

GIS-BASED ANALYSIS OF POTENTIAL WATER INFILTRATION IN THE DOG RIVER WATERSHED, MOBILE, AL.

Andrew K. Keith, Department of Earth Sciences, University of South Alabama, Mobile, AL 36688. E-mail: akk602@jaguar1.usouthal.edu.

Land cover, slope, and soil attributes affect water quality by regulating sediment and chemical concentration. Land cover types can serve as nutrient detention media or as nutrient transformers as dissolved or suspended solids move towards the stream. Geographic Information Systems, (GIS), offer a method by which potential water infiltration areas can be identified, so that later action toward the establishment of buffer zones and proper land use can be taken. The variables regulating permeability are classified and ranked according to their influence on infiltration in an ArcGIS environment. A series of maps are generated after the analysis, locating environmentally sensitive areas where Best Management Practices (BMP) should be implemented to prevent NPS pollution and increase infiltration. The research will focus on a subset of the Dog River Watershed that includes Rabbit Creek. Soil layer is provided by the United States Department of Agriculture (USDA) and the elevation data from United States Geological Survey (USGS) digital elevation models. Land use is compiled from the City of Mobile GIS department. The results indicate that areas of low infiltration are located inside the Mobile city limits. Higher infiltration areas are located in residential and lower in industrial.

Keywords: water infiltration, GIS, permeability

Introduction

The Dog River Watershed (DRW) is located on the west side of Mobile Bay in Mobile, AL. A watershed is an area of land drained by a given river, in this case, Dog River. The watershed has an area of 95 square miles and is located in a developed, urban-suburban land use. Seventy-one percent of the DRW is in the City of Mobile and 29% is in Mobile County. As the city grows, human impact on the watershed increases. Impervious surface area is increased; roads, buildings, parking lots, and armored streams increase the velocity and runoff of water. This alteration adds sediment, contaminating the water in the DRW. Rain water infiltration in the ground is decreased in an urban

environment, which reduces the natural ability of the watershed to filter contaminants before it enters a stream (Basnyat et al. 1999).

The United States Department of Agriculture ranks each soil type based on its permeability. The soils are given a hydrologic soil type letter, A, B, C, D, or dual class A/D or B/D, C/D. Letter “A” represents a soil that has high permeability and a “D” type has low permeability. A soil type “D” has greater runoff than an “A” type soil due to its permeability. Hydrologic group is a group of soils having similar runoff potential under similar storm and cover conditions. An “A” type soil is porous and sandy, while a “D” type soil is non-porous clay material. Soil properties that influence runoff potential are those that influence the minimum rate of infiltration for a bare soil after prolonged wetting and when not frozen. These properties are depth to a seasonally high water table, and saturated hydraulic conductivity after prolonged wetting, and depth to a layer with a very slow water transmission rate. Changes in soil properties caused by land management or climate changes also cause the hydrologic soil group to change. The influence of ground cover is treated independently (Soil Properties and Qualities 2010).

Impervious surfaces as a result of urbanization, increases water runoff. Roads, buildings, driveways and any type of paved surface prohibit the waters access to the soil. In an urban area with impervious cover, the peak storm water discharge is higher than in less developed watersheds. The more paved surfaces in the watershed, the faster the transport of water to the streams. The velocity of the water picks up sediment and hazardous materials and deposits them into the waterways. In most cases, when impervious cover is less than 10% of a watershed, streams remain healthy. Above 10%

impervious cover, common signs of stream degradation are evident such as erosion, sedimentation, and flooding (Center for Watershed Protection 2003).

According to the Environmental Protection Agency, EPA, runoff increases as slope and distance increase (Erosion, Sediment and Runoff Control for Roads and Highways 2010). Steep slope is defined as being greater than 25%. Any slope 25% or

greater will have more runoff than a slope less than this value. The high percent slope of the ground surface allows water to flow more easily due to gravity. A flat or no slope area does not catalyze the movement of water as well, allowing it time to penetrate the soil. A flat surface is better for water infiltration as it allows time for



Figure 1. Study Area.

penetration, whereas a steep slope forces the water rapidly across the surface.

The study area is located in the south portion of the DRW, in what is called the Lower Dog River Basin. This area encompasses Rabbit Creek, Bull Branch, Perch

Creek, Whiskey Branch, and Alligator Bayou (Figure 1). The three main components of potential water infiltration in this model are land use, slope, and soil type (Rokus 2005). Each variable is assigned a number 0 to 100, 0 for no infiltration and 100 for high infiltration and then weighted 33% in the final analysis. High infiltration requires no slope, sandy soil, and a vegetated land use. Poor infiltration is characterized by steep slope of greater than 25%, clay soil, and an impervious land use (Brito et al. 2006). The computer model calculates the given values and generates a map that weights each variable the same in the analysis.

