

Site Development Characteristics for Stormwater Modeling¹

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Introduction

In order for an urban runoff study to be successful, a careful evaluation of the study watershed is required. An urban area inventory of watershed development conditions is needed in order to use the calibrated version of WinSLAMM for a specific area. Past studies using WinSLAMM have demonstrated the importance of knowing the areas of the different land covers in each land use category, the pavement conditions, and the storm drainage characteristics (grass swales, curb and gutters, and the roof drains). Delineation of the watershed and neighborhoods is mandatory and an inventory sheet needs to be filled out at several locations in the watershed. About 6 to 12 homogeneous neighborhoods are usually needed to be surveyed for the inventory task per study area land use. Aerial photographs or satellite images are also needed for each location. They are used to measure the specific land cover areas at each inventory location.

Impervious cover has become an increasing used indicator in measuring the impact of land development on drainage systems and aquatic life (Schueler 1994). Impervious cover is also one of the variables that can be quantified for different types of land development, although there are many different types of impervious surfaces and how they are connected to the drainage system. Although much interest has been expressed concerning impervious areas in urban areas, actual data for the patterns of use of these surfaces is generally lacking. The procedures described in this paper to obtain this information has been used for many years in stormwater research projects, specifically several Nationwide Urban Runoff Program (NURP) projects that were conducted in the San Francisco Bay Area (Castro Valley, CA), in Bellevue, WA, and in Milwaukee, WI (EPA 1983). Pitt and McLean 1986 also extensively used these procedures to determine the characteristics in test watersheds in Toronto, Ontario.

The objective of this on-going research effort described here is to measure the variations in runoff quantity and quality associated with variations in site characteristics, especially impervious cover. In order to determine how land development variability affects the quantity and quality of runoff, different land surfaces (roofs, streets, landscaped areas, parking lots, etc.) for different land uses (residential, commercial, industrial, institutional, etc) were measured.

¹ Portions of this paper will be presented at the 78th Annual Water Environment Federation Technical Exposition and Conference. Washington, D.C. Oct. 29 – Nov. 2, 2005, as “Impervious Surfaces in Urban Watersheds,” by Celina Bochs and Robert Pitt. This information is being collected and evaluated by Celina as part of her MSCE thesis in the Department of Civil and Environmental Engineering, at the University of Alabama, Tuscaloosa, AL 35487-0205. The Stormwater Management Authority of Jefferson County, AL, and its employees, has been extremely helpful in supplying data and information to support these research efforts.

The field data will be used with WinSLAMM (the Source Loading and Management Model for Windows, Pitt and Voorhees 1995; 2002) to model the runoff quantity and quality for each neighborhood investigated. Statistical analyses will be conducted at several levels to establish the quantitative and qualitative runoff sensitivity associated with variations of site characteristics.

In this study, 125 neighborhoods were surveyed to determine the actual development characteristics representing 16 major land use areas (Table 1) located in the Little Shades Creek Watershed, near Birmingham, AL. This information was collected over a period of several years as part of a volunteer effort using the Jefferson County “Earth Team” of the local USDA office during the mid 1990s. Initially, this data was used along with source area and outfall monitoring data to calibrate WinSLAMM for the area. This current project is intended to measure the variability in stormwater characteristics associated with the variability of the development characteristics for each land use category. Currently, additional regional data from the NSQD (National Stormwater Quality Database) MS4 (municipal separate storm sewer system) database for Jefferson County, Alabama, is being used to conduct a re-validation of the model for current local conditions.

Field Data Collection

The new field data comes from six drainage areas that have been monitored as part of the Jefferson County, AL, stormwater permit program, by the Jefferson County Stormwater Management Authority. These field data are incorporated in the NSQD (National Stormwater Quality Database) MS4 (Municipal Separate Storm Sewer System) database for Jefferson County, Alabama (Pitt, *et al.* 2004; Maestre and Pitt 2005). This database is part of research conducted by the University of Alabama, Department of Civil and Environmental Engineering and can be found at the Internet location: <http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml>

The University of Alabama and the Center for Watershed Protection were awarded a 3-year Environmental Protection Agency (EPA) Office of Water 104(b) 3 grant in 2001 to collect and evaluate stormwater data from a representative number of NPDES (National Pollutant Discharge Elimination System) MS4 stormwater permit holders. The database, the National Stormwater Quality Database (NSQD, version 1.1) also contains information that was collected and reviewed to describe the characteristics of these data, to provide guidance for future sampling needs, and to have these data as a benchmark for comparison with locally collected data.

The field data used with WinSLAMM to model the runoff quantity and quality was collected during an earlier study of Little Shades Creek Watershed, near Birmingham, AL, as part of a cooperative study conducted by the University of Alabama at Birmingham, the Jefferson County office of the U.S. Soil Conservation Service (now The U.S. Natural Resources Conservation Service), U.S. Army Corps of Engineers, and other city and county governments. Local runoff quality data collected during EPA sponsored runoff projects (Pitt, *et al.* 1995), detailed development information (field information) conducted by volunteers of the Soil Conservation’s Earth Team and additional information provided by local government agencies, form the database for this research. Initially, this data was used along with source area and outfall monitoring data to calibrate WinSLAMM and to examine the alternative controls in this rapidly developing area. The present research uses the same field data and is intended to measure the variability in stormwater characteristics associated with the variability of the development characteristics for each land use category.

An “Area Description” field sheet is used to record the important characteristics of the study areas during field surveys (Figure 1). In addition, aerial photographs from TerraServer USA <http://terrasservice.net/> (Figure 2) and satellite images provided by Storm Water Management Authority in Birmingham (SWMA) <http://www.swma.com/> (Figure 3) were used to measure the actual coverage of each type of surface in each neighborhood studied. The following briefly explains the important elements of the field sheet. Field training of the people responsible for collecting the information was carried out to assure data consistency.

Table 1. Little Shade Creek Watershed, near Birmingham, AL: Average Source Areas by Land Use

Land Use	Curb Miles/ 100 ac	Street Area (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Driveways Unpaved (%)	Parking Paved Connected (%)	Parking Paved Disconnected (%)	Parking Unpaved (%)	Playground Paved Disconnected (%)	Playground Unpaved (%)
High Dens. Residential	6.87	7.85	1.56	1.90	0.00	0.00	0.00	0.00	0.00	0.00
Med. Dens. Residential (<1960)	4.95	5.59	1.13	2.00	0.00	0.00	0.00	0.00	0.00	0.00
Med. Dens. Residential (1961-80)	5.81	6.74	1.34	1.86	0.00	0.00	0.00	0.00	0.00	0.00
Med. Dens. Residential (>1980)	6.50	7.54	0.00	1.08	1.08	0.00	0.00	0.00	0.00	0.00
Low Dens. Residential	4.59	5.33	0.23	0.80	0.00	0.00	0.00	0.00	0.00	0.00
Apartments	8.23	9.79	0.52	1.03	0.00	6.56	3.87	0.00	0.84	0.00
Multi Family	6.34	7.26	0.60	0.60	0.00	8.68	0.00	0.00	0.16	0.00
Offices	13.37	15.52	1.07	0.62	0.00	24.72	1.90	0.00	0.00	0.00
Shopping Centers	13.90	16.11	0.74	0.00	0.00	29.20	0.00	0.61	0.00	0.00
Schools	3.55	4.15	0.10	0.10	0.00	5.73	0.00	0.00	0.00	15.35
Churches	15.76	18.29	0.38	0.38	0.00	24.53	0.00	4.76	0.00	0.00
Industrial	7.08	8.00	0.32	0.10	0.00	8.89	2.48	1.85	0.00	0.00
Parks	13.86	16.11	0.11	0.11	0.00	16.11	0.00	0.00	8.25	24.75
Cemeteries	0.00	6.90	0.00	0.07	3.33	0.00	9.16	1.78	0.00	0.00
Golf Courses	1.03	1.20	0.08	0.08	0.00	0.65	0.00	0.00	0.68	0.00
Vacant	4.11	4.77	0.00	0.00	1.31	0.00	0.00	0.00	0.00	0.00

