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TECHNICAL MEMORANDUM

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SUBJECT: Calibration of Rational Method Volume-Based Runoff Coefficients and Regional Time of Concentration to CUHP v2.0.0

DATE: February 10, 2017

The purpose of this memorandum is to document the development and calibration of updated Rational Method runoff coefficients and the regional time of concentration equation for the Denver area. The methodology outlined in this memorandum is primarily based on the approach used in the paper *Derivation and Calibration of Volume-Based Runoff Coefficients for Denver Area, Colorado* prepared by Dr. James C.Y. Guo for UDFCD in October 2013. The original work in 2013 by Dr. Guo to develop volume-based runoff coefficients and a regional time of concentration equation was based on calibration to runoff results from CUHP v1.3.3. In 2016, CUHP was recalibrated and version 2.0.0 was released, which produces slightly different peak flow results when compared to previous versions of CUHP. Therefore, the methodology used by Dr. Guo in 2013 was revisited and new volume-based runoff coefficients and a new regional time of concentration equation were developed by calibrating against CUHP v2.0.0 results to maintain consistency between the two runoff methods with respect to volume and peak flows. For more detailed information on the derivation of various Rational Method equations refer to the original 2013 paper by Dr. Guo.

## Volume-Based Runoff Coefficient

The first step in the calibration effort is to develop a new set of volume-based runoff coefficients that serve as the basis to establish optimal consistency between CUHP and the Rational method for runoff volume. The volume-based runoff coefficient refers to the volume ratio of the runoff hydrograph to the rainfall hyetograph as shown in Equation 1 (Equation 14 from Guo 2013).

$$C = \frac{V_F}{V_R} = \frac{Volume\ of\ Runoff\ Hydrograph}{Volume\ of\ Rainfall\ Hyetograph} \qquad \text{Equation 1}$$

The rainfall hyetograph volume in Equation 1 is a function of rainfall depth and catchment area. CUHP requires a 1-hour rainfall depth for each design storm return period. The 1-hour rainfall depths are obtained from NOAA Atlas 14 for each return period. Table 1 shows the default 1-hour rainfall depths for the Denver area. It should be noted that CUHP distributes the 1-hour rainfall depth over a 2-hour period with the resulting rainfall depth being approximately 116% of the 1-hour rainfall depth

(115.7% for 2- through 10-yr storms, 115.6% for 25- through 500-yr storms). The resulting 2-hour rainfall depth is then multiplied by the catchment area to determine the hyetograph volume as shown in Equation 2.

$$V_R(ft^3) = \frac{1.156 * P_1(in)}{12} * A(ac) * 43{,}560 \qquad \text{Equation 2}$$

*Table 1: Average one-hour rainfall depth in the Denver region, as a function of probability of occurrence.*

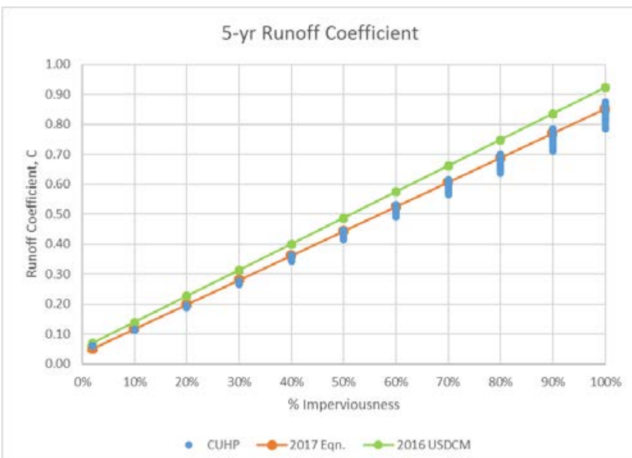
| Recurrence Interval (Years) | Probability of Occurrence | Rainfall Depth (Inch) |
|---|---|---|
| 2 | 0.50 | 0.83 |
| 5 | 0.20 | 1.09 |
| 10 | 0.10 | 1.33 |
| 25 | 0.04 | 1.69 |
| 50 | 0.02 | 1.99 |
| 100 | 0.01 | 2.31 |
| 500 | 0.002 | 3.14 |

The runoff hydrograph volume in Equation 1 is taken from CUHP v2.0.0 output results for the storm hydrograph. The input parameters for CUHP include catchment area, length of catchment, length to centroid, catchment slope, percent imperviousness, depression storage, soil infiltration losses, and one-hour precipitation depths. A wide range of potential catchment inputs were evaluated in CUHP to create a database of peak flow and runoff volume results. The CUHP output database includes 27,720 combinations of these input parameters (10 areas * 3 shape factors * 4 slopes * 11 imperviousness levels * 3 soil types * 7 return periods). The values of each input parameter evaluated are shown below:

- Catchment Area = 1, 10, 20, 30, 40, 50, 60, 70, 80, and 90 acres. (90 acres upper limit of applicability for Rational Method)
- Shape Factor (Shape = Length$^2$/Area ratio) = 2.0, 3.0 and 4.0.
- Catchment Slope = 1.0%, 2.0%, 3.0% and 4.0%
- Catchment Imperviousness, i = 2%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%
- Horton Infiltration parameters were default CUHP values for NRCS Soil Types: A, B, and C/D
- Design Storm Return Periods: 2-, 5-, 10-, 25-, 50-, 100- and 500-yr

Catchment length is based on the catchment shape factor and area, Length = (Shape * Area)$^{0.5}$. The length to centroid was set equal to half of the catchment length. Depression storage values were set to CUHP defaults of 0.35 (pervious) and 0.10 (impervious).

The CUHP results were then used to calculate volume-based runoff coefficients using Equation 1 (ratio of runoff hydrograph volume to rainfall hyetograph volume). The results indicated that the runoff coefficients are primarily dependent on imperviousness, soil type infiltration rates, and return period. The area, shape, and slope had negligible effects on the volume ratio (these parameters have a more pronounced impact on the peak flows). Based on these observations, a plot of the CUHP calculated volume-based runoff coefficients versus percent imperviousness (i) was created for each soil type and return period. Based on the plots it was then determined that a simple linear equation (a*i + b), or in cases of low runoff potential a power equation (a*i^b), could best represent the relationship between runoff coefficient and imperviousness. Excel's Solver was then used to determine the coefficients *a* and *b* to create a best fit equation for volume-based runoff coefficients by minimizing the sum of squared errors between the volume ratios and the linear or power equations. Figure 1 shows example plots for 5-yr and 100-yr coefficients on Type C/D soils. Figure 1 shows that the new equation provides a better fit to CUHP v2.0.0 results than the current coefficients presented in the 2016 USDCM.



