Article 9

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First Flush of Stormwater Pollutants Investigated in Texas

The concept of the first flush was first advanced in the early 1970s. Runoff sampling methods of this era required the collection of multiple flow and water quality samples over the duration of a storm event. As researchers examined monitoring data during storms, they discovered that pollutant concentrations tended to be much higher at the beginning of a storm compared to the middle or the end of the event.

It was reasoned that the store of pollutants that had accumulated on paved surface in dry weather quickly washed off during the beginning of the storm. Although runoff rates were greater at the middle and tail end of a storm, the store of pollutants available for washoff was depleted, and consequently the concentration of pollutants declined.

Stormwater managers quickly grasped the practical significance of the first flush phenomenon. If most of the urban pollutant load was transported in the beginning of a storm, then a much smaller volume of runoff storage would be needed to treat and remove urban pollutants. After further monitoring and modeling, the half inch rule was advanced. Essentially, the rule stated that 90% of the annual stormwater pollutant load was transported in the first half inch of runoff.

Many communities adopted this simple standard as the basis for providing water quality control in developing areas: size your stormwater practice to capture the first half inch of runoff, and you will treat 90% of the annual pollutant load. Other communities modified the treatment standard further, by requiring that stormwater practices only capture the first half inch of runoff produced from impervious areas of the site.

With the advent of sophisticated automated sampling equipment to measure stormwater runoff in the 1980s, entire storm events could be represented by a single composite sample-known as the event mean concentration (EMC). One consequence of this technological advance was that researchers were no longer analyzing multiple samples during storms, and therefore, could not examine the behavior of pollutant concentrations during individual storm events. Further research into the first flush waned, and the half-inch rule became somewhat an article of faith in the stormwater community.

Recent analysis by Chang and his colleagues (1990), however, suggests that both the first flush phenomenon and the half-inch rule may not always hold true. Chang analyzed pollutant concentration data from over 160 storm events at seven urban runoff monitoring stations operated by the City of Austin, Texas from 1984 to 1988. The entire dataset was divided into different runoff increments (0 to 0.1 inch, 0.11 to 0.2 inch and so on). For purposes of his analysis, Chang conservatively defined the first flush as the first tenth of an inch of runoff. The pollutant concentration during the first flush was then compared to the pollutant concentration during the entire runoff event (EMC).

The results of the analysis are shown in Table 1. Shaded cells in the table indicate situations where the first flush phenomena did not occur (i.e., the storm EMC either greater than or equal to 90% of the first flush concentration). As can be seen, the first flush effect is most pronounced for sites that are highly imperviousness, but is much weaker at lower levels of imperviousness (five to 30%). For certain pollutants, such as nitrate, copper, ortho-phosphorus, bacteria and sediment, the first flush phenomena effect is weak or absent altogether.

If the first flush effect is not as strong and universal as previously thought, should it still be used as a basis for determining the volume of stormwater treatment? To answer this question, Chang performed additional modeling to determine the proportion of the annual pollutant load that would be captured under the half-inch rule (Table 2).

The analysis does suggest that the half-inch rule works effectively for sites with less than 50% impervious cover for most of the stormwater pollutants examined. However, above this threshold, the rate of pollutant load capture drops off sharply. On average, only 78% of the annual pollutant load is captured for sites with 70% impervious cover, and a mere 64% for sites with 90% impervious cover.

To put these results into perspective, consider a stormwater practice designed under the half inch rule on a 90% impervious site. Further, assume that the stormwater practice removes on average 50% of the pollutants that it captures. The net annual pollutant removal rate for the stormwater practice, however, would only amount to 32% since a large fraction of the annual pollutant load is never captured by the practice. The clear design implication is that the half-inch stormwater

practice sizing rule is not adequate for sites with high impervious cover. Communities that still utilize the half-inch rule may wish to consider other sizing alternatives.

One alternative technique to size urban stormwater practices involves basing the required treatment volume on the runoff produced from a larger storm (e.g., the 1.25 inch rainfall event) using a simple runoff coefficient. This method results in a greater treatment volume as impervious cover increases, and therefore, should avoid the key deficiency associated with the half-inch rule.

—TRS

Reference

Chang, G., J. Parrish and C. Souer. 1990. *The First Flush of Runoff and Its Effect on Control Structure Design*. Environ. Resource Mgt. Div. Dept. of Environ.and Conservation Services. Austin, TX.

Table1: First Flush Concentration As a Function of Imperviousness (Mean concentration in mg/l of first tenth of an inch of runoff) (Chang *et al*., 1990)

Pollutant	5% Imp.	30% Imp.	50% Imp.	70% Imp.	90% Imp.
BOD (5-day)	9	10	14	16	19
COD	26	52	65	66	69
Total organic C	7	13	14	18	24
NO_3 + $N0_2$	0.15	0.71	0.52	0.55	0.67
Total Kjeldahl N	0.52	0.91	1.10	1.24	1.40
Ammonia	0.09	0.24	0.38	0.30	0.24
Phosphate	0.04	0.22	0.20	0.20	0.20
Total solids	80	170	212	220	123
Copper	0.01	0.01	0.01	0.01	0.01
Iron	0.36	0.68	0.48	0.54	0.58
Lead	0.004	0.045	0.03	0.04	0.06
Zinc	0.008	0.060	0.090	0.12	0.17
Fecal Coliform	9	39	28	28	31
Fecal Strep	9	30	27	27	30

Cells are shaded to indicate when the event mean concentration is within 90% of the recorded first flush concentration

Table 2: Percent of Annual Pollutant Load Captured Using the Half-inch Rule As a Function of Site Imperviousness (Chang *et al*., 1990)

Pollutant	10% Imp.	30% Imp.	50% Imp.	70% Imp.	90% Imp.
BOD (5-day)	100	93	86	80	70
COD	100	97	86	80	79
Total organic C	100	94	83	82	78
NO_3 + $N0_2$	100	91	84	79	72
Total Kjeldahl N	100	90	87	80	73
Ammonia	100	96	88	76	61
Phosphate	100	91	81	77	73
Total solids	100	81	75	53	43
Copper	100	93	80	76	74
Iron	100	99	81	84	66
Lead	100	99	94	83	81
Zinc	100	98	87	84	68
Fecal Coliform	100	93	83	77	62
Fecal Strep	100	91	82	756	5