Comparison of Curve Number Calibration Methods

Langston Hughes II[1] , Glenn Moglen[2]

[1]Charles Herbert Flowers High School; [2]USDA-ARS--Hydrology and Remote Sensing Laboratory (HRSL)

INTRODUCTION/ABSTRACT

The Natural Resources Conservation Service curve number equation (Eq.1) estimates runoff volume based on precipitation depth and watershed-averaged storage, and an initial abstraction ratio, λ. This study compares two methods used to calibrate the storage parameter in this equation under varying values of λ. The primary purpose of this study is to examine the role of λ on the "goodness-of-fit" between model estimates and actual observations. The two methods used are 1) **least-squares**, and 2) **median method**. This study uses an Agricultural Research Service rainfall-runoff database (USDA 2019) of approximately 12,700 individual storm events drawn from 31 watersheds in 11 locations across the United States.

METHODS

Identify the 31 watershed files being used for observation. The 31 watersheds are in 11 locations across the United States and are provided by USDA. Each file contains hundreds of rainfall-runoff events (specific numbers appear in Table 1 below). With every event in the files there is a date, total precipitation depth measurement, and total runoff depth measurement.

Site/ Location	Watershed Area (ha)	Period of Record	Years	Number of Observations
Safford, AZ(1)	210	1939-1969	31	110
Safford, AZ(2)	276	1940-1969	30	104
Safford, AZ(3)	309	1939-1969	31	90
Tifton, GA(1)	33,400	1971-1980	10	297
Tifton, GA(2)	1,570	1970-1980	11	441
Tifton, GA(3)	1,590	1968-1980	13	552
Reynolds, ID(1)	23,400	1963-1981	19	785
Reynolds, ID(2)	3,180	1968-1981	14	492
Monticello, IL(1)	33.2	1949-1981	33	222
Monticello, IL(2)	18.4	1949-1981	33	344
Treynor, IA(1)	60.7	1964-1986	23	602
Treynor, IA(2)	43.3	1964-1986	23	866
Treynor, IA(3)	33.5	1964-1986	23	762
Hastings, NE(1)	195	1940-1962	23	293
Hastings, NE(2)	166	1939-1967	29	332
Hastings, NE(3)	844	1938-1967	30	293
Hastings, NE(4)	1,410	1939-1967	29	303
Albuquerque, NM(1)	99.6	1939-1969	31	175

Table 1. Research watersheds used in this study.

Least-Squares Method (Numerical Optimization Program)

The relevant equation is provided by the Natural Resources Conservation Service (NRCS) rainfall-runoff equation(Mockus 1949; SCS 1975) shown below:

$$Q = \frac{(P-\lambda S)^2}{P+(1-\lambda)S} \quad \text{if } P > \lambda S \qquad (1)$$

Q is runoff (in inches), P is precipitation (in inches) and S is storage (in inches). P is the 24-hour rainfall depth. Curve number (CN) and S are related by Eq.2.

$$CN = \frac{1{,}000}{s + 10} \qquad (2)$$

Use a Numerical Optimization program to explore the rainfall-runoff S values. This program finds a storage(S) value that allows for the smallest "Z" as calculated in Eq.3.

$$Z = \sum_{i=1}^{n} \left(Q_{obs,i} - Q_i\right)^2 \qquad (3)$$

$Q_{obs,i}$ is the observed runoff from precipitation event, i, and Q_i are the modeled runoff for this same event.

Vary λ values (0.05 and 0.2) to assess differences in the goodness-of-fit with changing λ.

METHODS (Continued)

Median Curve Number Method (NEH Program)

Use a root-finding algorithm that reads as input a watershed file along with additional input parameters (rainfall threshold, λ value), and returns a median Curve Number value across all the rainfall-runoff observations where P exceeds the rainfall threshold in that watershed by solving for each individual storage(S) in Eq.1(Rallison and Cronshey 1979; SCS 1985).

Repeat for all watershed events while changing λ values(0.05 and 0.20)

Calculate S_e/S_y for both calibration methods and values of λ to identify which method and λ value performs best.