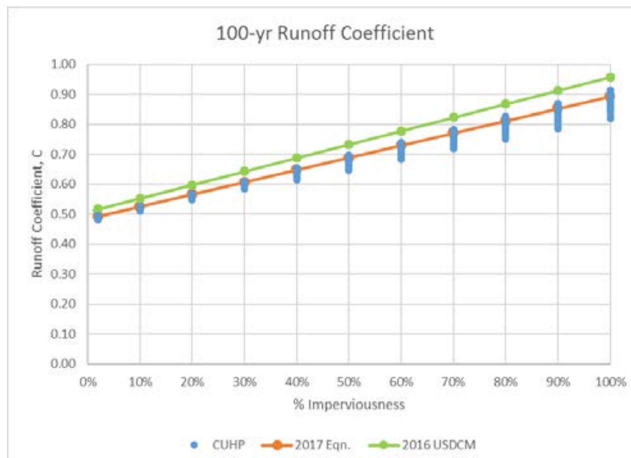




*Figure 1: Volume-Based Runoff Coefficients as a function of Catchment Imperviousness based on CUHP Results for Type C/D soils (Runoff Hydrograph Volume/Rainfall Hyetograph Volume)*

Table 2 shows the volume-based runoff coefficient equations for each soil type and return period. Tables 3, 4 and 5 provide calculated runoff coefficients for each soil type, respectively. Figures 2, 3 and 4 provide corresponding figures of the runoff coefficient equations.

*Table 2: Volume-Based Runoff Coefficient Equations based on NRCS Soil Group and Storm Return Period.*

| NRCS Soil Group | Storm Return Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2-Year** | **5-Year** | **10-Year** | **25-Year** | **50-Year** | **100-Year** | **500-Year** |
| A | $0.840i^{1.302}$ | $0.861i^{1.276}$ | $0.873i^{1.232}$ | $0.884i^{1.124}$ | 0.854i+0.025 | 0.779i+0.110 | 0.645i+0.254 |
| B | $0.835i^{1.169}$ | $0.857i^{1.088}$ | 0.807i+0.057 | 0.628i+0.249 | 0.558i+0.328 | 0.465i+0.426 | 0.366i+0.536 |
| C/D | $0.834i^{1.122}$ | 0.815i+0.035 | 0.735i+0.132 | 0.560i+0.319 | 0.494i+0.393 | 0.409i+0.484 | 0.315i+0.588 |

*Table 3: Volume-Based Runoff Coefficients for Type A Soils*

| % Imp | Storm Return Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year | 500-Year |
| 0% | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.11 | 0.25 |
| 5% | 0.02 | 0.02 | 0.02 | 0.03 | 0.07 | 0.15 | 0.29 |
| 10% | 0.04 | 0.05 | 0.05 | 0.07 | 0.11 | 0.19 | 0.32 |
| 15% | 0.07 | 0.08 | 0.08 | 0.10 | 0.15 | 0.23 | 0.35 |
| 20% | 0.10 | 0.11 | 0.12 | 0.14 | 0.20 | 0.27 | 0.38 |
| 25% | 0.14 | 0.15 | 0.16 | 0.19 | 0.24 | 0.30 | 0.42 |
| 30% | 0.18 | 0.19 | 0.20 | 0.23 | 0.28 | 0.34 | 0.45 |
| 35% | 0.21 | 0.23 | 0.24 | 0.27 | 0.32 | 0.38 | 0.48 |
| 40% | 0.25 | 0.27 | 0.28 | 0.32 | 0.37 | 0.42 | 0.51 |
| 45% | 0.30 | 0.31 | 0.33 | 0.36 | 0.41 | 0.46 | 0.54 |
| 50% | 0.34 | 0.36 | 0.37 | 0.41 | 0.45 | 0.50 | 0.58 |
| 55% | 0.39 | 0.40 | 0.42 | 0.45 | 0.49 | 0.54 | 0.61 |
| 60% | 0.43 | 0.45 | 0.47 | 0.50 | 0.54 | 0.58 | 0.64 |
| 65% | 0.48 | 0.50 | 0.51 | 0.54 | 0.58 | 0.62 | 0.67 |
| 70% | 0.53 | 0.55 | 0.56 | 0.59 | 0.62 | 0.65 | 0.71 |
| 75% | 0.58 | 0.60 | 0.61 | 0.64 | 0.66 | 0.69 | 0.74 |
| 80% | 0.63 | 0.65 | 0.66 | 0.69 | 0.71 | 0.73 | 0.77 |
| 85% | 0.68 | 0.70 | 0.71 | 0.74 | 0.75 | 0.77 | 0.80 |
| 90% | 0.73 | 0.75 | 0.77 | 0.79 | 0.79 | 0.81 | 0.84 |
| 95% | 0.79 | 0.81 | 0.82 | 0.83 | 0.84 | 0.85 | 0.87 |
| 100% | 0.84 | 0.86 | 0.87 | 0.88 | 0.88 | 0.89 | 0.90 |