Areas of low infiltration are also associated with higher runoff. Careful planning and proper construction practices should be adhered to in areas of poor infiltration. Encouraging development in areas of high infiltration and discouraging development in low infiltration areas, the DRW water quality can be improved (Basnyat et al. 1999). Best Management Practices (BMP) need to be monitored more closely in areas of low infiltration since the water is more susceptible to runoff.

Research Question

Land use, soils, and slope are major variables determining potential water infiltration. GIS, Geographic Information Science, based analysis is performed to located areas of high and low water infiltration. Where and how much land area in the southern part of the DRW is able to allow water to percolate in the ground?

Methods

The Lower Dog River Basin, a basin located in the south half of the DRW, was chosen as the study area. This location was delineated from the City of Mobile (COM)

GIS watershed data layer. The study area was chosen because Rabbit Creek is a black water creek and city expansion is recent to the area. A black water creek has little sediment contamination.

ArcGIS 9.3 was used to store, analyze, and map the necessary data layers. The COM maintains a GIS database compatible with the software. The map data used in the analysis from the COM is dated to 2006. All spatial data is converted to Alabama State Plane FIPS102.

Roads, buildings, and paved parking lots were clipped to the study area, Lower Dog River Basin, using the Proximity tool in ArcGIS 9.3, and then merged to create an impervious map layer. A new polygon is generated around all the impervious features using the Union tool. Percent infiltration attribute is added to the final impervious surface layer and given a value of “0”. The area outside the impervious surface is given a value of “1” (Rokus 2005). The impervious layer is then converted to a raster layer with a cell size of 10 using the Spatial Analyst extension. The same process is repeated to create the pervious surface raster with variation in percent infiltration. Water body, streams, woods, unpaved parking lots, wetlands, parks, and railroads were clipped to the study area and merged to produce a pervious map layer. A polygon is generated around the pervious features using the Union tool. A percent infiltration attribute field is added to the layer and computed for each land use type (Rokus 2005). The values for each land use used can be found in Appendix A. A new pervious raster map was generated with a cell size of 10.

The soil spatial and tabular map data was obtained from the Natural Resources Conservation Service (NRCS) and imported into ArcMap. The soil type is added to the spatial soil layer by using the Join function. The joining table was derived from a MS Access database provided by NRCS, called a SSURGO template. The table included the soil name and the Hydrologic Soil Type. This table was joined to the soil spatial layer by the "MUSymbol" field. The Hydrologic Soil Type ranks permeability of each soil type. The soil can be an "A", "B", "C", "D", or "A/D", where "A" is the best and "D" is the worst. A percent infiltration attribute field is added to the soils layer and each soil type is given a numerical value. The values for each soil type can be seen in Appendix A. A raster map is generated for soils with a cell size of 30. The raster layer is then reclassified to five classes using the said values in the percent infiltration attribute field using the Spatial Analyst extension.

Digital elevation models (DEM) are downloaded from the United States Geological Survey (USGS) and loaded into ArcMap. The study area requires two DEM files, Hollingers Island and Theodore. A slope map is created using each DEM with the Spatial Analyst extension, with a cell size of 30. The two slope maps are mosaiced together by the Mosaic to New Raster tool. The final slope raster is reclassified to three classes based on percent slope (Rokus 2005). Values can be seen in Appendix A.

The impervious and pervious raster map layers are meshed together using the Raster Calculator. The impervious layer is multiplied times the pervious layer. The percent infiltration values are multiplied with a possible combination of 0, 50, 70, 90, and 100. The Weighted Overlay tool is used to compose the final analysis of potential water infiltration. The impervious/pervious, reclassified slope, and reclassified soil raster maps

are inputted and weighted evenly based on 100 percent (Rokus 2005). Values are indicated in Appendix A. The output is a new thematic map showing the potential water infiltration in a given area based on slope, soils, and land use. Finally, area calculations are performed for high and low infiltration zones, in and outside of city limits.

