation axis and increase the maximum to some larger value (20 seems to work well) so the precipitation moves out of the way of the discharge and observations.

Change the precipitation data series to a “Clustered Column” chart.

Change the colors of the time series, if you wish, along with the date labels on the horizontal axis.
Visualize the Output

Follow the instructions from Module 1.3 to determine the NSCE, CC, and bias of this hydrograph

IMPORTANT – only compare the observations without points of missing data (marked as “nan” in Excel)
To do this, bring up “Find and Replace” by using CTRL+F
Find “nan” and replace it with nothing
Then click “Replace All”
Visualize the Output

Start with CC

- Use CORREL and compare discharge (Column B, rows 2 to 2920) to observations (Column C, rows 2 to 2920)
- You should get something around 0.70
Next try bias

- Add all the simulation values together
  - Use this formula: \( =\text{SUMIF}(C2:C2920,\"\<\"\&\"\",B2:B290) \)
  - Instead of ENTER, press CTRL+SHIFT+ENTER after you type it
- Add all the observed values together (84,753)
- Subtract observed values from simulated values (195,695.5)
- Divide by the sum of the observed values (2.309)
- And multiply by 100 (231%)
Finally let's look at NSCE

- Take the average of Column C (232.2) and fill all of Column I with this same value
- Use SUMXMY2 with Column C as the first argument and Column B as the second (402,406,803)
- Now use SUMXMY2 with Column C as the first argument and Column I as the second (14,231,524)
- Divide the first SUMXMY2 by the second, and subtract from 1 (-27.28)
What does this tell us?

- Well, it’s no surprise the bias is very high (over 200%) given how much of an overestimate the red line in our hydrograph is.
- The NSCE is < 0 which means our model shows “no skill”.
- But the correlation coefficient isn’t terrible, which indicates, in a very general sense, that the timing of the hydrograph is okay.

Taking all this into account, parameters that affect the magnitude of the hydrograph (a.k.a the water balance or CREST parameters) are going to be important.

- Let’s start there.
I want to reduce the values in my simulation

- I know WM is a parameter that has some importance
- It can range from 5 to 250
- Let’s increase it so the soil holds more water and the stream flow is reduced – try 200.0 mm in your control file
- My bias decreased to 167% from its previous 231%
- My NSCE “improved” to -15.0 from -27.3
Calibration Strategy

Play around with B

- Change it from 13.204 to something smaller, like 0.5
- Now check your bias – I got 57%, so we’re getting better!
- My NSCE is now -3.15
Further adjust B and WM

- I’m going to further increase WM to 250.0, decrease B all the way to 0.2, and increase KE to 0.4
- All of these should continue to reduce the simulated values
- My simulation looks a little slow, so I’m going to decrease ALPHA and BETA to 1.5 and 0.5, respectively
We’re adjusting multiple parameters at a time just for fun, but a real strategy probably would take this more slowly and deliberately

- My bias is now -14%, so we got closer, but went too far
- My correlation coefficient is 0.73, which suggests the timing improved slightly from the original 0.70
- My NSCE is now 0.01 – finally positive! This a great sign, but we would have a long way to go still to get really good results
Calibration Strategy

Adjusting the vertical axis on our hydrograph to see things better…
Calibration Results

You start to see why a warm-up period is desirable.

We now do a bad job of identifying the peak magnitude, though the timing seems generally okay.

The lack of a warm-up period is also fairly obvious now, with the simulation results in the first half of January.

In general, we respond too quickly (and too much) to precipitation and then drain it away too quickly at the end of the event – we need slower routing and more infiltration.

Can you manually calibrate to a NSCE value of 0.10?
Manual calibration can be useful to get us into the right neighborhood of parameters.

We now have a much better idea of the general range of good parameters for this example.

That makes automatic calibration an easier and better process!
The next module is

Automatic Calibration

You can find it in your \EF5\training\presentations directory

Module 2.2 References

EF5 v0.2 Readme, (March 2015).
EF5 Training Doc 4 – EF5 Control File, (March 2015).
EF5 Training Doc 5 – EF5 Parameters, (March 2015).