NEMO

NONPOINT EDUCATION
FOR MUNICIPAL OFFICIALS

TECHNICAL PAPER **NUMBER 4**

Do it Yourself! Impervious Surface Buildout Analysis

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Introduction

Impervious surfaces such as asphalt, concrete, rooftops, and compacted earth, prevent the infiltration of water into the ground. A growing body of research (see The Center for Watershed Protection's *'Watershed Protection Techniques'*, Vol. 1, No.3, Fall 1994) points to a direct relationship between the amount of impervious surfaces in a watershed and the quality and quantity of water found in that ecosystem (see NEMO Fact Sheet #3, *"Impacts on Development on Waterways*"). The following thresholds are suggested:

- Where <10 percent of a watershed is covered with impervious surfaces, streams are generally protected, although sensitive streams may begin to be stressed.
- Where 11-25 percent of a watershed is covered with impervious surfaces, streams are most likely impacted. Mitigation may be successful.
- Where over 25 percent of a watershed is covered with impervious surfaces, streams are most likely degraded. Mitigation will be difficult.

The research to date has not evaluated effects from the distribution of the impervious surfaces or the impacts of effective best management practices. The thresholds do provide a low cost qualitative assessment that the NEMO Project has found effective for educational purposes.

Intent

What follows are the methodologies used by the NEMO Project in Connecticut to determine how much impervious surface is present in a watershed and to conduct a zoning based, impervious surface 'build out' analysis. This paper is written for people or organizations that have GIS capability and assumes a working knowledge of GIS in order to perform the calculations. Although what is described here is specific to Connecticut, it can be applied elsewhere by substituting similar data sets. This paper is organized into four sections:

- Data You'll Need
- Additional Data
- Proceed As Follows
- Interpreting the Results

A discussion of sources and derivations of values for the amount of imperviousness associated with certain land use types is included as an appendix.

Data You'll Need

You must have data sets 1 through 4 listed below to perform the buildout analysis. The other described data layers are useful for proper interpretation and display of the information.

1. Landcover

Basic satellite interpretation has been the primary source of landcover information for the NEMO Project. The landcover data is used primarily to estimate how much impervious surface exists in the study area. It is available for the entire State of Connecticut. Dr. Daniel Civco and James Hurd created this data in 1991 at the University of Connecticut's Laboratory for Earth Resource Information Systems. Using computer analysis, they converted 30-meter pixel resolution satellite imagery from May 1988 and August 1990 images into a 23-category land cover map. This resolution of this data is relatively crude, but is appropriate for planning purposes down to the local watershed or neighborhood level.

There are several sources of landcover information ranging from ground survey to interpretations from satellite imagery. You must decide which source (level of accuracy) of landcover data is most appropriate for the purposes of your project (see NEMO Technical Paper #3 *"Methods for Deriving Impervious Cover*

Information") based on what you have available or on what you can afford to create.

Satellite Derived Landcover is available for Connecticut over the Internet at the UConn Library MAGIC Geo-Spatial Data Collection site magic.lib.uconn.edu or from the CT DEP NRC-GIS (860) 424-3555.

2. Watershed Boundaries

Since the goal of the impervious surface buildout is to see the effect impervious surfaces have on water resources, the appropriate framework is the watershed or drainage basin. It is necessary to know the boundary and area of a watershed in order to calculate the percentage of impervious surface.

The hierarchies of watershed boundaries that have been compiled by the CT DEP include major, regional, subregional and local. The NEMO Project uses sub-regional (for statewide or multi-town analysis) or local (approximately 1 square mile in area, for municipal level analysis) watersheds. These watersheds are small enough to highlight intensely developed areas and are useful for directing attention to specific water systems.

Watershed boundaries for Connecticut can be obtained from the MAGIC site or the CT DEP as referenced above.

3. Zoning Data

Zoning is a municipality's statement of how and where it intends to grow. Zoning data lets us calculate the amount and location of future land cover.

You may have to create this data but first check with your town's GIS, regional planning agency, water company or the local university's geography/GIS department for existing data sets.

4. Unbuildable areas

To get an accurate buildout based on present zoning, NEMO removes areas that will not be built upon in the future due to site limitations. These include waterbodies, wetlands (regulated in Connecticut) and committed open space. You must decide what is buildable in your area. Some data sets, available in Connecticut, you might consider include:

- Soils: The soils database can be used to identify wetland features since wetland regulations are soils based in CT. The soils data also contains attributes that can help identify prime farmland, flood plains and other areas of concern or value. The soils data has been generated from the Natural Resource Conservation Service's (formerly the Soil Conservation Service) County Soil Survey Maps.

  Soils for most of Connecticut are available on the MAGIC site.

- Elevation or slope data: Depending upon your local regulations, steep slopes may limit development. Determining slope is difficult because there are no standard data sets for Connecticut. However, there may be maps of steep slopes available at your regional planning area or town planner's office. NEMO cannot recommend a source for this data set.

