Module 3a: Site Development Characteristics and Impervious Cover Variability in Urban Watersheds

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How is stormwater pollution quantified?

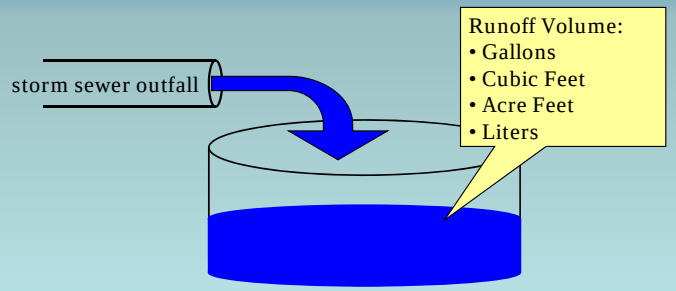
Two components of stormwater pollution measurement:

- **Volume (how much water over a period of time)**
- **Concentration (pollution)**
- **Multiplied together and often reported as a "Pollution Load" over a time period**

How is stormwater pollution quantified?

Two components of stormwater pollution:

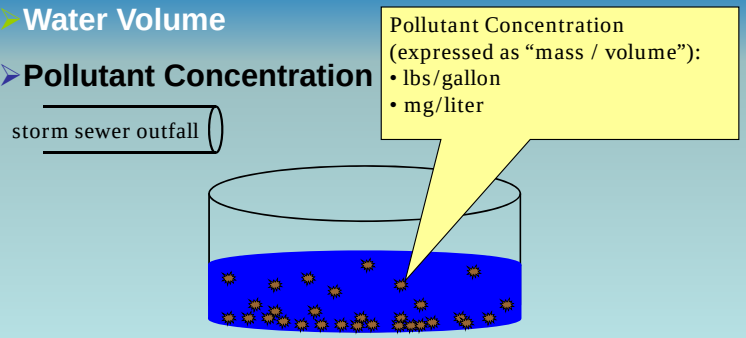
- **Volume (how much water)**



How is stormwater pollution quantified?

Two components of stormwater pollution:

- **Water Volume**
- **Pollutant Concentration**



How is stormwater pollution quantified?

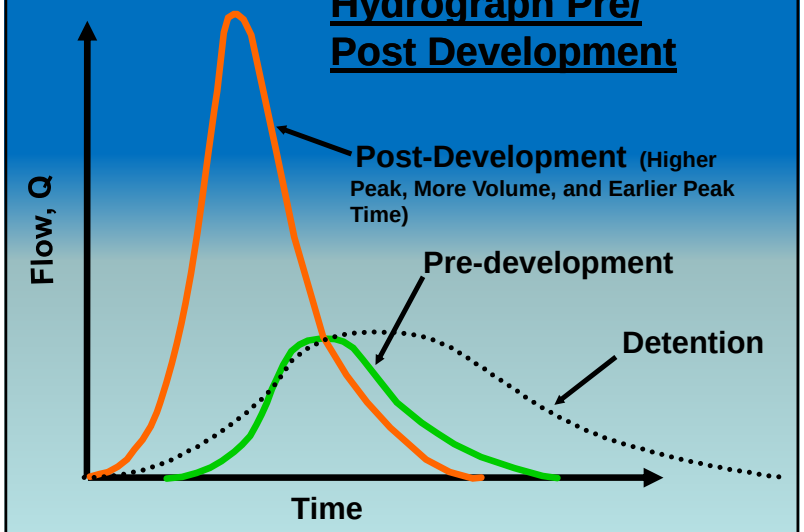
Volume x Concentration = Pollutant Load

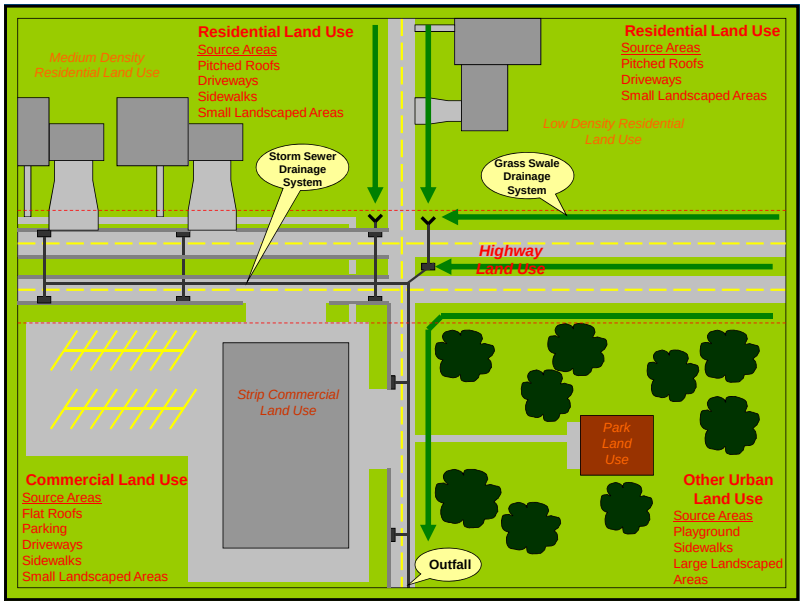
Example Calculation:

1. **Say: runoff volume from a 1" rain = 1,700 ft^3**
2. **Say: average sediment concentration = 50 mg/l**
3. **Then: Event Load = 1,700 ft^3 x 50 mg/l**

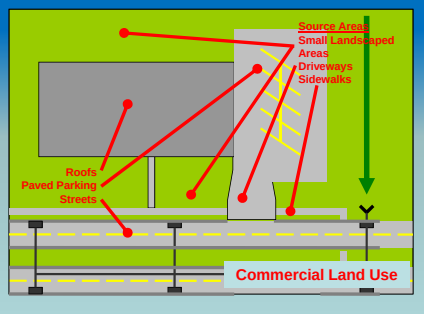
= 2,407 grams or 5.3 lbs. of Sediment

Hydrograph Pre/ Post Development

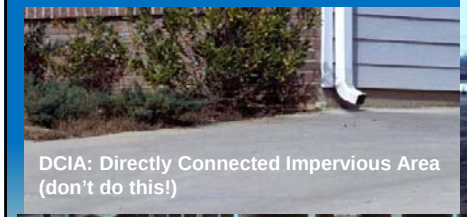




Source Areas within a Commercial Land Use



Roof drain disconnections



DCIA: Directly Connected Impervious Area (don't do this!)