Table 1. Little Shade Creek Watershed, near Birmingham, AL: Average Source Areas by Land Use – continuation

Land Use	Storage Paved Connected (%)	Storage Unpaved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Undeveloped (%)	Roof drained to Impervious (%)	Roof drained t Pervious (%)	Walkway (%)	Grave Area (%)	Total (%)
High Dens. Residential	0.00	0.00	39.96	32.22	0.00	3.88	4.58	8.05	0.00	0.00	100
Med. Dens. Residential (<1960)	0.00	0.00	58.29	23.45	0.00	0.00	4.00	5.54	0.00	0.00	100
Med. Dens. Residential (1961-80)	0.00	0.00	52.94	28.14	0.00	0.17	2.18	6.63	0.00	0.00	100
Med. Dens. Residential (>1980)	0.00	0.00	51.49	24.23	0.00	4.79	6.56	3.23	0.00	0.00	100
Low Dens. Residential	0.00	0.00	33.37	48.11	0.00	8.36	0.87	2.92	0.00	0.00	100
Apartments	0.00	0.00	31.71	22.79	0.00	3.28	3.60	16.01	0.00	0.00	100
Multi Family	0.00	0.00	28.19	30.10	0.00	6.90	10.79	6.67	0.05	0.00	100
Offices	0.00	0.00	23.99	14.68	0.00	0.00	17.18	0.33	0.00	0.00	100
Shopping Centers	0.00	0.00	30.14	1.78	0.00	0.00	17.78	3.64	0.00	0.00	100
Schools	0.00	0.00	22.83	25.96	13.95	1.03	6.05	4.75	0.00	0.00	100
Churches	0.00	0.00	20.93	11.52	0.00	7.04	10.44	1.74	0.00	0.00	100
Industrial	15.67	8.13	26.55	17.09	0.00	0.00	5.53	5.40	0.00	0.00	100
Parks	0.00	0.00	1.03	4.33	15.47	13.73	0.00	0.00	0.00	0.00	100
Cemeteries	0.00	0.00	8.28	0.00	0.00	0.00	0.00	0.98	0.00	69.52	100
Golf Courses	0.00	0.00	18.83	0.00	75.73	0.00	0.00	2.75	0.00	0.00	100
Vacant	0.00	0.00	0.00	0.00	26.93	66.99	0.00	0.00	0.00	0.00	100

Figure 1. LITTLE SHADES CREEK CORRIDOR TEST AREA DESCRIPTIONS

Location: Site number:
Date: Time:
Photo numbers:
Land-use and industrial activity:
Residential: low medium high density single family
 multiple family
 trailer parks
 high rise apartments
Income level: low medium high
Age of development: <1960 1960-1980 >1980
Institutional: school hospital other (type):
Commercial: strip shopping center downtown hotel offices
Industrial: light medium heavy (manufacturing) describe:
Open space: undeveloped park golf cemetery
Other: freeway utility ROW railroad ROW other:
Maintenance of building: excellent moderate poor
Heights of buildings: 1 2 3 4+ stories
Roof drains: % underground % gutter % impervious % pervious
Roof types: flat composition shingle wood shingle other:
Sediment source nearby? No Yes (describe):
Treated wood near street? No telephone poles fence other:
Landscaping near road:
Quantity: none some much
Type: deciduous evergreen lawn
Maintenance: excessive adequate poor
Leafs on street: none some much
Topography:
Street slope: flat (<2%) medium (2-5%) steep (>5%)
Land slope: flat (<2%) medium (2-5%) steep (>5%)
Traffic speed: <25mph 25-40mph >40mph
Traffic density: light moderate heavy
Parking density: none light moderate heavy
Width of street: number of parking lanes:
 number of driving lanes:
Condition of street: good fair poor
Texture of street: smooth intermediate rough
Pavement material: asphalt concrete unpaved
Driveways: paved unpaved
Condition: good fair poor
Texture: smooth intermediate rough
Gutter material: grass swale lined ditch concrete asphalt
Condition: good fair poor
Street/gutter interface: smooth fair uneven
Litter loadings near street: clean fair dirty
Parking/storage areas (describe):
Condition of pavement: good fair poor
Texture of pavement: smooth intermediate rough unpaved
Other paved areas (such as alleys and playgrounds), describe:
Condition: good fair poor
Texture: smooth intermediate rough
Notes:



Figure 2. Example of 1 m monochromatic aerial photograph (USGS photo)

- **Location:** The block number range and the street name are noted. A sub-area name could also be used to describe the drainage area. Descriptions were made for homogeneous block segments (neighborhoods) in the study area. Specific blocks to be surveyed were randomly selected and located on the aerial photographs before the survey began. Each site had at least two photographs taken: one was a general scene (Figure 4) and the other was a close-up showing about 25 by 40 centimeters of pavement (Figure 5). Additional photographs were usually taken to record unusual conditions. These photographs are very important to confirm the descriptions recorded on the sheets and to verify the consistency of information for the many areas. The photographs are also very important when additional site information is needed, but not recorded on the data sheets.

- **Land-use:** The land-use type that best describes the block is circled. If more than one land-use is present, the estimated distribution is shown. The approximate income level for residential areas is also circled. The specific types of industrial activities (warehouses, metal plating, bottling, electronics, gas station, etc.) for industrial and commercial areas are also written in. Also, the approximate age of development is circled.

- **Roof drainage:** The discharge locations of the roof drains are noted. The approximate distribution is also noted if more than one discharge location is evident. The “underground” location may be to storm sewers, sanitary sewers, or dry wells. Some areas have the roof drains apparently directed underground but are actually discharged to the roadside gutter or drainage ditch. If they lead to the gutter, then the “to gutter” category is circled. Additionally, if the flow path length is less than about five feet over pervious ground, it is functionally directly connected to impervious areas, requiring circling the “to impervious” category. The roof types and building heights are also indicated (again, the approximate distributions are noted if more than one type was present). It is necessary to take an inventory of all visible roof drains in the study block by keeping tallies of each type of drain connection. The distribution of the percentage per connection type is also put on the sheet. If other categories of characteristics vary



Figure 3. Example of high resolution color satellite image.

in the study block (paved or unpaved driveway categories is another common variation), then these are also tallied for each category. The roof types are also indicated.

- **Sediment sources:** Sediment sources near the drainage (street, drainage way, or gutter), such as construction sites, unpaved driveways, unpaved parking areas or storage lots, or eroding vacant land, are described and photographed.

- **Street and Pavement:** Traffic and parking characteristics are noted. Pavement condition and texture are quite different. Condition implies the state of repair, specifically relating to cracks and holes in the pavement. Texture implies roughness. A rough street may be in excellent condition: many new street overlays result in very rough streets. Some much worn streets may also be quite smooth, but with many cracks. A close-up photograph of the street surface is needed to make final determinations of street texture. An overview photograph of the street is also taken to make the final determination of the street condition. The gutter/street interface condition is an indication of how well the street pavement and the gutter material join. Many new streets overlay jobs are uneven, resulting in a several centimeter ridge along the gutter/street interface. If the street interface has poor condition or is uneven, an extra photograph is taken to show the interface close-up. The litter perception is also circled. Another photograph is also taken of heavily littered areas.

After the test area descriptions were filled out for each neighborhood surveyed, the corresponding aerial photographs were examined and the individual elements (roofs, parking areas, street areas, sidewalks, landscaping,



Figure 4. Example of Site General View.

etc) were measured, and the data were then summarized in an Excel spreadsheet. This information was used to build the WinSlamm files to describe each land use area. This information had to be manually measured from the photographs, as automated mapping software resulted in many errors and could not distinguish the necessary surface components. Mapping software may be used to total the main surface categories, but accuracy must be verified.

The field data collected for the six Jefferson County drainage basins was performed to supplement the aerial photographic information. Watershed maps and additional information about the outfalls location and safety issues were provided by Storm Water Management Authority Inc.

