Spatial database development, web mapping application design, and ArcSLAMM-WinSLAMM urban stormwater modeling for planning purposes in Cedarloo Watershed

UNI GeoTREE Center
Contact: John DeGroote, john.degroote@uni.edu

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Background/Scope of Work:

The GeoTREE Center has created detailed source area spatial data for the Cedarloo watershed in Waterloo and then used ArcSLAMM tools to prepare WinSLAMM compliant databases for 139 catchment or drainage areas in the Cedarloo watershed. Those databases were run through WinSLAMM 10.3.17 batch processing mode to model runoff volume and pollutant loads for each of these catchments or drainage areas.

As part of a previous Iowa Water Center (IWC) funded project, the University of Northern Iowa GeoTREE Center developed a novel ArcGIS geodatabase structure and a set of ArcGIS-based tools (together making the ArcSLAMM package) which provide a more efficient workflow for carrying out urban stormwater modeling for planning exercises using the WinSLAMM software for small to moderate sized urban watersheds. In addition, the GeoTREE Center has received a small amount of funding from PV & Associates (developer of WinSLAMM) and have continued to collaborate with them to improve ArcSLAMM.

The present work is being completed under a grant from the Iowa Department of Agriculture and Land Stewardship. The purpose of this grant is to improve upon ArcSLAMM and to demonstrate its applicability in several small pilot urban watershed projects in Iowa. The work described in this report serves to document an example of one of these watershed projects.

WinSLAMM and ArcSLAMM

The WinSLAMM model (http://www.winslamm.com/default.html) is a relatively widely used urban stormwater planning model which has been used in various areas throughout North America. Developed over several decades, and based on extensive field monitoring activities, the model is continually updated and calibrated using field monitoring data to generate relatively accurate predicted water quality and quantity results. Although characterizing urban watersheds is an inherently geospatial activity, WinSLAMM had not previously leveraged GIS software for developing land use input information or for visualizing results back in GIS software. Initially funded by a grant from the Iowa Water Center, a preliminary ArcSLAMM package was developed to couple ArcGIS to WinSLAMM by the UNI GeoTREE Center. The ArcSLAMM package, which consists of a customized geodatabase and a set of custom ArcGIS tools, greatly extends the capabilities for applying WinSLAMM to modeling small to moderate urban watersheds.

The effort described in this report was carried out as part of an Iowa Department of Agriculture and Land Stewardship project funded through a grant to the GeoTREE Center. The overall objectives of the project were to:

- Quantify annual stormwater pollution discharged in the urban area of Cedarloo watershed based on a representative annual rainfall file from Waterloo
- Develop maps and database that can be used to identify areas that produce high volumes of runoff and pollutant loads coming from individual sub-catchments
- Develop a web mapping application which displays BMPs in the Cedarloo watershed

Database development

Several UNI GeoTREE Center student research assistants participated in the digitization and quality control checking that led to the development of a comprehensive coverage of the urban areas of Cedarloo watershed (falling in Waterloo) in a copy of the customized ArcSLAMM geodatabase. The customized ArcSLAMM geodatabase is designed to greatly improve the efficiency in digitizing detailed source areas (land use). The student research assistants used high resolution imagery (2013 and 2015) provided by the Black Hawk County to digitize approximately 996 acres of detailed source areas in the urban part of the watershed.

The detailed source areas polygon feature class in the geodatabase contains 7,587 polygons, and the total area is 996 acres. Figure 1 shows the final digitized urban area in the Cedarloo watershed. The geodatabase allows the user to draw polygons and then enter the relevant characteristics of each polygon that WinSLAMM requires. WinSLAMM requires that each polygon have a land use type (residential, institutional, industrial, commercial, other urban) and a source area type (different types of roofs, driveways, parking lots, sidewalks, landscaped areas, etc.) along with other information that WinSLAMM requires (such as whether a roof is pitched or flat, whether a parking lot drains to a pervious/impervious area). As far as the land use type, residential area dominated both the total

number of polygons (~89.9%) and the area (581 acres). There were 8, 31, 257, and 119 acres of institutional, commercial, industrial, and other urban land uses in the digitized geodatabase. Table 1 indicates the area falling in general source area types.

Table 1: The area by major land use (source area types) in the Cedarloo watershed.

Area by Source Area		
Source Area	Total area (acres)	Area (percentage)
Landscape Areas	601.0	60.3%
Rooftops	107.3	10.8%
Streets	99.7	10.0%
Driveways	52.7	5.3%
Paved Parking	37.5	3.8%
Other Pervious Areas	28.7	2.9%
Water Body Areas	26.2	2.6%
Unpaved Parking	23.4	2.3%
Sidewalks	15.8	1.6%
Other Impervious Areas	2.9	0.3%
Undeveloped Areas	0.5	0.1%
Total	995.7	100%

