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Methods for Measuring and Estimating Impervious Surface Coverage

By Joel Stocker, *1998*

The NEMO Project focuses on the relationship of impervious coverage and water quality. To display this relationship, a method was devised to calculate the percent of impervious surface of local basins within individual towns. This paper gives an overview of procedures used to create impervious maps.

Local watersheds are used as the base area to delineate impervious cover. Local basins are small enough to highlight intensely developed areas and are useful for directing attention to specific water systems, but large enough not to “overstep” the limitations of our satellite derived land cover data.

Reliable methods for delineating imperviousness are required. Several options exist depending on the desired accuracy level. The tools available for measuring impervious area are similar to those used for traditional land cover mapping. They can include one or more of the following: Ground surveys; Global Positioning Systems; Aerial photogrammetry; Existing maps or digital data; or Satellite Remote Sensing. The relative accuracy of a given map feature's position or classification (whether it is impervious or not) will vary for each method. The cost to benefit tradeoffs need to be evaluated or methods derived to combine the strengths of the various techniques. *Figure 1* provides a visual description of the relative cost versus potential accuracy for the classification of a given point on the ground. The different methods and their applications for measuring imperviousness are described below.

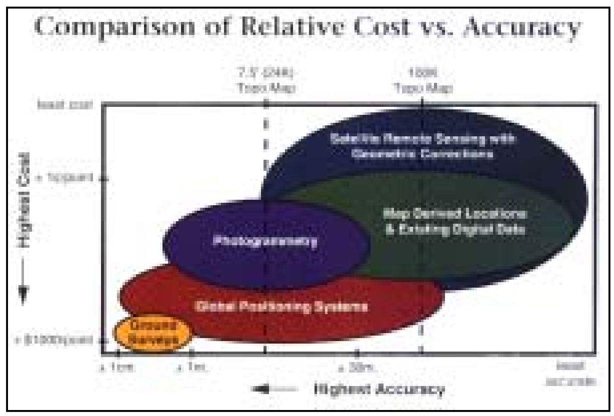

Figure 1 - USGS

Ground Survey - Traditional ground surveys provide the most accurate method for defining many natural and man made features. Valuable for updating or adding to existing maps, ground surveys are expensive and hence impractical for mapping large areas.

Global Positioning Systems - GPS technology can be a valuable tool for assisting with impervious data collection. The GPS provides precise location in the field that can later be matched to a location on a photograph or satellite image. Specific polygon and line features can also be “digitized” while on location. This is useful for accuracy assessment or for helping interpret a new feature. Limitations would include: field access (i.e. private property), size of the study area, and the technology itself.

As the technology improves positional accuracy and capabilities have increased while the costs of the units have dropped.

Aerial Interpretation - For mapping larger areas interpretations from aerial photographs may be practical. There are several different techniques for transferring map information from photographs. Cost and accuracy would determine the method used.

A. Stereo Photogrammetry - The most accurate method for acquiring land cover information from aerial photography is with a stereo plotter. Using precise large-scale photographs and specialized equipment most of the distortion caused by the camera lens, radial optics, and ground terrain can be removed. Depending on flight altitude and map scale individual buildings, streets, even sidewalks can be delineated. While an accurate method for creating land cover maps the process is time consuming, requires a professional photogrammetrist, and expensive equipment.

Some towns have invested in the process when creating assessor's maps or maps for city planning departments. A common example is a town wide land cover map, highlighting precise details such as building footprints and roads. The usual map scales are at 1 inch equals 100 or 200 feet. Town engineers will occasionally invest in maps designed at 1" to 40 feet for engineering projects. However, these maps rarely extend beyond specific work areas because of their high cost.

Photogrammetric maps are usually created or saved in a Computer Aided Design (CAD) format, then provided to the town as hard copy. Some towns acquire the digital data. Impervious information can be a byproduct. Along with building footprints and some natural features, these maps usually contain street and pavement outlines. GIS software requires closed polygons features if area values are to be calculated and summarized. As homes and other structures are usually the only features “closed” a town interested in impervious surfaces should stipulate that all appropriate land cover be captured as closed polygons.