Results

The majority of areas of high infiltration are located west and upstream from Dog River (Figure 2). These are residential areas outside the city limits of Mobile, AL. Forty-three percent of the land area outside the Mobile City limits has a high potential for water infiltration (Figure 3). This area has a permeable soil type, low slope, and vegetated land use. The majority of poor infiltration can be found in the recently annexed city limits of Mobile. Forty-six percent of the land area in the city of Mobile has a low potential water infiltration (Figure 4). This is centrally situated in the study area. As these areas develop, Best Management Practices (BMP) should be strictly enforced and adequate vegetation should be reserved to filter sediment contamination. The city of Mobile is responsible for urbanization and controls the majority of areas with high infiltration and areas of low infiltration. The heavy influence was derived from the soils and land use. Slope was a small factor in determining the infiltration in this area due to its lack thereof.

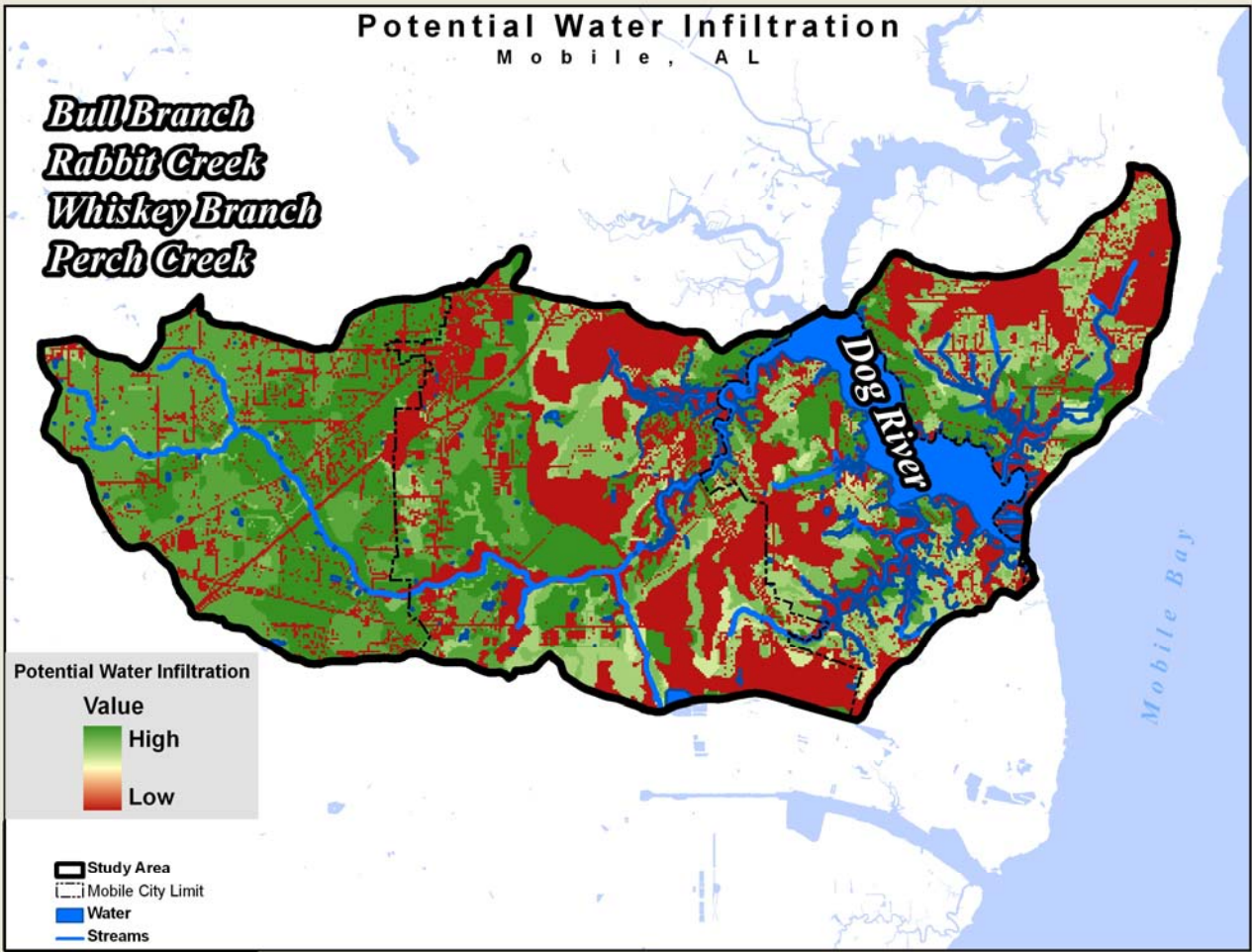


Figure 2. Potential Water Infiltration Areas.