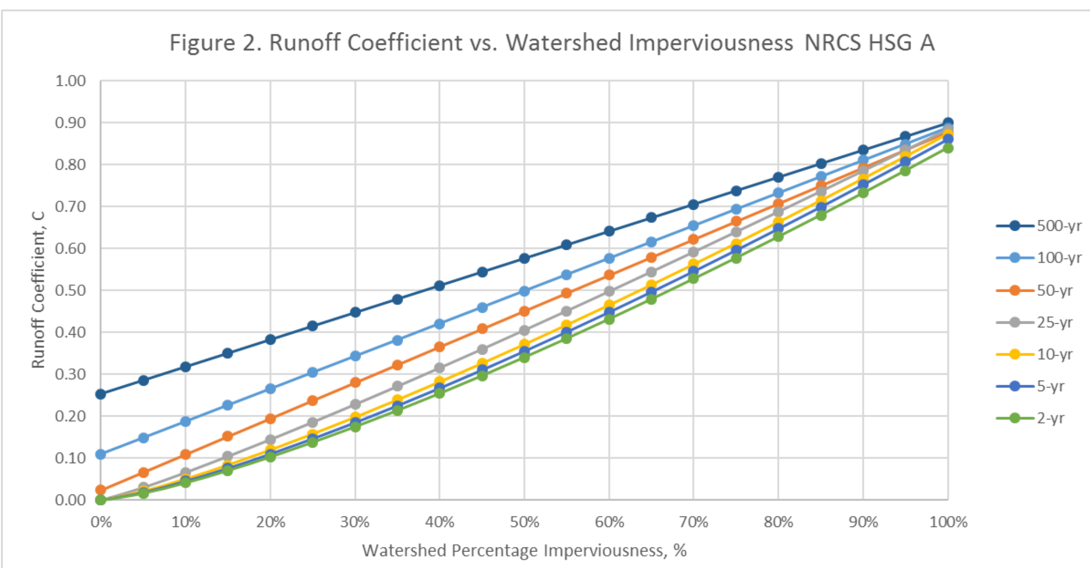


*Table 4: Volume-Based Runoff Coefficients for Type B Soils*

| % Imp | Storm Return Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year | 500-Year |
| 0% | 0.00 | 0.00 | 0.06 | 0.25 | 0.33 | 0.43 | 0.54 |
| 5% | 0.03 | 0.03 | 0.10 | 0.28 | 0.36 | 0.45 | 0.55 |
| 10% | 0.06 | 0.07 | 0.14 | 0.31 | 0.38 | 0.47 | 0.57 |
| 15% | 0.09 | 0.11 | 0.18 | 0.34 | 0.41 | 0.50 | 0.59 |
| 20% | 0.13 | 0.15 | 0.22 | 0.38 | 0.44 | 0.52 | 0.61 |
| 25% | 0.17 | 0.19 | 0.26 | 0.41 | 0.47 | 0.54 | 0.63 |
| 30% | 0.20 | 0.23 | 0.30 | 0.44 | 0.49 | 0.57 | 0.65 |
| 35% | 0.24 | 0.27 | 0.34 | 0.47 | 0.52 | 0.59 | 0.66 |
| 40% | 0.29 | 0.32 | 0.38 | 0.50 | 0.55 | 0.61 | 0.68 |
| 45% | 0.33 | 0.36 | 0.42 | 0.53 | 0.58 | 0.64 | 0.70 |
| 50% | 0.37 | 0.40 | 0.46 | 0.56 | 0.61 | 0.66 | 0.72 |
| 55% | 0.42 | 0.45 | 0.50 | 0.60 | 0.63 | 0.68 | 0.74 |
| 60% | 0.46 | 0.49 | 0.54 | 0.63 | 0.66 | 0.71 | 0.76 |
| 65% | 0.50 | 0.54 | 0.58 | 0.66 | 0.69 | 0.73 | 0.77 |
| 70% | 0.55 | 0.58 | 0.62 | 0.69 | 0.72 | 0.75 | 0.79 |
| 75% | 0.60 | 0.63 | 0.66 | 0.72 | 0.75 | 0.78 | 0.81 |
| 80% | 0.64 | 0.67 | 0.70 | 0.75 | 0.77 | 0.80 | 0.83 |
| 85% | 0.69 | 0.72 | 0.74 | 0.78 | 0.80 | 0.82 | 0.85 |
| 90% | 0.74 | 0.76 | 0.78 | 0.81 | 0.83 | 0.84 | 0.87 |
| 95% | 0.79 | 0.81 | 0.82 | 0.85 | 0.86 | 0.87 | 0.88 |
| 100% | 0.84 | 0.86 | 0.86 | 0.88 | 0.89 | 0.89 | 0.90 |

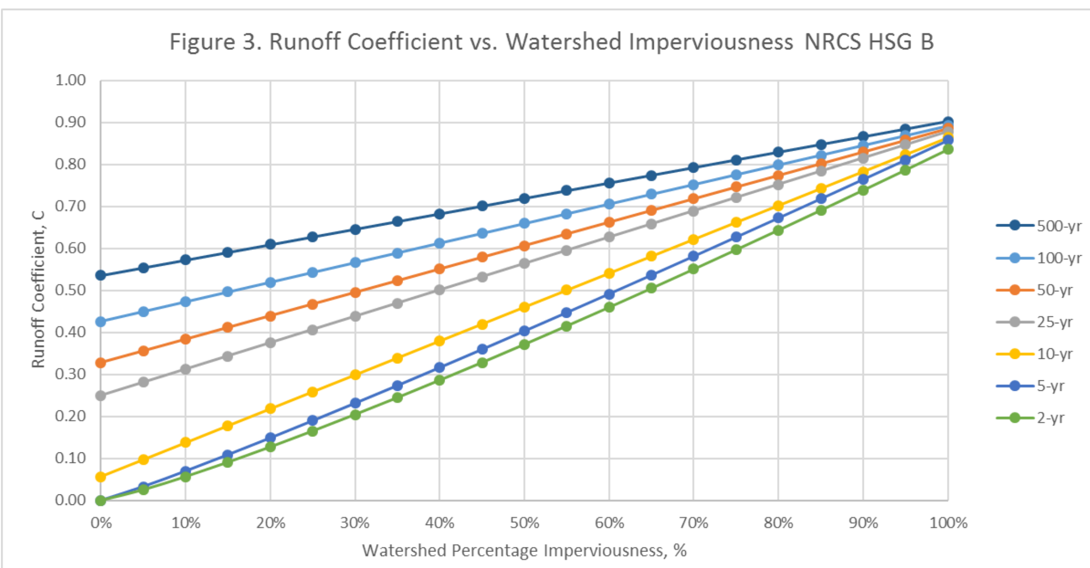
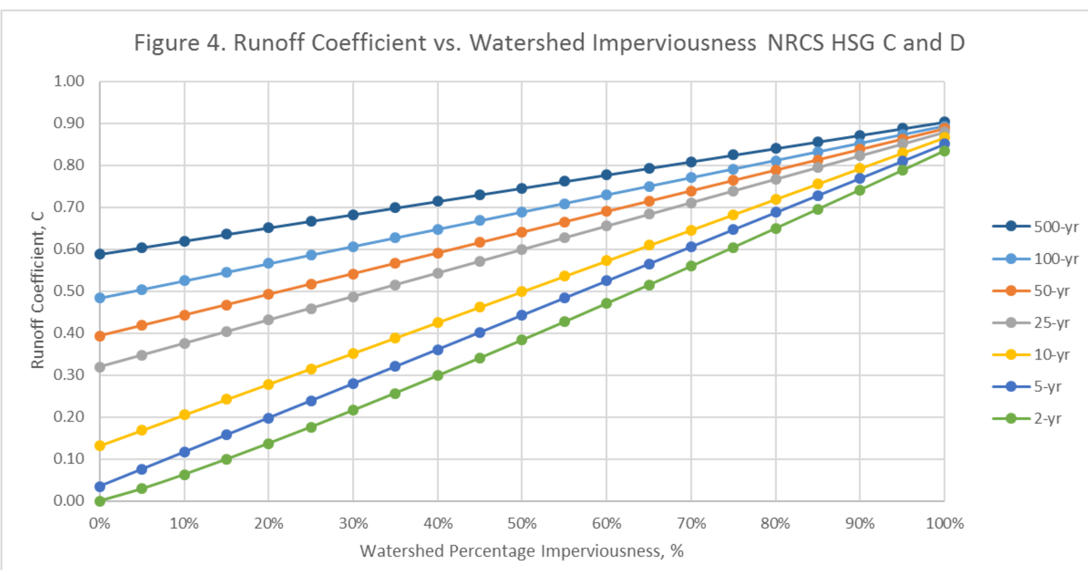