- Committed open space: Generally, these are areas that will not be built upon. They might include some state owned lands, preserves, wildlife management areas, municipal parks, land trust lands, cemeteries (see NEMO Open Space Packet for more detail on how to classify open space).

Additional Data

These data layers are useful for interpretation and display as well as for additional analysis of the information.

1. Parcels

If parcel data are available they can be used to help educate groups of property owners such as riparian property owners or lake side property owners. Parcel data can also be used to increase the accuracy of your buildable area analysis.

If available, parcel information, will be available at the town level.

2. Water Features (streams, lakes)

Water features can be used to help understand the drainage patterns, the link between the uplands and Long Island Sound, or the proximity of land features and areas of high imperviousness to given water resources.

“Hydrography” can be obtained from the MAGIC site or the CT DEP.

3. Roads

Road features can be used directly as familiar landmarks, or they can be manipulated within the GIS to assist with estimates of impervious area. Visually, they provide a quick view of urban concentrations.

They are available from the MAGIC site or the CT DEP.

Proceed as follows!

Calculate Existing Imperviousness

Existing NEMO impervious calculations were based on literature values (SCS 1972) applied to the 1991 Satellite derived land cover. The values are meant to reflect general estimates of impervious cover for each land cover category (see Table below). See Appendix A for a discussion of how the NEMO team assigned these coefficients.

Within the 1991 coverage database there is an item for the 23 land cover categories (AV_LEGEND), their associated number code (LU_CODE) and an item for area in square meters (AREA). For the calculations, summarize the total area for each

Landcover Category (AV_Legend)	LU_code	NEMO Assigned Percent Impervious Estimates
Impervious Surfaces	1	100
High density residential & commercial	2	85
Roof	4	100
Pavement	5	100
Barren land	19	
Medium density residential	3	35.6
Turf and Grass	6	
Soil/grass & hay	7	
Grass, hay, pasture	8	
Soil/Corn	9	
Grass/Corn	10	
Soil/Tobacco	11	
Grass/Tobacco	12	
Bare Soil	20	
Deciduous Forest	13	
Coniferous Forest	14	
Non-Forested Wetland	17	
Forested Wetland	18	
Low Coastal Marsh	21	
High Coastal Marsh	22	
Deep Water	15	
Shallow Water	16	
Major Roads	25	50

Step 1:

**Note: codes 23, 24 are not used for the GIS images. Where no value for percentImpervious is shown, use zero.*

land cover category over the local drainage basin, then multiply the yields the total area covered by impervious surface for each basin. Dividing that area by the area of each basin provides the fraction of impervious cover. Multiply by 100 for the percent.

Buildout Imperviousness

Step 1 - Identify areas that can be developed in the future.

The purpose of this step is to identify those areas that are currently undeveloped and that may be developed in the future. Using the landcover data, remove the following developed landcover classes from consideration: impervious surface, high density residential and commercial, roof, pavement, medium density residential and major roads. Land areas you have determined to be unbuildable (such as forested and non-forested wetlands, low and high coastal marsh and deep and shallow water) are also removed. The remaining area is used to perform the impervious surface buildout.

Step 2 - Assign impervious values to anticipated future land use.

The goal here is to determine the categories and density of future development and the amount of imperviousness that may be present. Overlay your zoning data with the areas that can be developed in the future (step 1 results). Assign impervious values using the following table.

Step 3 - Calculations

To calculate future imperviousness, use the same procedure outlined to determine existing imperviousness, but replace landcover categories with zoning categories. The values you calculate for future imperviousness are then added to the value basin area to get a build out percentage of imperviousness for the watershed.

Minimum Lot Sizes Where Available (Acres)	Minimum Lot Sizes Where Available (HA)	Description	Percent Impervious (NRCS Study Values*)
0.12	0.05	Individual Residential Lot	65
0.25	0.10	Individual Residential Lot	38
0.32	0.13	Individual Residential Lot	30
0.50	0.20	Individual Residential Lot	25
1.0	0.40	Individual Residential Lot	20
		Town House/Garden Apt.	44
		Commercial/Business	85
		Industrial	72

Step 2:

*NOTE: Values are taken from the Natural Resource Conservation Service's report *"Urban Hydrology for Small Watershed Basins: 1975.*

Telling the Story

The University of Connecticut Cooperative Extension System's *Nonpoint Education for Municipal Officials Project* (NEMO) was created in 1991 in partnership with two other branches of the University, the Department of Natural Resources Management and Engineering, and the Connecticut Sea Grant Program. The project was originally conceived as a pilot, to explore the potential of using advanced technologies—geographic information systems (GIS), remote sensing (RS), and the Internet—as tools to educate the target audience of local land use decision makers about the links between land use and water quality.

