Technical Note #58 from Watershed Protection Techniques. 2(1): 282-284

Methods for Estimating the Effective Impervious Area of Urban Watersheds

by Roger C. Sutherland, P.E.

One of the most difficult and important parameters that must be estimated for accurate hydrologic analyses is the effective impervious area (EIA) of a watershed or basin of interest. EIA is the portion of the total impervious area (TIA) within a basin that is directly connected to the drainage collection system. EIA includes street surfaces, paved driveways connecting to the street, sidewalks adjacent to curbed streets, rooftops which are hydraulically connected to the curb or storm sewer system, and parking lots.

EIA is usually reported as a percentage of total basin or subbasin area. In traditional urban runoff modeling or hydrologic analysis, the EIA for a given basin is usually less than the TIA. However, in highly urbanized basins, EIA values can approach and equal TIA values.

The EIA of a basin is an important parameter in the rainfall/runoff process because it directly affects the volume of runoff. Many hydrological models assume all the precipitation that falls on impervious areas becomes direct runoff. In actuality, the precipitation falling on impervious areas which are not hydraulically connected to the drainage collection system does not always result in direct runoff. Impervious area that does not contribute directly to runoff should be subtracted from the total impervious area to obtain the *effective* impervious area, in order to get a more accurate estimate of runoff volumes.

Determination of Effective Impervious Area

The methodology for determining EIA has been refined through three levels:

1. Direct measurement in the field

The direct measurement of EIA is a tedious exercise which is rarely undertaken since most consultants cannot afford its excessive labor cost. To actually measure the EIA of a basin, it is necessary to catalog and evaluate the effectiveness of the hydraulic connection between *each* of the impervious areas and the major collector systems. This extremely time consuming exercise is impractical for most drainage planning and design related activities.

2. Derivation from models run on gauging data

If a basin is gauged, the effective impervious area can be estimated by employing a rainfall-to-runoff model like HEC-1 or SWMM to calibrate the EIA parameter. This calibration is performed by fixing reasonable estimates of the precipitation loss components for the pervious portions of the basin and impervious areas, then adjusting the value of EIA to correlate computed and observed runoff volumes. The calibration process should be undertaken for several observed rainfall events, with the final estimate of EIA representing the weighted average of those values calibrated for each individual storm.

3. Empirical equations derived from whole-basin or subbasin parameters

Empirical equations can be developed to compute realistic values of EIA based on physical basin parameters that are easy to estimate. For example, the United States geological Survey (USGS) developed estimates of EIA for over 40 watersheds throughout the metropolitan areas of Portland and Salem, Oregon (Laenen, 1980 and 1983). Working with this database, the USGS also developed an empirical equation to estimate EIA as a function of total impervious area.

It should be noted that the modeling technique used by the USGS lumped all of the precipitation excess into a single optimized percentage of the basin area that was assumed to be contributing runoff. This optimized value was defined as the effective impervious area. Working with these optimized values, the USGS (Laenen, 1983) developed the following equation:

$$EIA = 3.6 + 0.43\,(TIA) \qquad (1)$$

Equation (1) has been found to work well for TIA values greater than 10% and less than 50% but provides unrealistic EIA values for TIA values outside of this range (i.e., more urbanized areas). In surface water management master planning, one commonly deals with *small subbasins* (i.e. 20 to 70 acres) in which the ultimate mapped impervious area can routinely exceed 50%, and may be as high as 90%.

Therefore, there is a need to develop a better relationship between TIA and EIA and several alternative equations based upon the USGS data have recently been developed to satisfy this need, known as the Sutherland Equations.

The general form of the equation to describe the relationship between TIA and EIA is as follows:

$$EIA = A\,(TIA)^{B} \qquad (2)$$

In Equation (2), A and B are a unique combination of numbers such that the following criteria are satisfied:

1. If TIA = 1 then EIA = 0%
2. If TIA = 100 then EIA = 100%

Based on the USGS calibrated values of EIA for all basins with TIA ≥ 4%, several empirical equations were developed to apply to various generalized conditions of subbasins which may be encountered in the drainage master planning process. The first equation presented below (Equation 3) provided the best fit for all of the TIA versus EIA data used in the analysis. The remaining equations were based primarily on engineering judgement and experience as related to the various subbasin conditions which affect EIA.

The **Sutherland EIA Equations** are as follows:

1. *Average basins* where the local drainage collector systems for the urban areas within the basin are predominantly storm sewered with curb and gutters, no dry wells or other drainage infiltration areas are known to exist, and the rooftops in the single family residential areas are not connected to the storm sewer or piped directly to the street curb.

$$EIA = 0.1\,(TIA)^{1.5},\; TIA \geq 1 \qquad (3)$$

2. *Highly connected basins* where everything in Condition 1 applies except the residential rooftops are predominantly connected to the streets or storm sewer system.

$$EIA = 0.4\,(TIA)^{1.2},\; TIA \geq 1 \qquad (4)$$

3. *Totally connected basins* where 100% of the urban area within the basin is storm-sewered, with all impervious surfaces appearing to be directly connected to the system.

$$EIA = TIA \qquad (5)$$

4. *Somewhat disconnected basins* where at least 50% of the urban areas within the basin are not storm sewered, but are served by grassy swales or roadside ditches, and the residential rooftops are not directly connected. Alternatively, Condition 1 may apply, but the basin is known to have a few dry wells or other infiltration areas.

$$EIA = 0.04\,(TIA)^{1.7},\; TIA \geq 1 \qquad (6)$$

5. *Extremely disconnected basins* where only a small percentage of the urban area within the basin is storm sewered, or a large portion of the basin area (i.e. 70 percent or more) drains to dry wells or other infiltration areas.