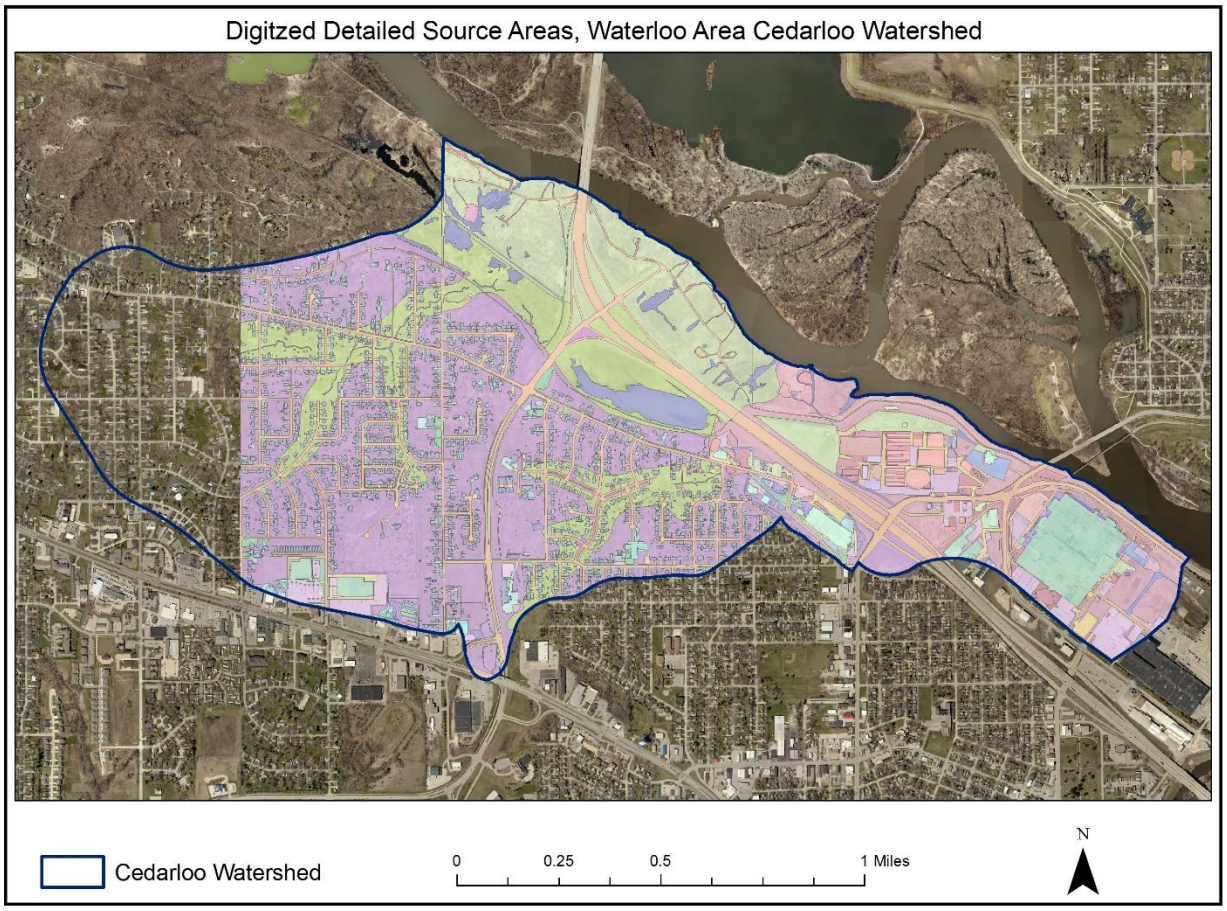

Figure 1: The digitized urban areas in the Cedarloo watershed (within Waterloo) storing WinSLAMM source areas.

Subwatershed Delineation

ArcSLAMM tools were used to derive several sets of subwatersheds that fall in the Cedarloo watershed based on the topography of the area as defined by the Iowa Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) which was downloaded from the Iowa Department of Natural Resources GIS Library (https://programs.iowadnr.gov/nrgislibx/). Before delineating the subwatersheds, the DEM was hydrologically enforced using the Hydrologically Enforce Digital Elevation Model (DEM) ArcSLAMM tool and using the detailed stream lines produced by the Iowa DNR and Flood Center as part of their statewide floodplain mapping project (http://iowafloodcenter.org/projects/floodplain-mapping/). Using the hydrologically enforced DEM and the ArcSLAMM Catchment Delineation tools, subwatersheds for the entire urban area of the Cedarloo watershed were derived and are shown in Figure 2. The subwatersheds for the whole area were defined by entering a parameter for the tool indicating the approximate size, or upstream drainage area, to use to define the subwatersheds. This was set to 5000 cells (approximately 3.7 acres).