*Table 5: Volume-Based Runoff Coefficients for Type C/D Soils*

| % Imp | Storm Return Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2-Year | 5-Year | 10-Year | 25-Year | 50-Year | 100-Year | 500-Year |
| 0% | 0.00 | 0.04 | 0.13 | 0.32 | 0.39 | 0.48 | 0.59 |
| 5% | 0.03 | 0.08 | 0.17 | 0.35 | 0.42 | 0.50 | 0.60 |
| 10% | 0.06 | 0.12 | 0.21 | 0.37 | 0.44 | 0.52 | 0.62 |
| 15% | 0.10 | 0.16 | 0.24 | 0.40 | 0.47 | 0.55 | 0.64 |
| 20% | 0.14 | 0.20 | 0.28 | 0.43 | 0.49 | 0.57 | 0.65 |
| 25% | 0.18 | 0.24 | 0.32 | 0.46 | 0.52 | 0.59 | 0.67 |
| 30% | 0.22 | 0.28 | 0.35 | 0.49 | 0.54 | 0.61 | 0.68 |
| 35% | 0.26 | 0.32 | 0.39 | 0.51 | 0.57 | 0.63 | 0.70 |
| 40% | 0.30 | 0.36 | 0.43 | 0.54 | 0.59 | 0.65 | 0.71 |
| 45% | 0.34 | 0.40 | 0.46 | 0.57 | 0.62 | 0.67 | 0.73 |
| 50% | 0.38 | 0.44 | 0.50 | 0.60 | 0.64 | 0.69 | 0.75 |
| 55% | 0.43 | 0.48 | 0.54 | 0.63 | 0.66 | 0.71 | 0.76 |
| 60% | 0.47 | 0.52 | 0.57 | 0.65 | 0.69 | 0.73 | 0.78 |
| 65% | 0.51 | 0.56 | 0.61 | 0.68 | 0.71 | 0.75 | 0.79 |
| 70% | 0.56 | 0.61 | 0.65 | 0.71 | 0.74 | 0.77 | 0.81 |
| 75% | 0.60 | 0.65 | 0.68 | 0.74 | 0.76 | 0.79 | 0.82 |
| 80% | 0.65 | 0.69 | 0.72 | 0.77 | 0.79 | 0.81 | 0.84 |
| 85% | 0.70 | 0.73 | 0.76 | 0.79 | 0.81 | 0.83 | 0.86 |
| 90% | 0.74 | 0.77 | 0.79 | 0.82 | 0.84 | 0.85 | 0.87 |
| 95% | 0.79 | 0.81 | 0.83 | 0.85 | 0.86 | 0.87 | 0.89 |
| 100% | 0.83 | 0.85 | 0.87 | 0.88 | 0.89 | 0.89 | 0.90 |



## Regional Time of Concentration

The next step in the calibration effort is to develop a new regional time of concentration equation that serves to establish optimal consistency between peak flows from CUHP and the Rational Method. First the computed time of concentration is calculated using Equations 3, 4, and 5 below (Equations 6-2, 6-3, and 6-4 from the USDCM).

$$t_{computed} = t_i + t_t \qquad \text{Equation 3}$$

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L_i}}{S_i^{0.33}} \qquad \text{Equation 4}$$

$$t_t = \frac{L_t}{60K\sqrt{S_t}} = \frac{L_t}{60V_t} \qquad \text{Equation 5}$$

Where:

$t_{computed}$ = computed time of concentration (minutes)

$t_i$ = overland (initial) flow time (minutes)

$t_t$ = channelized flow time (minutes)

$C_5$ = runoff coefficient for 5-year frequency (from Table 2 in this memorandum)

$L_i$ = length of overland flow (ft)

$S_i$ = average slope along the overland flow path (ft/ft)

$L_t$ = length of channelized flow (ft)

$S_t$ = average slope along the channelized flow path (ft/ft)

$V_t$ = travel time velocity (ft/sec) = $K*S_t^{0.5}$

K = NRCS conveyance factor (Table 6-2 in USDCM)

The computed time of concentration from Equation 3 (sum of Equations 4 and 5) is solely determined by catchment characteristics using a set of empirical formulas. Therefore, a regional time of concentration equation specific to the Denver area was developed in the 2013 paper by Dr. Guo to calibrate the Rational Method peak flows to the CUHP peak flows as shown in Equation 6 below (Equation 19 from Guo 2013, Equation 6-5 from the USDCM). The methodology in the 2013 paper then suggests that the selected time of concentration shall be the lesser of the computed or regional time of concentration as shown in Equation 7. The final check in Equation 8 is to ensure that a minimum time of concentration of at least 5 minutes for urbanized areas and 10 minutes for rural areas is used even when Equation 7 results in a lesser time of concentration.

$$t_{regional} = t_* + \frac{L_t}{60K_*\sqrt{S_t}} = t_* + \frac{L_t}{60V_*}$$ Equation 6

$$t_{selected} = min\left(t_{regional}, t_{computed}\right)$$ Equation 7

$$t_c = max(t_{selected}, t_{min})$$ Equation 8

Where:

$t_{regional}$ = regional time of concentration (minutes) for the Denver area

$t_*$ = calibrated overland (initial) flow time (minutes) as a function of imperviousness (a – b*Imp)

$K_*$ = calibrated NRCS conveyance factor as a function of imperviousness (c*Imp + d)

$V_*$ = calibrated travel time velocity (ft/sec) = $K_* * S_t^{0.5}$

$t_{selected}$ = selected time of concentration (minutes)

$t_{min}$ = minimum time of concentration (minutes), 5 for urbanized, 10 for rural

$t_c$ = final time of concentration (minutes)