Description of Land Use

General Land Use Description

A stormwater/watershed study should use the locally available land use data and definitions. The watershed surveys conducted during the field data collection activities revealed the existence of several distinct sub categories of land uses in the Birmingham area. The following briefly explains the land use descriptions used in this research, according to the documentation supplied with WinSLAMM (Pitt and Voorhees 2000). In all cases, all the land surfaces are included in the land uses, such as the streets, building roofs, parking lots, walkways, landscaped areas, undeveloped parcels, etc.



Figure 5. Example of Close-up View of the Street Texture Photograph.

• ***Residential Land Uses***

- High Density Residential: Urban single family housing at a density greater than 6 units/acre. This land use includes the house, driveway, yard, sidewalks, and streets.
- Medium Density Residential: Urban single family housing at a density of 2 -6 units/acre. The same as above, the house, driveway, yard, sidewalks and streets adjacent with the house are included.
- Low Density Residential: Like previous residential areas, except the density is 0.7 – 2 units/acre.
- Multiple Families: Housing of three or more families having 1 to 3 stories in height. Units may be adjoined up-and-down, side-by-side or front-and-rear. This land use includes the streets, buildings, yards, parking lots, and driveways.
- Apartments: Multiple family units of 4 or more stories in height.
- Trailer Parks: A mobile home or trailer park that includes all vehicle homes, the yard, driveways, streets, walkways, and office area.

• ***Commercial Land Uses***

- Strip Commercial: Includes buildings for which the primary function is the sale of goods or services. Some institutional land use such as post offices, fire and police stations, and court houses are also included in this category. The strip commercial land use includes the buildings, parking lots, and streets. This category does not include buildings used for the manufacturing of goods or warehouses, nurseries, tree farms, or lumber yards.

- Shopping Centers: These are commercial areas where the related parking lot is at least 2.5 times the building roof area. The buildings in this category are usually surrounded by parking lots. This land use includes the buildings, parking lots, and the streets, plus any landscaping.
- Office Parks: It is the land use where non-retailed businesses take place. The buildings are usually multi-story buildings surrounded by larger areas of lawn and other landscaping. This land use includes the buildings, the lawn, and streets. Types of establishments usually found in this category may be: insurance offices, government buildings, company headquarters, etc.
- Downtown Central Business District: Highly impervious downtown areas of commercial and institutional land use.

• ***Industrial Land Uses***

- Manufacturing Industrial: Those buildings and premises which are devoted to the manufacture of products, with many of the operations conducted outside, such as power plants, steel mills, and cement plants.
- Medium Industrial: This category includes businesses such as lumber yards, auto salvage yards, junk yards, grain elevators, agricultural coops, oil tank farms, coal and salt storage areas, slaughter houses, and areas for bulk storage of fertilizers.
- Non-Manufacturing: Those buildings which are used for the storage and/or distribution of goods awaiting further processing or sale to retailers. This category mostly includes warehouses and wholesalers where all operations are conducted indoors, but with truck loading and transfer operations conducted outside.

• ***Institutional Land Uses***

- Hospitals: Medical facilities that provide patient overnight care. Includes nursing homes, state, county, or private facilities. This land use includes the buildings, grounds, parking lots, and drives.
- Education (Schools): Includes any public or private primary, secondary, or college educational institutional grounds. The land use consists of the buildings, playgrounds, athletic fields, roads, parking lots, and lawn areas.
- Miscellaneous Institutional: Churches and large areas of institutional property not part of strip commercial and downtown areas.

• ***Open Space Land Uses***

- Cemeteries: Includes cemetery grounds, roads, and buildings located on the grounds.
- Parks: Outdoor recreational areas including municipal playgrounds, botanical gardens, arboretums, golf courses, and natural areas.
- Undeveloped: Lands that are private or publicly owned with no structures and have an almost complete vegetative cover. This includes vacant lots, transformer stations, radio and TV transmission areas, water towers, and railroad rights-of-way (may be part of industrial areas if surrounding areas are such)..

• ***Freeway Land Uses***

- Freeways: They are limited access highways and the interchange areas, including any vegetated rights-of-ways.

Little Shades Creek Watershed Land Use Characteristics

The Little Shades Creek Watershed (Figure 6) has an area of almost eight square miles and was about 70% developed at the time of these surveys (mid 1990s). It lies under the jurisdiction of several municipal governments (Hoover, Vestavia Hills, and Cahaba Heights) as well as the county government (Jefferson County), which made land development highly variable and uncoordinated. Many types of land developments are represented, even though the residential areas, mostly as single family residential units, are predominant. Table 2 shows the areas of the local planning agency categories in the watershed.

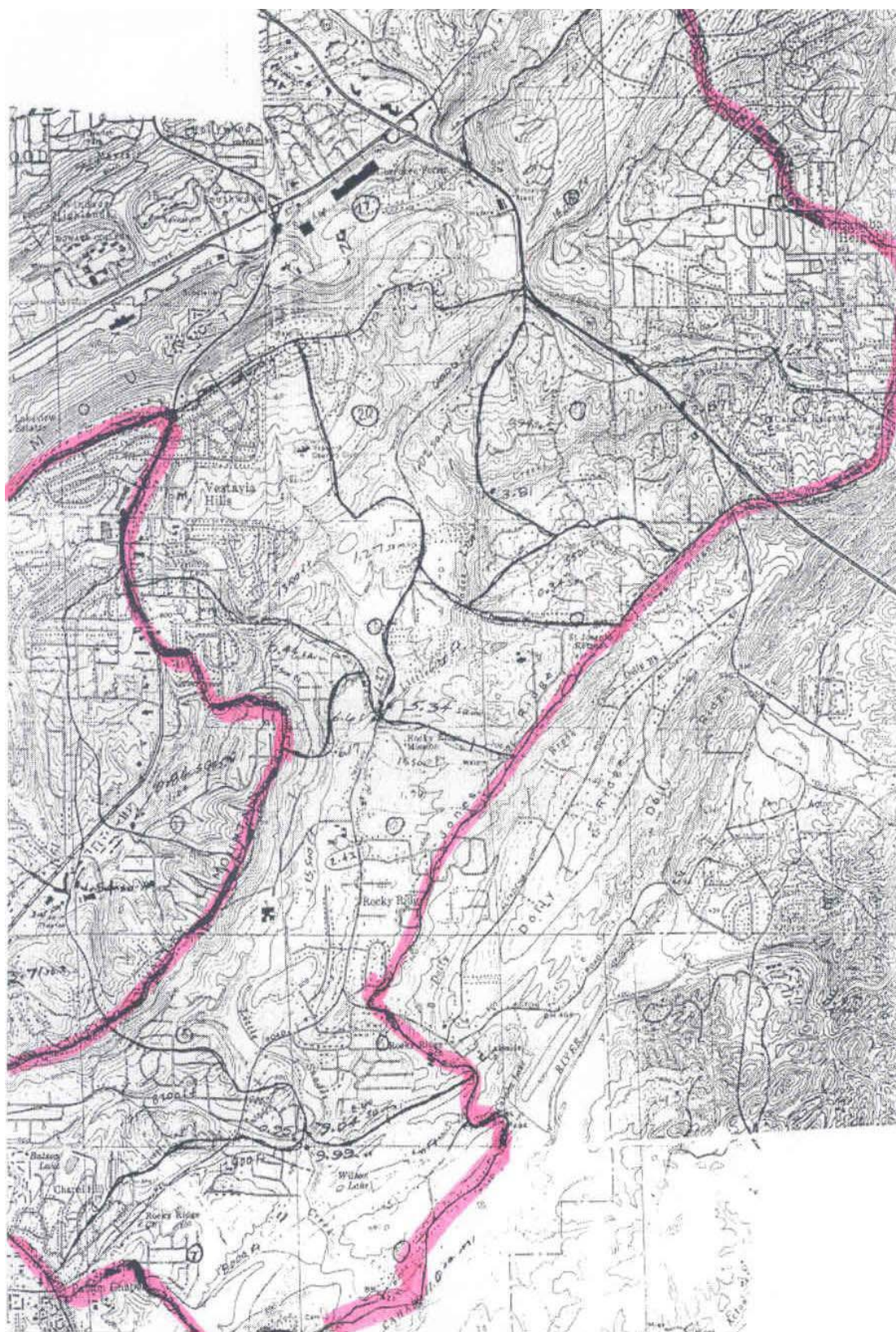


Table 2. Local Planning Agency Land Use Categories in the Little Shades Creek Watershed

