Relationships between urban stream characteristics and impervious surface networks

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Abstract

Urban development impacts streams in many ways including degradation of stream ecosystem, water quality, and increases flooding possibilities. Through Furman's River Basins Research Initiative (RBRI) program, previous researchers have studied the relationships between the intensity of urban development in a watershed, measured by percent impervious cover, and the physical characteristics of streams draining these urban areas. This project aims to use GIS to advance this research by studying how the interconnected imperviousness relates to the physical stream characteristics. Within each site's subwatershed the road density, total stream length network, stream order, and the number of upstream road crossings were calculated using ArcMap. This data was used to create a dimensionless ratio of total number of road crossings to stream order (RC/SO) that was then compared with stream characteristics. Results show that RC/SO ratio was strongly correlated with the incision ratio for streams (r=0.677, p=0.022) where as there was no statistically significant correlation between RC/SO ratio and other variables such as bankfull depth and width (r=-0.354, p=0.286 and r=-0.427, p=0.190 respectively). Previous results show the correlation between impervious cover percentage and incision ratio to be weakly correlated (r=0.460, p=0.154). Overall, the new ratio (RC/SO) developed here provides better understanding of the reasons for stream incision than considering just the total imperviousness within a drainage area.

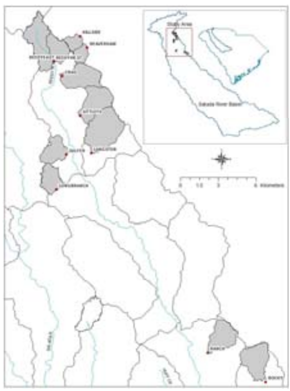
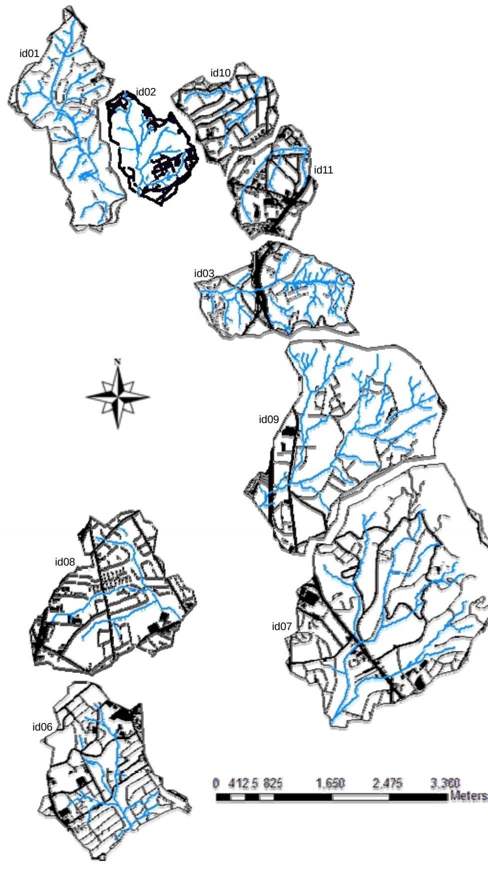
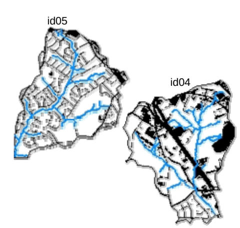


Figure 1. Locator Map of Study Sites With Drainage areas delineated.

