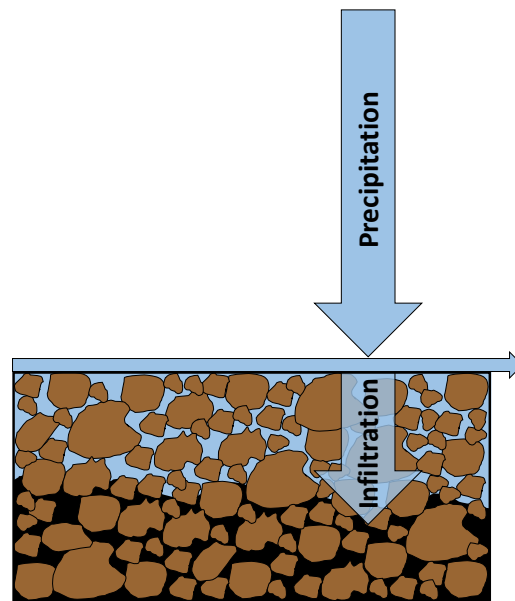




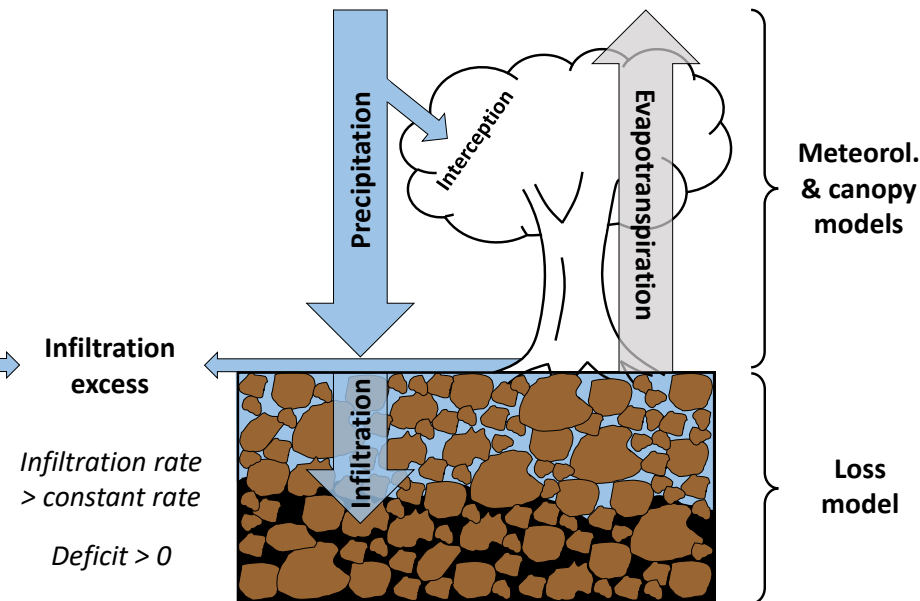
# SSCAFCA research program update

10/19/2023

Event-based simulation



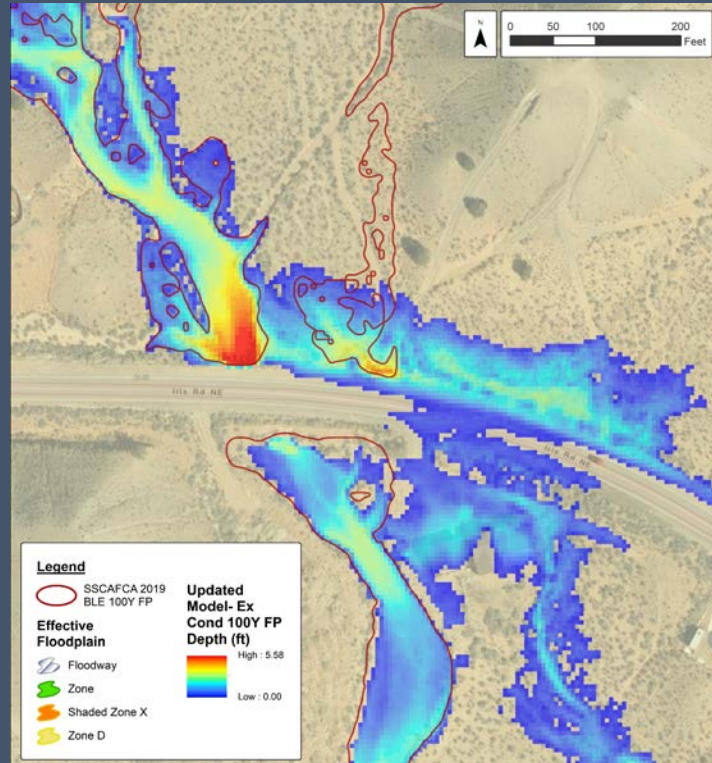
Continuous simulation





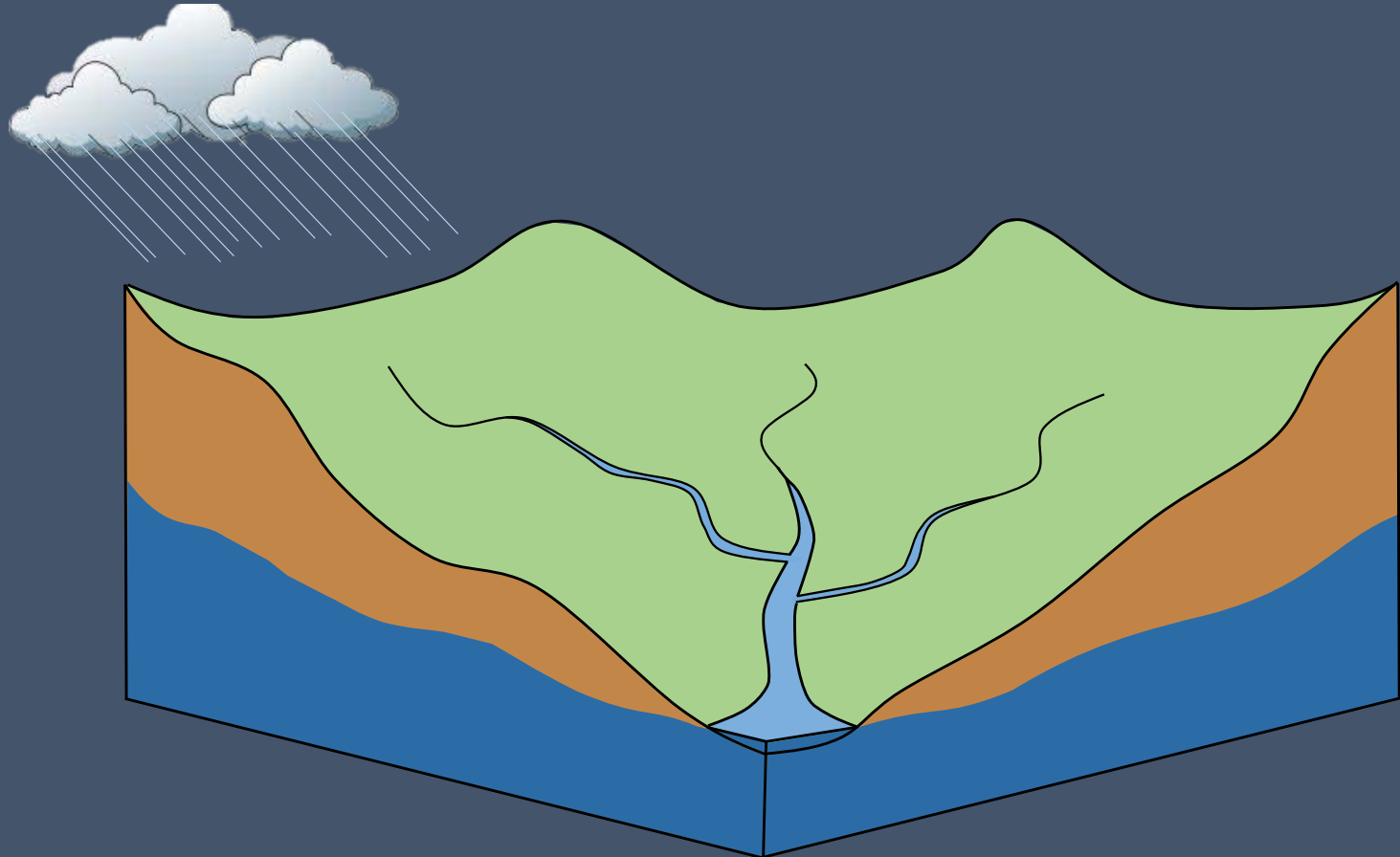
# SSCAFCA research focus:

- Improving hydrologic models
- Why do we need hydrologic models?