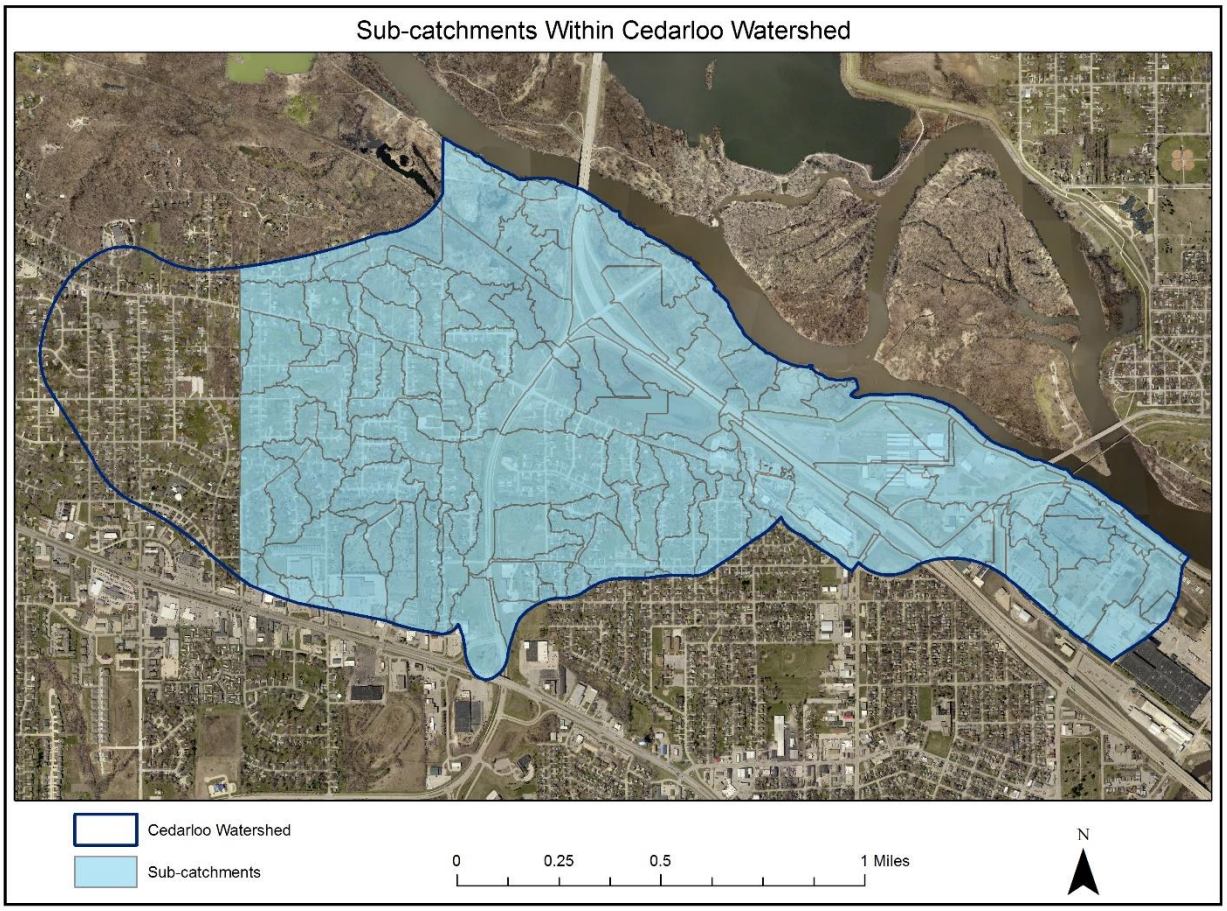

Figure 2: The subwatersheds used for generating WinSLAMM compliant databases.

WinSLAMM File Generation

Two further tools in the ArcSLAMM package allow the completion of the pre-processing steps which result in the creation of one WinSLAMM compliant database file per subwatershed. In the first instance, the Intersect Catchments with WinSLAMM Detailed Source Areas ArcSLAMM tool was used to prepare a GIS feature class that is an intersection of the subwatersheds with their unique identifier and all detailed WinSLAMM source areas. There were 139 urban subwatersheds delineated for the Cedarloo watershed in areas with detailed source areas (i.e urban areas). The final preprocessing step was to run the Create WinSLAMM Compliant Databases ArcSLAMM tool to create one WinSLAMM compliant database for each unique subwatershed. WinSLAMM uses the Microsoft Access .mdb file format to store a wide variety of information in approximately 20 separate tables. The Create WinSLAMM Compliant Databases ArcSLAMM tool reads data from the intersected subwatershed/source area feature class and translates this data into the necessary file format that WinSLAMM can read. At this point there was one unique file for each subwatershed. Figure 3 illustrates an example screenshot of these files in Windows Explorer.