Drains to Pervious Area

Drains to Pervious Area

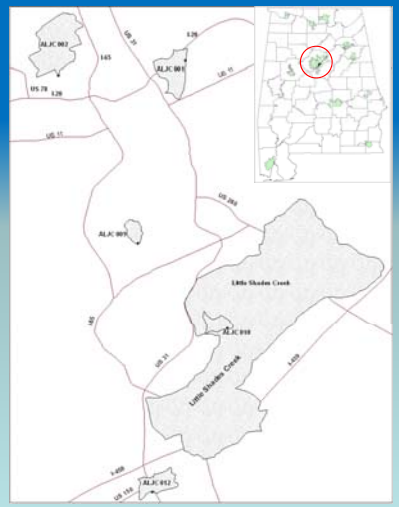
Objectives

- The purpose of this research was to measure the variability associated with land surface covers for different land uses in a large urban area in the state of Alabama and show how this information affects runoff quality and quantity.
- Little Shades Creek watershed and 5 other highly urbanized drainage areas situated in Jefferson County, AL (around Birmingham) were surveyed in detail to determine the actual development characteristics and their variability

Land Use Categories Examined

- Residential
  - High, medium, low density
  - Apartments, Multi- family units
- Commercial
  - Strip commercial, shopping centers
  - Office parks, downtown business district
- Industrial
  - Manufacturing (steel mills, cement plants)
  - Non-manufacturing (warehouses)
  - Medium Industrial (lumber yards, junk and auto salvage yards, storage areas, railroad tracks)
- Institutional
  - Schools and churches
- Open Space
  - Parks, cemeteries, golf courses
  - Vacant spaces, undeveloped areas
- Freeways – drained by swales

Study Area



6 highly urbanized drainage areas

10 major land uses

165 neighborhoods

- Land surface covers were directly measured
- Impervious cover was checked in the field for its connectivity

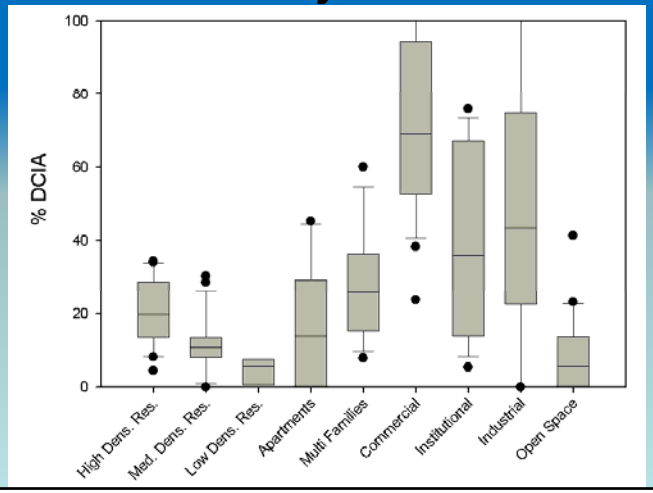
Average Impervious Cover

Land Uses	TIA (total impervious area) (%)	DCIA (directly connected impervious area) (%)	Pervious (%)
High Dens. Residential	30	19	70
Med. Dens. Residential	22	13	78
Low Dens. Residential	18	9	83
Apartments	42	17	58
Multi Family	35	27	65
Commercial	73	72	27
Institutional	46	41	54
Industrial	59	50	41
Open Space	13	9	87
Freeways	58	0	42

Directly Connected Impervious Areas

Land Uses	Range (%)	Average (%)	COV
High Dens. Residential	4 - 34	19	0.48
Med. Dens. Residential	0 - 34	13	0.68
Low Dens. Residential (some drained by swales)	0.3 - 30	***9***	**1.03**
Apartments	0 - 45	17	0.97
Multi Family	8 - 60	27	0.53
Commercial	34 - 100	**72**	***0.29***
Institutional	5 - 76	41	0.61
Industrial	0 - 100	50	0.66
Open Space	0 - 41	***9***	**1.21**

Jefferson Co. Drainage Areas DCIA by Land Use

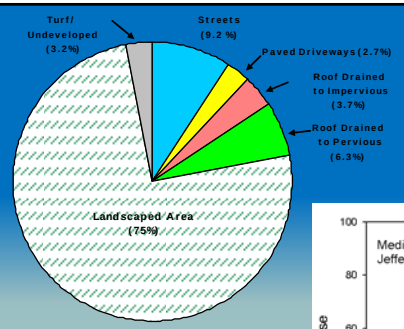


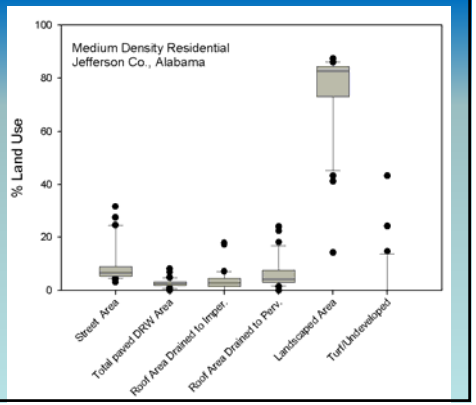
Average Percent Directly Connected Impervious Area

Land Use	Local Conditions	TR – 55 (using interpolation)
HDR (> 6 units/ac)	19	52
MDR (2-6 units/ac)	13	39
LDR (< 2 units/ac)	9	23
APARTMENTS	17	65
COMMERCIAL	72	85
INDUSTRIAL	50	72

- TR- 55 assumes all impervious areas to be directly connected to the drainage system
- Overestimation of impervious cover for local conditions

Medium Density Residential
Variation in Land Cover



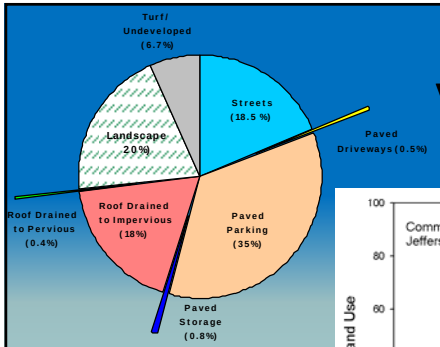


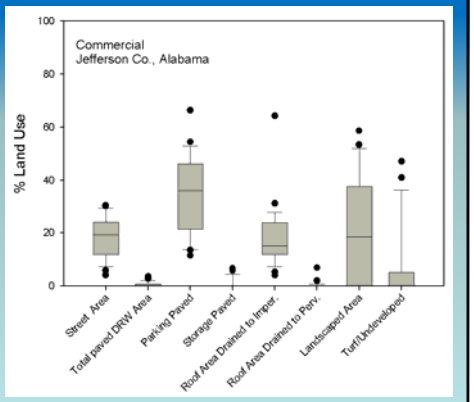
Predominant land cover:
Landscaped Area

The amount of impervious area does not vary too much

A lot of variability in landscaped land cover

Commercial
Variation in Land Cover





Predominant land cover:
- Streets
- Parking lots
- Roof directly connected
- Landscaped