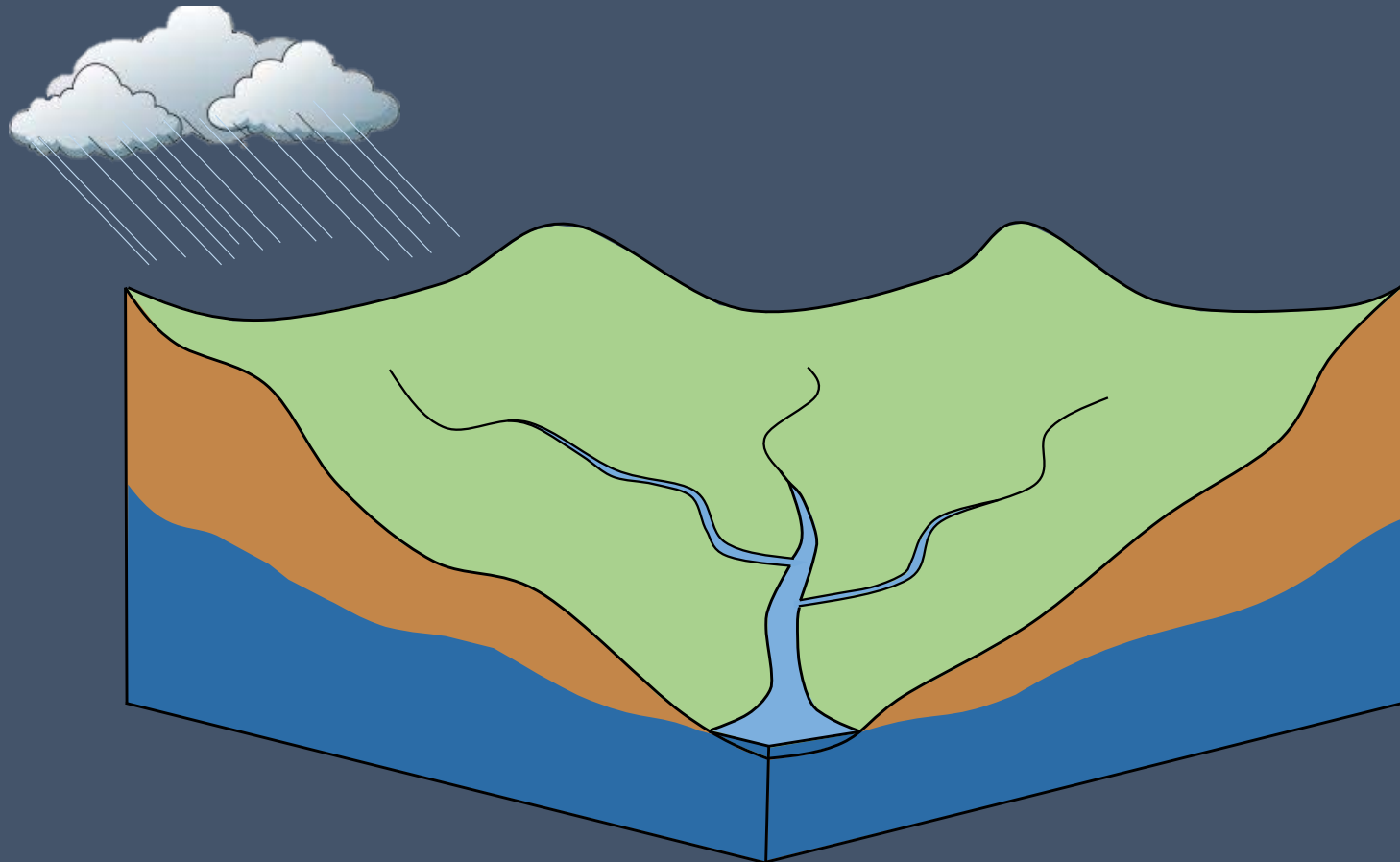
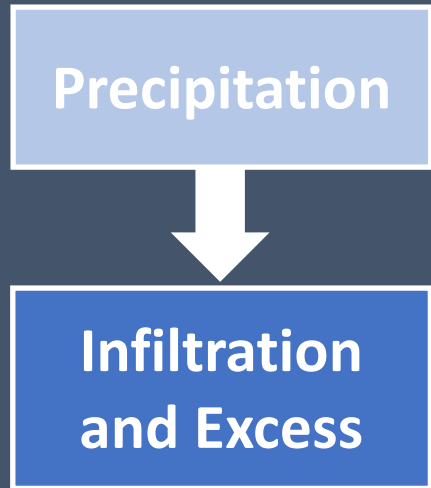


