Coastal Area Impervious Surface Assessment
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This project was funded through two agencies: the Center for Community and Regional Research and Minnesota DNR’s Lake Superior Coastal Program. This project contributes critical data to the Coastal Area Impervious Surface Assessment and Education research funded by Minnesota DNR’s Lake Superior Coastal Program which is building a foundation of data and research in support of the Nonpoint Education for Municipal Officials Program in the coastal region of Lake Superior’s North Shore, Minnesota.
INTRODUCTION

This Coastal Area Impervious Surface Assessment project component funded by the Center for Community and Regional Research provided digital geographic data to implement the Nonpoint Education for Municipal Officials (NEMO) program to many communities in the Minnesota Lake Superior basin. The NEMO program is defined as an educational program for local land-use officials that addresses the relationship of land use to natural resource protection. This program was initiated through collaborators at the University of Connecticut Sea Grant and Cooperative Extension System and has been growing for ten years Nationwide. The goal of the NEMO program is to educate city planners and decision makers using visual tools and models to illuminate potential surface and ground water quality hazards in various development scenarios.

The NEMO program presented to the communities is based on geographic data created with remote sensing and Geographic Information System technology. Community planners are provided with a visual tool to identify critical areas for habitat fragmentation, water quality degradation, and erosion and incorporate smart community growth into their comprehensive plans. The visual inspection of the location, concentration, and rate of growth of impervious surfaces can help civil engineers, local officials, and community members make informed choices in development plans that can affect water quality, environmental, and aesthetic issues in their community.

The MN Sea Grant coordinator and Principal Investigator of this project, Jesse Schomberg, has experience developing and presenting the NEMO process in Duluth, Minnesota. At least three Minnesota regions encompassing several municipalities are serious about taking
advantage of NEMO processes and information in the near future. The goal of this project was to make NEMO available to all interested communities in this region by preparing the geographic data foundation of the program.

Impervious surfaces are those features in the environment which do not allow rainwater or stormwater to infiltrate the soil. Impervious surfaces include rooftops, sidewalks, parking lots, and streets. In urban areas they are usually connected to one another which causing water to channel through them, washing sediment, garbage, pesticides, pet waste and other contaminants into storm drains, and eventually into our creeks and lakes. Therefore, the quantity of impervious surface in a watershed is an effective indicator of water quality. According to data compiled through the National NEMO program (nemo.uconn.edu), when impervious surface values are greater than 25% of the total landscape surface, streams are likely to have water quality problems, and values from 10-25% indicate the watershed is "at risk" for degraded water quality and habitat.

The calculation of impervious surface area in a watershed is one of the most time-intensive steps in NEMO. There are multiple methods which have been used to calculate impervious surface amounts, each with certain benefits and drawbacks. This project funded by CCRR provided these data using one method, the most precise method, of obtaining impervious surfaces quantification for a set of North Shore watersheds. The areas of impervious surface (rooftops, parking lots, roadways, etc) were manually digitized as polygons from aerial photographs. This project was a critical piece to a larger project funded by the Minnesota Department of Natural Resources Lake Superior Coastal Program, which includes a comparison of the accuracy and efficiency of each of three additional methods of obtaining impervious surface area estimates. Due to the time consuming hand digitization,
automated classification of aerial photography or satellite imagery is the preferred method to obtain impervious surface data for the remainder of the region. The three subsequent methods utilized in the follow-up Lake Superior Coastal Program project incorporate the manually digitized areas as “ground truth” and will be compared for their combined efficiency and accuracy. Following that analysis, the most accurate and time efficient method to calculate current impervious surface areas will be used to create a continuous digital dataset representing the entire coastal zone of North Shore of Lake Superior in Minnesota. The mapping of impervious surfaces on a regional basis will reduce both the cost and the time required to bring the NEMO program to all communities in this region. The results from both the Center for Community and Regional Research work and the Lake Superior Coastal Program project can be used in other regions where large amounts of detailed impervious surface area needs to created from images.

Past NEMO workshops in Duluth and Superior left attendees with the words, technology, and motivation to catch the attention of municipal officials and demonstrate that good planning will allow communities to preserve water quality and accommodate economic growth. The creation of the missing spatial data needed is a critical component to sharing and implementing the NEMO program in North Shore communities. Communities as they develop and integrate water quality concepts into their comprehensive plans.
Coastal Area Impervious Surface Assessment

METHODS

The sample watersheds to be hand-digitized were chosen so as to adequately incorporate the variety of land uses, land covers, and topography which exist across the coastal area (Figure 1). Sixty of 328 watersheds in the coastal area were identified as the sample watersheds. These manual digitizations will serve as validation watersheds for the image analysis techniques used in the other three methods of automated impervious surface interpretation.