Total amount of impervious area vary substantially

Pearson Correlation Matrix

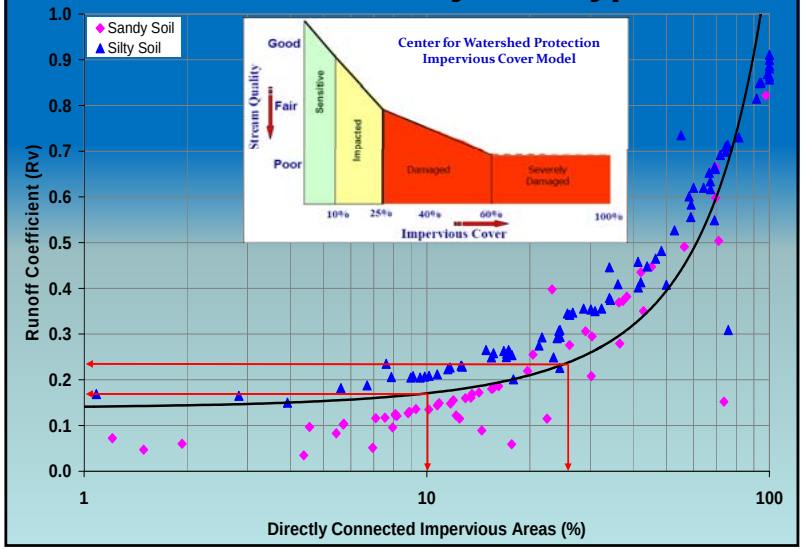
Measures the degree of association between field measurements for those highly urbanized drainage areas.
the stronger the relationship between the two variables

	PER	DCIA	TIA	STR	PRK	ROOF	LAND	RVL
PER	1.000							
DCIA	***-0.871***	1.000						
TIA	***-1.000***	***0.871***	1.000					
STR	***-0.606***	0.382	***0.606***	1.000				
PRK	***-0.824***	***0.828***	***0.824***	0.378	1.000			
ROOF	***-0.637***	***0.711***	***0.637***	0.143	0.495	1.000		
LAND	0.536	-0.566	-0.536	-0.351	-0.541	-0.359	1.000	
RVL	***-0.886***	***0.900***	***0.886***	***0.516***	***0.823***	***0.671***	***-0.604***	1.000

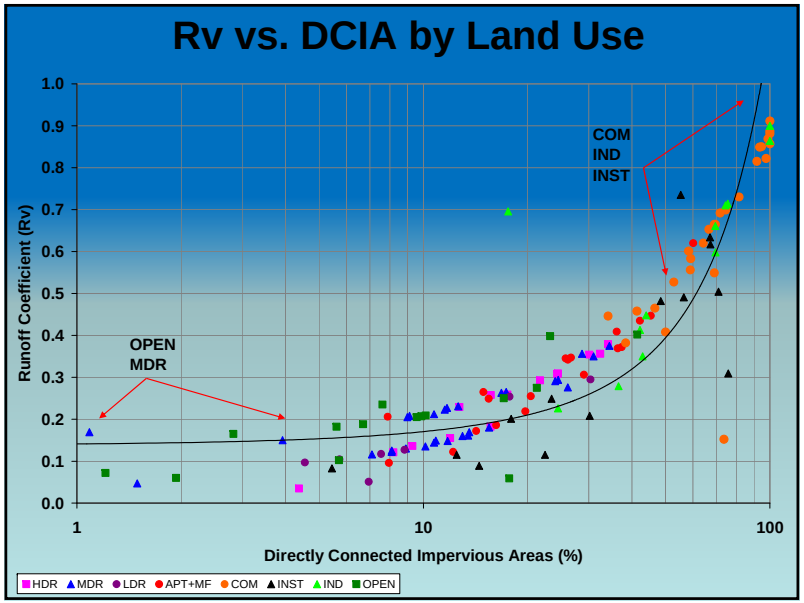
Parking, streets and connected roofs are important components of TIA and DCIA.

Runoff volume can be predicted by using DCIA, TIA, parking areas, and connected roofs.

Rv vs. DCIA by Soil Type



- These graphs 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.
- 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.



Expected Biological Conditions as a Function of Impervious Area

Drainage Area ID	DCIA (%)	Volumetric Runoff Coefficient (Rv)	Biological Conditions
ALJC001	72	0.67	Poor
ALJC002	53	0.51	Poor
ALJC009	34	0.37	Poor
ALJC010	28	0.30	Poor
ALJC011	61	0.61	Poor
Little Shades Creek	21	0.29	Poor

Example of 1 m monochromatic aerial photograph (USGS photo)

Example of high resolution color satellite image (Google)

Example Google aerial photo for Tuscaloosa, AL

Higher resolution Google aerial photo for Hoover, AL

Typical high resolution mixed land use area in Toronto

High density residential area in Toronto

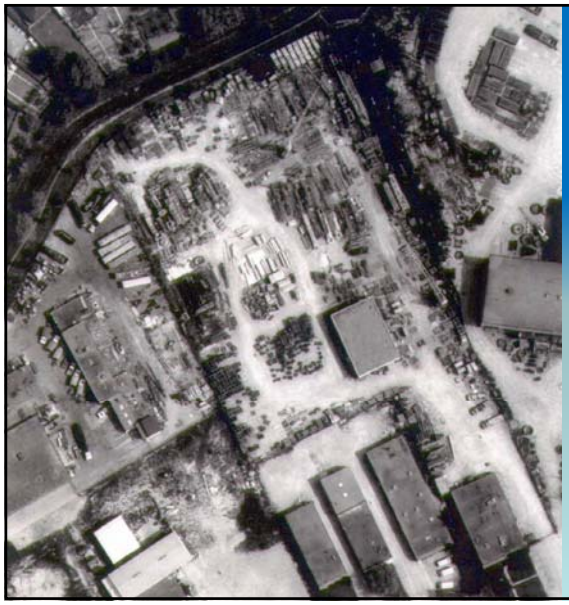
New and older medium density residential area in Toronto

High rise apartments in Toronto

Cemetery in Toronto

Urban highway interchange in Toronto

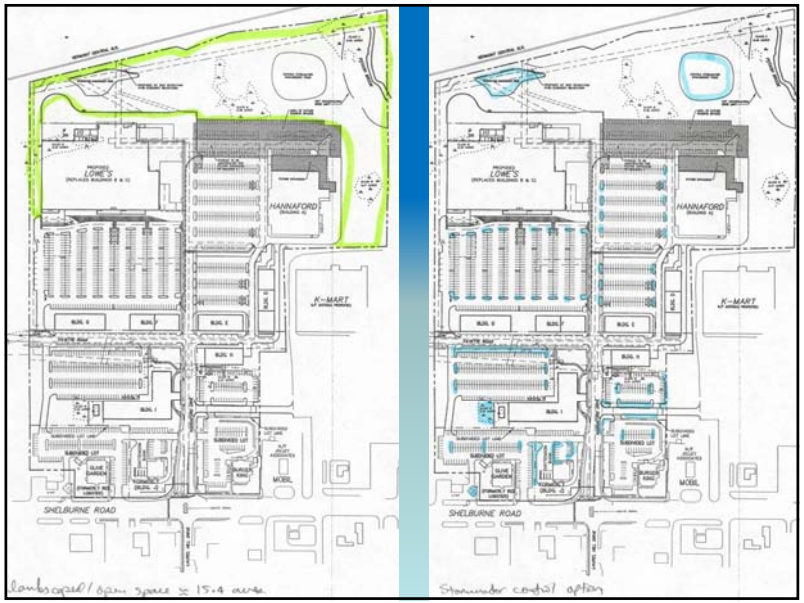
Non-manufacturing industrial area in Toronto