# Some background on hydrologic modeling

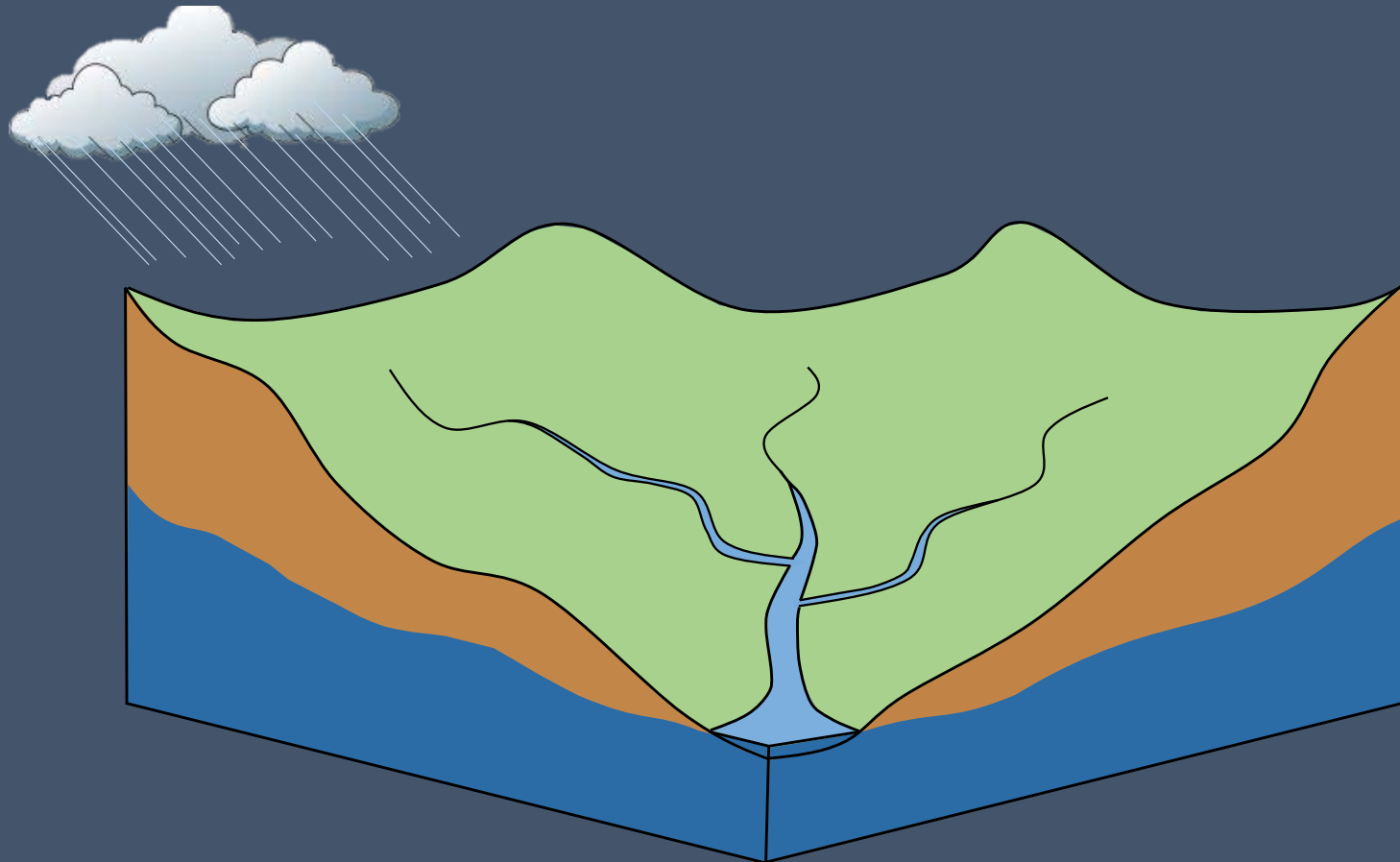
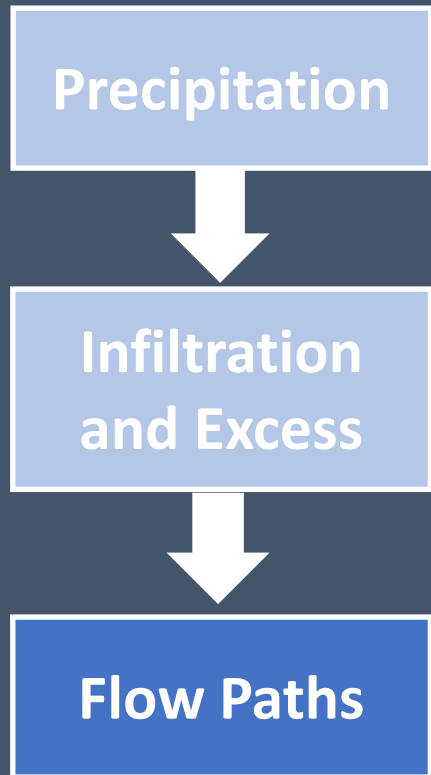
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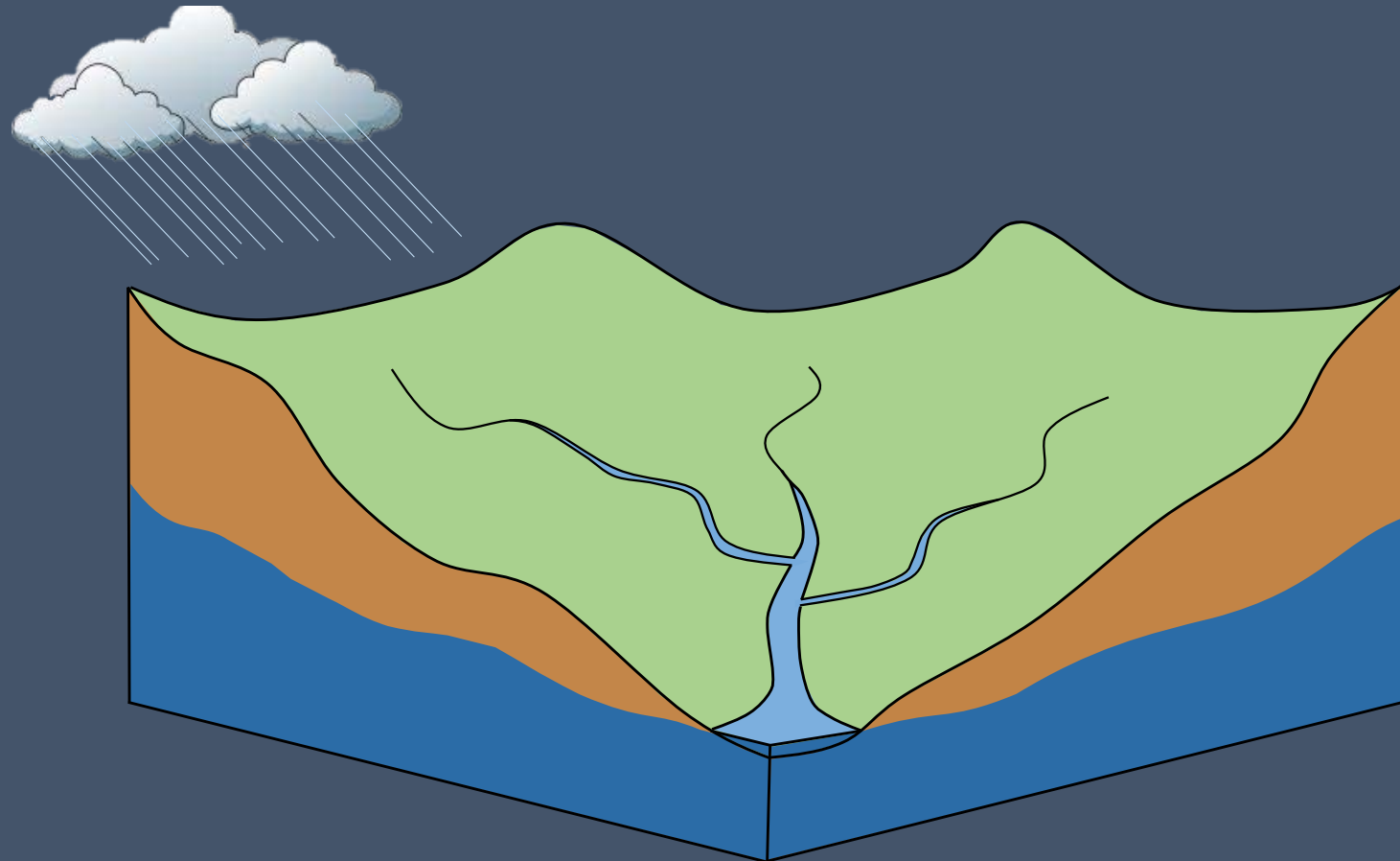
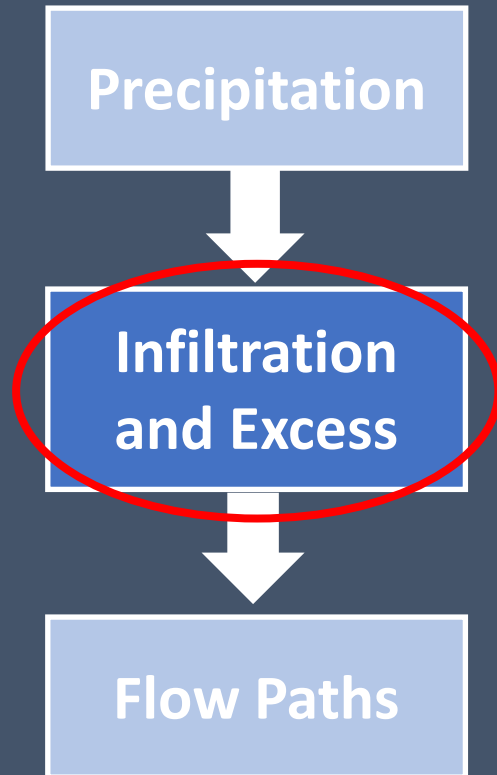
# Some background on hydrologic modeling



