Stormwater Runoff Reduction

Summary

The CITY green stormwater runoff analysis estimates the amount of stormwater that runs off a land area during a major storm, as well as the time of concentration and peak flow. The program determines runoff volume based on the percentage of tree canopy, and other landcover features as digitized by the user in the CITYgreen view or as reported in a raster data set.

The analysis also considers a variety of localized information identified automatically by CITYgreen or entered by the user, such as local rainfall patterns, soil type, and other site characteristics.

The Stormwater Runoff program incorporates procedures and formulas developed by the USDA Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), to estimate runoff volume as well as percent changes in time of concentration and peak flow. The Urban Hydrology for Small Watersheds model, commonly referred to as Technical Release 55 or TR-55, was incorporated into CITYgreen. The program uses NRCS curve numbers that represent the relative amount of imperviousness and water infiltration properties of soil and land cover. Curve numbers range from 30-98; the smaller the number the less the runoff.

TR-55 was customized with the help of Don Woodward, PE, a hydraulic engineer with NRCS, to determine the benefits of trees and other urban vegetation with respect to stormwater management.

Technical Methodology

CITYgreen's stormwater runoff analysis enables a user to map urban land cover features (grassland/shrub, trees, buildings, and impervious surfaces) and determine percentages of each landcover feature.

Landcover percentages are then combined with average precipitation data, rainfall distribution information, percent slope, and hydrologic soil group, to estimate how trees affect runoff volume, time of concentration, and peak flow. In addition, the program estimates, in cubic feet, the additional volume of water that would have to be managed if trees were removed. This volume estimate can be associated with an economic value since planners generally know the cost per cubic foot to build a retention pond in their municipality. CITYgreen also enables the user to model different landcover and precipitation scenarios to determine acceptable development or conservation practices.

The TR-55 model was designed to analyze runoff patterns during a 24-hour single storm event. Engineers and non-engineers typically design stormwater management facilities for average storm events, usually 24 hours in duration, according to NRCS. CITYgreen allows the user to input values for the amount of rain that would fall during a typical 24-hour event observed within a 2-year span. This value is based on NRCS estimates of rainfall distributions for different regions of the country.

Slope information is taken from georeferenced data. Alternatively,the user can input a slope, which can be best thought of as the estimated average slope of the site. The following formulas are used to estimate curve numbers, stormwater runoff, time of concentration, and peak flows.

Formulas Used in Calculations

Curve Numbers:
CN (weighted) = Total Product of (CN x Percent landcover area)/Total Percent Area or 100

Potential Maximum Retention after Runoff begins:
$S = ((1000/CN) - 10)$

Runoff Equation:
$Q = [P - 0.2 ((1000/CN) - 10)]^2/P + 0.8 ((1000/CN) - 10)$

Flow Length:
$F = (\text{total study area acres}^{0.6}) \star 209.0$

Lag Time:
$L = ((F^{0.8}) \star((S + 1.0)^{0.7}) / (1900 \star ((\text{slope})^{0.5})))$

Time of Concentration:
$Tc = 1.67 \star L$

Unit Peak Discharge:
$\log(qu) = C_0 + C_1\log(Tc) + C_2[\log(Tc)]^2$

Peak Flow:
$\text{Peak} = (qu \star Am \star Q \star Fp)$

Storage Volume:
$Vs = Vr \star(C_0 + (C_1(qo/qi)) + (C_2 ((qo/qi) (qo/qi))) + (C_3 (qo/qi) \star (qo/qi) \star (qo/qi))) \star \text{study area acres} \star 43560.17/12$

Variable Definitions

P = Average rainfall for a 24-hour period (inches)

Am = Study area acres/640 to determine square miles

Fp = Swamp pond percentage adjustment factor

qo = Existing peak flow condition with trees

qi = Peak flow without trees

C_0 = TR-55 coefficents in accordance with raintype

Output Values

Peak = Peak Flow (cfs)

Vs = Storage volume (cubic feet)

Vr = Runoff volume (inches)

CN = Runoff curve number (weighted)

Q = Runoff (inches)

F = Flow length (feet)

S = Potential maximum retention after runoff begins (inches)

L = Lag time (hours)

Tc = Time of concentration (hours)

qu = Unit peak discharge (csm/inches)

TR-55 formulas are used in most engineering firms, soil conservation districts, and municipalities around the country. As of 1994, more than 300,000 copies of the TR-55 manual have been sold by the U.S. National Technical Information Service. The NRCS methods used in TR-55 are very effective in evaluating the effects of land-cover/land use changes and conservation practices on direct runoff. For more information about TR-55, see the following website:
www.wcc.nrcs.usda.gov/water/quality/common/tr55/tr55.html

The CITYgreen stormwater runoff analysis is not intended to be used to design stormwater management facilities, culverts, or ditches. The program is used to estimate the effects of vegetation, especially trees, on runoff volume and peak flow. Percent changes in runoff volume and peak flow are determined automatically by comparing two different scenarios for the same site.

References

1. Cronshey, Roger G. 1982. "Synthetic Regional Rainfall Time Distributions, Statistical Analysis of Rainfall and Runoff." Proceedings of the International Symposium on Rainfall-Runoff Modeling. Littleton, CO: Water Resources Publications.
2. Engineering Field Handbook, Chapter 2. 1990. Washington, DC: USDA Soil Conservation Service,.

3. National Engineering Handbook, Chapter 15, Section 4, "Hydrology," 1985. Washington, DC: USDA Soil Conservation Service.

4. Kibler, David F., Small, Aaron B. and R. Fernando Pasquel. "Evaluating Hydrologic Models and Methods in Northern Virginia," Virginia Tech Research Paper Evaluating Runoff Models.Blacksburg, VA: Virginia Polytechnic Institute and State University.

5. Rallison, Robert E. and Norman Miller. 1981. "Past, Present, and Future SCS Runoff Procedure" Rainfall-Runoff Relationship." Proceedings of the International Symposium on Rainfall-Runoff Modeling. Littleton, CO: Water Resources Publications.

6. Technical Release 55, Urban Hydrology for Small Watersheds. June 1986. Washington, DC: USDA Soil Conservation Service.

7. Water Environment Federation-American Society of Civil Engineers. 1992. Design and Construction of Urban Stormwater Management Systems. New York: American Society of Civil Engineers.

8. Woodward, Donald M. and Helen Fox Moody. 1987. "Evaluation of Stormwater Management Structures Proportioned by SCS TR-55." Engineering Hydrology: Proceedings of the Symposium. New York: American Society of Civil Engineers.

9. Sanders, Ralph A. 1986. "Urban Vegetation Impacts on the Hydrology of Dayton, Ohio," Urban Ecology, vol. 9. Amsterdam: Elsevier Science Publishers B.V.

Trees and Energy Conservation

Summary

CITYgreen's energy conservation analysis utilizes methods developed by Jill Mahon of AMERICAN FORESTS, interpolated from research by Dr. Greg McPherson of the USDA Forest Service. The program estimates the energy conservation benefits of trees resulting from direct shading of one- and two-story residential buildings.

Trees are most effective when located to shade air conditioners, windows, or walls and when located on the side of the home receiving the most solar exposure (in addition to other criteria). In many parts of the country the west side is most valuable, followed by the east and south, although this ranking can change based on geographical considerations.

CITYgreen assigns each tree an energy rating, 1 through 5, based on location characteristics listed above and information about tree size and shape. For many parts of the country, for instance, a large tree located near the west side of a building and shading an air conditioner or window would be assigned a near-maximum energy rating.