RRAWFLOW: Rainfall-Response Aquifer and Watershed Flow Model—user's guide

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This document contains an explanation of model input and output for RRAWFLOW (Long, 2014). See the file 00_ReadMe.pdf in the main directory for instructions on running RRAWFLOW from the R command line and, alternatively, from the Microsoft® Windows command line.

1. Abbreviations and other notes

IRF:	Impulse-response function
L:	Length
L^3/t:	Volume per time

Cautions

- When editing input files in Microsoft® Excel with a "csv" extension name, make sure to save the file with adequate variable precision. Excel truncates precision in the text file in some cases, especially when formatted in scientific notation. These files can be checked or edited in any text editor, which also is the safest method for editing.
- The output files "rf_output.csv" and "rf_summary.csv" cannot be open in Excel when executing the R-version of RRAWFLOW.

All equations cited by number are described in Long (2014) along with detailed parameter descriptions. The following explanation contains a list of file names and variables with a description following the colon. All files must be present in the directory structure, but not all files are read by RRAWFLOW, depending on the options selected.

2. List of model input and output files

2.1 Input files

rf_input.csv:	Time-series input datasets.
rf_vars.csv:	Model parameters.
control_pts.csv:	IRF control points to which a curve will be fit (applies to IRFtype = 2 and 3).
rf_irf.csv:	User-defined nonparametric IRF. The number or rows should be equal to the number of rows in “rf_input.csv.” Zeros should be added to the end of the IRF to extent the record length.

2.2 Output files

rf_output.csv:	Model output time series.
rf_outut.txt:	Model output time series.
rf_summary.csv:	Metrics quantifying model calibration, model validation, and system memory.

3. Input file rf_input.csv

This file is read for all options

Year:	Year.
Month:	Month.
Day:	Day.
input:	Observed system input that is used as model input. Options are precipitation as a height of water [L], flow rate for sinking-stream recharge [L^3/t], or solute concentration [units vary].

response: Observed system response that is used for model calibration as a comparison to simulated response. Options are groundwater level [L], flow rate of stream or spring [L^3/t], or solute concentration [units vary]. The string "NaN" indicates missing data.

tempMean: Mean daily air temperature near the land surface.

decYear: Date, in fractional years.

WetDry: Indicates wet periods with a value of 1 and dry periods with a value of 0.

4. Input file rf_vars.csv

This file is read for all options. Some parameters are ignored, depending on the options selected. See Long (2014) for further description.

4.1 Model options

inputType: describes the system input

1 = System input is precipitation, resulting in recharge to the system.
2 = System input is recharge estimated outside of RRAWFLOW (skip equations 1–4). This includes sinking-stream recharge; e.g., for karst aquifers.
3 = System input is solute concentration (skip equations 1–4).

modelType: describes the system output

1 = System output is groundwater level (inputType = 1 or 2).
2 = System output is springflow or streamflow (inputType = 1 or 2).
3 = System output is solute concentration (inputType = 3).

IRFtype: the type of IRF

1 = Parametric IRF—gamma functions.
2 = Nonparametric IRF—spline fit to IRF control points (file "control_pts.csv").
3 = Nonparametric IRF—linear fit to IRF control points (file "control_pts.csv").
4 = Nonparametric IRF—user-defined IRF (file "rf_irf.csv").

timeVarMode: time-variance mode for convolution

1 = Time-invariant (static) IRF. This option uses the dry-period IRF for the entire simulation. Wet-period IRF parameters are ignored.
2 = Wet-period IRF and dry-period IRF are defined separately, and each are time invariant within these respective periods.

3 = Variable IRF vertical scale: β in equation 11 is variable. This option uses the dry-period IRF only because the wet period is not defined separately.

TempOpt: option to omit equation 2 if air-temperature data are not available. This applies only when inputType = 1.
1 = Use air-temperature adjustment.
2 = Do not use air-temperature adjustment. Air-temperature data are ignored.

valStart: the date in decimal years at the beginning of the conditional validation period. All observations prior are included in the calibration period. All subsequent observations are included in the conditional validation period. If using PEST (Doherty, 2005) for calibration, all observations listed that have a date after valStart should be assigned a weight of zero in the PEST control file. If a conditional validation period prior to the calibration period is desired, this can be specified by setting the validation-period observations to a weight of zero in the PEST control file. In this case, Ecal and Eval computed by RRAWFLOW should be ignored and computed outside of RRAWFLOW, or the script batch_R.r could be edited to compute the correct Ecal and Eval.