Mobile County

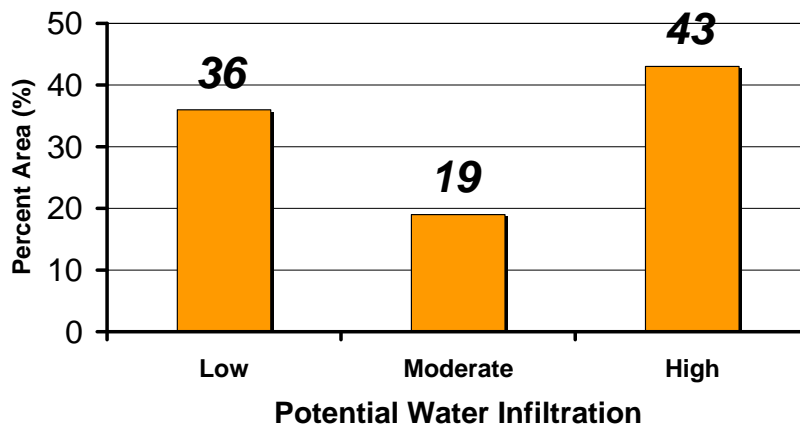


Figure 3. Low, Moderate, and High Potential Water Infiltration Land Area in Mobile County

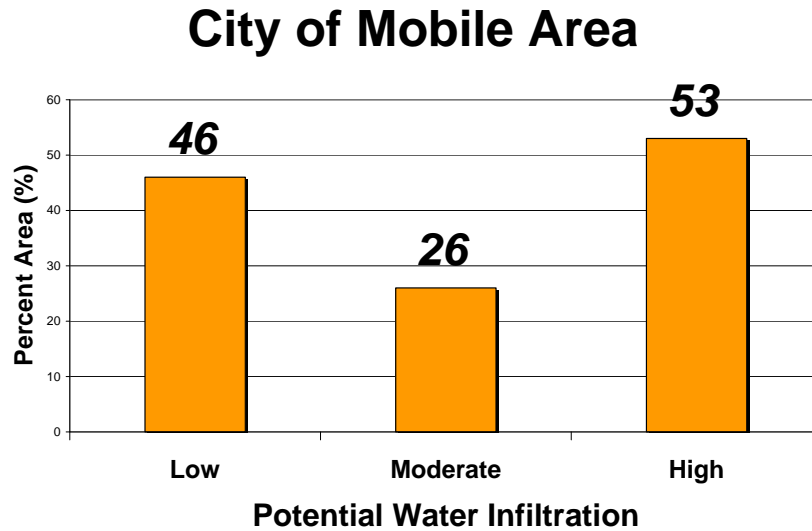


Figure 4. Low, Moderate, and High Potential Water Infiltration Land Area in the City of Mobile

Discussion and Conclusions

I can conclude that urbanization of the DRW will impact water infiltration. As the land becomes urbanized and impervious surface increases, the water will become more turbid. This will result from an increase in storm water runoff. By mapping the areas of high and low potential water infiltration, the information can be used as a historical marker for future research. The map information can also be used to properly monitor BMP practices in areas of low infiltration. Areas with low infiltration will have an increase in runoff. The maintenance and implementation of BMP's should be monitored more closely in these areas. The city of Mobile controls the majority of land area that has low infiltration and that has high infiltration. Land use is affected more in the city and will be a primary factor in the future of the water quality in the DRW. Since the area includes Rabbit Creek, a black water stream, future changes to the water quality can be monitored and an updated map of water infiltration can be produced for

correlation. The City of Mobile updates the layers on a four year interval. Updated planimetric data will be available in 2010 to repeat the research and compare the changes in infiltration and water quality.

The research did not involve rainfall as one of the variables. This is a factor in determining water infiltration, so there are limitations. A sample cell size of only 30 for the slope, caused poorer resolution. If the research were to be repeated, infiltration measurements should be taken in the field to correlate with model generated data.

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Appendix A: Input Data

Potential Infiltration Model Weights		
<i>Land Use</i>	<i>Infiltration %</i>	
Forest	100	
Water	100	
Park	100	
Grass	90	
Unpaved Parking	70	
Wetland	50	
Railroads	50	
Roads	0	
Buildings	0	
Paved Parking	0	
<i>Slope</i>	<i>Infiltration %</i>	
0-10% (Low)	100	
10-25% (Moderate)	50	
> 25% (High)	0	
<i>Soil Type</i>	<i>Infiltration %</i>	
A (Sand / Loam)	100	
B (Silt / Loam)	67.7	
A/D (Clay Mix)	50	
C (Sand /Clay /Loam)	33.3	
D (Clay)	0	