Land Use	Total Acres
Single family residential	3,611
Town home	122
Multi-family residential	87
Schools and churches	109
Recreation	112
Public lands	5
Cemeteries	3
Open space	26
Office parks	62
Commercial areas	82
Industrial areas	9
Utility	2
Vacant land	989
Total	5,218

Sixteen land uses categories in the watershed were surveyed by investigating about 10 neighborhoods in each area. The predominant land use in the watershed was residential land, subdivided according to the density type, and age. All surveyed residential areas (high density, medium density, low density, apartments, and multi-family complexes) had pitched roofs that drained mainly to pervious surfaces with the only exception being multi-family areas. The soil is represented by sandy loam and silt loam soils, in about equal amounts. The land is mostly flat or with medium slopes. Some landscaping was present near the roads and was mostly lawns and evergreen shrubs. Streets and driveways had asphalt as the most common pavement material and had intermediate texture. The predominant drainage system was composed of concrete curbs and gutters in good or fair condition with a small percentage of grass swales in high and medium density residential areas.

Commercial land use was represented in the watershed by office parks and shopping centers with flat roofs draining mostly to impervious areas. Lawns and evergreen shrubs in excellent condition were found near the roads. The paved parking lots represented the largest connected impervious source areas. The runoff from the roofs drains directly to parking areas and then to the drainage systems that were mostly curbs and gutters in good condition. The streets, driveways and parking area were paved with asphalt having intermediate or smooth texture.

Schools and churches represented the institutional land use category of the watershed. The school roofs were flat and drained slightly more to impervious surfaces than to pervious areas. However, school playgrounds were mostly unpaved. Churches had pitched roofs that drained to impervious areas. Landscape areas had an even distribution of deciduous and evergreen shrubs. Lawns were near the streets. Streets and parking lots were paved with asphalt and had intermediate textures. The drainage systems had both grass swales and curbs and gutters, all in fair condition.

The industrial land uses included a lumber manufacturing facility, several equipment storage and office complexes, a public mini-storage facility, a construction supply center, door manufacturer, and an automobile junkyard. The facilities were similar with all buildings being directly connected to the stormwater collection system. All facilities were closely bounded by other developments, roads, steep banks, and for one site, by Little Shade Creek. The industrial sites were relatively small, covering no more than a few acres and they were all dominated by parking and storage areas, and roofs.

The open space land use included parks, cemeteries, a golf course, vacant land, and areas under construction. The few roofs that were found in the vacant land use and golf course areas drained to pervious areas. The parking lots were paved and directly connected to the drainage system. The stormwater drainage system was a combination of curbs and gutters and grass swales.

The drainage system in the freeway land use was comprised of grass swales in the medians and at the shoulders. The pavement was asphalt, with a smooth texture.

Jefferson County Stormwater Permit Monitoring Sites Land Use Description

The sites that will be used to re-validate the WinSLAMM model are in Jefferson County, AL, and are being monitored for the counties MS4 (municipal separate storm sewer system) stormwater permit program. This data is incorporated in the National Stormwater Quality Database (NSQD) database (Pitt, *et al.* 2004 and Maestre and Pitt 2005). About 10 events have been sampled at each of these areas by the Storm Water Management Authority of Jefferson County since 2001. Manual sampling was used, with composite samples collected during the first three hours of the rains. Each of the six sampling sites is described in the following paragraphs and in Table 3.

ALJC001 (Light Industrial) - Drainage area is 341 acres. The sampling location is in a drainage ditch running parallel to the railroad tracks near the 10th Avenue viaduct and 35th Street, Birmingham, AL. The drainage ditch is a western tributary of the Cotton Mill Branch Creek within the Village Creek watershed. This area drains approximately 62% industrial property, 12% commercial land use (shopping centers), a small percentage of high density residential (8.5%) and open space (6.4%). About 11% of this watershed is represented by freeways.

ALJC002 (Heavy Industrial) - Drainage area is 721 acres. The sampling location is in a creek that discharges into Village Creek off Third Street West in the vicinity of the East Thomas Railroad yards located along Finley Boulevard, Birmingham, AL. Approximately 75% of the drainage area is industrial land uses, while 14.5% is high density residential, and a small percentage (2.5%) is represented by commercial land use and open space (6.7%).

ALJC004 (Downtown Commercial) - Drainage area is 1,048 acres. These sampling locations are at two culvert outfalls on 5th Avenue N and 7th Street in the downtown Birmingham area. Outfall 004N drains an old commercial area and a dense portion of downtown office buildings in the City of Birmingham, along with residential and institutional areas. The flows from the south and north culverts are being sampled and analyzed separately. The aerial photograph surface area measurements for this large area are not completed yet and are therefore not represented on Table 3.

ALJC009 (High Density Residential) - Drainage area is 102 acres. The sampling location is at a 60 inch pipe downstream from a paved channel along Woodland Drive in the Edgewood community of Homewood, AL. The majority of the drainage area is comprised of residential lots 1/4 of an acre, or less in size. A small portion of the land use within the basin is institutional (6.7%) and commercial (4.1%) which includes an elementary school, a small church, and a small strip commercial area consisting of small shops, restaurants, and a grocery store. This was found to be typical for many dense residential neighborhoods where small isolated institutional and commercial land uses are not large enough to be assigned separate land use categories.

ALJC010 (Low Density Residential) - Drainage area is 133 acres. The sampling location is in a paved channel along Ponderosa Circle in the Tanglewood subdivision of Vestavia Hills, AL. The drainage area is almost entirely residential lots greater than 1/3 of an acre (82.5%), except for a small portion of undeveloped land (17.5%) on a steep slope that is wooded with heavy cover. This sampling point is on a designated blue line on the USGS quad map; however, this was not a perennially flowing stream.

ALJC012 (Commercial Mall) - Drainage area is 228 acres. The sampling location is at a large culvert running under Highway 31 just south of where Highway 31 intersects Highway 150, in Hoover, AL. A majority of the drainage basin is composed of strip commercial shopping centers and a fragment of the Riverchase Galleria shopping mall, except for some apartments which make up 25% of the drainage area along with some undeveloped woodland which is 5% of the drainage area.

Data Processing

Aerial photograph measurements

The second step in this study was the aerial photograph data processing, using GIS Tools and statistical tools (Excel, MINITAB, and SigmaPlot). After the field data description sheets were filled out during each neighborhood survey, the corresponding aerial photographs from TerraServer USA and satellite images provided by Storm Water Management Authority in Birmingham were examined, and the individual elements (roofs, parking areas, street areas, sidewalks, landscaping, etc) were measured using GIS Tools (ArcGIS 9.0). The aerial photograph area

Table 3: Jefferson County Alabama, MS4 watersheds: Average Source Areas by Land Use

ALJC001 Watershed

LAND USE ALJC001	Curb Miles/ 100 ac	Street (%)	Street Unpaved (%)	Parking paved (%)	Parking Unpaved (%)	Storage paved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Un- developed (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)
COMMERCIAL	6.76	22.59	0.0	37.08	0.97	1.30	3.58	2.92	0.0	16.10	15.45	0.0
R. HIGH DENS.	7.78	21.11	0.0	0.0	0.0	0.0	25.76	29.92	0.0	0.0	0.0	23.23
INDUSTRIAL	7.00	24.31	1.61	44.60	3.97	0.0	0.0	0.0	0.0	5.32	18.87	1.33
UNDEVELOPED	2.37	7.16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.84	0.0	0.0
OPEN SPACE	10.93	21.26	0.0	0.0	0.0	0.0	0.0	0.0	78.74	0.0	0.0	0.0
FREEWAY	0.0	54.71	0.0	0.0	0.0	0.0	0.0	0.0	45.3	0.0	0.0	0.0