# Some background on hydrologic modeling

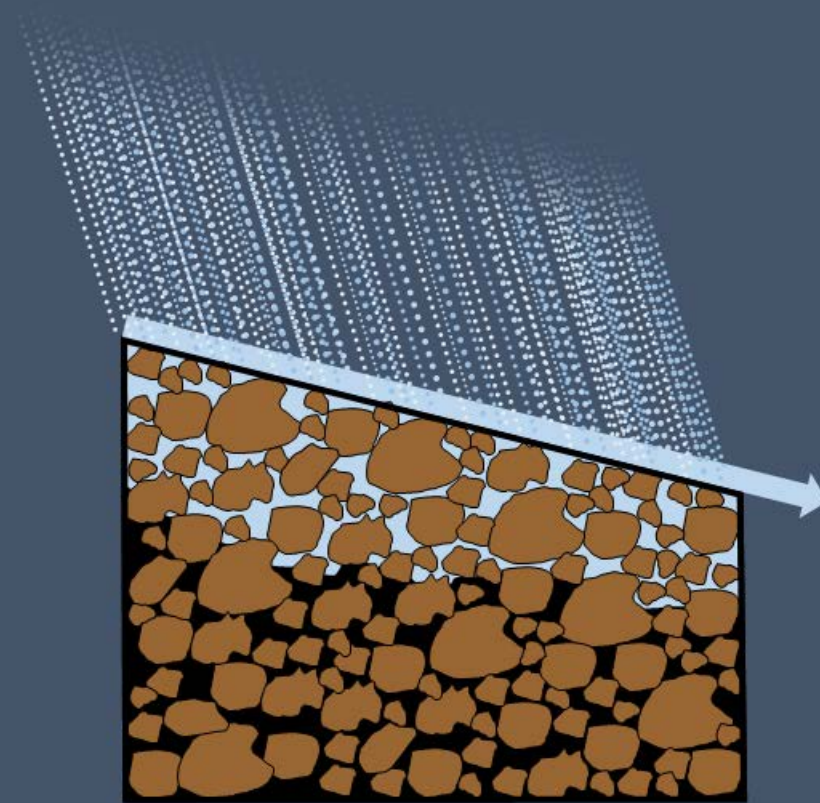
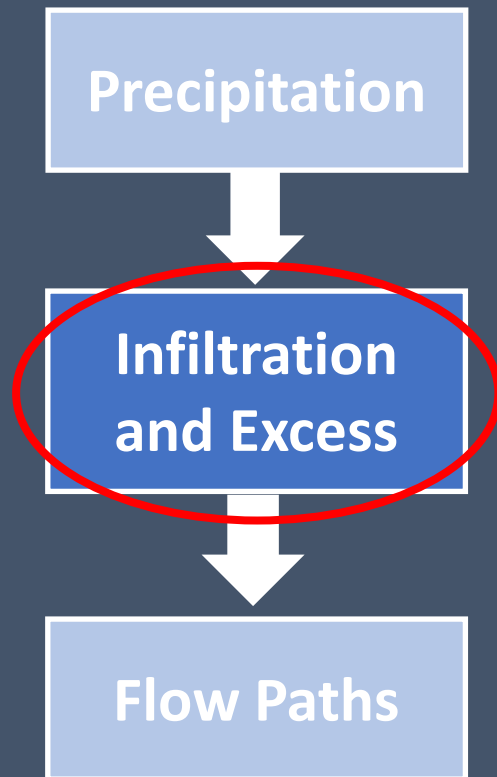


Our research currently focuses on the **infiltration and excess** component



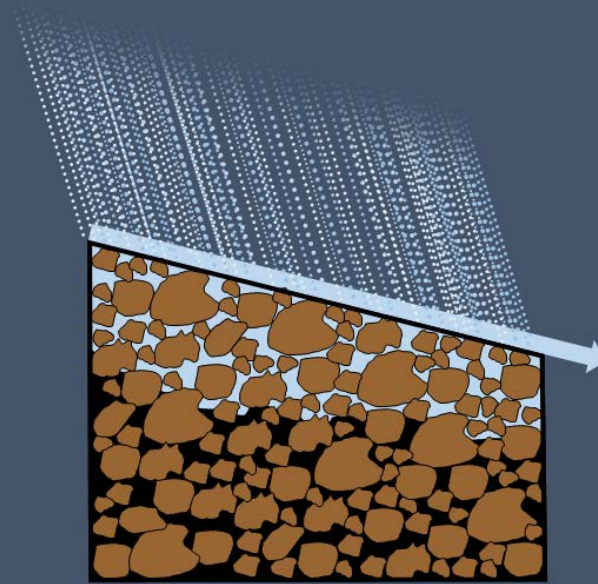


Our research currently focuses on the **infiltration and excess** component



# The problem

Theory



Practice



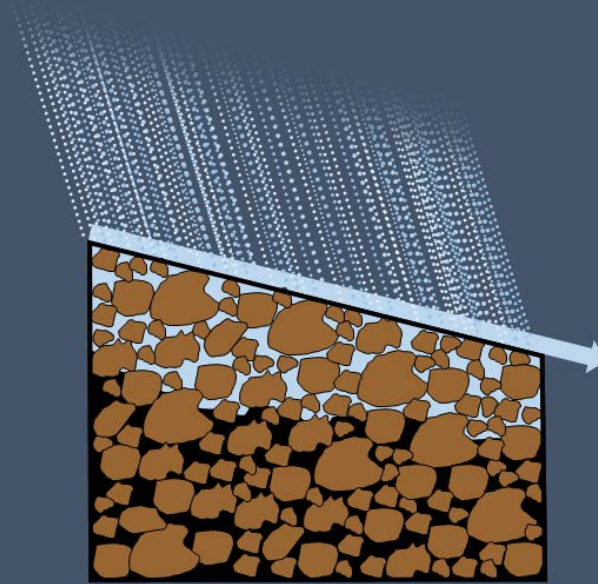


# The problem

## Theory



- Many methods
- Often complex
- Can be very accurate



## Practice

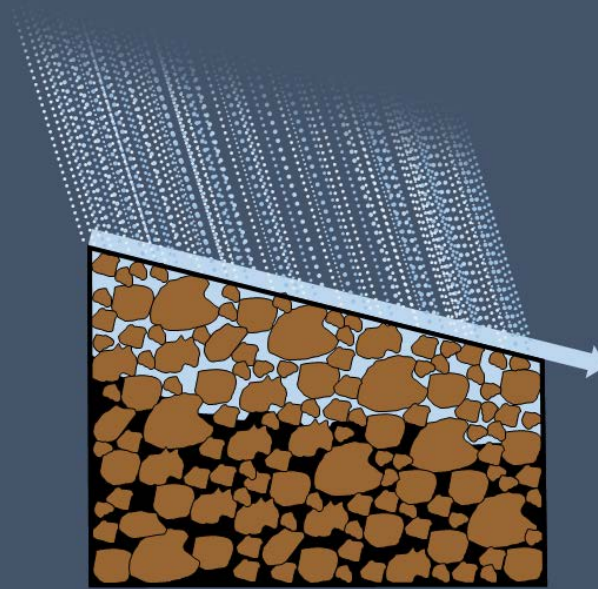


# The problem

## Theory



- Many methods
- Often complex
- Can be very accurate



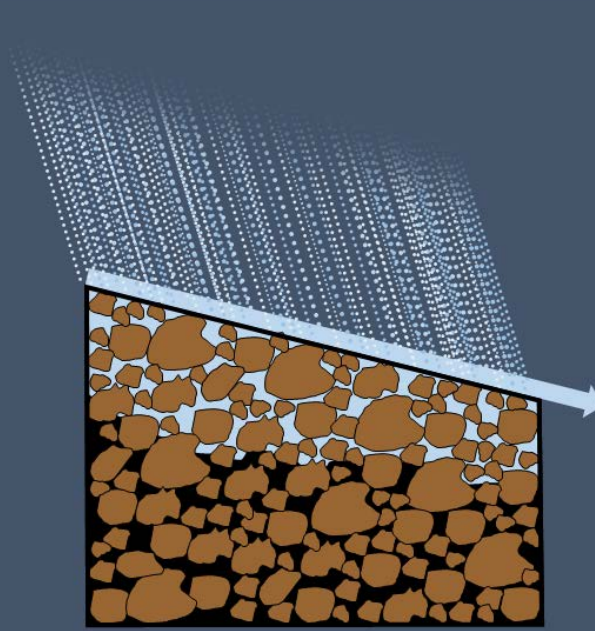
## Practice



- Limited data
- Limited time/resources
- Need for simple methods
- Can be less reliable



# Theory



# Practice



# US Army Corps of Engineers HEC-HMS Model

The screenshot displays the HEC-HMS software interface. On the left is a navigation menu with the following items: HEC-HMS, Features, Downloads, Documentation, Training Material, Known Issues, Bug Report, Suggestions, Email List, and Support Policy. The main window shows a 3D topographic map of the Truckee River basin with various junctions and elements labeled, such as 'Farad', 'Mammoth Dam', and 'TruckeeRv\_R60'. A graph titled 'Graph for Junction "Farad"' is overlaid on the map, showing flow in cubic feet per second (cfs) over time from late December 1996 to early January 1997. The graph shows a sharp peak in flow reaching approximately 14,000 cfs on January 1, 1997, followed by a gradual decline and stabilization around 7,000 cfs.

