Green Values Stormwater Calculator Methodology

The CNT Green Values Stormwater Calculator (greenvalues.cnt.org) is designed to arrive at a first approximation of the hydrologic and financial conditions for a site that is defined by the user. In order to calculate the conditions, a variety of assumptions are made. The following paragraphs describe the process of calculation and underlying assumptions. The calculations are based on procedures contained in the report "Urban Hydrology for Small Watersheds," Technical Release 55, which are commonly used in the Chicago region. (The TR-55 Report)

Site Template

The series of steps that occur in the calculator when the Site Statistics are entered is:
The total size of the site is converted to a square – the length and width of the neighborhood/site is shown in the scenario detail
The area of each lot is calculated by dividing the total site size by the number of lots
The ratio of width to length of each lot is assumed to be 1:3 – the dimensions of each lot are shown in the scenario detail
The total length of frontage streets is assumed to be equal to the lot width times number of lots
The lot street area is calculated by multiplying the lot width by one half of the street width and the lot sidewalk area is the lot width times the sidewalk width – each is shown in the scenario detail

Curve Numbers

Each of the land use types is assigned a Curve Number (CN). The CNs are traditionally used as a factor to estimate the characteristic runoff from a land surface area as a function of the rainfall amount and pattern. The CNs, as adapted from comparable land uses in Table 2-2 of TR-55, are shown below for each soil type. (The CNs were developed decades ago. CNT and others are conducting research to improve the accuracy of the CNs for use with green infrastructure projects.)

Soil Type	"A"	"B"	"C"	"D"
Lawn	39	61	74	80
Impervious Surfaces	98	98	98	98
Woods/Trees	32	58	72	79
Porous Pavement	40	40	40	40
Swale/Garden	35	51	63	70
Green Roof	75	75	75	75

A weighted average curve number is calculated for each scenario. The average CNs are shown in the scenario detail.

Lot Discharge

The lot discharge is calculated for an assumed 2-year, 24-hour storm (a storm having a chance of occurring of 50% each year), with total precipitation of 2.95 inches. The procedure contained in Chapter 2 of TR-55 is used, with the time of concentration assumed to be the time for overland flow to travel the length of the lot with a lawn cover. The result is the runoff discharged, in cubic feet, from each lot due to the 2.95-inch rainfall.

Lot Peak Discharge

The lot peak discharge is calculated for the same 2.95-inch storm. The procedure contained in Chapter 4 of TR-55 is used. A typical rainfall pattern is used to calculate the peak rate of runoff, in cubic feet per second (cfs) from each lot.

Runoff Coefficients

Each of the land use types is also assigned a runoff coefficient, or C Value. The C Values are used in the "Rational formula"

$$Q = C*I*A$$

where Q = peak runoff rate (cfs)

C = dimensionless runoff coefficient used to adjust for abstractions from rainfall

I = rainfall intensity for a duration that equals the time of concentration (in/hr)

A = the area of the tributary basin (acres)

While there are a number of limitations to the use of the Rational formula, as discussed by Mays, it is very common for regulators and engineers to utilize it for local infrastructure design. Thus, the Green Values Calculator uses this formula. The C-Values for land uses in the calculator are shown below, as shown in Mays. They are not affected by soil types.

Lawn	0.30
Impervious Surfaces	0.90
Woods/Trees	0.10
Porous Pavement	0.50
Swale/Garden	0.15
Green Roof	0.75

A weighted average C Value is calculated for each scenario. The average C Values are shown in the scenario detail.

Pipe Routing

In order to estimate the costs of stormwater conveyance (either by pipes or swales), the street pattern is assumed to be parallel streets containing the individual lots. As an illustration, imagine that the streets are oriented from east to west. Each street would contain a number of lots equal to twice the width of the site divided by the width of a lot. (The streets are assumed to have lots on both sides.) This would probably result in streets having fractions of some lots and of fractions of streets, but that is assumed not to be of consequence.

In the cases where storm sewer pipes are used to conduct stormwater runoff from the individual lots to the discharge point or detention basin, it is assumed that each street contains a storm sewer pipe in the right-of-way that collects runoff from both sides of the street. The water from these small pipes then flows to a centrally-located pipe that goes from one end of the neighborhood to the discharge point or detention basin. (This pipe would flow from north to south in our illustration.)

The sizes of the pipes vary depending on the flows they must handle. The diameter and length of each segment of pipe is shown in the scenario details. The small pipes are sized to handle the flow from half of the lots on a street. In order to estimate costs of the central pipe, it is assumed that it is constructed with three sizes – the upstream fourth of the central pipe has the capacity to handle flow from one entire street, the middle half of the central pipe has the capacity to handle half of the flow from the entire site, and the downstream half of the central pipe has the capacity to handle the total flow from the site.