ALJC 002 Watershed

LAND USE ALJC002	Curb Miles /100 ac	Street Gutter (%)	Curb Miles /100 ac	Street Grass Swales (%)	Street Unpaved (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Parking Paved Connected (%)	Parking Unpaved (%)	Storage paved (%)	Storage unpaved (%)
INDUSTRIAL	3.78	11.77	1.12	1.82	3.21	0.0	0.0	22.28	15.60	8.04	4.93
COMMERCIAL	11.86	25.35	0.0	0.0	0.0	0.0	0.0	46.94	0.0	1.61	0.0
R. HIGH DENS.	11.72	23.84	0.0	0.0	0.0	1.81	1.81	0.23	0.0	0.0	0.0
INSTITUTIONAL	9.55	29.79	0.0	0.0	0.0	0.0	0.0	18.80	0.0	0.0	0.0
OPEN	0.0	0.0	7.62	17.69	0.0	0.0	0.0	0.0	0.0	0.0	0.0

LAND USE ALJC002	Playground unpaved (%)	Front Landscape (%)	Back Landscape (%)	Large Turf (%)	Un- developed (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Tracks (%)	Pond (%)	Other Pervious (%)	TOTAL (%)
INDUSTRIAL	0.0	0.0	0.0	3.59	4.61	14.97	3.62	3.80	0.47	1.30	100
COMMERCIAL	0.0	0.0	0.0	1.66	8.22	16.22	0.00	0.0	0.0	0.0	100
R. HIGH DENS.	0.21	16.74	29.03	5.86	6.81	3.81	9.87	0.0	0.0	0.0	100
INSTITUTIONAL	18.09	20.56	0.0	3.48	0.0	9.28	0.0	0.0	0.0	0.0	100
OPEN	0.0	0.0	0.0	30.42	0.0	0.0	0.0	0.0	0.0	51.9	100

ALJC009 Watershed

LAND USE ALJC009	Curb Miles/ 100 ac	Street (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Parking Paved (%)	Play-ground Paved (%)	Play-ground Unpaved (%)	Front Landscape (%)	Back Landscape (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)
COMMERCIAL	7.70	30.55	0.0	0.0	38.2	0.0	0.0	0.0	0.0	31.24	0.0
R. HIGH DENS.	10.46	19.91	1.55	1.55	0.0	0.0	0.0	25.49	33.60	6.89	11.02
INSTITUTIONAL	7.99	14.33	7.05	7.05	16.53	12.45	8.26	3.02	8.07	23.32	0.0

ALJC010 Watershed

LAND USE ALJC010	Curb Miles/ 100 ac	Street Gutter (%)	Curb Miles /100 ac	Street Grass Swales (%)	Driveways Paved Connected (%)	Driveways Paved Disconnected (%)	Front Landscape (%)	Back Landscape (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Other Pervious (%)	TOTAL (%)
RESID. MEDIUM DENS.	8.50	19.93	2.55	3.27	2.58	2.58	32.38	24.47	7.84	6.96	0.0	100
UNDEV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	100

ALJC012 Watershed

LAND USE ALJC012	Curb Miles/ 100 ac	Street Gutter (%)	Parking paved (%)	Storage paved (%)	Large Turf (%)	Undeveloped (%)	Roof drained to Impervious (%)	Roof drained to Pervious (%)	Other Pervious (%)	TOTAL (%)
APARTMENTS	5.27	11.92	14.75	0.0	0.0	0.0	13.57	0.0	59.75	100
COMMERCIAL	4.70	16.32	35.93	5.67	28.11	0.0	13.96	0.0	0.0	100

measurements were tabulated and summarized in Excel spreadsheets. These data were used to build the WinSLAMM files to describe each land use area.

The aerial photograph measurements for Little Shades Creek Watershed were provided by the early study mentioned before. This information was manually measured from the aerial photographs and recorded on “Aerial Photograph Area Measurements” data sheets, one sheet for each site surveyed. An example of this measurement sheet is showed in Figure 7.

The first step in the study of the Jefferson County monitoring watersheds was to procure the satellite imagery taken during 2001 and 2003, plus the watersheds paper maps from SWMA. All images were originally purchased from Space Imaging and acquired by IKONOS Satellite imagery which is a high-resolution satellite operated by Space Imaging LLC. IKONOS produces 1-meter black-and-white (panchromatic) and 4-meter multi-spectral (red, blue, green, near infrared) imagery that can be combined in a variety of ways to accommodate a wide range of high-resolution imagery applications. The satellite was launched on September 24, 1999 and has been delivering commercial data since early 2000. It was the first commercial satellite to deliver photographic high resolution satellite imagery of anywhere in the world. Its applications include both urban and rural mapping of natural resources and of natural disasters, tax mapping, agriculture and forestry analysis, mining, engineering, construction, and change detection. Space Imaging’s IKONOS earth imaging satellite has provided a reliable stream of image data that has become the standard for commercial high-resolution satellite data products.

The second step was the electronic delineation of the six watersheds using the map digitizing technique and GIS tools. The multi-spectral image (“Jefferson.sid”; raster format “MrSID,” number of raster bands: 3) of Jefferson County and the paper maps of the watersheds were used to manually digitized and then cut each one of the six watersheds using ArcGIS 9 (ArcMap). Each watershed was saved separately as a shape file (.SHP) giving the matching name (ALJC001, ALJC002, etc).

The multi-spectral Jefferson.sid image was originally NAPP (National Aerial Photography Program) aerial photos which SWMA further processed. Aerial photography of Jefferson County was obtained during flights in 1999. Film negatives were purchased by SWMA from the USGS and were scanned and saved into digital format, orthorectified and sid’ed into USGS quad arrangements (one singular layer). They were not scanned by a metric scanner (which would have resulted in sharper and more precise output image; this should be considered for further research in this area).

The National Aerial Photography Program was initiated in 1980 and coordinated by USGS. The purpose was to acquire aerial photography of 48 “conterminous” (contiguous) states, every five years. They were acquired at 20,000 feet elevation and centered on 1:24,000 scale USGS maps. They are centered on USGS ¼ quads – eight frames make up one USGS quadrangle map. Each frame represents 32.3 sq.mi. at 2-FT pixel. Final output should be digital ortho quarter quads (DOQQ) and revised approximately every five years. For more information about NAPP see: <http://edcwww.cr.usgs.gov/glis/hyper/guide/napp>

The next step used the two 1-M panchromatic satellite images (“Leafoff.img” flown December 2000 and “Leaffon.img”, flown summer 2001; raster format “ERDAS IMAGE”, number of raster bands: 1) of Jefferson County to overlap and after that cut the corresponding satellite image for each watershed. These images were purchased by SWMA from Space Imaging and have been assembled into mosaics into PLSS-Township arrangement. It is complete for the entire county area, but with cloud obstructions in some areas. The overlapping/cutting process made use of GIS Tools: ArcInfo, ArcToolbox and ArcMap 8.9. Each image was saved separately (.IMG extension) having the equivalent name of the watershed.

The satellite image measurement process was initially used to describe the different land uses within the watersheds. For residential land uses, the most visible neighborhoods (having minimal tree cover) were selected and their individual elements were electronically measured. However, for industrial, commercial, and institutional areas, it was necessary to take account of all the elements incorporated into the land use due to greater variabilities of the

Little Shades Creek Stormwater Study - Site Characteristics

Site #: 66 Land use: Single-Family Zoning: R-1 Govt: West.

Description: High density buildings

Location: Chestnut Road

Total area: 11.6 ha.