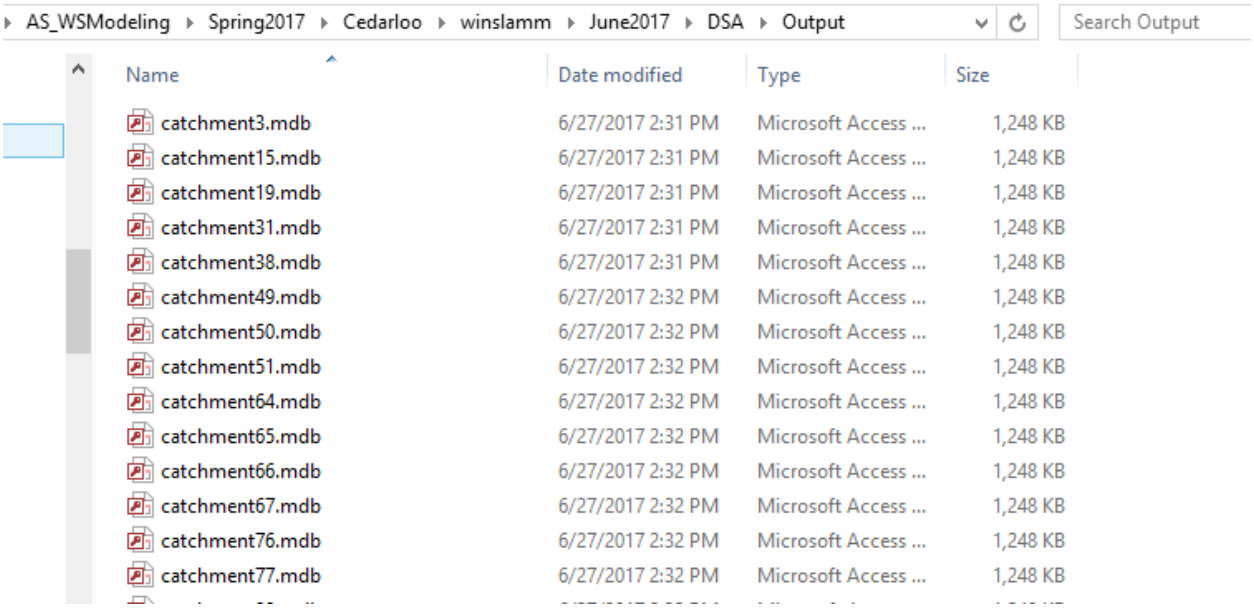

Figure 3: A screenshot demonstrating WinSLAMM compliant databases.

WinSLAMM Base Modeling

The WinSLAMM model was used to carry out simulations for all urban subwatersheds in the Cedarloo watershed. The purpose of this modeling was to meet the first two objectives mentioned above: to quantify stormwater runoff per subwatershed thereby providing data and to indicate higher pollutant contributing areas (hot-spots). This modeling was carried out using WinSLAMM and the files created as described above using the ArcSLAMM – i.e. one simulation per subwatershed. Figure 4 demonstrates a file opened in WinSLAMM. So in this example, the source areas from industrial, institutional, and residential areas of a subwatershed have been translated from the ArcSLAMM geodatabase land use and source area types to the WinSLAMM format which can be used for carrying out a simulation. The WinSLAMM model can be run for a single file or batch processing can be carried out for a set of files.

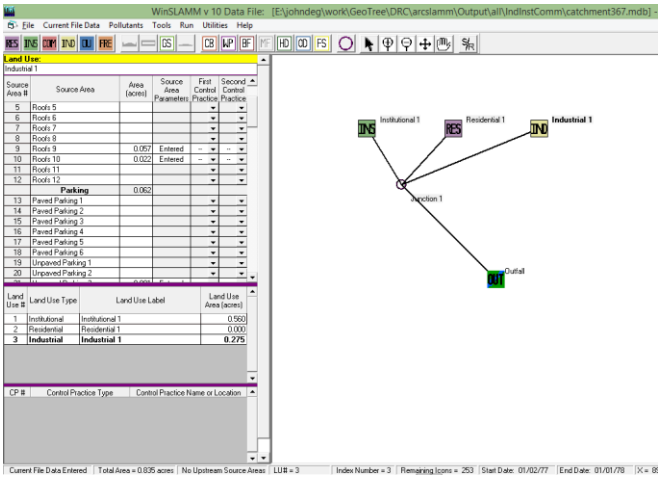

Figure 4: A single subwatershed WinSLAMM database open in the WinSLAMM software.

The base modeling carried out represents a single year of simulation utilizing a rainfall file from Waterloo, Iowa from 1977. The rainfall file contains a record for each rainfall event.

The WinSLAMM model requires several other files that are used to model estimates of particulate solids concentrations by source areas and land use, other pollutant concentrations, and runoff volumes from different source areas. Table 2 indicates the files used in the base WinSLAMM modeling. The same files were used for all of these simulations except for the Street Delivery File which is varied by WinSLAMM depending on the type of land use for a given source area. The model also can use a Winter Season Range which in our case was set to dates (12/01 to 03/12) recommended for Madison, WI (http://wi.water.usgs.gov/slamm/readme10.0.html).

Table 2: The files used in WinSLAMM base modeling.

File Name	Description
WlooRain1977.ran	Start/end time and date of all rainfall events in typical year – an example file from Waterloo, IA was used
V10.1 WI_AVG01.pscx	Particulate solids concentration file. Varies based on source area, land use, and rainfall depth. Based on numerous stormwater monitoring studies in Wisconsin by USGS and Wisconsin DNR
WI_GE003.ppd	Pollutant probability distribution file for all pollutants besides sediments. Varies per source area/land use combination. Based on numerous stormwater monitoring studies in Wisconsin by USGS and Wisconsin DNR
WI_SL06 Dec06.rsvx	Runoff coefficient file used to calculate runoff volume for each different source area as a function of rainfall depth. Based on numerous stormwater monitoring studies by the USGS and Wisconsin DNR from various urban land uses and source areas in Wisconsin
WI_Com Inst Indust Dec06.std or WI_Res and Other Urban Dec06.std	Street delivery file which describe the fraction of total particulates that are washed from the streets during rain events but are subsequently redeposited due to lack of energy in the flowing water. WinSLAMM adjusts the file used based on the land use being modeled for individual source areas.