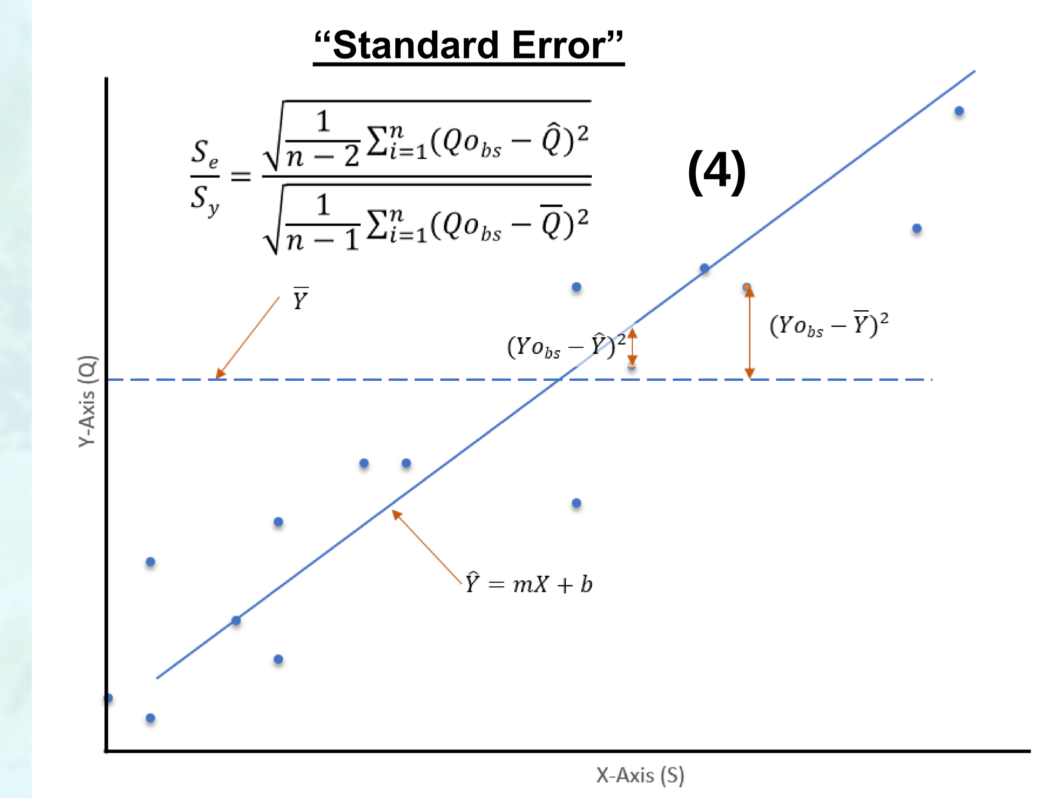

Figure 1. S_e/S_y formula and example graph.

FINDINGS

$\lambda = 0.20$					
Least-Squares Method (Numerical Optimization Program(1)					
Median CN Method (NEH Program)(2)					
Watershed Name	Watershed	CN(1)	CN(2)	Se/Sy(1)	se/Sy(2)
arizona	45001 W-I	83.4	80.7	0.555	0.761
arizona	45002 W-II	85.6	83.8	0.537	1.27
arizona	45003 W-IV	56.2	69.1	0.124	2.11
georgia	74002 W-TB	58.8	66.1	0.108	1.23
georgia	74003 W-TN	60.2	68.4	0.114	1.33
georgia	74004 W-TO	62.5	68.9	0.114	1.16
idaho	68001 W-1	56.2	66.3	0.123	1.21
idaho	68003 W-3	58.1	60.6	0.108	1.28
illinois	61001 IA	66.1	65.9	0.825	0.936
illinois	61002 IB	60.8	65.3	0.873	0.929
iowa	71004 W-4	48.1	67.7	0.119	1.46
iowa	71003 W-3	59.2	67.7	0.662	0.844
iowa	71002 W-2	73.1	71.2	0.648	1.15
nebraska	W-3	78.9	78.6	0.686	1.05
nebraska	W-5	71.7	71.2	0.659	1.16
nebraska	W-8	70.2	72.3	0.851	1.22
nebraska	W-11	65.6	69.1	0.794	0.950
new mexico	47001 W-I	72.2	73.3	0.860	1.39
new mexico	47002 W-II	84.3	85.9	0.115	1.67
new mexico	47003 W-III	77.3	77.1	0.129	1.51
ohio	26001 102	66.9	65.6	0.733	0.747
ohio	26003 129	69.2	70.4	0.837	1.07
ohio	26015 110	70.2	70.8	0.811	1.10
texas	42010 W-10	78.8	82.1	0.866	1.15
texas	42011 Y	70.0	72.1	0.770	1.22
texas	42012 Y-2	74.4	76.9	0.703	1.02
vermont	67002 W-2	74.2	74.7	0.114	1.72
vermont	67003 W-3	71.7	73.5	0.976	1.23
virginia	13008 B.C.	63.6	74.7	0.134	1.62
virginia	13009 P.C.	68.6	74.7	0.125	1.24
virginia	13010 L.W.C.	63.7	70.5	0.955	1.29
			Averages	0.517	1.23