The final time of concentration is then used to calculate the rainfall intensity using the Denver area intensity-duration equation shown in Equation 9 (Equation 5-3 from the USDCM). The resulting intensity is then multiplied by the catchment area and volume-based runoff coefficient to calculate the peak flow as shown in Equation 10.

$$I = \frac{28.5 * P_1}{(10 + t_c)^{0.786}}$$ Equation 9

$$Q = CIA$$ Equation 10

Where:

I = rainfall intensity (in/hr)

$P_1$ = 1-hour point rainfall depth (in)

$t_c$ = final time of concentration (minutes)

C = volume-based runoff coefficient (from Table 2 equations)

A = catchment area (acres)

Q = peak flow (cfs)

The values of $t_*$ and $K_*$ in the regional time of concentration equation are determined by calibrating the resulting Rational Method peak flows to the CUHP peak flows database of 27,720 catchments. CUHP input parameters were used to calculate the corresponding Rational Method input parameters. A few generalized assumptions were necessary to develop the input parameters including:

- The urban vs. rural threshold was set at 20% imperviousness, such that catchments with an imperviousness greater than 20% are considered urban whereas catchments with an imperviousness less than or equal to 20% are considered rural.
- The length of overland flow, $L_i$ was set to 300 feet for urban areas and 500 feet for rural areas.
- The length of channelized flow, $L_t$ was set equal to the total length in CUHP minus $L_t$.
- The average slope for the overland and channelized flow paths were both set to the catchment slope from CUHP.
- The conveyance factor, K was set to 20 fps for urban areas (paved areas) and 15 fps for rural areas (grassed waterways).

As noted above and in the USDCM, the value of $t_*$ and $K_*$ were determined to be linear functions of percent imperviousness where: $t_* = a - b*i$ and $K_* = c*i - d$. These linear relationships were used to calculate the regional time of concentration when determining the Rational Method peak flow for each of the CUHP catchments. Excel's Solver was then used to determine the coefficients *a, b, c*, and *d* necessary to create a best fit equation for the regional time of concentration by minimizing the sum of squared errors between the computed and regional time of concentrations and then comparing the resulting Rational Method peak flows and the CUHP database peak flows.

The Excel Solver results indicated that $t_* = 26 - 17*i$ (minutes) and $K_* = 14*i + 9$. These coefficients resulted in the best fit between the computed and regional time of concentrations. The calibrated overland flow time, t* ranges from 26 minutes at 0% imperviousness down to 9 minutes at 100% imperviousness. The calibrated NRCS conveyance factor ranges from 9 fps at 0% imperviousness up to 23 fps at 100% imperviousness. This is consistent with the standard conveyance factors in Table 6-2 of the USDCM where 7 fps represents short pasture and lawns and 20 fps represents paved areas and shallow paved swales. Plugging the linear functions of imperviousness and the optimized coefficients into Equation 6, results in a regional time of concentration as shown in Equation 11.

$$t_{regional} = (26 - 17i) + \frac{L_t}{60(14i+9)\sqrt{S_t}} \qquad \text{Equation 11}$$

As shown in Figure 5, when the regional time of concentration equation results in a shorter time than the computed time of concentration, it becomes the controlling time of concentration value and results in a much better fit between the peak flows from the Rational Method and CUHP. Of the 27,720 catchments in the database, the regional time of concentration controls for approximately 10,000 of the catchments (36%) while the remaining catchments use the standard computed time of concentration.

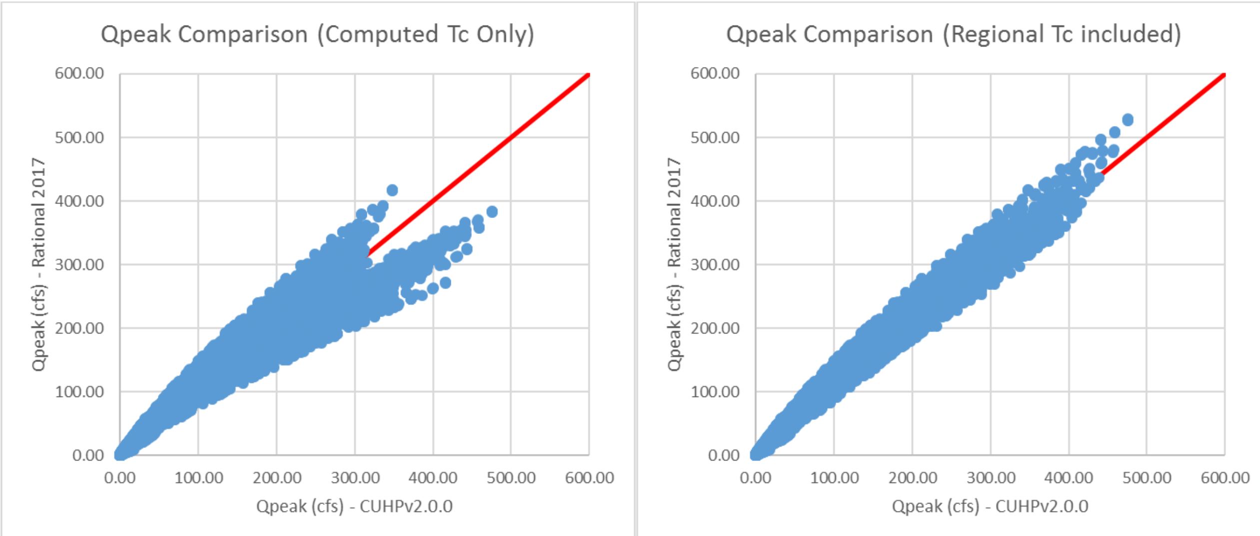



*Figure 5: Peak Flow Comparisons between CUHP v2.0.0 and the Rational Method*
*The figure on the left is based only on Computed Time of Concentration and the figure on the right is based on the Excel Solver solution for Regional Time of Concentration Equation*

## Comparison of CUHP v2.0.0 Results against the Rational Method

The goal of this memorandum was to document the revision to volume-based runoff coefficients and the regional time of concentration equation as compared to previous versions documented in the USDCM. The recalibration of CUHP required that the methodology used previously be reevaluated in order to maintain consistency between the two runoff methods. Below are several figures comparing the CUHP v2.0.0 results against the Rational Method results from the 2007 USDCM (prior to recommended updates in Dr. Guo's 2013 paper), 2016 USDCM (including recommended updates from Dr. Guo's 2013 paper), and recommended 2017 updates based on this memorandum.