Figure 5-9 shows the modeled results by subwatershed in the urban areas of the Cedarloo watershed. These results are presented after running an ArcSLAMM tool to join back modeled results back to a dissolved version of the intersected detailed source area/catchment feature classes. The results are presented in map form after adjusting for catchment area. The actual data underlying these maps will be delivered as part of a package with this report.

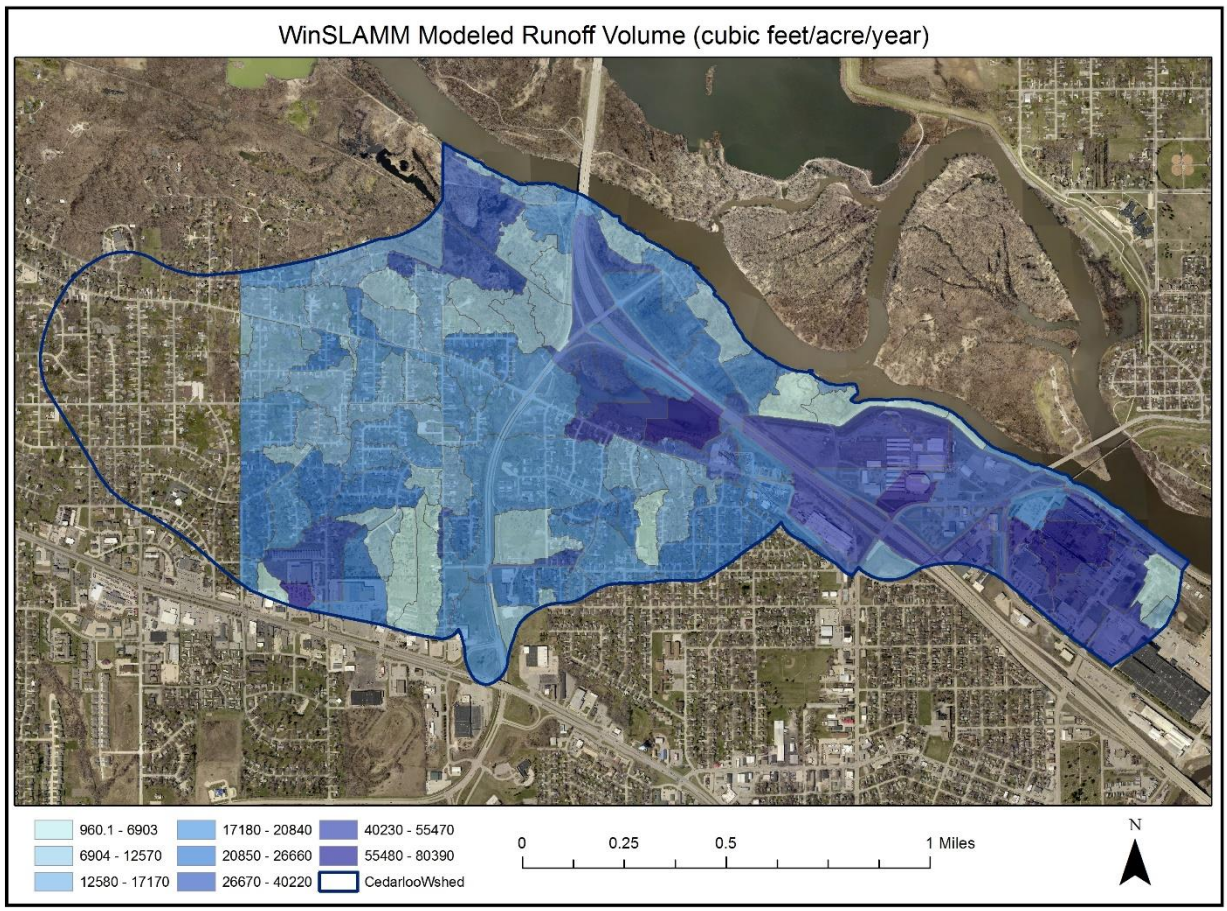

Figure 5: WinSLAMM modeled total runoff for all subwatersheds normalized by the area (acres) of the catchment.

