WATER PROCEDURES

Background

The surface water component of the ecosystem services calculation is based on the single event concepts of Natural Resources Conservation Service (NRCS) Technical Release 55 "Urban Hydrology for Small Watersheds" (TR-55). The purpose of the TR-55 computer program is to evaluate the impact of urbanization on the runoff volume and peak flow. The ecosystem services calculation determines the differences in runoff volumes for various scenarios' present conditions or present tree cover conditions and no trees or increase in trees.

The ecosystem services calculation provides an estimate of the percent increase in the storage required to mitigate the increased runoff volume associated with urbanization. The benefits are associated with the saving or increase in construction costs for stormwater management structures. The ecosystem services calculation uses local construction costs to estimate these benefits when available or $2.00 per cubic foot. Normally these savings are based on the 2 year 24 hour storm over the sample area. There have been many papers describing the use of TR-55 to evaluate the impacts of urbanization/tree cover on runoff volumes (Walton 1997,1996).

The ecosystem services calculation also determines the decrease in infiltration volume on a percentage basis for the 2 year 24 hour storm with the increase in urbanization. This is based on the change in runoff curve number for the various scenarios.

This same concept of per cent change in loadings is applied to the water quality component of the Ecosystem services calculation program. This concept is used in other water quality programs. A study by the VPI for the Northern Virginia Planning Commission related loadings to land use on a desk top computer model(NVPDC 1979). The results for this component are expressed as a change in the per cent loading.

Ecosystem services calculation uses ARC view concept with aerial photographs and NRCS STATSGO digitized soil information to compute the runoff curve numbers (RCN) for various scenarios. The standard procedure is to verify the digitized land cover information with field sampling techniques. The ecosystem services calculation used by the Global Ecosystem Center for the Urban Ecosystem Analyses are standard subroutines available in ARCview

Literature Search. The search of the literature did not provide any indication of a simple single event hydrologic model that could be incorporated with TR-55 in Urban Ecosystem Analysis methodology to provide the desired water quality results. There is a spread sheet model from EPA and Perdue University called Long Term Hydrologic Impact Analysis (L-THIA) (Lim et al 1999). This program computes annual and event runoff and the impact changes in land use on certain water quality pollutants. T. R. Schueler in Controlling Urban Runoff: A Practical Manual for Planning and Designing BMP's uses the concept of relating loading with land use (Schueler 1987). Although this model does not include a soils variable K. J. Robinson used the concept of relating loadings to land use and soil in his Masters thesis (Robinson, 1993).

There is additional information in the literature that correlates pollutants with land use. Table 1 provides the pollutants from L-THIA (Lim, et. al 1999). The default EMC loading values in L-THIA are for various land uses as shown in Table 1 and apparently do not vary by soil type which is very logical for urban land uses. However, variation by hydrologic soil type might be true for agricultural lands uses. Table 2 provides the pollutants from Central Park in NY for various land uses (Lenz, 2000). There was no indication of the associated hydrologic soil groups for the land uses selected in Central Park.

Table 1 Pollutants from L-thia computer program

Land Use	Curve number	Nitrogen ppm	Phosphorus Ppm	Suspended Solids Ppm	Lead ppm	Copper ppm	Zinc ppm	Cadmium ppm	Chromium ppm	BOD ppm	COD ppm
Commercial	92	1.34	0.32	55.5	0.0130	0.1450	0.18000	0.00960	0.0118	116.0	23.0
Industrial	88	1.26	0.28	60.5	0.0150	0.1500	0.24500	0.00200	0.0070	45.50	14.0
Resident	85	1.82	0.28	60.5	0.0090	0.0800	0.00075	0.00075	0.0021	49.50	25.5
Open space	69	1.82	0.28	60.5	0.0090	0.0800	0.00075	0.00075	0.0021	49.50	25.5
Agricultural	75	16.4	1.30	107.0	0.0015	0.0015	0.01600	0.00100	0.0100	0	4.0
Forest	55	16.4	1.30	107.0	0.0015	0.0015	0.01600	0.00100	0.0100	0	4.0
Grass/pasture	61	0.7	0.01	1.0	0.0050	0.0010	0.00600	0.00100	0.0075	0	0.5
Paving	98	1.82	0.57	41.0	.009	.009	.08	.0075	.0021	49.5	28.5

Table 2 Pollutants from Central Parks

Pollutant	Paved	Open/pasture mg/l	Wood/grass mg/l	Forest/Woodland mg/l	Urban commercial mg/l	Managed lawns mg/l

TP	0.443	0.12	0.135	0.15	0.209	7.75
TN	1.807	1.51	1.145	0.78	2.096	33.5
TSS	212.33	70	54.5	39	69	87
CN	98	79	76	73	83	79

Table 3 relates annual pollutants loadings for two types of land uses (Schuler, 1994). The available literature provided no indication of the hydrologic soils group with the associated land use.