The diameters of the sewer pipes are dependent on the peak flows each must handle, their slopes, and the materials that they are made of. It is customary to design storm sewers and swales to handle a larger storm than is assumed for the overland runoff. A 10-year design storm is used in this calculation – one with a chance of occurrence of 10% in any year.

Swale Routing

For those cases where swales are substituted for pipes, it is assumed that swales are located along the rear lot line of each lot. This is often done in new development. The alternative of using roadside swales is also feasible, but that may require two swales along every street as well as drainage pipes at each driveway. The size of the swales depend upon the peak flows, the slope, and the velocity of flow. The small swales that drain the lots can be shallow and almost imperceptible in the landscape. As with the pipes, these small swales flow into a larger, centrally-located swale that goes from one end of the neighborhood to the discharge point or detention basin. The swales are designed for peak flows from a 10-year design storm. The assumption made in the calculator is that they are designed to maintain a maximum flow velocity of 1.6 feet per second (cfs) so that they are safe and not subject to erosion. The dimensions of the swales are shown on the scenario detail.

Detention

For cases involving development of open land, there is a requirement that the outlet flows be controlled to avoid peak flows that exceed the capacity of local streams. The most common approach to this is construction of one or more detention basins. A key factor in sizing a detention basin is the allowable outlet flow. Many jurisdictions require an outlet no higher than 0.15-cfs per acre of development. Thus, for a 40-acre site, the outlet is limited to 6 cfs. The inlet flows are calculated using a design storm that is also specified by the jurisdiction. It is assumed for this calculation that the design storm is a 100-year storm, or one that has a 1% chance of occurring each year. Detention basins are sized for both the traditional case and the green case. The Modified Rational Method is used to size the detention basin.

The reductions in detention capacity with green alternatives cannot be assumed. Many regulators are concerned about the performance of BMPs over time and may not be willing to reduce the detention size. However, as experience is gained with green infrastructure, the requirements for detention may be more flexible.

If the neighborhood contains existing development, detention may not be required. In that case, the peak outlet flows and total runoff quantities from the pipe or swale system are key and their impact on the receiving stream and downstream communities must be assessed.

Financial Costs and Benefits

Each of the scenarios that is characterized on the "Hydrologic" screen is also shown on the "Financial," "Financial Detail," and "Scenario Detail" screens. The cost of a scenario is estimated by calculating the costs of components of the infrastructure and adding them together. The cost of components of the infrastructure for a scenario can be seen by clicking on the "Scenario Detail" screen and scrolling down. Both construction and annual maintenance costs are shown. The annual benefits of a scenario can be found in the same way. An attempt has been made to include financial estimates for each type of benefit, but many of them have not been quantified.

For simplicity's sake, only the costs of the stormwater infrastructure components that change between the green infrastructure and conventional infrastructure scenarios are utilized. For example, the cost of the rain garden as compared to a turf area of the same size was modeled, but the cost of the remaining turf that makes up the yard was not, because the cost would be the same for both scenarios.

The "Financial" screen includes additional information on how costs or are determined under the link "See how costs are calculated." A table in that section gives low, middle and high estimates of construction costs, annual maintenance costs, and component lifespan for each component. In each case, CNT has used the "mid" cost Sources of figures are linked from the estimates, allowing users to investigate and assess what costs are most appropriate. In many cases there is a direct link to the original source of the costs.

Information about the basis for estimating benefits, while less specific in most cases, can likewise be evaluated for applicability by the user. At this time, the costs and benefits used in the calculator cannot be changed by the user, but a little figuring using the information in the "Scenario Detail" screen can help arrive at other estimates.

Data Sources
Construction costs, maintenance costs, and lifespan data were gathered from the available literature for both green infrastructure and standard stormwater infrastructure. The impact of inflation was equalized across the sources by adjusting older construction and maintenance cost data with the Engineering News-Record's Construction Cost Index for 2005. Data were also converted into a standard set of units that would match the units in our hydrology model, such as cost per square foot or cost per linear foot.

Cost models

5, 10, 20, 30, 50, and 100 year costs
These costs equal (construction cost) X (number of times the component would have to be replaced) + (annual maintenance costs) X (total number of years) – (annual benefits) X (total number of years).

Net Present Value of Costs
The net present value worksheet calculates the 5,10, 20,30, 50, and 100 year costs as described above, but discounts future year costs at a Real Discount Rate "*r*" annually using the following equation:

Urban Hydrology for Small Watersheds – Technical Release 55, US Department of Agriculture Soil Conservation Service, 1986.
Stormwater Collection Systems Design Handbook, Larry W. Mays, P.E., McGraw-Hill, 2001.
Ibid, pg. 7.17.

$$NPV = \sum_{t=0}^{T} \frac{Cost_t}{(1+r)^t}$$