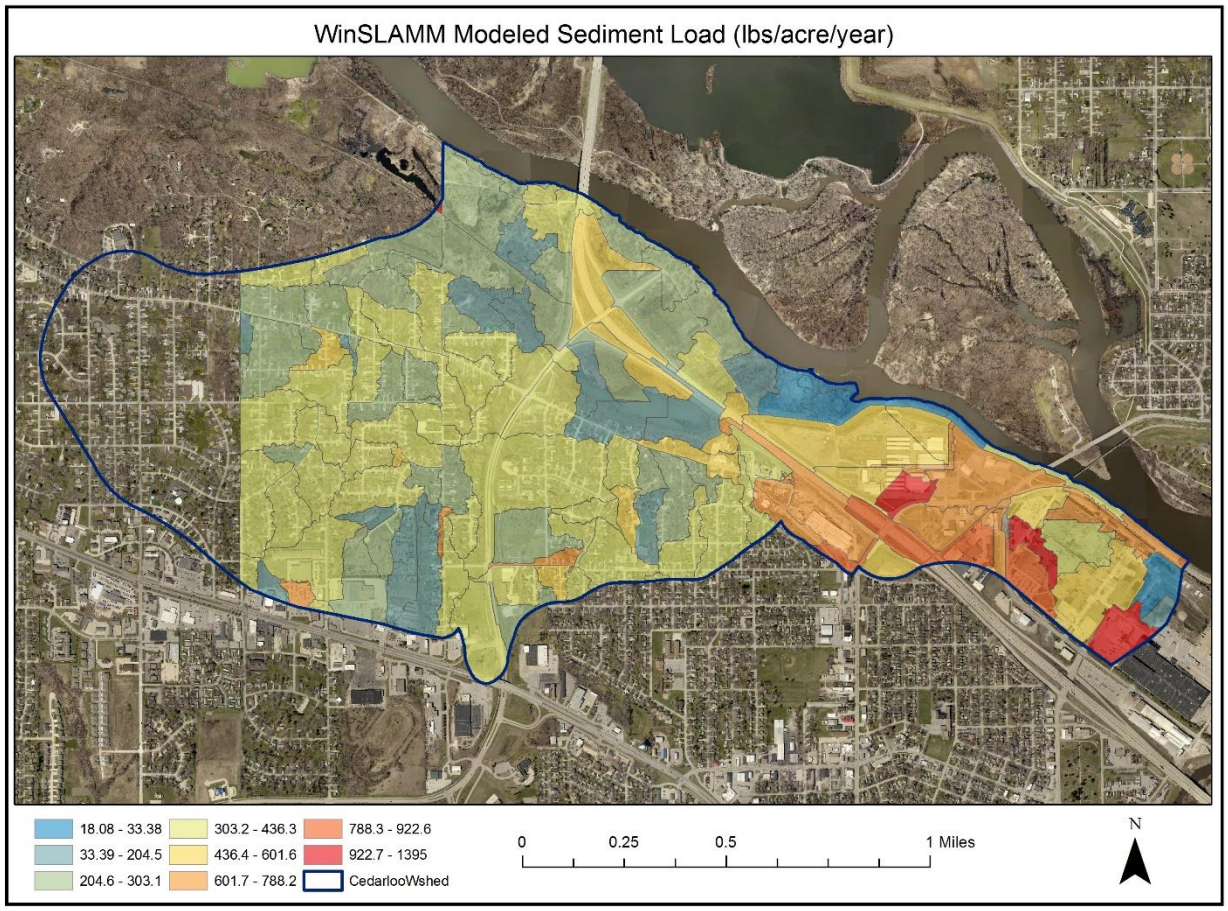

Figure 6: WinSLAMM modeled total sediment load for all subwatersheds normalized by the area (acres) of the catchment.