Special hardware and software allows on screen processing of stereo photographs. Using special shutter glasses and screens with high refresh rates the operator can actually digitize contours and land features in a 3D environment. Improved computer technology and software will eventually allow “in house” applications.

B. Interpretation from Standard Aerial Photographs - Less precise than stereo photogrammetry, transferring data from existing aerial photographs (sometimes referred to as 9" photographs) to a standard base map can be a practical alternative. Without photogrammetric equipment it is difficult to remove distortion from the camera lens and terrain, therefore this method is more commonly used to highlight general regions of common land cover types. For example, clusters of a residential or commercial land cover type rather than individual building footprints or road outlines. Using a combination of orthophotographs and recent aerials, positional accuracy can increase.

Impervious amounts would then be estimated over the given land cover types. If standardized photo interoperation categories are assigned (Level I, II, etc.), literature values for impervious estimates might be applicable.

With improvements in computing technology and software the options for processing the files in a completely digital environment increase. Software for digitizing off screen using base maps of digital orthophotographs or scanned photographs already exists. Transferring to paper maps before digitizing may not be necessary.

Existing Digital Information - The simplest way to create a data set is to find or convert existing digital files. However, the final product is limited to the type, quality and scale of the data source. Most of the data used for the NEMO project is provided by the State of Connecticut. Created from 1:24000 topographic maps, with the exception of a few layers most of the coverage's they provide are limited to what can be found on USGS quads. Few or none of these data sets are specific to impervious information. Some towns may have detailed land cover information in the form of CAD drawings or surveys. If this information already digital and is compatible with available software, it may be possible to select for land cover and impervious features. Problems arise when converting between various file types and when the data itself is incomplete (polygons not closed, etc…)

Satellite Interpretation - An option often used for large areas (statewide or larger) is computer assisted interpretation of satellite imagery. Selecting from a combination of satellite platforms many state and federal organizations have already created extensive land cover data sets—often created in partnership with Universities.

There are some limitations to these data sets. The spatial results are restricted to the capture size on the chosen satellite. As an example, current Landsat Thematic Mapper imagery is restricted to a pixel size of 30 meters – too large for detailing homes or small roads. Also theme accuracy, the confidence a given pixel is or is not classified properly, can be a limiting factor. The accuracy can vary depending on the reflection characteristics of the surface, cloud cover, how closely the automated classification is monitored, ground truth procedures, and other factors. Generally the impacts of misclassified pixels are minimized if the study area is large.

Impervious Estimates from Satellite Interpretation - This is the method used for the first part of the NEMO project. Impervious values were calculated using estimates from existing land cover data provided by The University of Connecticut. This base data was from a state wide digital land cover created in 1991 by Dr. Daniel Civco and James Hurd. Using computer analysis they converted satellite imagery from May 1988 and August 1990 images into a 23-category land cover map. The NEMO project uses the residential and urban features within this data layer to estimate the impervious values. The method provides a quick overview of the level of impervious area within each local basin. The results are very general. The correlation between impervious estimates for each land cover type varies considerably over the state and the resolution of the satellite imagery limits study to large areas.

Methods and values specific to the project in Connecticut are outlined in the NEMO Technical Paper #4 "*Do It Yourself! Impervious Surface Buildout Analysis*".

Deriving Impervious Values Directly from Satellite Imagery The Department of Natural Resources at the University recently tested a neural networking software program as a means for separating the spectral characteristics of impervious surface covers from the satellite imagery. The purpose of the study was to derive a method for directly separating impervious data, bypassing the land cover interpretation phase. The final product shows the fraction of impervious area over any given pixel. This helps to avoid the problems associated with assigning single values to an entire pixel when only a fraction of that pixel is actually impervious. An individual pixel or display unit can be displayed with an intensity value that is directly related to its impervious cover.

This method has limitations. To provide training sites for the neural network program as well as for the accuracy assessment extensive aerial interpretation is required. For the NEMO project we scanned several aerial photographs, rectified them to the coordinate system of the satellites, and then used them as base maps for digitizing training sites. The rectification is general and the resolution is poor for these scanned images. Aerial photogrammetry would be ideal for creating training sites, however, at the time of this project we did not have access to photogrammetry equipment. Preliminary testing with this method appears successful, but a detailed accuracy assessment needs to be completed.

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