Scrap yard/metal recycling facility in Toronto

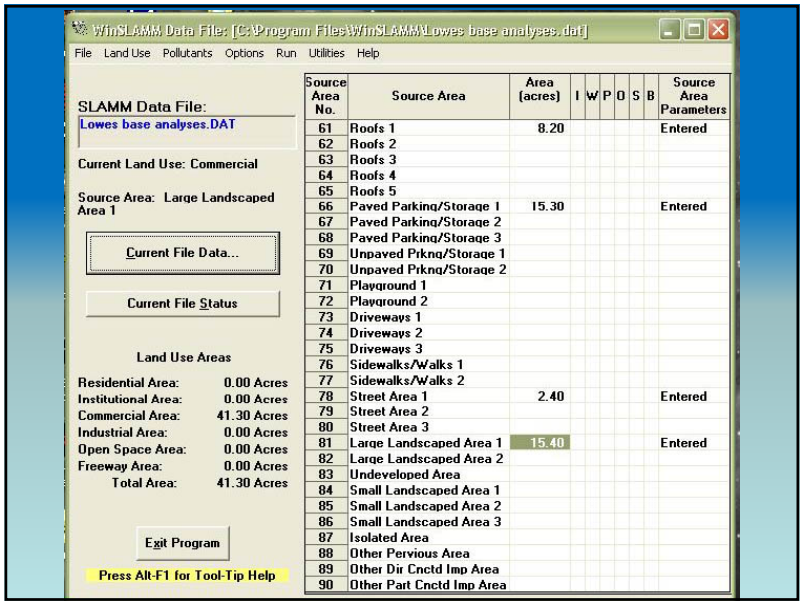
Strip commercial area in Toronto

“Big Box” development source areas

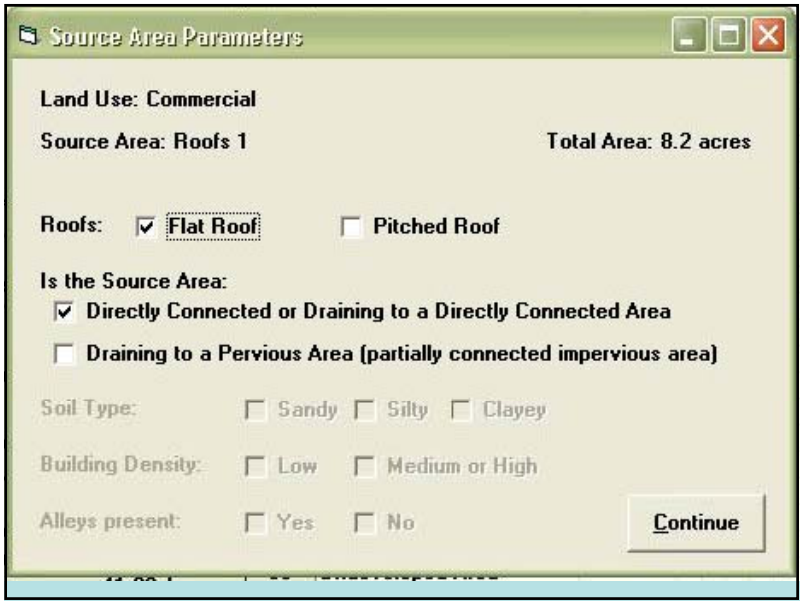


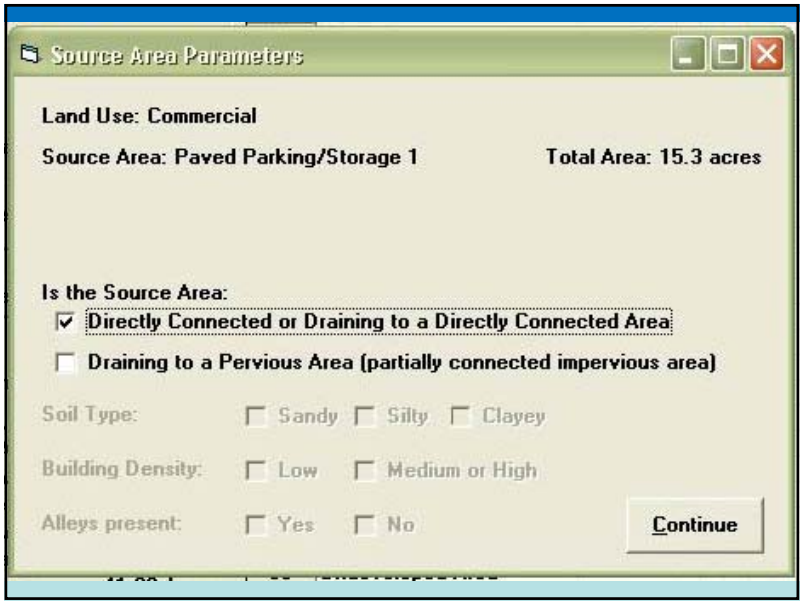
Summary of Measured Areas

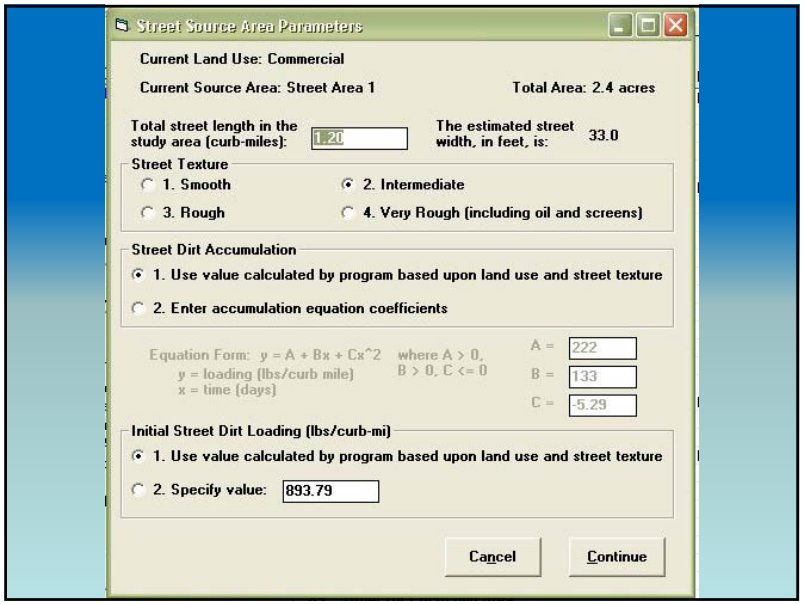
- Totally connected impervious areas: 25.9 acres
  - parking 15.3 acres
  - roofs (flat) 8.2 acres
  - streets (1.2 curb-miles and 33 ft wide) 2.4 acres
- Landscaped/open space 15.4 acres
- Total Area 41.3 acres