Total number of units in area: 31 Density: 2.67 /ha

Streets: Total street length: 992.2 m Street length density: 85.53 m/ha

Average street width: 6.05 m Street area: 6002.8 m²

Street area density: 517.48 m²/ha

Grass area between sidewalk and street: width: _____ m length: _____ m

area: _____ m² density: X m²/ha

Sidewalk: width: _____ m length: _____ m area: _____ m² density: X m²/ha

Front landscaping: average per unit 2350 m² x 31 # units = 72838 m²

density: 6279 m²/ha

Driveways: avg. per unit 78.65 m² x 31 # units = 2438.15 m² density: 210.19 m²/ha

100 % paved; 210.19 m²/ha

0 % unpaved; 0 m²/ha

Parking areas: _____ m² density: X m²/ha

_____ % paved; ✓ m²/ha

_____ % unpaved; ✓ m²/ha

Storage areas: _____ m² density: ✓ m²/ha

_____ % paved; ✓ m²/ha

_____ % unpaved; X m²/ha

Playgrounds: _____ m² density: X m²/ha

_____ % paved; ✓ m²/ha

_____ % unpaved; ✓ m²/ha

Figure 7. Site 66 Example of "Aerial Photograph Area Measurements" Sheet

different surface cover areas. The areas of the individual elements were calculated using ArcGIS and stored in the shape file attribute table.

Data Measurements Storage and Processing

The older Little Shades Creek area measurements from aerial photographs were recorded on paper sheets and then manually transferred into electronic format (Excel Worksheet). For comparison purposes, it was assumed that each neighborhood represents 100% of all areas. Normalizing of the actual area measurements was used to account for minor rounding errors. The normalized data (percentages) were then used to build the WinSLAMM files.

The individual elements of the six Jefferson County watersheds were measured in square feet units and recorded directly in an electronic format (.dBASE IV). For easier handling of the data, these files were later converted into Excel Worksheet files. Data normalizing was also performed to account for rounding errors.

Discussion

Urban pollutant loads in aquatic systems are directly related to watershed imperviousness. It is generally found that stream degradation occurs at low levels of imperviousness (about 10 to 15%), where sensitive stream elements are lost from the system. There is a second threshold at around 25 to 30% impervious cover, where most indicators of stream quality change to a poor condition (Schueler 1994).

This data shows that the Little Shades Creek watershed in Birmingham, Alabama, has a watershed impervious cover of about 35%, of which about 25% is directly connected to the drainage system and 10% drains to pervious areas (Table 4). As expected, the land use with the least impervious cover is open space (parks, cemeteries, golf course), and the land uses with the largest impervious covers are commercial areas, followed by industrial areas (Figures 8 and 9).

WinSLAMM will be used to investigate the relationship between watershed and runoff characteristics for each of the individual 125 neighborhoods investigated. A preliminary evaluation is shown on Figures 10 and 11 which illustrate the relationships between the directly connected impervious area percentages and the calculated volumetric runoff coefficients (Rv) for each land use category (using the average land use characteristics), based on 43 years of local rain data. As expected, there is a strong relationship between these parameters for both sandy and clayey soil conditions. The fitted exponential equations are:

$$\text{Sandy soils: } y = 0.062e^{0.031x} \quad (R^2 = 0.83)$$

$$\text{Clayey soils: } y = 0.15e^{0.017x} \quad (R^2 = 0.72)$$

Where y is the volumetric runoff coefficients (Rv) and x is the directly connected impervious areas (%) for the areas. It is interesting to note that the Rv is relatively constant until the 10 to 15% directly connected impervious cover values are reached (at Rv values of about 0.07 for sandy soil areas and 0.16 for clayey soil areas), the point where receiving water degradation typically is observed to start. The 25 to 30% directly connected impervious levels (where significant degradation is observed), is associated with Rv values of about 0.14 for sandy soil areas and 0.25 for clayey soil areas, and is where the curves start to greatly increase in slope.

The Storm Water Management Authority of Jefferson County is currently conducting biological and habitat surveys in Little Shades Creek in this study area at five locations. These mid summer and early spring surveys will be used to verify the assumed relationship between impervious areas and biological conditions for this watershed. WinSLAMM is also being modified to track the amounts of directly connected and partially connected impervious areas in modeled areas, along with predicting equivalent directly connected impervious amounts for different stormwater control scenarios. The model currently calculates outfall flow rates at closely spaced intervals for both wet and dry weather conditions. The model is being modified to present this information in flow-duration probability curves to also assist stormwater managers in predicting receiving water responses to alternative stormwater management programs.

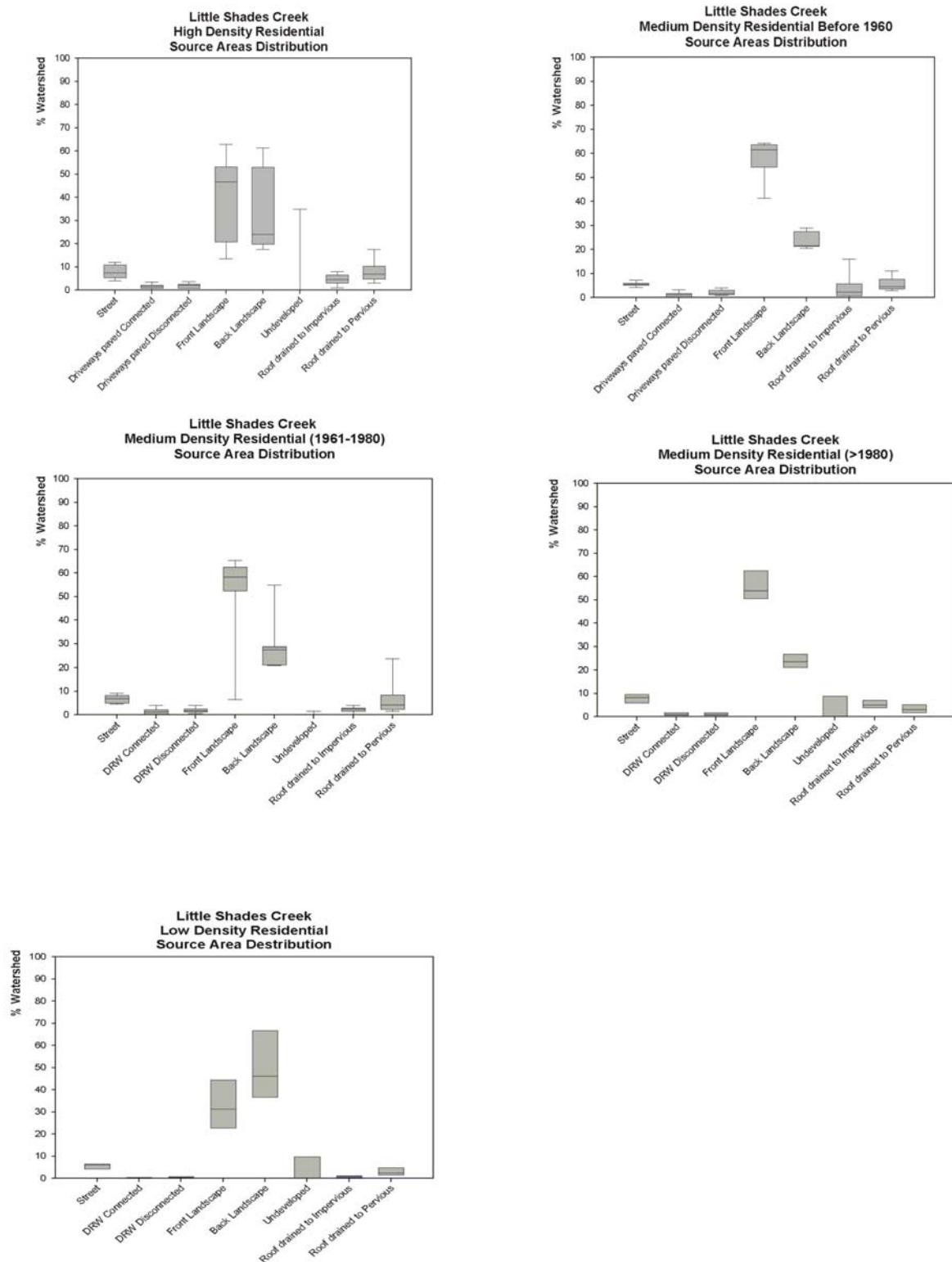


Figure 9: Little Shades Creek Watershed: Source Area Distribution using Box Plots