The project employs many different technologies and produces a wide range of publications, but our main educational vehicle remains the simple slide presentation to our target audience. One of the project's major objectives is to enable local officials to visualize the future impacts of their current land use policies and plans. This paper has enabled you to complete NEMO's zoning-based "build-out" analysis, which contrasts current levels of impervious surface (known to be a reliable indicator of the potential for water quality degradation), with future levels estimated from zoning regulations. The results are based on the following thresholds from Schuler's *"Watershed Protection Techniques"* (Vol. 1, No. 3, Fall 1994):

1. Where less than 10 percent of a local basin is covered with impervious surfaces, streams are generally protected, although sensitive streams may begin to be stressed. The emphasis here is on protective planning strategies.

The NEMO Project stresses the importance of comprehensive planning to prevent impacts and balance conservation and growth. Comprehensive planning efforts should include:

- inventory natural resources
- prioritize areas for protection
- target development to most appropriate areas
- incorporate open space planning
- develop a plan of action.

Keep in mind that zoning and subdivision regulations must support any planning efforts. With knowledge about your resources and a sense of priorities you will be able to focus your planning strategies to priority areas.

2. Where between 11 and 25 percent of a local basin is covered with impervious surfaces, streams are impacted and can be expected to experience some degradation with further development. Mitigation may be achievable with effective best management practices. The NEMO Project is developing a "Site Design Guide" which will illustrate design elements that are water resource friendly.

3. Where over 25 percent of a local basin is covered with impervious surfaces, streams are degraded. Predevelopment stream form and health cannot be fully maintained even when best management practices or retrofits are fully maintained. Restoration projects may improve conditions in these basins.

Having completed the impervious surface build out analysis for your town or watershed, you have the key component of the NEMO educational slide presentation on nonpoint source pollution targeted at local land use officials. The NEMO Team can work with you to tailor the slide presentation to your town or watershed by incorporating your impervious surface buildout and other area photographs and GIS images.

References

Tom Schueler, The Center for Watershed Protection – "Watershed Protection Techniques" (Vol. 1, No. 3, Fall 1994):

Urban Hydrology for Small Watersheds, Technical Release no. 55. Engineering Division, soil Conservation Service, USDA, January 19

Appendix A

Assign Impervious Values to Land Cover Categories

The table below provides the impervious values used by the NEMO Project as estimated for the 1991 satellite derived land cover. These values were based upon a review and subsequent averaging of similar nonpoint studies [Natural Resources Conservation Service (NRCS formerly SCS) report "Urban Hydrology for Small Watershed Basins: 1975].

NRCS's industrial and commercial categories were 72 percent and 85 percent respectively. A single combined category (High density residential and commercial) is represented by the satellite-derived data set, therefore the value of 85 percent is assigned.

The residential categories from the NRCS report are averaged to a single value of 35.6 percent and assigned to the Medium Density Residential category.

Large impervious surfaces, roofs, and paved areas show as individual categories in the land cover set. These were assigned values of 100 percent.

The 1991 satellite derived land cover includes road features from the USGS digital line graphs (DLGs). When converting the roads from the vector DLG line data to match the 30-meter pixel resolution of the land cover, the road features, on average, cover more surface area. To compensate the values assigned to roads were reduced to 50 percent.

The spectral (reflective) characteristics of satellite imagery vary considerably over the landscape, yet we are forced to group these characteristics into a limited number of categories. As a result, the true impervious cover within an assigned category can vary from one pixel to the next. For example, the impervious area for pixels classified as residential within dense urban areas may actually have higher values than those located in a surrounding rural sections. The simplification of these variables into one estimate and the course resolution of the satellite image (30 meters) generalize the result over a given area. Therefore, the estimates below should only be considered as guidelines for imperious coverage - valuable for quick estimates over large areas. When summarizing impervious coverage over areas less than one or two square miles a more detailed approach should be used.

NRCS Category	NRCS % Impervious	NEMO Satellite Category	NEMO Assigned % Impervious
Industrial	72	High density residential and commercial.	85
Commercial	85		
Residential < 1/8 acre	65	Medium density residential	35.6
1/4 acre	38		
1/3 acre	30		
1/2 acre	25		
1 acre	20		
Not listed	-	Impervious surfaces/Roof/Paved	100
Not listed	-	Major Roads	50
Not listed	N/A	Water	0
Other	-	Other	0

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NEMO is an educational project of the University of Connecticut, Cooperative Extension System, Connecticut Sea Grant College Program and Natural Resource Management and Engineering Department. In addition to support from UConn, NEMO is funded by grants from the CT DEP Nonpoint Source Program and the NOAA National Sea Grant College Program. NEMO is a program of the Center for Land use Education And Research (CLEAR). For more information about CLEAR, visit www.clear.uconn.edu. The Connecticut Cooperative Extension System is an equal opportunity employer. © 2002 University of Connecticut 11-02