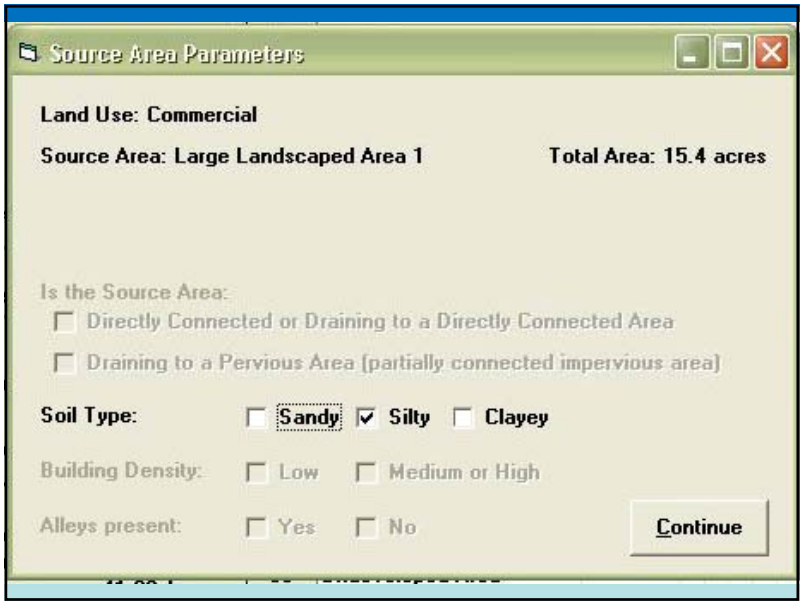


Source Area No.	Source Area	Area (acres)	I	W	P	O	S	B	Source Area Parameters
61	Roofs 1	8.20							Entered
62	Roofs 2								
63	Roofs 3								
64	Roofs 4								
65	Roofs 5								
66	Paved Parking/Storage 1	15.30							Entered
67	Paved Parking/Storage 2								
68	Paved Parking/Storage 3								
69	Unpaved Prkng/Storage 1								
70	Unpaved Prkng/Storage 2								
71	Playground 1								
72	Playground 2								
73	Driveways 1								
74	Driveways 2								
75	Driveways 3								
76	Sidewalks/Walks 1								
77	Sidewalks/Walks 2								
78	Street Area 1	2.40							Entered
79	Street Area 2								
80	Street Area 3								
81	Large Landscaped Area 1	15.40							Entered
82	Large Landscaped Area 2								
83	Undeveloped Area								
84	Small Landscaped Area 1								
85	Small Landscaped Area 2								
86	Small Landscaped Area 3								
87	Isolated Area								
88	Other Pervious Area								
89	Other Dir Cnctd Imp Area								
90	Other Part Cnctd Imp Area								


Source Area Parameters
Land Use: Commercial
Source Area: Roofs 1
Total Area: 8.2 acres
Roofs:
Flat Roof
Pitched Roof
Is the Source Area:
Directly Connected or Draining to a Directly Connected Area
Draining to a Pervious Area (partially connected impervious area)
Soil Type:
Sandy
Silty
Clayey
Building Density:
Low
Medium or High
Alleys present:
Yes
No
Continue


Source Area Parameters
Land Use: Commercial
Source Area: Paved Parking/Storage 1
Total Area: 15.3 acres
Is the Source Area:
Directly Connected or Draining to a Directly Connected Area
Draining to a Pervious Area (partially connected impervious area)
Soil Type:
Sandy
Silty
Clayey
Building Density:
Low
Medium or High
Alleys present:
Yes
No
Continue

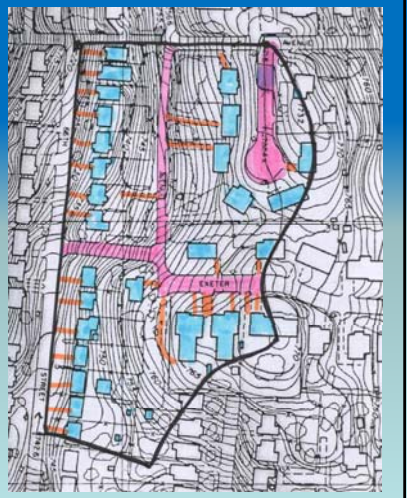

Street Source Area Parameters
Current Land Use: Commercial
Current Source Area: Street Area 1
Total Area: 2.4 acres
Total street length in the study area (curb-miles):
1.20
The estimated street width, in feet, is:
33.0
Street Texture
1. Smooth
2. Intermediate
3. Rough
4. Very Rough (including oil and screens)
Street Dirt Accumulation
1. Use value calculated by program based upon land use and street texture
2. Enter accumulation equation coefficients
Equation Form: y = A + Bx + Cx^2 where A > 0, B > 0, C <= 0
y = loading (lbs/curb mile)
x = time (days)
A = 222
B = 133
C = -5.29
Initial Street Dirt Loading (lbs/curb-mi)
1. Use value calculated by program based upon land use and street texture
2. Specify value:
893.79
Cancel
Continue

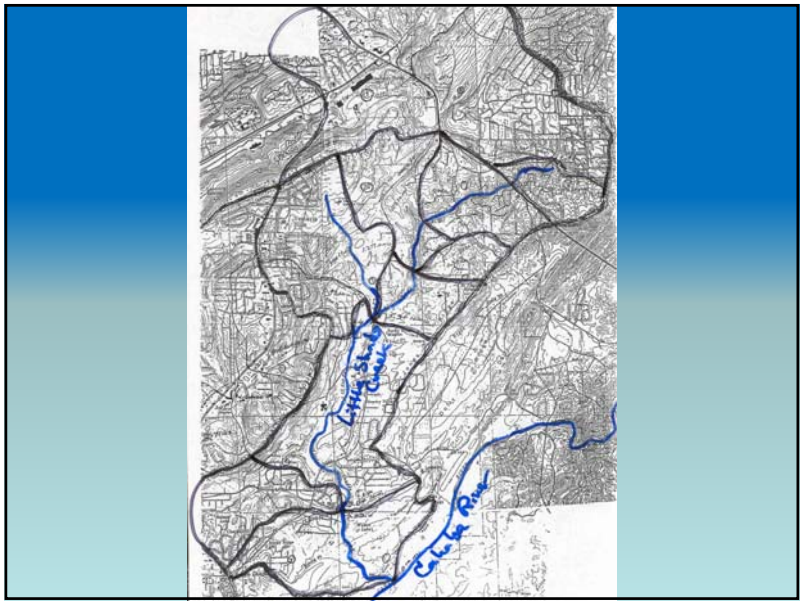

Source Area Parameters
Land Use: Commercial
Source Area: Large Landscaped Area 1
Total Area: 15.4 acres
Is the Source Area:
Directly Connected or Draining to a Directly Connected Area
Draining to a Pervious Area (partially connected impervious area)
Soil Type:
Sandy
Silty
Clayey
Building Density:
Low
Medium or High
Alleys present:
Yes
No
Continue