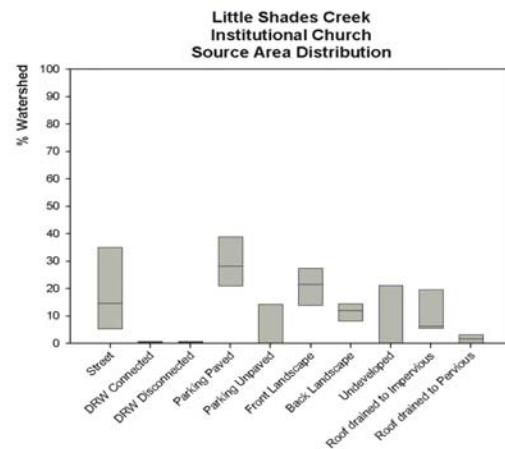
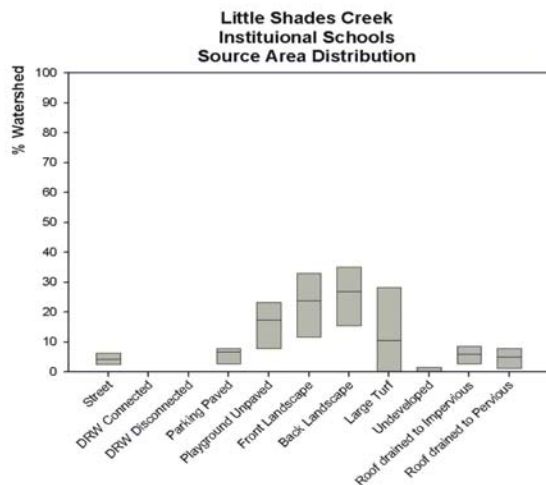
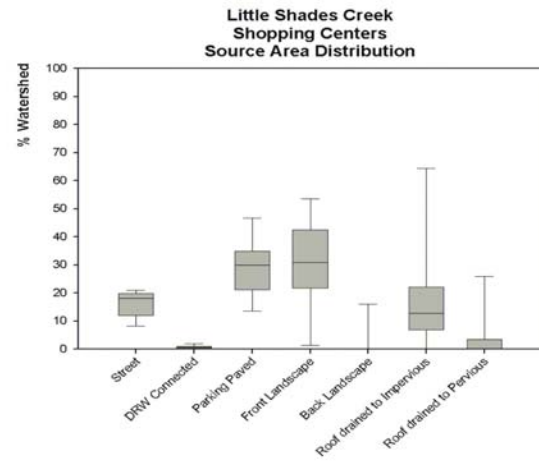
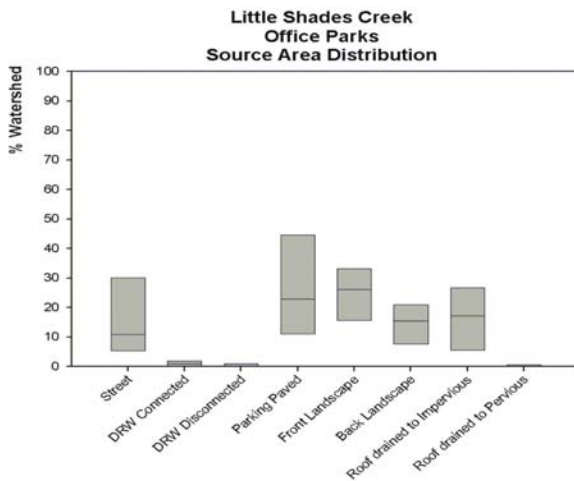
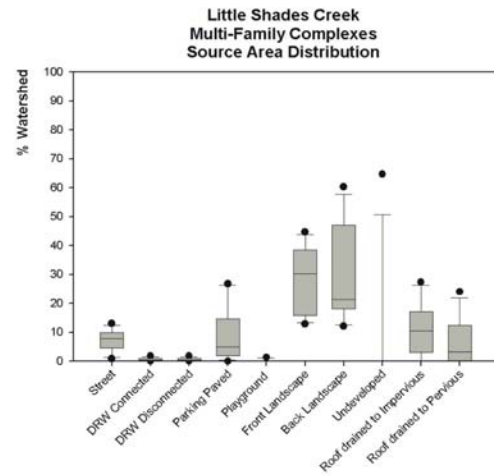
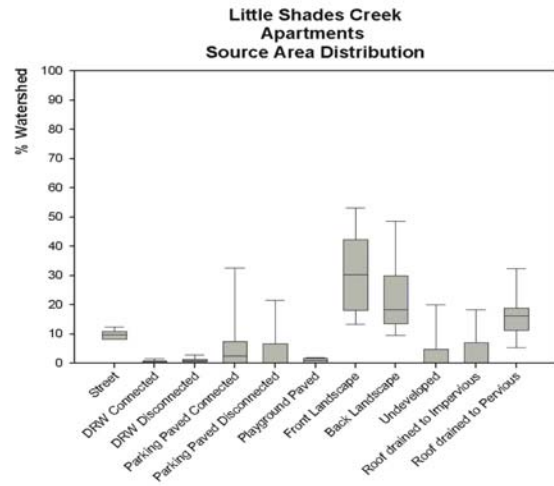


Figure 9: Little Shades Creek Watershed: Source Area Distribution using Box Plots (continued)

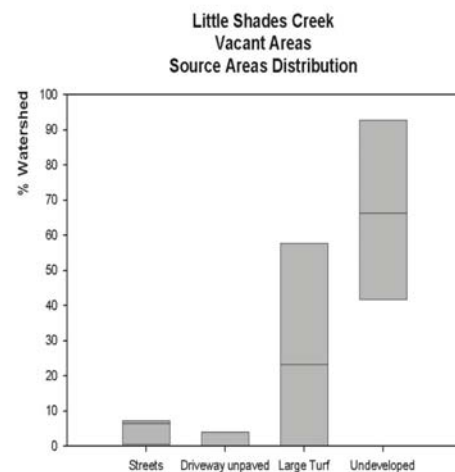
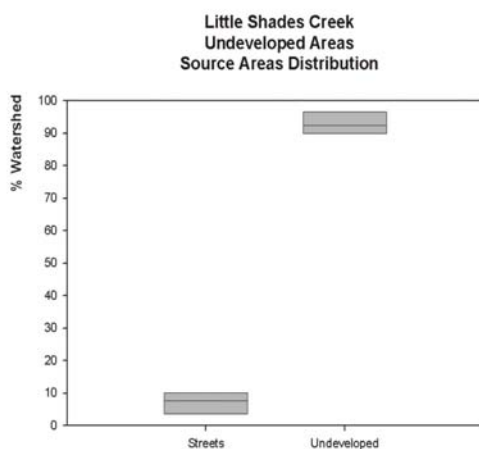
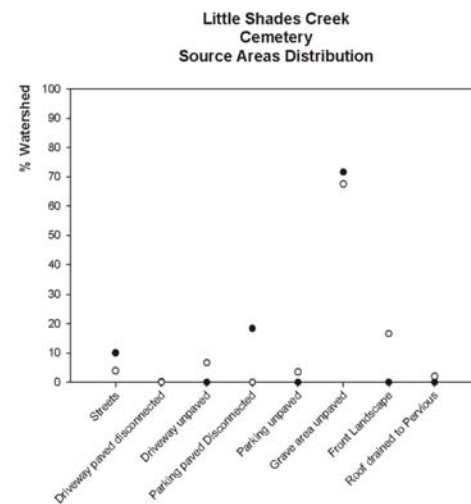
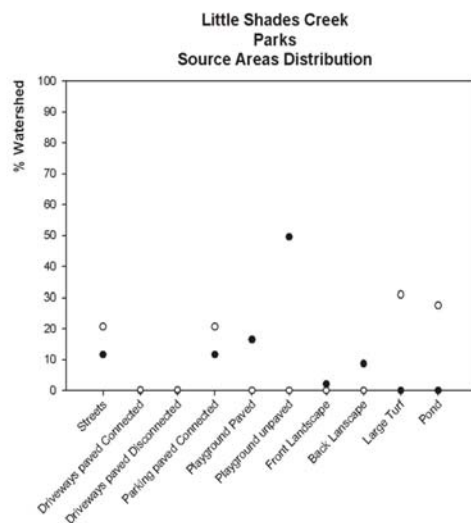
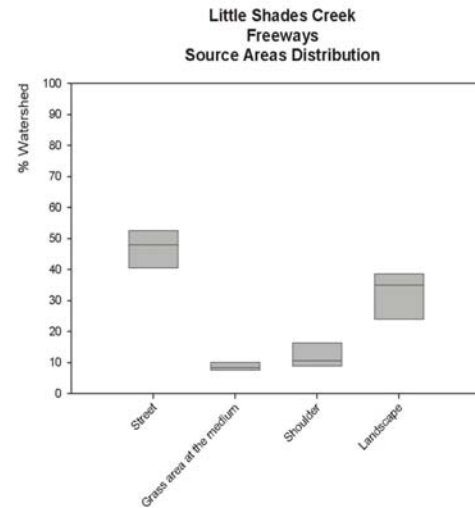
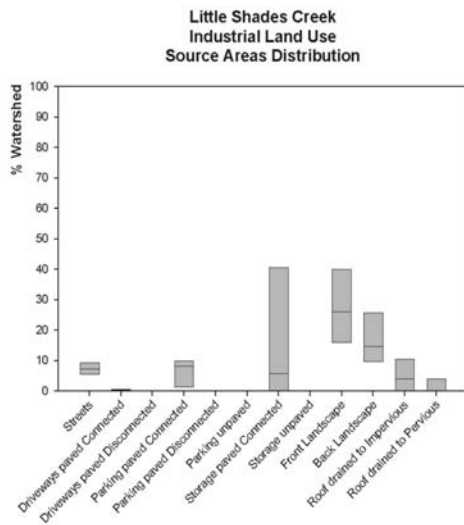