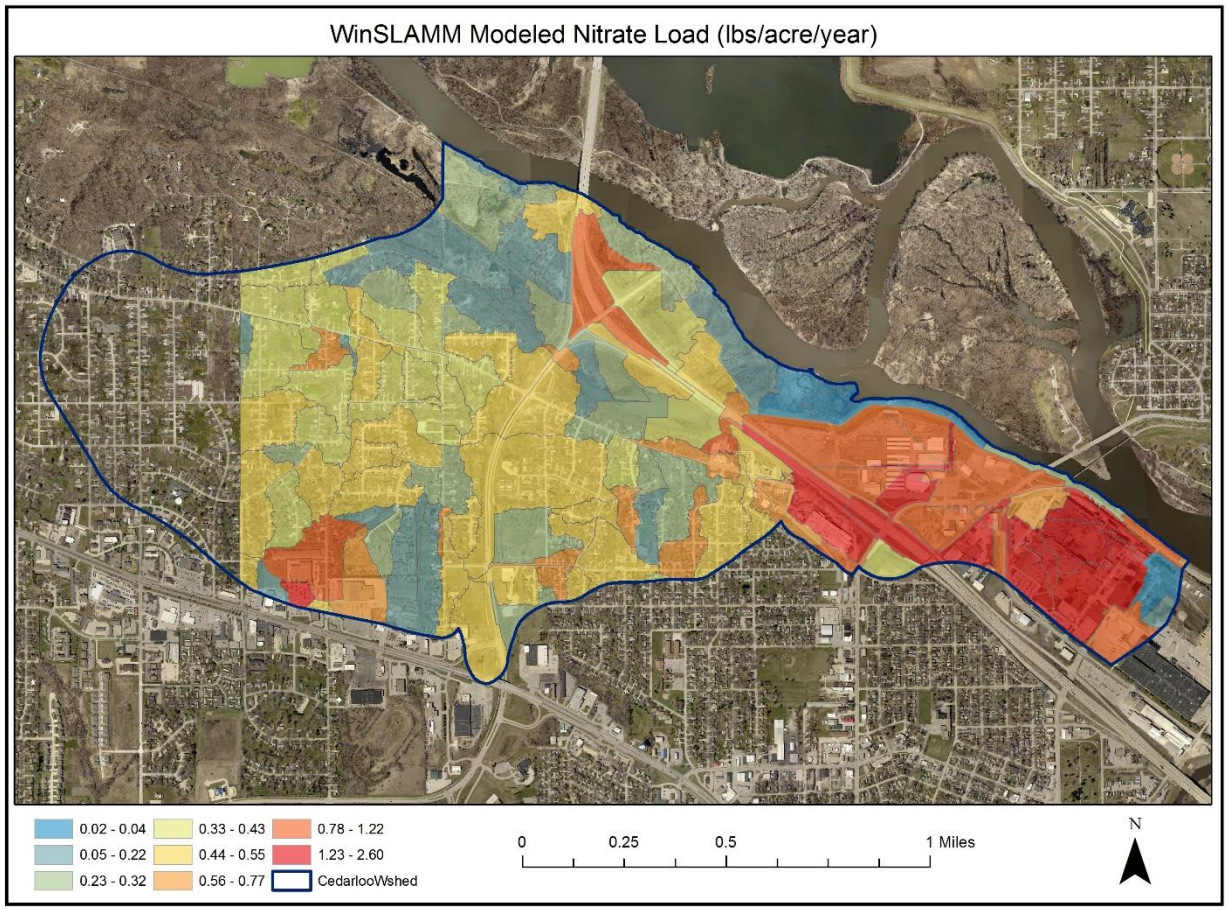

Figure 7: WinSLAMM modeled total nitrate load for all subwatersheds normalized by the area (acres) of the catchments.

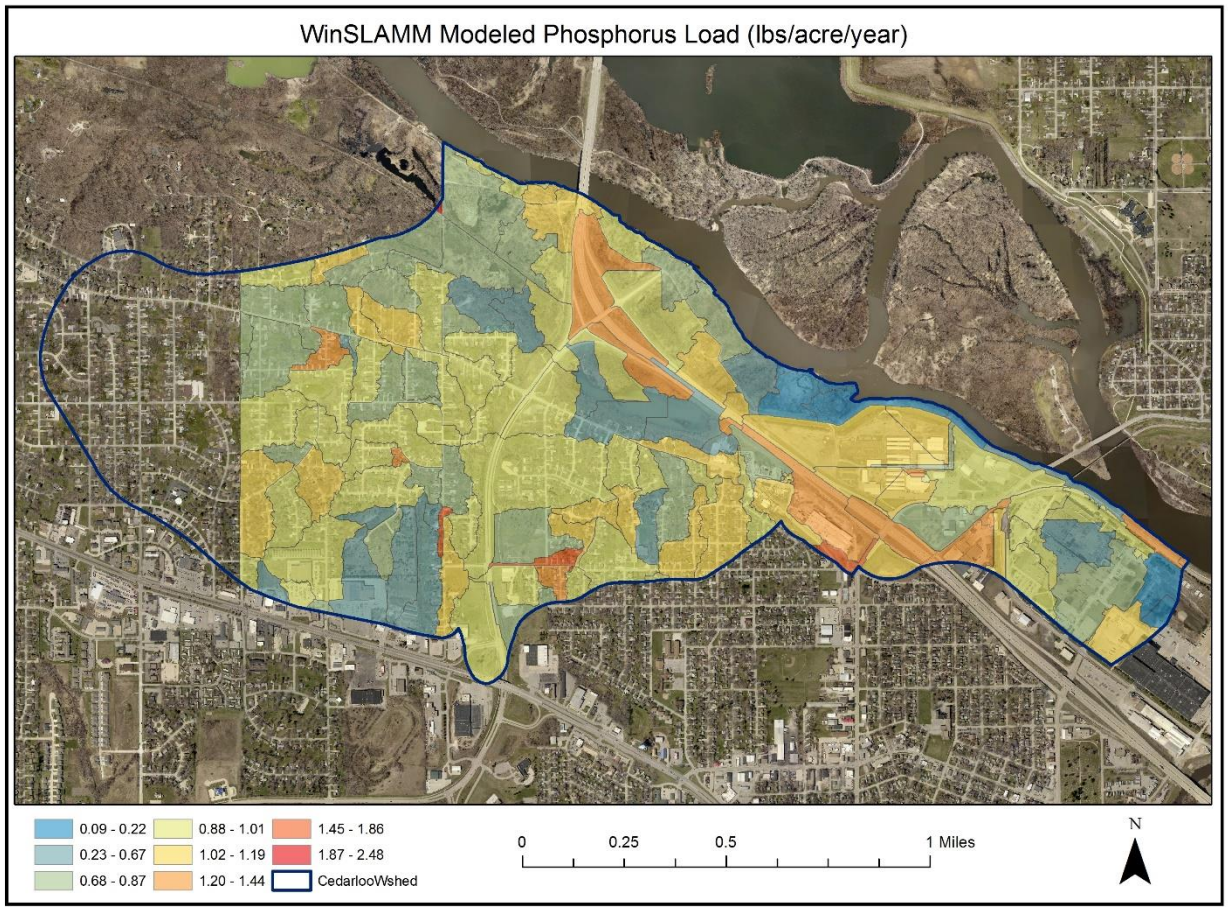

Figure 8: WinSLAMM modeled total phosphorus load for all subwatersheds normalized by the area (acres) of the catchment.