4.2 Model parameters

c1: Parameter c in equation 1 [L^{-1}]. For parameter estimation, set lower limit to ≥0.01.

alpha: Parameter α in equation 2, or κ in equation 1 if air-temperature adjustment is not used (TempOpt = 2) [unitless].

f: Air-temperature coefficient f in equation 2 [unitless].

sblfrct: Snow sublimation fraction S_f in equation 4 [unitless].

hshift: The datum h_0 at which hydraulic head equals zero used for modelType = 1 (units are the same as system-response units).

T_s: Air temperature threshold T_s (°C) that determines when precipitation occurs as snow.

T_m: Air temperature threshold T_m (°C) that determines when snow melts.

MAwindow: Window size to calculate a moving average of the system input x in equation 12; e.g., a window size of 365 days results in a 1-year moving average.

slope: The coefficient m in equation 12 (generally $m > 0$).

First gamma function for dry-period IRF (equations 7 and 10).

lamda1: Shape parameter λ
eta1: Shape parameter η
epsilon1: Scaling coefficient ε

Second gamma function for dry-period IRF (equations 7 and 10). Set these values to zero if not used.

lamda2: Shape parameter λ
eta2: Shape parameter η
epsilon2: Scaling coefficient ε

First gamma function for wet-period IRF (equations 7 and 10; used only if timeVarMode = 2). Set these values to zero if not used.

lamda3: Shape parameter λ
eta3: Shape parameter η
epsilon3: Scaling coefficient ε

Second gamma function for wet-period IRF (equations 7 and 10; used only if timeVarMode = 2). Set these values to zero if not used.

lamda4: Shape parameter λ
eta4: Shape parameter η
epsilon4: Scaling coefficient ε

Note: gamma functions are used when IRFtype = 1. The first and second gamma functions are superposed (added together). The second gamma functions are optional.

5. Input file control_pts.csv

This file is read when IRFtype = 2 or 3. The IRF must have values defined for a record length equal to that of the input record. A series of control points with values of zero should be defined after the end of the non-zero part of the IRF. These should be set at intervals small enough to allow the spline curve to have a zero value between control points. See example included with this documentation.

Dry-period IRF variables.

pdName: Variable names for IRF control points.
pdTime: Time-step indices for IRF control points.
pDry: Values of IRF control points (units are dependent on system input and output units).

Wet-period IRF variables (used only if timeVarMode = 2).

pwName: Variable names for IRF control points.

pwTime: Time-step indices for IRF control points.
pWet: Values of IRF control points (units are dependent on system input and output units).

6. Input file rf_irf.csv

This file is read when IRFtype = 4.

TimeStep: Time-step index.
hDryNP: Ordinates of the dry-period IRF.
hWetNP: Ordinates of the wet-period IRF (used only if timeVarMode = 2).

7. Output files rf_output.csv and rf_output.txt

decYear: Year in decimal format.
response: Simulated system response. This can be groundwater level, streamflow, springflow, or solute concentration, depending on the value of modelType.
hDry: Dry-period IRF. If IRFmode = 1 or 3, hDry is the only IRF used.
hWet: Wet-period IRF. If IRFmode = 1 or 3, hWet is not used.
s: Soil-moisture index.
conv_input: Input to convolution. This can be effective precipitation, infiltration recharge, sinking-stream rate, or solute concentration, depending on the values of inputType and modelType. For inputType = 2 or 3, conv_input is equal to the system input (variable "input") in the file rf_input.csv.
tDay: Time-step index.

8. Output file rf_summary.csv

Ecal: Coefficient of efficiency for calibration period E_{cal}.
Eval: Coefficient of efficiency for conditional validation period E_{val}.
memoryDry: System memory for the dry period [number of time steps].
memoryWet: System memory for the wet period [number of time steps].

See Long (2014) for further description of these model outputs.

9. References

Doherty, J.: Pest: Model-Independent Parameter Estimation. User Manual, fifth ed. Watermark Numerical Computing, variously paged, http://www.pesthomepage.org/, 2005.

Long, A. J.: RRAWFLOW: Rainfall-response aquifer and watershed flow model, Hydrology and Earth System Sciences, *in review,* 2014.