Table 3 Annual Loadings Pollutants from two land uses

Land Use	Curve Number	Phosphorus Lbs/ac/yr	Nitrogen Lbs/ac/yr	Zinc Lbs/ac/yr
Parking lot	98	2	15.4	0.3
Meadow	58	0.5	2	0

The comparison of the various loading was difficult because the loadings in Tables 1 and 2 are Event Mean Concentrations (EMC) and in Table 3 are annual loadings. There are other loadings reported in the literature but the units are not consistent or similar to the unit for the EMC loadings in Ecosystem services calculation program.

Ben Urbonas reported in "Stormwater: Best Management Practice and Detention for Water Quality , Drainage and CSO Management", that the final NURP report indicates that there is little significant differences in constituent EMC's between geographic regions (Urbonas etal 1993). This would strongly suggest the loadings are relative uniform across the United States. Hence, it was decided to use default values in Ecosystem services calculation program. The User still has the option of supplying his/her own EMC values.

There is considerable literature indicating that urban erosion rates are not related to changes in land use or curve number. The erosion rates are a function of the slope, soils, and cover type (NRCS 1978). It was decided to incorporate the USLE formulation into ecosystem services calculation methodology the erosion tool. The crop and practice in the Ecosystem services calculation program were taken from information provided by the South Tahoe Soil and Water Conservation District. (1986)

A recent US Geological Survey open file report entitled "US Geological Survey Urban-Stormwater Data Base of Constituent Storm Loads: Characteristics of Rainfall, Runoff and Antecedent Conditions and Basin Characteristics" Water Resources Investigation Report 87-4036 provided some data that was used to verify the ecosystem services calculation. The comparison of the rainfall-runoff data from 94 watersheds across the county indicated that the urban curve numbers used for the ecosystem services model are reasonable. The average curve number for the 94 watersheds from land use and soils data was 86.6 and the average curve number from the storm data was 85.3. (Woodward, 2003). There was a total of 1144 storms analyzed.

The individual watershed loading were too variable to determine a statistical significant trend with curve number (Woodward 2003). The values appeared to agree in general terms with the values being used for the ecosystem services model being used by the Global Ecosystem Center.

Procedure: After the literature review and considering the purpose of ecosystem services calculation model used by the Global Ecosystem Center which is to indicate the impact and not to predict the results, it was decided to relate the pollutant loading to the Curve Number for the land use and then determining the percent reduction in the pollutant as the cover is changed. This means that the results is an indication of the impact of land use change rather than a change in the hydrology.

The default values in Table 4 were developed from the information in Tables 1 and 2. The values in Table 3 indicate that there is a trend between pollution loadings and curve number. A review of the loading data from the NURP report as reported by Urbona and Stahre (1993) indicate a decreasing trend with land use from Commercial to agricultural.

The ecosystem service modeluses default equations developed from the information in Table 4. The computer program gives the user the option of providing local pollutant loadings if desired. These are EMC, which is consistent with the event concepts of TR-55 and ecosystem services calculation.

Table 4 Recommended default loadings for ecosystem services

Land Use	Curve Number	Nitrogen mg/l	Phosphorus mg/l	Suspended Solids mg/l	Zinc Ppm	Lead ppm	Copper ppm	cadmium ppm	Chromium ppm	BOD ppm	COD ppm
Paving Lot	98	1.807	0.443	212.33	0.080	0.009	0.0090	0.0075	0.0021	49.5	25.5
Commercial	85	2.096	0.443	69.00	0.180	0.013	0.0090	0.0075	0.0100	116.0	23.0
Urban	83	2.096	0.209	69.00	0.080	0.009	0.0090	0.0075	0.0021	49.5	25.5
Forest	73	0.780	0.150	39.00	0.006	0.005	0.01	0.0010	0.0075	0	0.5

The linear relationships based on the information in Table 4 are shown in Tables 5 and 6. Table 5 is based on the data and