Figure 1. Study Watersheds in the Coastal Region of Lake Superior’s North Shore.
The DNR Color Infrared (IR) aerial photographs provided the basis for most of the
digitization, however, in some cases where coverage was incomplete, other imagery was
used. Generally in an IR photo, pavement, concrete and rooftops look a white to grayish-
blue color.

In some watersheds impervious surface features had previously been digitized, this data was
incorporated into the final datasets. The Farm Service Agency (FSA) aerial photographs
from 2003 were a secondary source of imagery used to aid with interpretation. This true
color imagery was processed to 1-meter orthorectified photos and is freely distributed by
Minnesota’s Land Management Information Center. The DNR IR photos, flown primarily
in 1992, were used in this study to correspond with the time period of the satellite imagery
for the investigation of automated methods of extracting impervious surfaces. Table 1
summarizes the availability of the imagery used for manual digitizing and the names of the
North Shore watersheds in the study.

This project included the acquisition and georectification of the DNR IR aerial photography
in the 1991-1992 time period and the acquisition and preparation of satellite imagery for
those watersheds not covered by the 1991-1992 set of aerial photography. The
georectification was accomplished primarily by DNR Resource Assessment. The IR aerial
photography was the basis for the digitization of area polygons representing impervious
surfaces (Figure 2). Other GIS base layers, such as roads, streams, railroads were collected
to aid in the interpretation of the photos. Guidelines were developed to standardize what to
digitize, at what scale, and how to manage the datasets. Samples of the results of the
impervious surface area data creation are shown in Figures 3 and 4.
<table>
<thead>
<tr>
<th>Major Watershed</th>
<th># of Minor Watersheds</th>
<th>DNR Infrared photos for digitization</th>
<th>2003 FSA photos available</th>
<th>Other imagery used for digitization</th>
<th>Past NEMO data created?</th>
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<tr>
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Table 1. Major watersheds digitized and imagery used.
Figure 2. Color Infrared aerial photography.
Figure 3. Example of digitized (red) impervious surface areas for Miller, Chester, Tischer and Amity Creek watersheds in Duluth, MN.
Figure 4. Detailed example of impervious surface digitization in Chester Creek watershed. Infrared aerial photo is draped over the polygon shapes representing impervious surface areas.
This project was highly dependent on student involvement: the impervious surface data was created from over 520 hours of student time. The students benefited from learning techniques of aerial photograph interpretation and advanced editing techniques using ESRI ArcEditor 9.0. In most cases, students worked with more than one aerial photograph (and therefore, time period) to interpret the imagery. The change in landscape in just a short period of time due to increase in impervious surfaces was immediately apparent in most of the watersheds.

The completion of automated impervious surface interpretation methods to complete the data creation for the entire North Shore coastal area was not a part of the Center for Community and Regional Research funded project. Landsat Thematic Mapper (TM) satellite imagery will be classified for land-cover then impervious surface, following methods developed at the University of Minnesota\(^6\), to produce impervious surface maps at 30-meter (0.9 ha, .22 ac) resolution across the coastal area. The resulting raster layers will show the percentage of impervious surface within each 30-meter picture element in the urban and developed land cover class. The Minnesota DNR will be performing this step in of the project.

Next, staff at the Minnesota Sea Grant and Natural Resources Research Institute will compare each of the methods of calculating imperviousness with the digitized amounts of impervious surface, by watershed. The comparison will result in an estimate of the accuracy of the two methods of calculating impervious surface directly (aerial photo and Quickbird satellite image analysis), and second an analysis of the accuracy of the four methods in extrapolating impervious surface measurements across the landscape. The time series of
Landsat-calculated imperviousness will be analyzed, looking at trends in the change of imperviousness by watershed in order to project imperviousness to future dates. The Impervious Surface Analysis Tool (ISAT) will be used to calculate impervious surfaces for all coastal area minor watersheds not included in the sample set. ISAT relies on a land use classification to interpolate percentage impervious surface in each of several different land-use types (i.e. dense urban, industrial, rural, etc). We will use the impervious data from the training sites alone to calibrate the ISAT, but calculate impervious surfaces for both the training and validation watersheds.
RESULTS