Navigation Menu:

- HEC-HMS
- Features
- Downloads
- Documentation
- Training Material
- Known Issues
- Bug Report
- Suggestions
- Email List
- Support Policy

Map Labels:

- BocaBridge
- TruckeeRv\_R70
- TruckeeRv\_S70
- Farad
- TruckeeRv\_R60
- TruckeeRv\_S10
- DogCreek
- TruckeeRv\_S60
- DogCk\_CF
- TruckeeRv\_R50
- TruckeeRv\_S50
- Mogul
- TruckeeRv\_R40
- TruckeeRv\_S40
- Reno
- ProsserCk\_R10
- Farad
- ManlyTubDam
- SpanishSprings
- TruckeeRv\_R10
- TruckeeRv\_S10
- SteamboatCk\_R20
- Steamboat
- WashoeLk\_CUT
- WashoeLk
- SteamboatCk\_S40
- LakeTahoe\_IN
- TruckeeRv\_R100
- MammothDam
- MammothCk\_IN
- MammothCk\_S10
- TruckeeRv\_R100
- TruckeeRv\_S100
- TruckeeRv\_R200
- TruckeeRv\_S200
- TruckeeRv\_R300
- TruckeeRv\_S300
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- TruckeeRv\_R500
- TruckeeRv\_S500
- TruckeeRv\_R600
- TruckeeRv\_S600
- TruckeeRv\_R700
- TruckeeRv\_S700
- TruckeeRv\_R800
- TruckeeRv\_S800
- TruckeeRv\_R900
- TruckeeRv\_S900

Graph Data:

Date	Flow (cfs)
27 Dec 1996	2,000
28 Dec 1996	2,000
29 Dec 1996	2,000
30 Dec 1996	2,000
31 Dec 1996	2,000
1 Jan 1997	14,000
2 Jan 1997	8,000
3 Jan 1997	7,000
4 Jan 1997	7,000
5 Jan 1997	7,000
6 Jan 1997	7,000
7 Jan 1997	7,000
8 Jan 1997	7,000
9 Jan 1997	7,000
10 Jan 1997	7,000
11 Jan 1997	7,000
12 Jan 1997	7,000
13 Jan 1997	7,000
14 Jan 1997	7,000



# Complex



# US Army Corps of Engineers HEC-HMS Model

A screenshot of the HEC-HMS software interface. The top navigation bar includes 'About', 'Newsletters', 'Software', 'Publications', 'Training', 'Visitors', 'Links', and 'Contact'. The main content area shows a project titled 'HEC-HMS 4.4' with a file explorer on the left listing various components like 'TruckeeRv\_R70', 'DogCk\_S10', etc. The central part of the screen displays a 3D topographic map of a river basin with a network of blue lines representing the river system. On the right, a window titled 'Graph for Junction "Farad"' shows a hydrograph with 'Flow(cfs)' on the y-axis (ranging from 0 to 16,000) and time on the x-axis (from Dec 1996 to Jan 1997). The graph shows a sharp peak in flow around January 1, 1997.

# Simple



## Green and Ampt

(4 parameters)

## Initial and Constant

(2 parameters)

## Curve Number

(1 parameter)

# Complex



**Green and  
Ampt**  
(4 parameters)

## US Army Corps of Engineers HEC-HMS Model

A screenshot of the HEC-HMS software interface. The top navigation bar includes 'About', 'Newsletters', 'Software', 'Publications', 'Training', 'Visitors', 'Links', and 'Contact'. The main content area shows a project tree on the left with elements like 'BocaBridge', 'TruckeeRv\_R70', etc. The central map displays a hydrologic model with various junctions and streams. A graph window titled 'Graph for Junction "Farad"' shows flow (cfs) over time from Dec 1996 to Jan 1997, with a peak flow of approximately 14,000 cfs.

**Linear and  
Constant**  
(2 parameters)

**Initial and  
Constant**  
(2 parameters)

# Simple



**Curve  
Number**  
(1 parameter)

# Project Timeline

Dec 2021: Idea presented to USACE

Aug 2022: Submitted proposal

Oct 2022: Proposal funded (\$ 50K)

Apr 2023: Preliminary version available

Oct 2023: Beta version of the software released



## Model:

<https://www.hec.usace.army.mil/software/hec-hms/downloads.aspx>

The screenshot shows the 'Downloads' page for HEC-HMS. The page has a dark navigation bar with a search icon and links for 'About', 'Newsletters', 'Software', 'Publications', 'Training', 'Visitors', 'Links', and 'Contact'. Below the navigation bar is the US Army Corps of Engineers logo and the text 'US Army Corps of Engineers Hydrologic Engineering Center'. A breadcrumb trail reads 'HOME > SOFTWARE > HEC-HMS > DOWNLOADS'. On the left is a vertical menu with items: 'HEC-HMS', 'HEC-HMS', 'Features', 'Downloads', 'Documentation', 'Training Material', 'Known Issues', 'Bug Report', 'Suggestions', 'Email List', and 'Support Policy'. The main content area has a heading 'HEC-HMS' followed by a paragraph: 'HEC-HMS has been developed for the U.S. Army Corps of Engineers. However, software developed at the Hydrologic Engineering Center is made available to the public whenever appropriate. Use is not restricted and individuals outside of the Corps of Engineers may use the program without charge. HEC will not provide user assistance or support for this software to non-Corps users. Downloading this software indicates full acceptance of your responsibility in the use of this program. Please see the [distribution policy](#) for more details.' Below this is a 'Windows' section with a blue header. The text in this section reads: 'The Windows setup package contains HEC-HMS 4.11. After starting the program, Documentation and Sample projects are available from the Help menu. HEC-HMS 4.11 has been tested on Windows 10 64-Bit.' Underneath, there are three download options: 'Beta Version:' with a link 'Download HEC-HMS 4.12 Beta 1 (238 MB) [Release Notes]' circled in red; 'Current Version (Primary Download Site):' with two links: 'Download HEC-HMS 4.11 for Windows (207 MB) [Release Notes]' and 'Download HEC-HMS 4.11 Portable Version (243 MB) [Release Notes]'; and 'Archived Versions:' with a right-pointing chevron.

**HEC-HMS**

HEC-HMS

Features

Downloads

Documentation

Training Material

Known Issues

Bug Report

Suggestions

Email List

Support Policy

HEC-HMS has been developed for the U.S. Army Corps of Engineers. However, software developed at the Hydrologic Engineering Center is made available to the public whenever appropriate. Use is not restricted and individuals outside of the Corps of Engineers may use the program without charge. HEC will not provide user assistance or support for this software to non-Corps users. Downloading this software indicates full acceptance of your responsibility in the use of this program. Please see the [distribution policy](#) for more details.

### Windows

The Windows setup package contains HEC-HMS 4.11. After starting the program, Documentation and Sample projects are available from the Help menu. HEC-HMS 4.11 has been tested on Windows 10 64-Bit.