Figure 9: Little Shades Creek Watershed: Source Area Distribution using Box Plots (continued)

Table 4. Little Shade Creek, Birmingham, AL: Average of Source Area Drainage Connections by Land Use

Land Use	Pervious Areas (%)	Directly Connected Impervious Areas (%)	Disconnected Impervious Areas (%) (draining to pervious areas)	Volumetric Runoff Coefficient (Rv) if Sandy Soils	Volumetric Runoff Coefficient (Rv) if Clayey Soils
High Dens. Residential	76.07	13.41	10.52	0.09	0.17
Med. Dens. Residential (<1960)	81.74	9.06	9.20	0.06	0.14
Med. Dens. Residential (1961-80)	81.24	8.80	9.96	0.07	0.15
Med. Dens. Residential (>1980)	81.59	14.09	4.31	0.09	0.17
Low Dens. Residential (drained by swales)	89.84	4.92	5.24	0.05	0.17
Apartments	57.79	15.86	26.36	0.09	0.17
Multi Family	65.19	27.38	7.43	0.13	0.14
Offices	38.67	56.77	4.57	0.41	0.43
Shopping Centers	32.53	63.83	3.64	0.43	0.47
Schools	79.12	16.03	4.86	0.12	0.17
Churches	44.24	53.64	2.12	n/a	n/a
Strip Commercial	7.90	87.80	4.30	0.60	0.61
Industrial	53.61	35.79	10.60	0.46	0.49
Parks	59.32	32.32	8.36	0.29	0.34
Cemeteries (drained by swales)	82.90	0.00	17.10	0.08	0.16
Golf Courses (drained by swales)	94.56	1.93	3.51	0.04	0.15
Freeways (drained by swales)	40.91	0.00	59.09	0.08	0.26
Vacant (drained by swales)	95.23	0.00	4.77	0.06	0.17

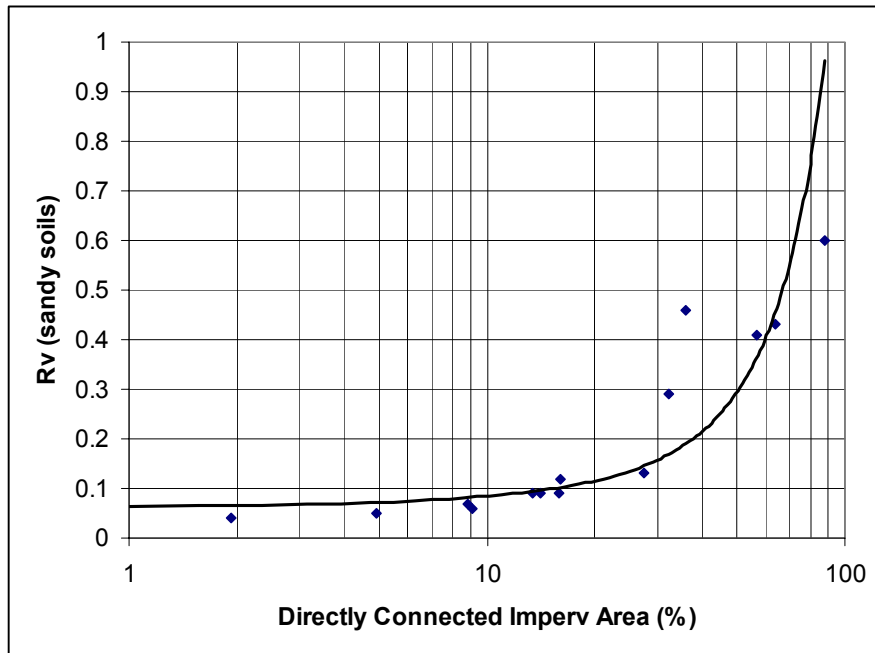


Figure 10. Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (Rv) for each land use category for sandy soil.

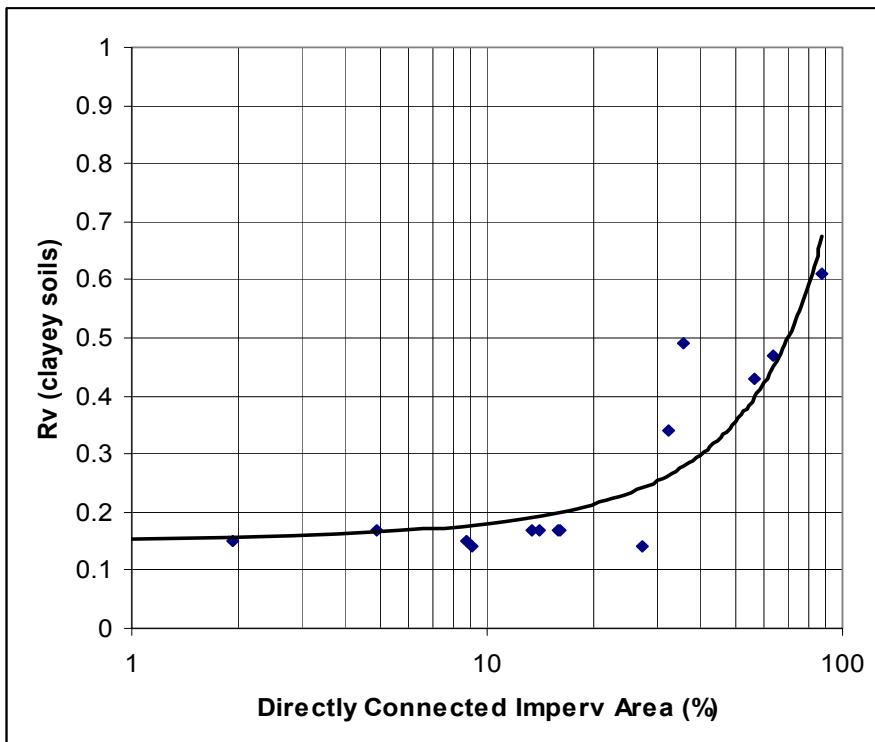


Figure 11. Relationships between the directly connected impervious area (%) and the calculated volumetric runoff coefficients (Rv) for each land use category for clayey soil.

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