Shapefiles of polygon features representing impervious surface area for 18 watersheds (60 subwatersheds) were created using the manual digitization methods. Digitization was completed by one of six students. After the features were digitized, the shapefiles were reviewed for consistency and adherence to methodology and guidelines outlined by the Principal Investigators of the project. Each image was scanned with the impervious surface shapefile overlay for any missed features. One of four possible values was given as an attribute to each feature, and these were also reviewed. The four possible values were as follows:

0 – not impervious
1 - Yes, it’s a hard impervious surface.
2 – Roads. This does not include driveways.
3 - Railroad tracks.
4 – Other mostly impervious, but feature doesn’t fit in category above. (Will include dirt parking lots)

The interpretation of road/driveway (imp_code equals 1 or 2) in some cases was a judgment call. In rural areas, “long” access roads to a residence were classified as a road. In urban areas, driveways to homes were labeled “1”. The value of “4” was used more of a placeholder when the impervious surface did not fit into one of the other categories – there are not many features using this value.

In some cases, positional accuracy errors were fixed at the quality control stage. If the digitization seemed to fairly represent the quantity of impervious surface, but there were
positional errors, they were generally not fixed. Different students used different precision
with vertices. All met the minimum standards set out in the instructions for digitizing and
standards the Principal Investigators found appropriate for the purpose of this project

Many of the watershed boundaries provided for use in this project (created by the Minnesota
DNR) were not accurate to the same scale at which we were digitizing. The impervious
surfaces were only digitized to about 50 meters beyond the boundaries, so some impervious
surfaces in the "real" watershed may have been missed.

The impervious surfaces were interpreted from the DNR Infrared photos primarily. In the
Manitou, Beaver, and Poplar Rivers, the NAIP photos or DNR Black and White DOQs were
used to complete the coverage. In a few cases, students had digitized from the NAIP even
when there was Infrared coverage. In these cases, the positional accuracy of the features was
changed only if features were significantly misrepresented. In most cases, they were left as
is, unless the features did not exist in the DNR Infrared photos. In that case, they were
deleted from the impervious feature shapefile,

In some watersheds, more than one Infrared photo covered the same feature (overlapping
images). Sometimes the registration was up to 50 meters different in the two. Features
were digitized from one, so obviously will not line up with all images.
land planners to target watersheds for careful planning that are likely to reach the 25% impervious surface threshold using current building restrictions if the watershed is “built out”.

The calculated imperviousness will be used in basic NEMO program presentations by the Duluth NEMO program coordinator in coastal zone communities of the North Shore of Lake Superior that are coincident with the watersheds analyzed in the CCRR study. The “build out” scenarios described above, along with maps of existing land-use types and impervious surfaces, provide a valuable illustration to help land use planners prioritize and proceed with appropriate planning that will preserve water quality. The volume of water percolating into the ground decreases and the amount of runoff increases with greater impervious surface area. This results in larger quantities of pollution flowing to Lake Superior. Non-point source pollutants, such as sediment, pathogens, nutrients, toxic chemicals, and other pollutants are difficult to manage and threaten human health. Nonpoint source pollution is the leading cause of water quality impairment in the nation, accounting for the degradation of about 40 percent of surveyed waters, according to the U.S. Environmental Protection Agency.7

The data created in this project will be made available through two outreach efforts: a website, and the community-specific NEMO programs using the calculated data. A website funded by the Minnesota Department of Natural Resources Lake Superior Coastal Program will be developed where non-technical impervious surface information will be made available, including explanations of what impervious surfaces are, why they are useful as an indicator of water quality, and alternative methods of reducing the amounts of impervious surface and stormwater runoff. This website will also house community-specific information
for all the communities where NEMO programs have been presented, including current zoning and build-out scenarios, where the zoning is used to estimate potential imperviousness if all lands are built to the extent allowed by current law.

ENDNOTES

1 NEMO Home Page. http://nemo.uconn.edu/. Middlesex County Extension Center, Haddam, CT


3 NEMO Home Page. http://nemo.uconn.edu/. Middlesex County Extension Center, Haddam, CT

4 Minor watersheds, digital data. Minnesota DNR - MIS Bureau, 500 Lafayette Road, Saint Paul, MN 55155