Residential Area Source Areas

Area (acres)	Large lots	Small lots	Total area
Roofs	0.39	0.52	0.91
Driveways	0.15	0.12	0.27
Sidewalks	0.06	0.04	0.10
Landscaped areas	1.61	1.07	2.68
Subtotals	2.21	1.75	3.96
Streets			0.57
Undeveloped area			1.07

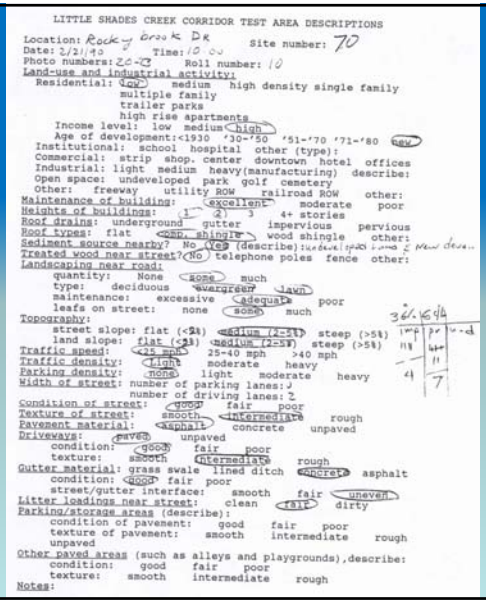
Total area: 5.60 acres





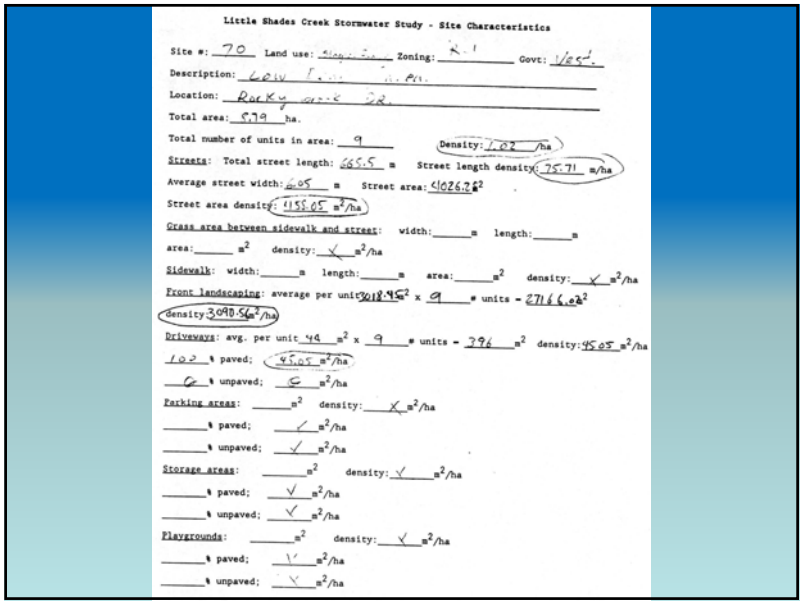
Little Shades Creek Subwatersheds

Area (acres)	1	2	3	4	All others	Total
Single family	339	448	676	401	1747	3611
Town homes	0	20	8	0	94	122
Multi-family	0	47	13	0	27	87
School/ church	0	0	38	13	58	109
Commercial	8	8	17	7	42	82
All other	70	153	199	164	621	1207
Total	417	676	951	585	2589	5218



LITTLE SHADES CREEK CORRIDOR TEST AREA DESCRIPTIONS

Location: Rocky Brook Dr. Site number: 70
Date: 2/21/90 Time: 10:00
Photo numbers: 20-12 Roll number: 10
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: <1930 '30-'50 '51-'70 '71-'80 new
Institutional: school hospital other (type):
Commercial: strip shop. 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 conv. shingle wood shingle other:
Sediment source nearby? No Yes (describe): new dev.
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: <25 mph 25-40 mph >40 mph
Traffic density: light moderate heavy
Parking density: none light moderate heavy
Width of street: number of parking lanes: 2
number of driving lanes: 2
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:



Little Shades Creek Stormwater Study - Site Characteristics

Site #: 70 Land use: [illegible] Zoning: R1 Govt: [illegible]

Description: [illegible]

Location: Rocky [illegible] Dr.

Total area: 5.79 ha.

Total number of units in area: 9 Density: 1.82 /ha

Streets: Total street length: 665.5 m Street length density: 75.71 m/ha

Average street width: 6.05 m Street area: 4026.2 m²

Street area density: 4155.05 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 3018.9 m² x 9 # units = 27166.0 m²

density 3098.5 m²/ha

Driveways: avg. per unit 49 m² x 9 # units = 396 m² density: 45.05 m²/ha

102 % paved; 45.05 m²/ha

6 % unpaved; 6 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; ____ m²/ha

Playgrounds: ____ m² density: X m²/ha

____ % paved; ____ m²/ha

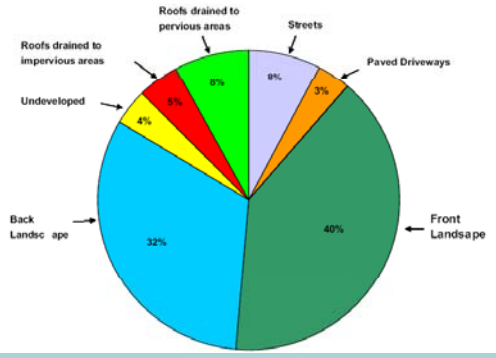
____ % unpaved; ____ m²/ha

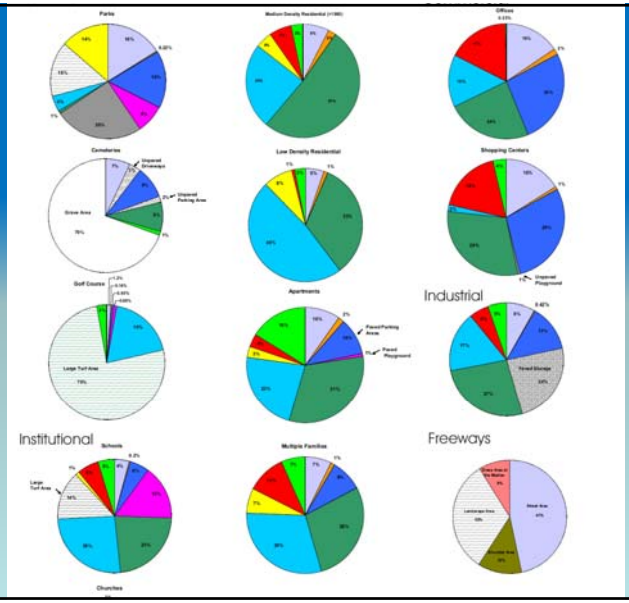
Characteristics of Land Development in Rocky Ridge