Table 2. Curve number and Standard Error (S_e/S_y) values corresponding to λ=0.20.

$\lambda = 0.05$					
Least-Squares Method (Numerical Optimization Program(1)					
Median CN Method (NEH Program)(2)					
Watershed Name	Watershed	CN(1)	CN(2)	Se/Sy(1)	Se/Sy(2)
arizona	45001 W-I	76.4	67.9	0.608	0.714
arizona	45002 W-II	80.3	74.9	0.552	0.601
arizona	45003 W-IV	40.0	43.2	0.115	1.40
georgia	74002 W-TB	40.0	38.0	0.103	1.16
georgia	74003 W-TN	42.1	43.4	0.103	1.20
georgia	74004 W-TO	45.8	47.7	0.105	1.06
idaho	68001 W-1	40.0	32.3	0.361	1.21
idaho	68003 W-3	40.0	29.3	0.440	1.28
illinois	61001 IA	51.0	40.9	0.781	0.972
illinois	61002 IB	45.0	36.3	0.847	0.931
iowa	71004 W-4	40.0	40.1	0.120	1.16
iowa	71003 W-3	41.4	40.7	0.653	0.850
iowa	71002 W-2	61.5	47.1	0.650	1.09
nebraska	W-3	69.9	65.1	0.678	0.873
nebraska	W-5	59.0	53.2	0.637	0.748
nebraska	W-8	56.2	53.5	0.781	1.04
nebraska	W-11	50.4	46.6	0.746	0.915
new mexico	47001 W-I	54.5	54.8	0.754	1.02
new mexico	47002 W-II	76.4	74.5	0.109	1.41
new mexico	47003 W-III	64.1	64.0	0.116	1.23
ohio	26001 102	51.3	38.0	0.755	0.898
ohio	26003 129	53.9	47.2	0.680	0.973
ohio	26015 110	55.8	47.2	0.787	0.987
texas	42010 W-10	70.6	74.2	0.828	0.743
texas	42011 Y	58.1	56.2	0.746	1.14
texas	42012 Y-2	64.6	63.1	0.746	0.946
vermont	67002 W-2	57.8	55.1	0.102	1.64
vermont	67003 W-3	55.0	51.9	0.927	1.20
virginia	13008 B.C.	47.8	55.5	0.109	1.35
virginia	13009 P.C.	54.9	57.4	0.114	1.18
virginia	13010 L.W.C.	47.9	47.7	0.858	1.02
			Averages	0.513	1.06

Table 3. Curve number and Standard Error (S_e/S_y) values corresponding to λ=0.05.

Tables 2&3. Red values indicate the lower S_e/S_y calculation corresponding to the λ value. The circled values in the λ=0.05 chart were the only calculation where the median approach was better than the least-squares approach.

APPLICATIONS

An accurate curve number(CN) calibration is important because the CN is used to estimate discharges which are used for hydrologic and hydraulic designs. Bridges, dams, and drainage pipes/culverts are examples of hydrologic and hydraulic designs.

CONCLUSIONS/ RESULTS

Results show that the calibrated storage for individual runoff events vary, that calibrated storage differs depending on the calibration method used, and that goodness-of-fit is both a function of the calibration method and λ. Goodness-of-fit measured by standard error is almost universally stronger when using the least-squares calibration method. Two values of λ were explored, (0.05 and 0.20) with 0.05 producing better goodness-of-fit in 8 out of 31 instances using least-squares method and 6 out of 31 instances using median method.

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