Figure 6 shows a comparison between the 2-year volume-based runoff coefficients from CUHP v2.0.0 versus the various sets of impervious based equations for all three soil types. Figure 7 shows the same comparison for the 10-year runoff coefficients. Figure 8 shows the same comparison for the 100-year runoff coefficients.

Figure 9 shows a comparison between the computed time of concentration values versus the different regional time of concentration equations that have been used in the USDCM

Figure 10 shows a comparison between the peak flow estimates from CUHP v2.0.0 versus the various Rational Method approaches used in the USDCM.

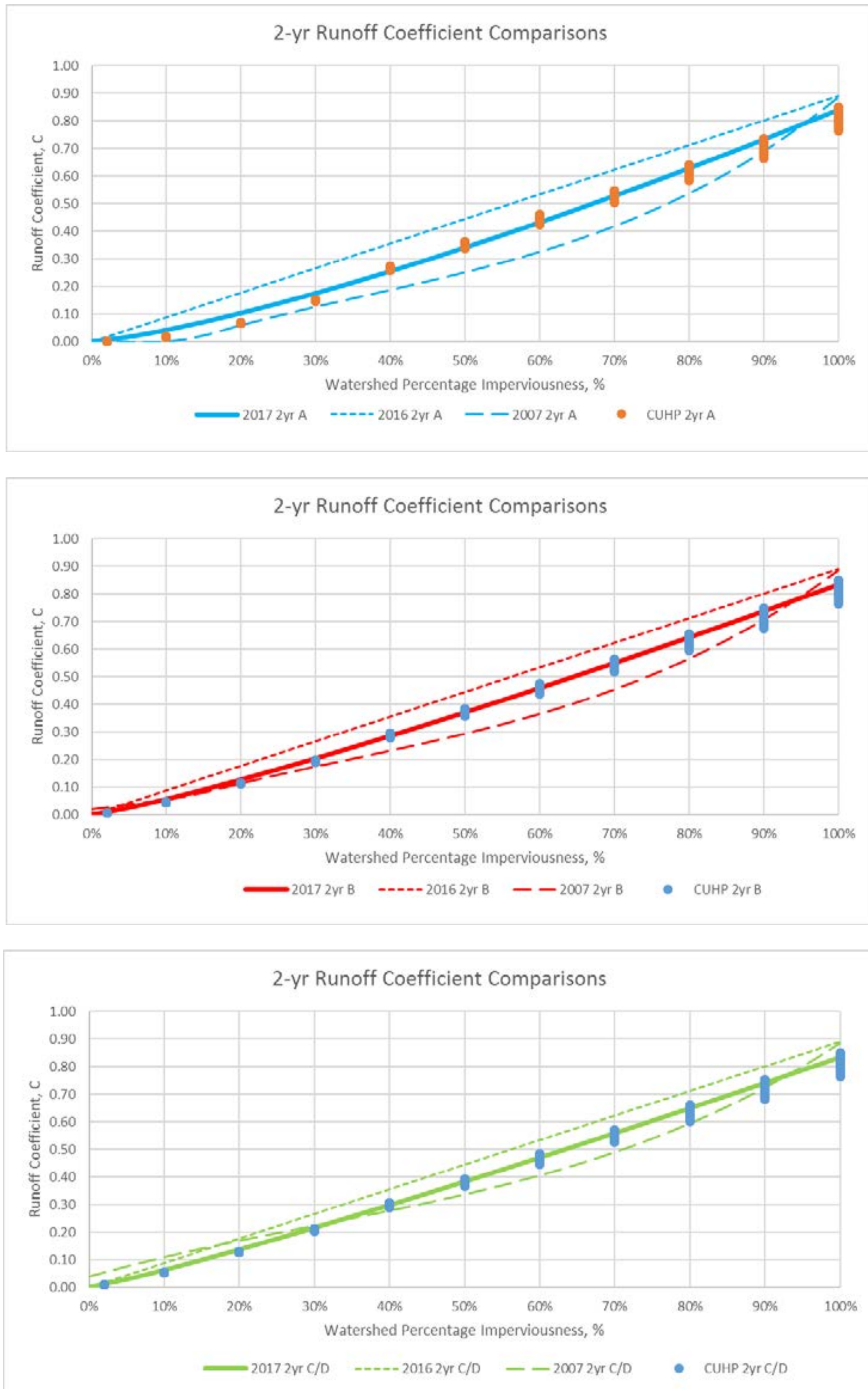



*Figure 6: Runoff Coefficient Comparisons for 2-yr Return Period (Soil Types A, B, & C/D) (2007 USDCM, 2016 USDCM, and Proposed 2017 Equations)*