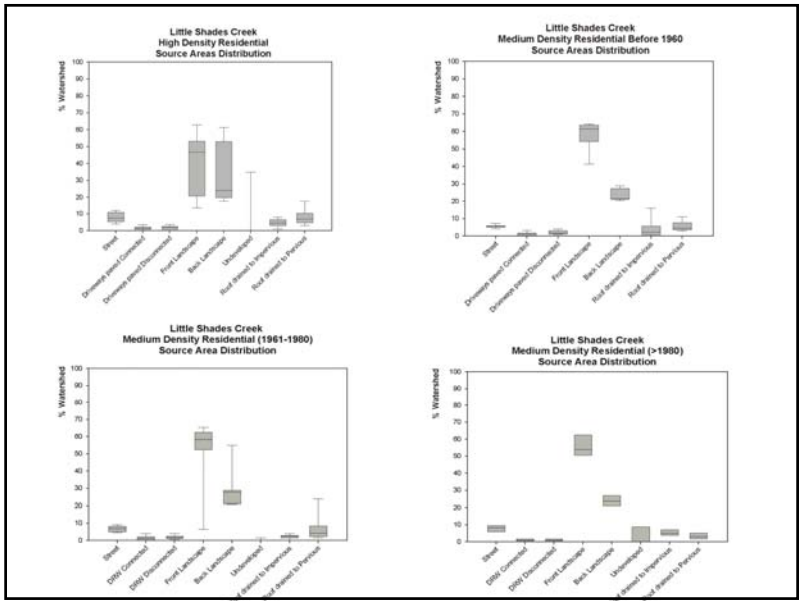
	Low density	Medium density pre 1960	High density	Strip commercial	Office parks
Directly connected imperviousness	6.11	8.98	15	90.6	60.19
Impervious areas draining to pervious areas	4.7	6.2	9	0	1.14
Pervious Areas	89.19	84.82	76	9.4	38.67
Total	100	100	100	100	100

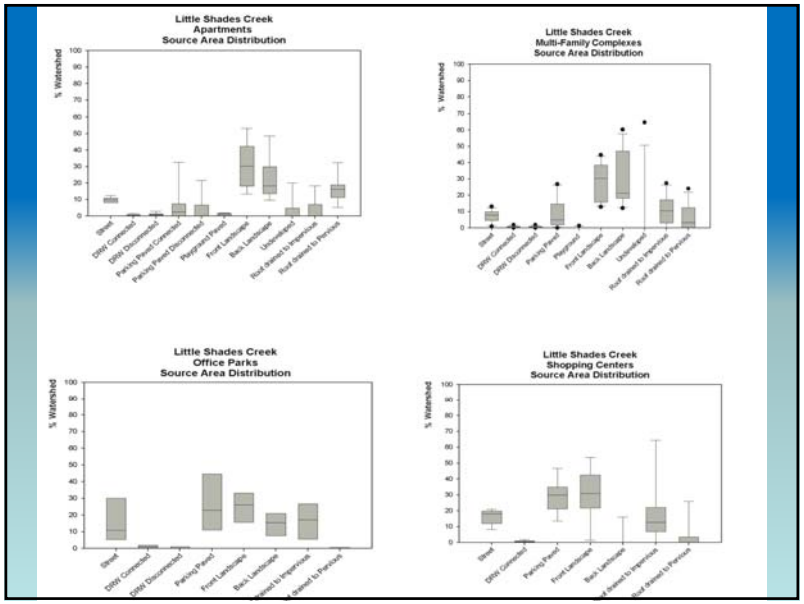
Little Shade Creek Watershed: Source Areas