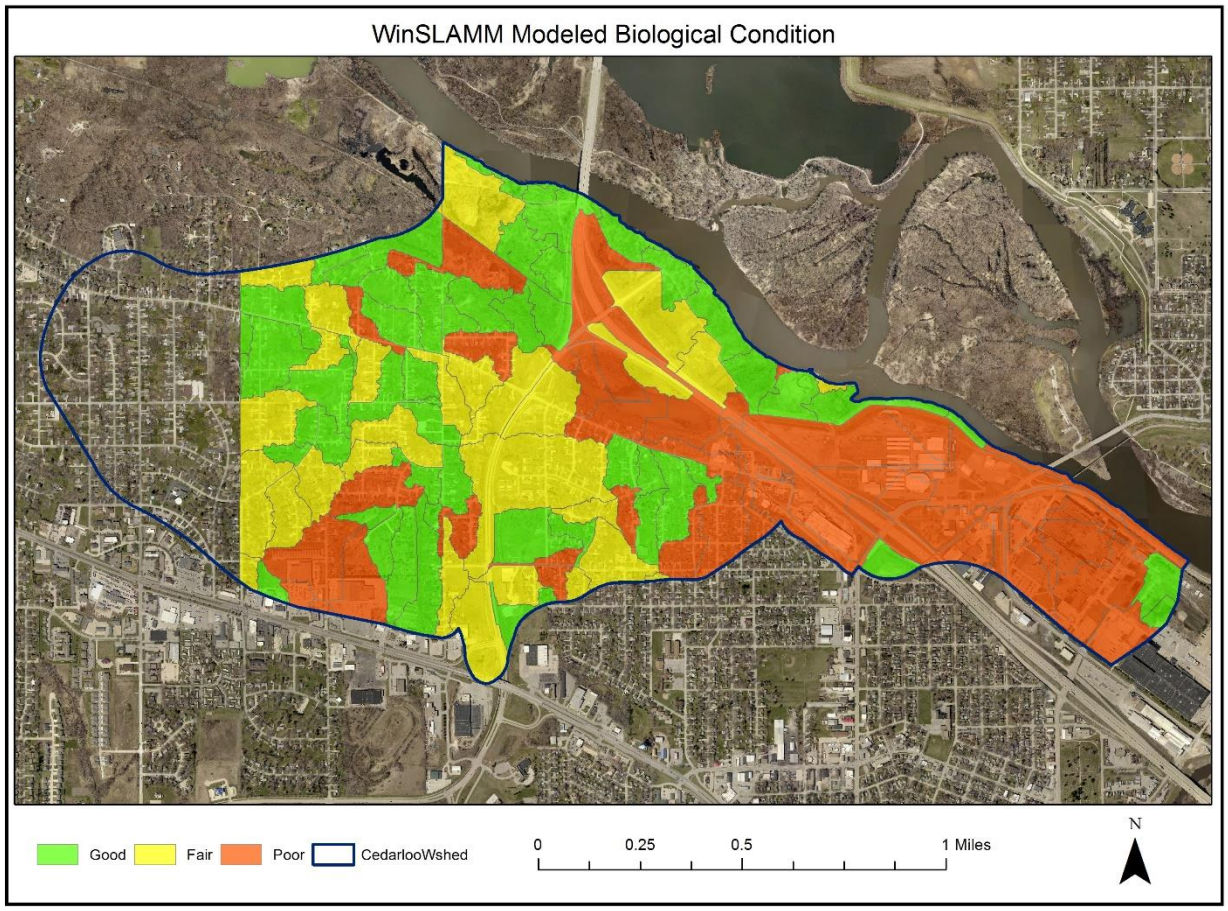

Figure 9: WinSLAMM modeled biological conditions for all subwatersheds.

Conclusion

The GeoTREE Center used the ArcSLAMM/WinSLAMM system to characterize detailed urban land use in the Cedarloo watershed and then used those data to model urban runoff and pollutant loads for 139 separate sub-catchments. This report has detailed those efforts. All data are also being delivered to interested stakeholders. These results could be useful in providing a quantified database of modeled runoff conditions as well as estimated pollutant loads. The data also can be used to help guide future decision making in regards to where to locate BMPs.

There are several potential limitations of the methodology utilized. Delineation of all subwatershed boundaries was based on the LiDAR DEM which was used to derive drainage areas or subwatershed polygon boundaries. The LiDAR was collected approximately 5-6 years ago meaning that some landscape features likely have changed. In addition, there are likely subtle surface and engineered features of the landscape that might not have been captured and thus delineated boundaries might not reflect the actual drainage areas or subwatersheds.

The project has resulted in a number of products that should be useful for management and planning purposes in the Cedarloo Watershed. The development of the detailed source area polygons in the geodatabase also allow for the potential for modeling for even more detailed subwatersheds or for new simulations to be developed for existing BMPs or for potential what-if BMP simulations to be carried out in other areas.

Acknowledgements:

Numerous Geography students served as student research Assistants participated in this project carrying out tasks including digitizing, database quality control checking, ArcSLAMM/WinSLAMM modeling, web map development, and report writing. These students included Megan Schneider, Aaron Padilla and Garrett Jepsen.