**Beta Version:**  
[Download HEC-HMS 4.12 Beta 1 \(238 MB\) \[Release Notes\]](#)

**Current Version (Primary Download Site):**  
[Download HEC-HMS 4.11 for Windows \(207 MB\) \[Release Notes\]](#)  
[Download HEC-HMS 4.11 Portable Version \(243 MB\) \[Release Notes\]](#)

> **Archived Versions:**



# Documentation:

<https://www.hec.usace.army.mil/confluence/hmsdocs/hmstrm/infiltration-and-runoff-volume/linear-deficit-and-constant-model>

## Linear Deficit and Constant Loss Method

### Basic Concepts and Equations

The linear deficit and constant loss method (LC method) is a modification of the initial and constant method (see Schoener et.al, 2021):

$$f_t = \begin{cases} m F_t + f_0 & \text{if } F_t < F_c \\ K_{eff} & \text{if } F_t \geq F_c \end{cases} \quad (f_0 \geq K_{eff})$$

Where  $f_t$  (mm/hr or in/hr) is the potential infiltration rate at time  $t$ ,  $F_t$  (mm or in) is the cumulative infiltration at time  $t$ ,  $F_c$  (mm or in) is the initial deficit,  $m$  (1/hr) is the infiltration rate decay factor with respect to cumulative infiltration, and  $K_{eff}$  (mm/hr or in/hr) is the constant infiltration rate or effective hydraulic conductivity.

### Infiltration

The LC model lets the potential infiltration rate  $f$  start at an initial value  $f_0$  (mm/hr or in/hr) and decrease linearly as a function of cumulative infiltration until reaching a constant rate  $K_{eff}$  when cumulative infiltration is equal to initial deficit  $F_c$ . Due to the linear relationship, only  $m$  and  $F_c$  need to be defined in addition to  $K_{eff}$ . Compared to other simple loss methods such as the initial and constant or curve number model, the LC method has the advantage that it does not use an initial abstraction term and will simulate runoff from the start of a rainfall event if precipitation intensity for a given time step exceeds potential infiltration rate.

### Event-Based Simulation

The LC model accounts for a single, hypothetical soil layer, hereafter referred to as the *active soil layer*. The soil layer has a maximum capacity to hold water. Figure 1 below shows a conceptual representation of the linear deficit and constant loss method when the active soil layer is not completely saturated, i.e., the layer contains less water than the maximum storage capacity. The deficit, measured in mm or in, is the amount of water required at any point in time to bring the active layer to saturation. During event-based simulation (Figure 1, left), water will infiltrate into the soil at a rate determined by the initial deficit, decay factor, and cumulative infiltration since the onset of the storm. If at any point in time the precipitation rate exceeds the potential infiltration rate, the difference (infiltration excess) will become runoff. If the precipitation rate at a given time is equal to or less than the potential infiltration rate, all rainfall infiltrates into the soil.

### Continuous Simulation

The LC method also allows for continuous simulation (see Figure 1, right) when used in combination with a canopy method that allows extraction of water from the soil due to evapotranspiration. Continuous simulation requires the specification of another loss parameter, the maximum deficit. This value can be interpreted as the porosity multiplied by the thickness of the active layer and is measured in millimeters or inches.

For continuous simulation, the modeler must select a canopy method (under subbasin elements) and specify an evapotranspiration (ET) method (under meteorologic models). ET removes water from the active soil layer between and, depending on user setting, during storm events. The potential

evapotranspiration rate is taken from the meteorologic model, where a variety of methods are available for representing that process. The ET rate is used as specified by the meteorologic model without any modification. There is no further evapotranspiration after the water in the soil layer is reduced to zero. ET will start again as soon as water is present in the soil layer. Unless a canopy and ET method are selected, no soil water extraction will occur. The canopy method also allows the modeler to simulate interception, the portion of precipitation intercepted by vegetation that never reaches the ground.

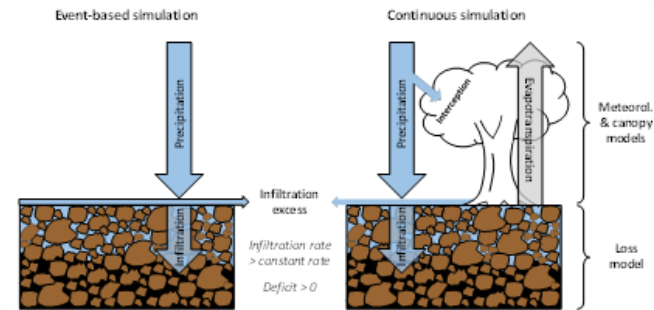


Figure 1: Conceptual representation of the linear deficit and constant loss method for event-based simulation (left) and continuous simulation (right) when the active soil layer has a deficit greater than zero.

### Percolation

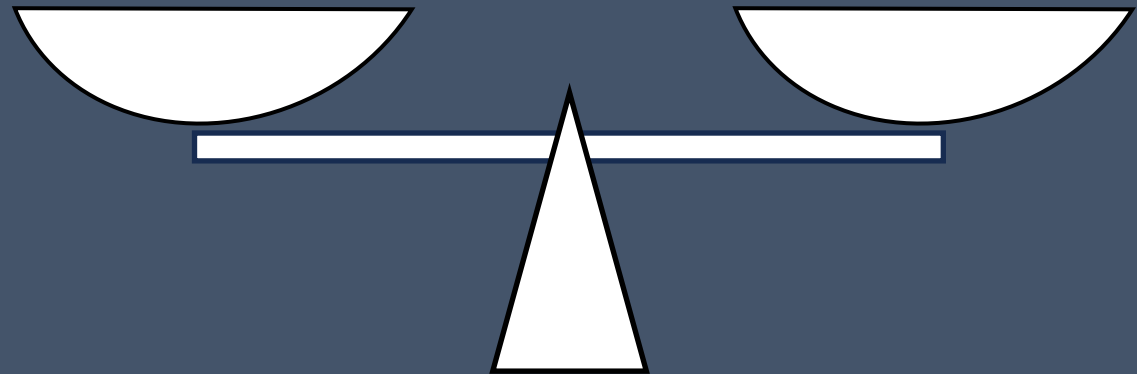
Once the active layer has saturated (the deficit is equal to zero), the potential infiltration rate becomes equal to the constant rate. Water will percolate out of the bottom of the active soil layer at a rate equal to the actual infiltration rate (see Figure 2). Percolation water is lost from the system. Percolation will continue as long as the soil layer is at maximum storage capacity, and precipitation continues. The linear deficit and constant method should therefore not be used for systems where:

- The water table is close to the surface, and the vadose zone could saturate completely during the analysis period; or
- An impermeable layer is present at a depth sufficiently shallow that a perched aquifer could form during the analysis period.

In both cases, there would be no percolation once the active layer is saturated, and all additional precipitation would become runoff.