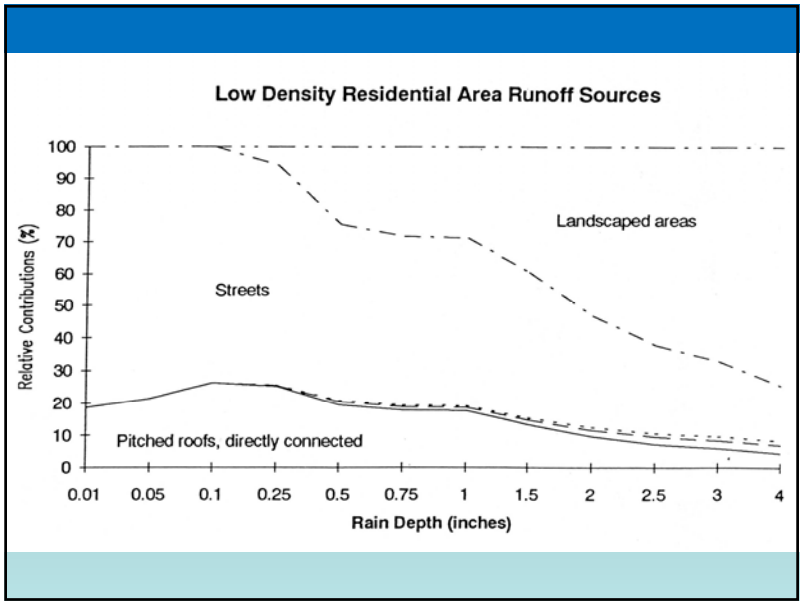
High Density Residential

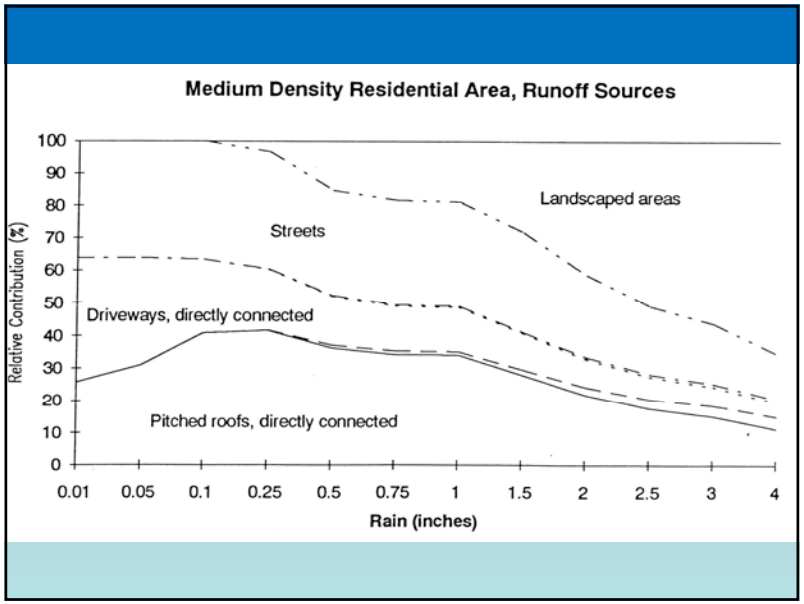


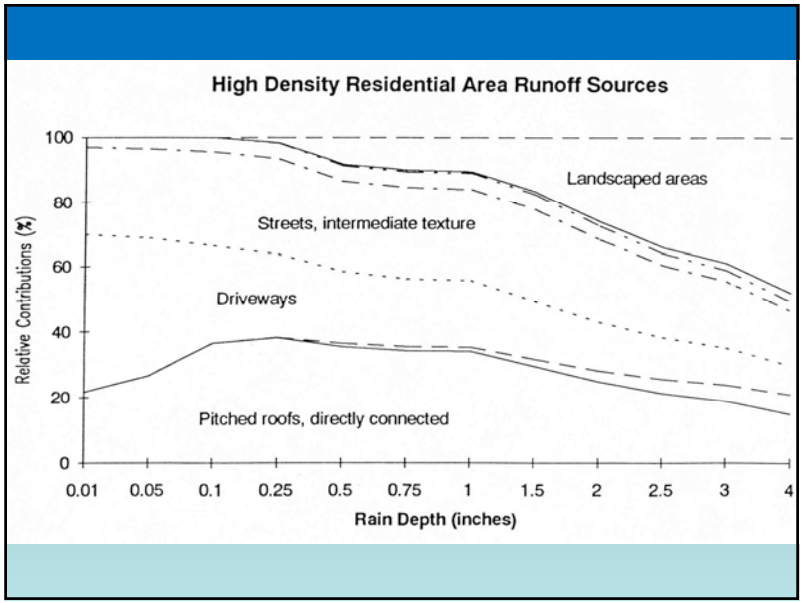


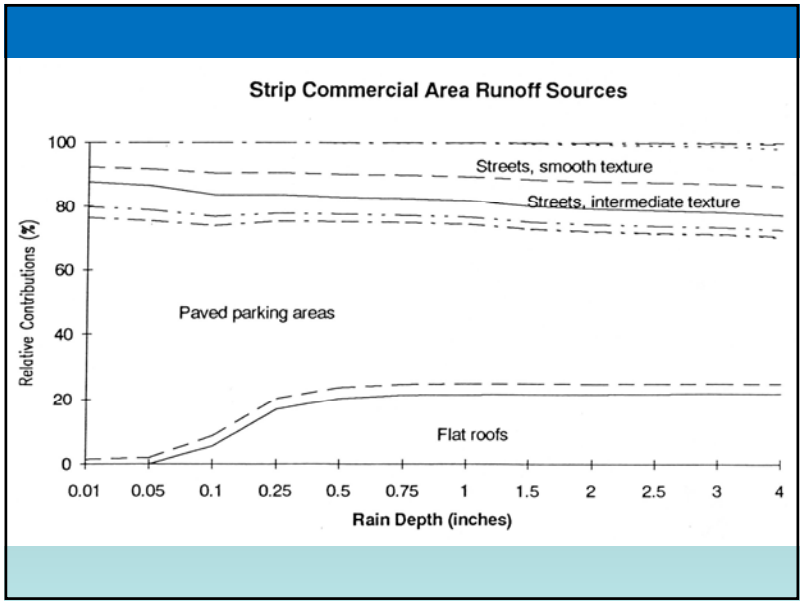

Little Shades Creek
High Density Residential
Source Areas Distribution
Little Shades Creek
Medium Density Residential Before 1960
Source Areas Distribution
Little Shades Creek
Medium Density Residential (1961-1980)
Source Area Distribution
Little Shades Creek
Medium Density Residential (>1980)
Source Area Distribution
% Watershed

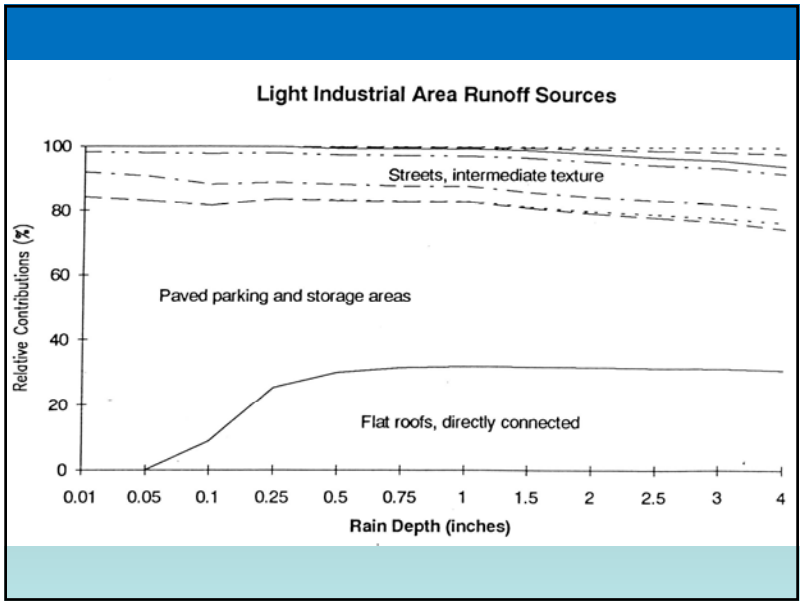

Little Shades Creek
Apartments
Source Area Distribution
Little Shades Creek
Multi-Family Complexes
Source Area Distribution
Little Shades Creek
Office Parks
Source Area Distribution
Little Shades Creek
Shopping Centers
Source Area Distribution
% Watershed


Low Density Residential Area Runoff Sources
Relative Contributions (%)
Landscaped areas
Streets
Pitched roofs, directly connected
0.01 0.05 0.1 0.25 0.5 0.75 1 1.5 2 2.5 3 4
Rain Depth (inches)


Medium Density Residential Area, Runoff Sources
Relative Contribution (%)
Landscaped areas
Streets
Driveways, directly connected
Pitched roofs, directly connected
0.01 0.05 0.1 0.25 0.5 0.75 1 1.5 2 2.5 3 4
Rain (inches)







Conclusions

- Jefferson County watersheds have a wide range of impervious cover (TIA = 0.6-100%) with almost all impervious surfaces directly connected
- Variability within land uses is small compared with the variability between land uses for total amount of impervious cover
- There is a lot of variability in runoff volume which is closely related to variability in development characteristics
- Development characteristics are very different and are influenced by the geographical location, so geographical location is an important factor to consider when developing equation to predict DCIA

Conclusions (Cont.)

- Land use does a pretty good job by separating the main geographical regions, so it is important to know how land use vary
- Modeling showed that stream quality in the receiving waters is in poor condition, confirmed by in-stream investigations by the SWMA biologists
- Literature assumptions on impervious cover are not very accurate when applied to local conditions