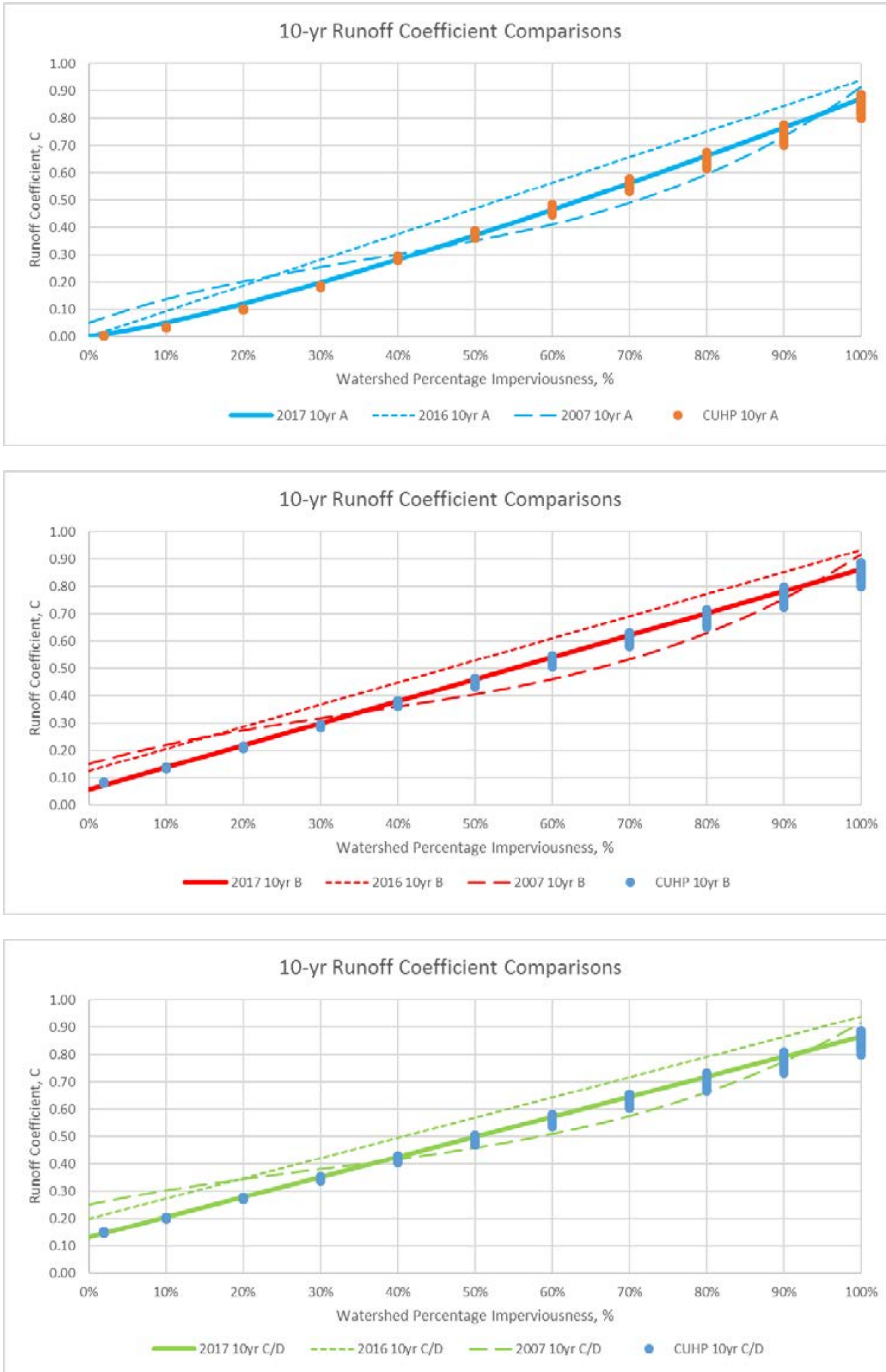



*Figure 7: Runoff Coefficient Comparisons for 10-yr Return Period (Soil Types A, B, & C/D) (2007 USDCM, 2016 USDCM, and Proposed 2017 Equations)*

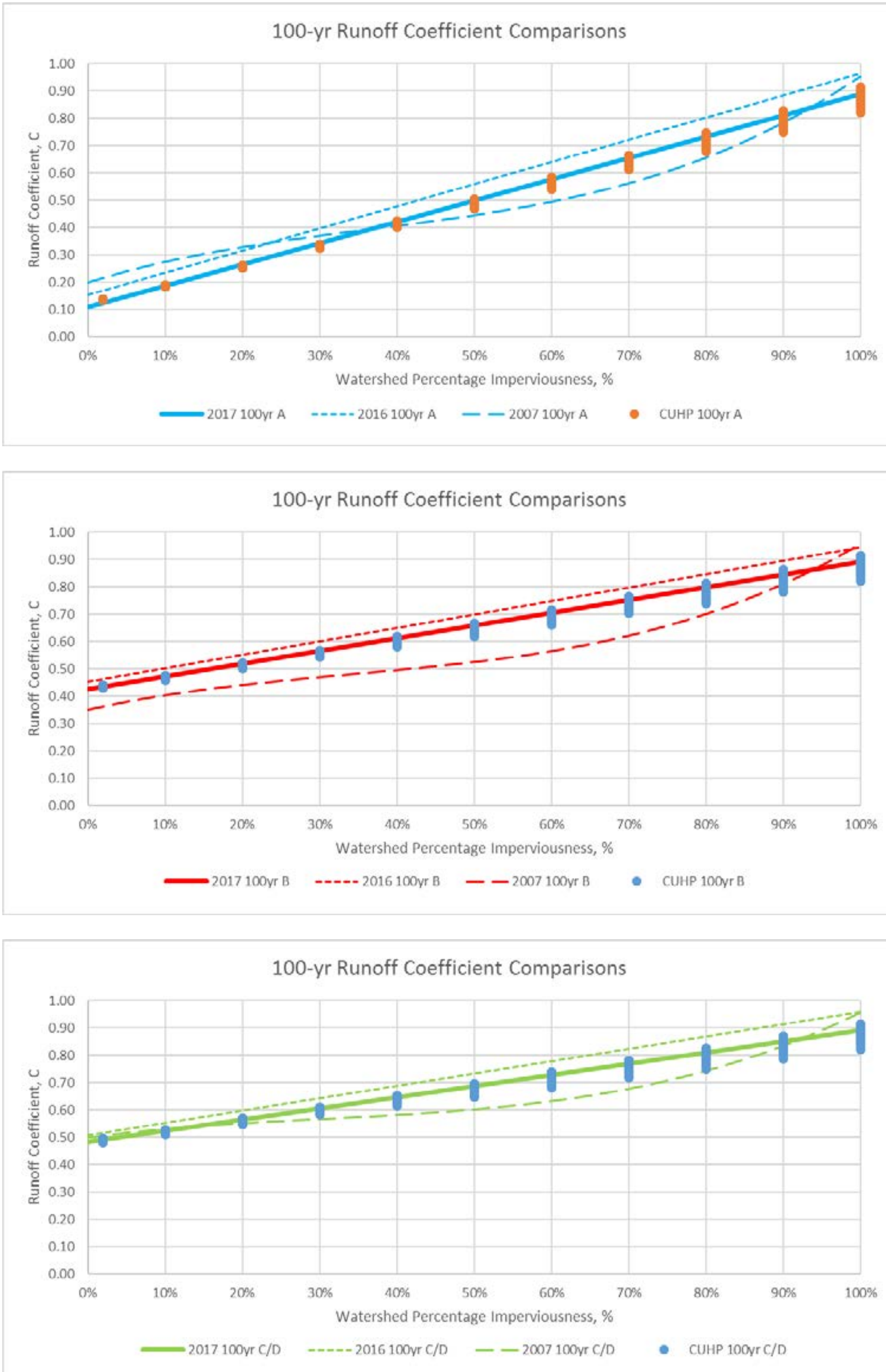



*Figure 8: Runoff Coefficient Comparisons for 100-yr Return Period (Soil Types A, B, & C/D)*
*(2007 USDCM, 2016 USDCM, and Proposed 2017 Equations)*