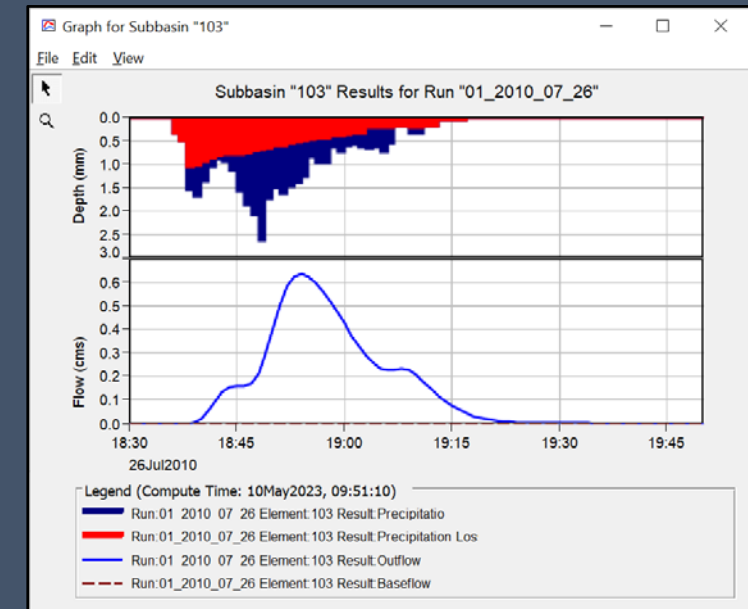
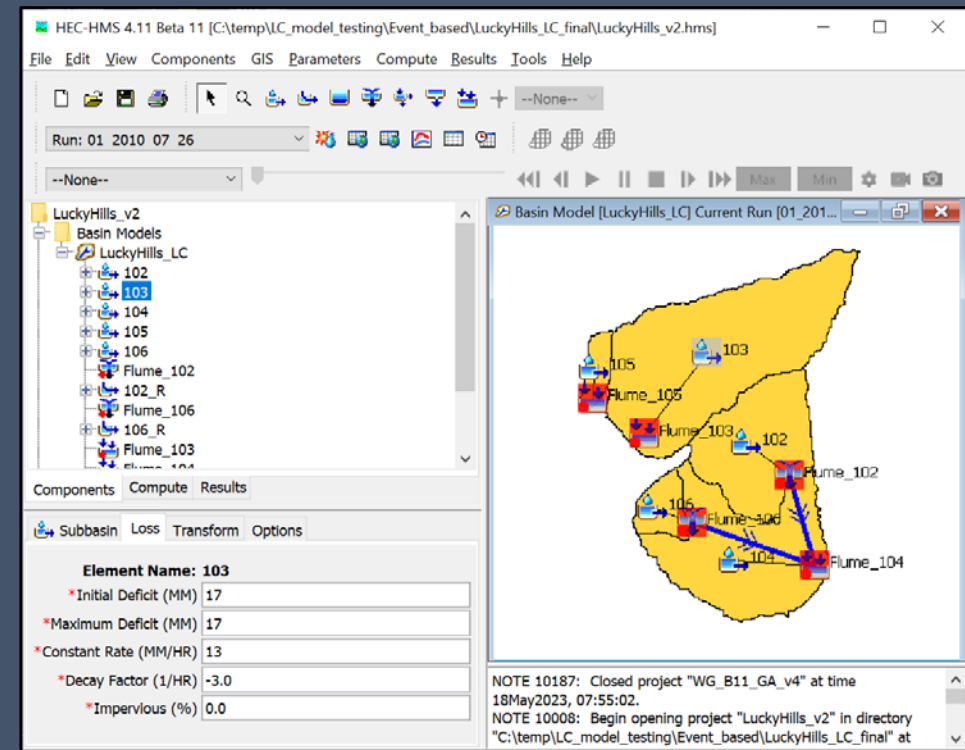
# Project Goals

- Improved model performance
- Balance between complexity and practicability
- Balance between accuracy and simplicity



# What's next:

- Evaluate model performance (Sara's Masters Thesis)
- Test model in SSCAFCA watershed (Calabacillas)



Theory



SSCAFCA



Practice

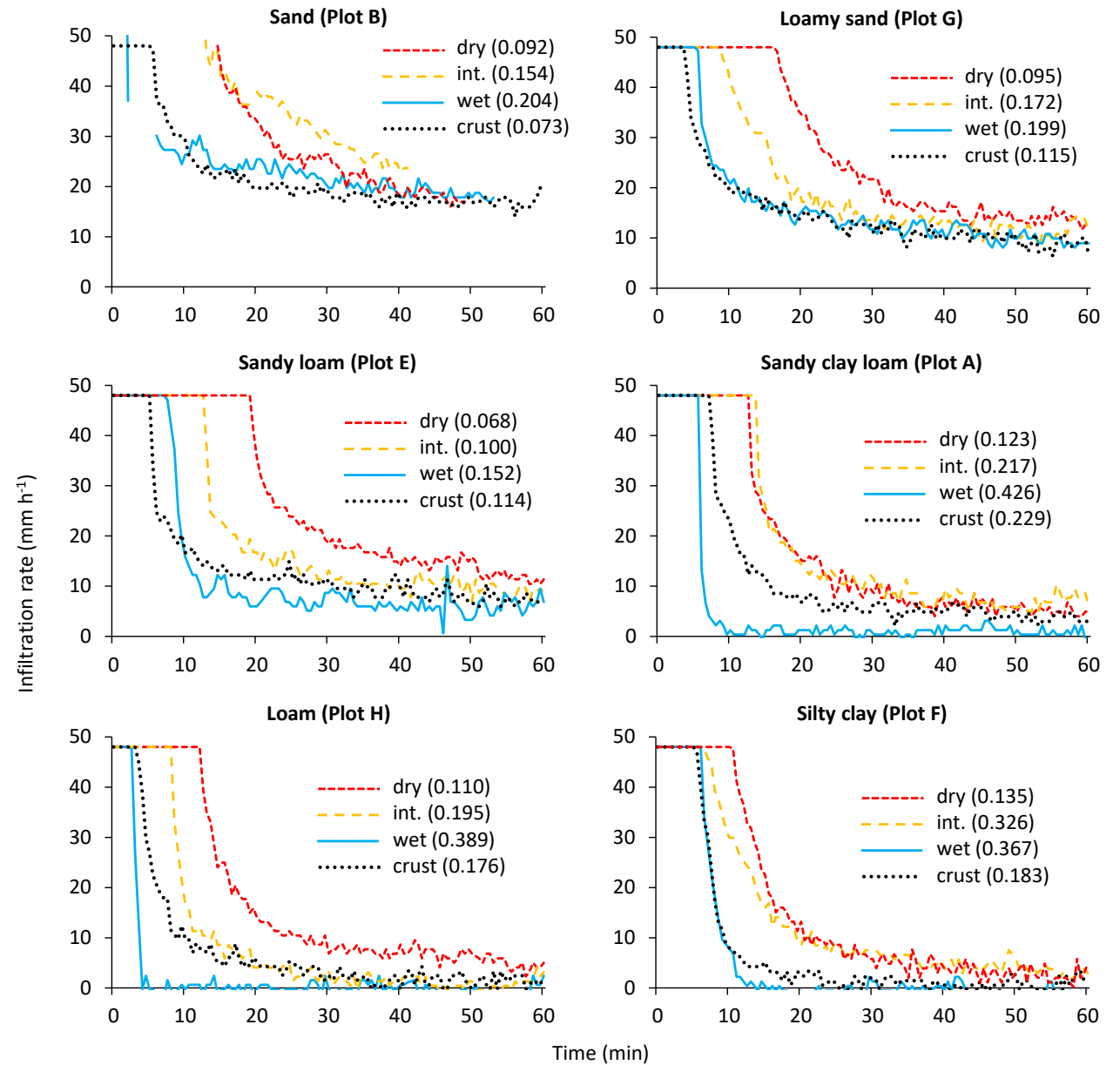




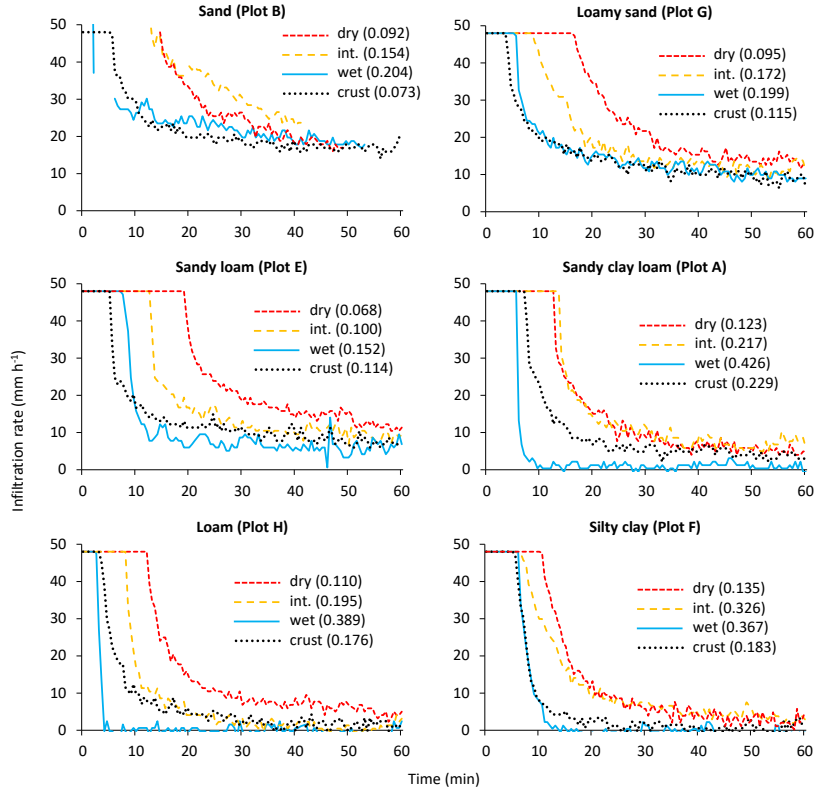
One more update:



# One more update:



# One more update:



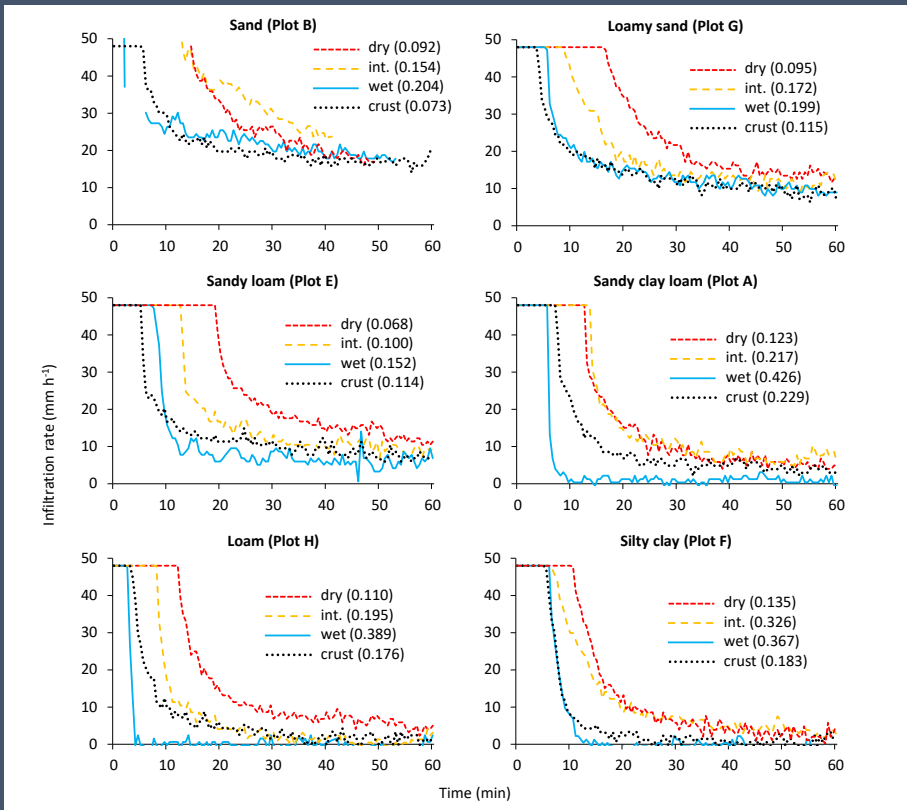
**Table 2.** Proposed infiltration model parameter values for sand, loamy sand, and sandy loam for varying antecedent soil moisture conditions

Antecedent soil moisture (m <sup>3</sup> m <sup>-3</sup> )	Parameters for sand, loamy sand, and sandy loam		
	$I_a$ (mm)	$F_c$ (mm)	$\psi$ (mm)
0.02	30 (23–45)	48 (36–72)	133 (84–183)
0.06	21 (15–36)	36 (23–66)	104 (55–155)
0.10	13 (6–28)	23 (10–54)	76 (27–126)
0.14	4 (0–19)	10 (0–41)	47 (0–98)
0.18	0 (0–11)	0 (0–28)	19 (0–69)
0.22 (or presence of physical soil crust)	0 (0–2)	0 (0–16)	0 (0–41)

Note: Values were calculated using the median slope and intercept (first and third quartiles in parentheses) from linear regressions.



# One more update:



**Table 2.** Proposed infiltration model parameter values for sand, loamy sand, and sandy loam for varying antecedent soil moisture conditions



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Note: Values were calculated using the median slope and intercept (first and third quartiles in parentheses) from linear regressions.



# One more update:

Technical Note

## Infiltration Model Parameters from Rainfall Simulation for Sandy Soils

Gerhard Schoener, Ph.D., A.M.ASCE<sup>1</sup>; Sara Rassa<sup>2</sup>; Matthew Fleming, P.E.<sup>3</sup>; David Gatterman, P.E.<sup>4</sup>; and Jacob Montoya<sup>5</sup>

**Abstract:** Flash flooding is among the most hazardous natural events in the US and globally. Hydrologic simulations are key tools for flash flood forecasting, particularly in poorly gauged or ungauged catchments, and infiltration models are a crucial component of any hydrologic simulation. Ideally, model parameters are calibrated based on observations. In practice, calibration and validation are often not possible due to a lack of observations. This paper contributes new guidance for parameter estimation of three infiltration models using plot-scale rainfall simulation. All three models, namely, initial-constant (IC), linear-constant (LC), and the Green-Ampt (GA) models, will be available in the next release of the widely used Hydrologic Engineering Center-Hydrologic Modeling System software. Results show that model parameters are sensitive to soil texture, antecedent moisture conditions, and the presence of a physical soil crust. **DOI:** 10.1061/JHYEFF.HEENG-6025. © 2023 American Society of Civil Engineers.

**Author keywords:** Rainfall simulation; Infiltration model parameterization; Initial-constant (IC); Linear-constant (LC); Green-Ampt (GA).

### Introduction

Flash floods are among the most hazardous natural events (Hapuarachchi et al. 2011) in the US and around the world (Alipour et al. 2020), particularly in arid and semiarid areas (Wang and Vivoni 2022). The risk of flash flooding has increased in recent years due to climate change and rapid urbanization (Ding et al. 2021). Hydrological models are key tools for flash flood forecasting, particularly in poorly gauged or ungauged watersheds (Hapuarachchi et al. 2011). Infiltration models are a crucial component of any hydrologic simulation. Due to the flashy and episodic nature of runoff in dryland basins, event-based models are commonly used (Huang et al. 2016). Numerous event-based infiltration models of varying complexity have been developed over the last decades (Mishra et al. 2003).

Ideally, model parameters are calibrated based on observations. In reality, model calibration and validation using measured rainfall-runoff data are often not possible due to a lack of observations. This is particularly true for arid and semiarid regions where flows are episodic and gauge data are rare (Schoener 2018; Mengistu et al. 2019). Without observations for model calibration, published

guidance is often the only source of information available to practicing hydrologists for estimating infiltration model parameters. Depending on the infiltration model, the availability of published guidance for parameter estimation varies widely. Moreover, existing guidance is often based on laboratory tests (Rawls et al. 1983; Saxton and Rawls 2006) and does not account for surface effects such as raindrop impact (Bhardwaj and Singh 1992), soil crusting (Casenave and Valentin 1992), or the effect of variations in rainfall intensity on runoff generation (Martínez-Mena et al. 1998).

Several researchers have employed rainfall simulation to quantify the effects of soil surface processes on the infiltration and runoff response (Dunkerley 2012; Ziadat and Tameh 2013). Risse et al. (1994) showed that hydraulic conductivities measured under simulated rainfall were more representative of field conditions than those obtained from laboratory tests. Data from the semiarid southwestern US showed that infiltration models can be parameterized successfully using plot-scale data collected with a rainfall simulator (Schoener et al. 2021). The present study builds on those findings. Based on 79 individual rainfall simulator tests, it contributes valuable new guidance that—in the absence of rainfall-runoff data—can be used to estimate infiltration model parameters for sandy soils. The main objectives of this study are to (1) assess the impact of soil texture, antecedent soil moisture, and surface crusting on infiltration and runoff at the plot scale, and (2) develop parameter guidance for three infiltration models available in the widely used Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model software.

### Infiltration Models



The HEC-HMS hydrologic modeling software developed by the US Army Corps of Engineers is widely used in the US and around the world (Joo et al. 2014). In this study, we optimize parameters for three infiltration models: two are currently available in HEC-HMS (Green-Ampt model and initial-constant model). A third, the linear-constant model, is being added to HEC-HMS by the Hydrologic Engineering Center and will be available in version 4.12. Models are briefly described as follows.

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J. Hydrol. Eng., 2024, 29(1): 06023001

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