Adjusting NRCS Curve Number for Rainfall Durations Less Than 24 Hours

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ABSTRACT. The primary use of the NRCS curve number (CN) is to compute total storm runoff based on total rainfall. During development of this method, CN values were determined using daily, i.e., 24 hour, rainfall and runoff data, which is the implicit duration for values input to the curve number runoff model. Because most models used to design stormwater ponds and BMPs incorporate the NRCS CN method and since some designs now are based on rainfalls with durations less than 24 hours, there is need for a way to modify CN values for shorter events. Not yet formally published, the NRCS recently developed a standard procedure for modifying CN values for rainfall durations less than 24 hours. Introducing that method to the engineering community, with encouragement from the NRCS, is a goal for this paper.

Adjusted CN values were used in an assessment of the performance of a stormwater detention pond in a residential subdivision. Runoff hydrographs were simulated for pre-development, construction phase, and post-development land use conditions. Two pond designs were considered. One limited the post-development peak outflow for the 24 hour rainfall at or below the pre-development runoff peak; the second limited the peak outflow during construction phase at or below the pre-development runoff peak. Stormwater hydrographs were simulated for rainfalls of 1, 2, 3, 6, 12, and 24 hour duration. The simulation results emphasize pond design calculations and decisions should include pond performance for events with duration less than 24 hours and should use modified CN values. It is recommended controlling regulations specify design events such as the 2- and 10-year 24-hour rainfalls, but include a mandatory check of other events, such as the 1, 2, 3, 6 and 12 hour events, and other return periods. Prudent and ethical practice suggests the pond design be upgraded for the critical rainfall event.

INTRODUCTION

The primary use of the NRCS curve number (CN) is to compute total storm runoff based on total rainfall. During development of this method, CN values were determined using daily, i.e., 24 hour, rainfall and runoff data, which is the implicit duration for values input to the curve number runoff model. Duration is not factored into the calculation. As explained by William Merkel, Hydraulic Engineer, USDA-Natural Resources Conservation Service, Beltsville, MD, you cannot use the standard curve number for any duration other than 24 hours. If you do, you need to increase it for durations less than 24 hours and decrease it for durations longer than 24 hours.

In most locations, the design of stormwater management systems, such as detention ponds, must satisfy the regulation to limit the post-development peak discharge rate at or below the pre-development peak runoff rate for the 2 and 10 year frequency 24 hour duration storm events. During recent years, some locations added shorter duration events for stormwater pond design, such as 6 and 12 hours. At many locations, stormwater quality control using Best Management Practices (BMPs) also involves design rainfall events with durations less than 24 hours.

Because most models used to design stormwater ponds and BMPs incorporate the NRCS CN method and since some designs now are based on rainfalls with durations less than 24 hours, there is need for a way to modify CN values for shorter events. Not yet formally published, the NRCS recently developed a standard procedure for modifying CN values for rainfall durations less than 24 hours. Introducing that method to the engineering community, with encouragement from the NRCS, is a goal for this paper.

PROJECT DESCRIPTION

A basic hydrologic principle is that after initial abstractions have been satisfied, water infiltrates into the soil at nearly a steady rate. For a given rainfall depth, if the event duration is extended over a longer period of time, more rainfall will infiltrate. If the storm occurs over a shorter duration, less rainfall will infiltrate and more will go to runoff.

This concept was explained by Merkel as follows. At a watershed with CN value of 80, for 4 inches of rainfall, the runoff is 2.04 inches. For rainfall duration of 1 hour, the runoff would be 2.04 inches and for 24 hours rainfall duration, the runoff also would be 2.04 inches. If you use the standard curve number for a 60 minute storm, it assumes that you have 24 hours of infiltration in just 60 minutes. In these modern times, this concept is technically invalid.

The CN adjustment procedure is founded on the basic hydrologic principle that after initial abstractions have been satisfied, water infiltrates into the soil at nearly a steady rate. For a given rainfall depth, if the event duration is extended over a longer period of time, more rainfall will infiltrate. If the storm occurs over a shorter duration, less rainfall will infiltrate and more will go to runoff.