Table 6 is based on the assumption that the regression equation must pass through zero.(Woodward, 2003)

Table 5 Statistical Characteristics for the data

Variable	Nitrogen	Phosphorus	Suspended Solids	Zinc	Lead	Copper	Cadmium	Chromium	COD	BOD
R	0.603968	0.811333	0.936943	0.4062	0.47677	0.78234	0.76234	0.407626	0.783234	0.407626
R Square	0.364778	0.659262	0.877863	0.1650	0.22731	0.581163	0.581163	0.166159	0.613455	0.166159
S E	0.609951	0.110278	33.36819	0.0799	0.00352	0.00396	0.002576	53.24625	9.244804	53.24625
	mg/l	Mg/l	mg/l	ppm	Ppm	Ppm	Ppm	ppm	ppm	ppm
Intercept	-1.41799	-0.719463	-505.1142	-.0153	-.00384	0.012394	-0.01456	-106.3185	-59.8039	-106.318
Coefficient	0.036728	0.012162	7.108515	0.0028	0.00015	-0.000037	0.000241	1.88713	0.925414	1.888713

It should be noted that in all cases the R or R^2 are lower for the regression equations passing through zero.

Table 6 Regression coefficients for equation passing through zero

Variable	Nitrogen	Phosphorus	Suspended Solids	Zinc	Lead	Copper	Cadmium	Chromium	COD
	Thru Zero	Thru Zero	Thru Zero	Thru Zero	Thru Zero	Thru Zero	Thru Zero	Thru Zero	Thru Zero
R	0.538428	0.583977	0.517179	0.313792	0.455168	NA	0.53791	0.306029	0.510545
R Square	0.289905	0.341029	0.267474	0.098465	0.207178	NA	0.289347	0.093645	0.260656
S E	0.526556	0.125034	66.72289	0.067823	0.002908	NA	0.00274	45.32615	10.43917
	mg/l	Mg/l	mg/l	ppm	Ppm	ppm	Ppm	ppm	ppm
Intercept	0	0	0	0	0	NA	0	0	0
Coefficient	0.02018	0.003765	1.213459	0.00104	0.000107	NA	0.00007	0.647898	0.227459

There is some logic to have the regression equation pass through zero. There should be zero pollutant loadings with a Curve Number of zero. However based on the limited data in Table 4 there is no support for making the regression equation pass through zero. (Woodward, 2003)

Because of the limited data in Table 4 and that NRCS recommends that the minimum Curve Number should be 30, it was decided that the information in Table 5 be used in the computer program. Thus the range of Curve Number should be 30 to 98 for the development impacts of the change in tree cover.

After a review of the information in an initial version of the computer program, it was decided to limit the Curve Number to 50. If the pollutant was a negative value from the regression equations it was decided to limit the pollutant to the minimum value rather than a value of zero since a negative value makes no sense. One reason for a limited value of 50 in the Curve Number range is that normally a weighted Curve Number is used rather than a Curve Number for a single land use. Also in all cases the weighted urban curve numbers are greater than 50.

The procedure is (Loading for initial conditions – loading for tree conditions) (100)/ Loading for initial conditions

Conclusions The concept for determining the volume of runoff using the NRCS Curve Number procedure is sound and is supported by documentation. (Kibler, Small and Pasquel 1995 and Woodward an Moody It is important to remember that Ecosystem services calculation only considers the per cent change in the runoff volume and not the actual runoff and peak rate of runoff. The ARS/NRCS Runoff Curve Number Work Group has completed a detailed study of small watershed data and believes that this data supports the original curve numbers in TR-55. The study by Woodward for the ecosystem service calculation indicates that the urban runoff curve numbers are reasonable (Woodward 2003b). Several recent papers support the ecosystem services calculation used by the Global Ecosystem Center for tree removal.(Carl 2002, Martin 2004 and Bruns 2003).

The same is true for the infiltration component of the methodlogy. This component of the calculation is not directly documented, the volume component is supported. Therefore, it is logical that the loss function is accurate.

The water quality component of Ecosystem services calculation is based on the default values shown in Table 4. It should be noted that copper increases with decreasing CN. The other pollutants decrease with decreasing CN. Additional research might improve the product by adding a continuous water quality routine. This concept of relating the loadings to land use and hence curve number is sound and supported by the literature. It should be remember that the Ecosystem services calculation program reports the per cent change in the loadings and not the loading itself.

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