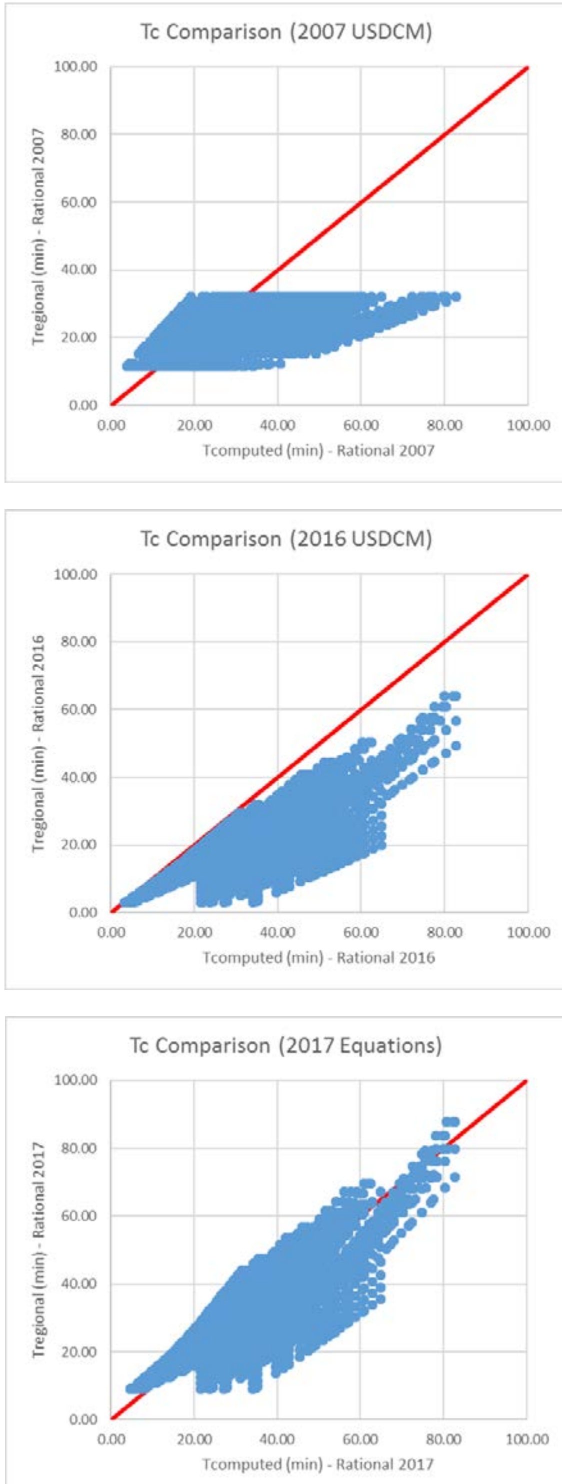



*Figure 9: Computed Time of Concentration vs. Regional Time of Concentration (2007 USDCM, 2016 USDCM, and Proposed 2017 Equations)*

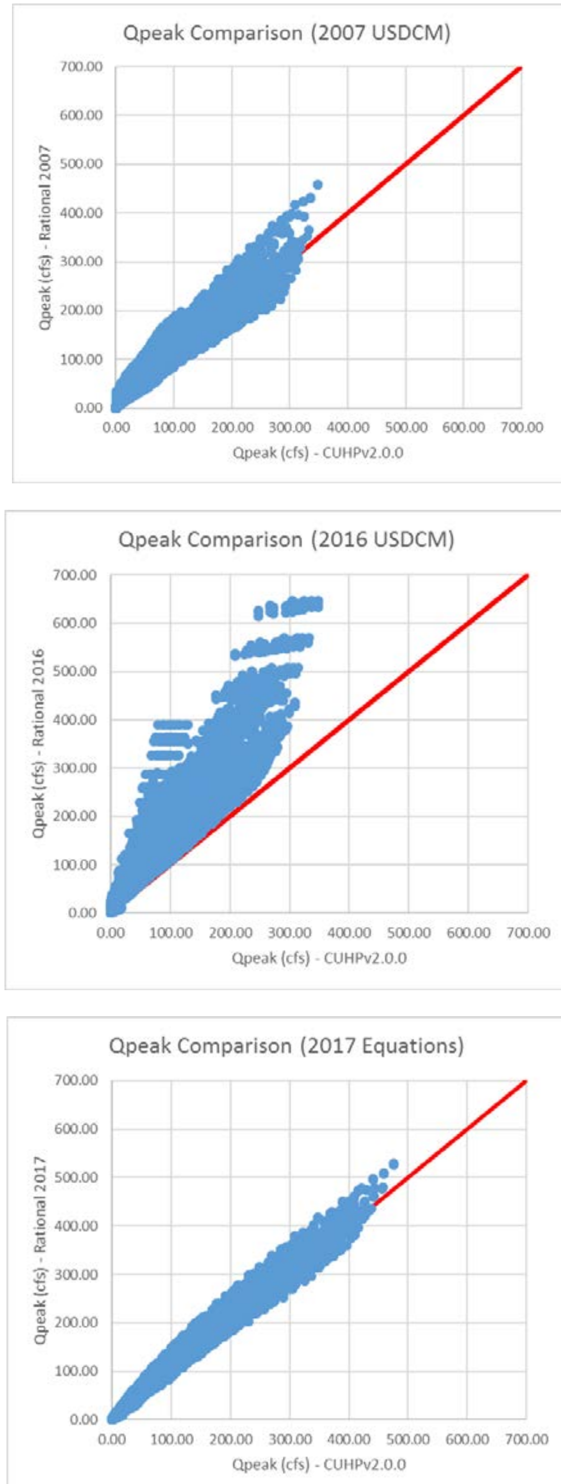



*Figure 10: Peak Flow Comparisons between CUHP v2.0.0 and the Rational Method (2007 USDCM, 2016 USDCM, and Proposed 2017 Equations)*

## Conclusions and Recommendations

The purpose of this memorandum was to document the development and calibration of updated Rational Method volume-based runoff coefficients and the regional time of concentration equation for the Denver area. Due to recalibration of CUHP v2.0.0 in 2016, it was necessary to revisit the methodology used by Dr. Guo in 2013 to maintain consistency between CUHP and the Rational Method with respect to volume and peak flows. This memorandum summarizes the recalibration effort and provides new runoff coefficient equations and a new regional time of concentration equation. It is recommended that the new runoff coefficient equations in Table 2 above be used to replace the equations in Table 6-4 of the USDCM. Similarly, it is recommended that the tabular runoff coefficients provided in Tables 3, 4, and 5 (for Soil Types A, B, and C/D) be used to replace Table 6-5 in the USDCM. Lastly, it is recommended that the regional time of concentration in Equation 11 above be used to replace Equation 6-5 in the USDCM.