METHOD

The following table shows steps to compute the adjusted CN value for storm duration less than 24 hours. Calculations are explained in the different rows of the table.

For this example, the standard CN is 75 and storm duration D is 3 hours. Standard CN refers to the CN obtained from the published NRCS CN table based on land use and soils information. This value is labelled 24-Hour CN. The objective of the following calculations is to compute the 3-Hour CN. As described, this value will be higher than the standard 24-hour CN.

	24 Hours
24-hr CN =	75
24-hr S =	3.33
24-hr Ia =	0.67
D -hr =	**3 Hours**
D-hr P =	2.50
Assume D-hr P occurs in 24 hours and compute 24-hr Q_{CN} =	0.65
24-hr Infiltration = 24 hr F = D-hr P minus 24-hr Ia minus 24-hr Q_{CN} =	1.18
24-hr Infiltration Rate = 24-hr F divided by 24 =	0.05
24-hr Infiltration Rate multiplied by D hours = D-hr Infiltration =	0.15
D-hr Infiltration plus Ia =	0.81
D-hr P minus D-hr Infiltration plus Ia = D-hr Runoff =	1.69
Use D-hr P and D-hr Runoff to compute D-hr CN =	91.9

RESULTS

To assess the impact of adjusting CN values, adjusted values were used in an assessment of the performance of a stormwater detention pond. Runoff hydrographs were simulated for pre-development, construction phase, and post-development land use conditions. Two pond designs were considered. One limited the post-development peak outflow for the 24 hour rainfall at or below the pre-development runoff peak; the second limited the peak outflow during construction phase at or below the pre-development runoff peak. Stormwater hydrographs were simulated for rainfalls of 1, 2, 3, 6, 12, and 24 hour duration.

The pond design based on post-development peak outflow less than or equal to pre-development runoff peak yielded peak outflows for all duration events less than the corresponding pre-development peak runoff rates. However, when comparing the peak outflows for the different duration storms with the peak runoff for the pre-development 24-hour event, all shorter duration events had a peak outflow that exceeded the pre-development peak runoff for the 24-hour rainfall by as much as 10 to 67%. The construction phase peak outflow rates were 36 to 97% greater than the pre-development peaks, and all shorter duration events exceeded the pre-development peak runoff for the 24-hour rainfall by as much as 118 to 138%. Stated differently, the pond outflow peak rates for the 1, 2, 3, 6 and 12 hour events were all more than double the pre-development peak runoff rate for the 24-hour rainfall event.

The pond design based on construction phase peak outflow less than or equal to pre-development peak runoff yielded peak outflows for all duration events less than the corresponding pre-development peak runoff rates. However, when comparing the peak outflows for the different duration storms with the peak runoff for the pre-development 24-hour event, all shorter duration events had a peak outflow that exceeded the pre-development peak runoff for the 24-hour rainfall by as much as 10 to 30%.

These results emphasize pond design calculations and decisions should include pond performance for events with duration less than 24 hours and should use modified CN values. Also, controlling regulations should specify design events such as the 2- and 10-year 24-hour rainfalls, but include a mandatory check of other events, such as the 1, 2, 3, 6 and 12 hour events, and other return periods.

DISCUSSION

An obvious implication of these results is that traditional design guidelines based on 24-hour rainfall events, unbeknownst before the adjusted CN concept was available, were wrongly founded and not supported by science. Designs based on those regulations are wrong, incomplete, and fail to perform to the standard which designers, regulators, and the general public expect. Those regulations should be modified. But what if we do not modify the standards, what should designers do? They should accomplish a design that minimally meets the regulations and then check system performance using the adjusted CN values. If the system performance fails, modify the design. An appropriate design is one that will uphold public welfare, health, and safety, and will not damage on-site, adjacent, and offsite property, as a minimum. Development property owners and designers may argue this approach will increase the cost. Wouldn’t it be better to pay more upfront for a safe design than incur sizeable costs later mandated by the legal system to pay for damages resulting from an unsafe system that only satisfies the minimum standard?