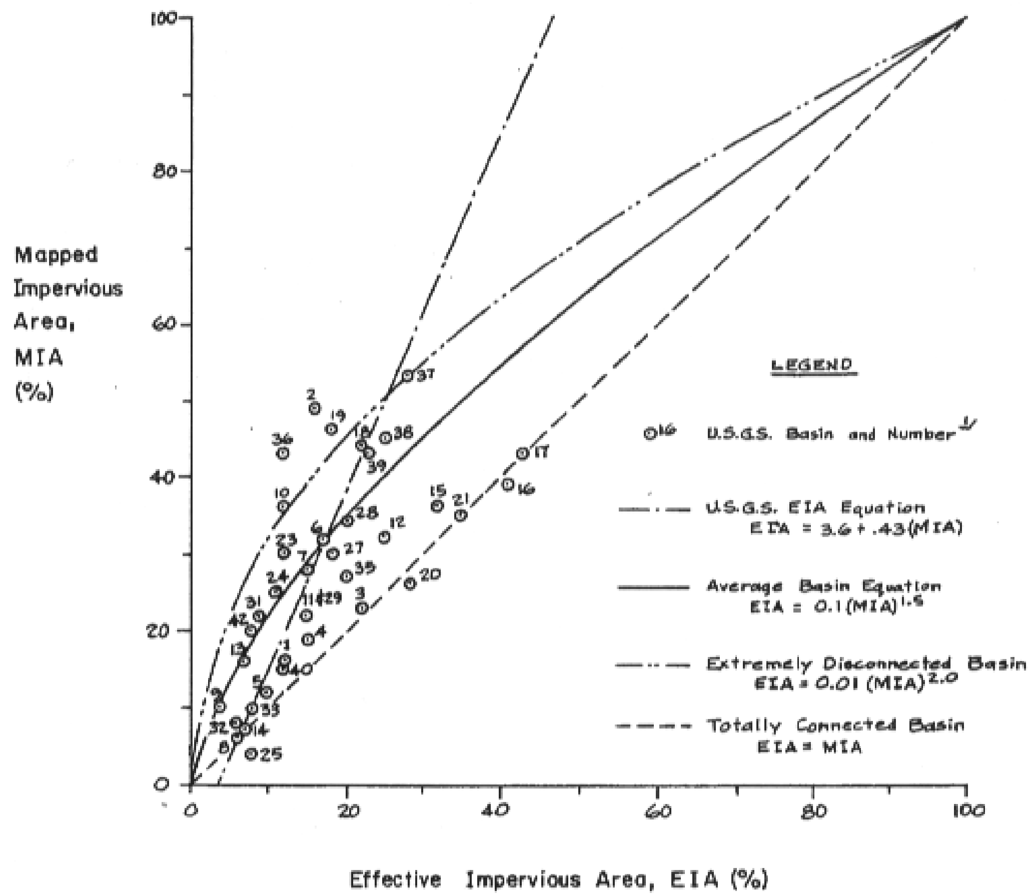
$$EIA = 0.01\,(TIA)^{2.0},\; TIA \geq 1 \qquad (7)$$

Figure 1 compares the Sutherland EIA Equations along with the original USGS Equation for the range of impervious data collected in Oregon. The variation in the 42 actual subbasin data presented in Figure 1 demonstrates the difficulty in accurately estimating the EIA of a drainage basin. It is imperative that the drainage planner or engineer performs some degree of on-site investigation of the basin to determine which EIA equation may apply to the given circumstance. The greatest strength of the Sutherland EIA Equations is their consistency in providing reasonable estimates of EIA over the entire range of TIA. Therefore, they can be used in the surface water management planning process to estimate the change in EIA which will occur as a basin becomes urbanized.

References

Laenen, A. 1980. *Storm Runoff as Related to Urbanization in the Portland, Oregon - Vancouver, Washington Area, U.S.G.S.* Water Resource Investigations Open File Report 80-689.

Laenen, A. 1983. *Storm Runoff as Related to Urbanization Based on Data Collected in Salem and Portland and Generalized for the Willamette Valley, Oregon, U.S.G.S.* Water Resources Investigations Open File Report 83-4143.



[1] EIA values were based on a U.S.G.S. rainfall to runoff model study. Only points with MIA ≥ 4 were plotted (Laenen, 1980 and 1983).

Figure 1: Plot of Sutherland Equations and USGS Equation That Illustrates Relationships Between Total and Effective Impervious Area for a Range of Watersheds