Background Information

Urbanization, with the accompanying loss of vegetation, replacement of natural soil with impervious surfaces, and routing of storm water runoff directly to stream channels, has a considerable impact on the processes that control a stream's physical characteristics (Rose et al., 2000). Stream channels typically respond to hydrologic changes from urbanization through physical changes to the streams banks and bed in the form of severe erosion causing channel widening, incision, or deposition. Understanding and finding way to predict these morphologic changes is necessary to improve stream integrity, and manage future development that minimizes the effects of urbanization in a watershed. One factor that has been studied to try and predict channel changes is imperviousness. Imperviousness is collectively known as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces, and this factor is one of the few variables that can be quantified, managed, and controlled within a catchment (Schueler, 1994). Roads usually drain to sewer systems, which are connected to nearby streams, so if there are more roads, then theoretically there will be more runoff entering the streams. Creating predictable relationships between physical stream characteristics in urban areas, and the connectivity of roads to streams in each site's drainage area, can help improve urban planning techniques. The study's purpose is to utilize road connectivity as an explanatory variable for stream measurements such as incision ratio and bankfull measurements in urban streams.





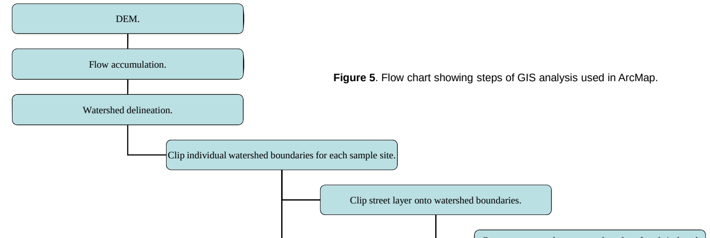


Figure 5. Flow chart showing steps of GIS analysis used in ArcMap.

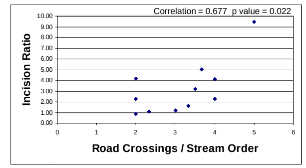


Figure 2. As more road crossings increase and stream order decreases, the incision ratio decreases. Incision ratio is the low bank height divided by the maximum bankfull depth and this ratio indicates how much a stream is downcutting into the earth.

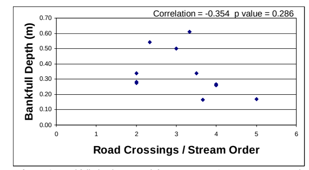


Figure 3. Bankfull depths ranged from .17m to .61m. As more road crossings appear within a stream network, the bankfull depth of the stream in that network decreases.

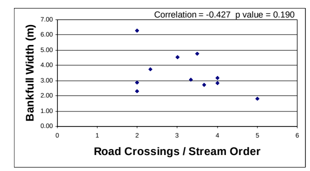


Figure 4. Bankfull widths for the streams ranged from 1.81m to 6.30m. As more road crossings appear within a stream network, the bankfull depth of the stream in that network decreases.

Table 1.

Name	Site	*UPRD (m)	**RD	+SNL (m)	++TRC	Stream Order	Area (km2)	Imperviousness %
Reedy River West Fork	id01	150	0.11	67369	6	3	2.76	13.44
Reedy River East Fork	id02	1710	0.07	32842	7	3	5.68	8.66
Crag Creek	id03	615	0.15	65984	10	3	4.78	17.32
Rocky Creek	id04	610	0.27	38562	6	3	4.59	32.50
Ranch Creek	id05	1040	0.15	35143	9	3	4.15	21.45
Longbranch Creek	id06	700	0.22	23845	11	3	2.98	29.65
Langston Creek	id07	1150	0.13	50665	12	3	7.55	17.04
Sulfer Springs Rd	id08	705	0.20	17950	8	2	3.25	27.34
Little FU (behind chapel)	id09	250	0.09	61129	14	4	4.92	11.62
Hillside Creek	id10	240	0.25	11982	10	2	1.30	31.44
Beaver Dam Creek	id11	500	0.32	10739	6	3	1.33	39.52

***UPRD**: Upstream distance to nearest road crossing. ****RD**: Total area of roads divided by the total area of the subwatershed. **+SNL**: Total length of the stream network draining to the sample site. **++TRC**: Total road crossings upstream of the sample site.

Sources and Data: **Projection**: NAD_1983_UTM_Zone_17N. **Data Sources**: hydro_l_03.shp for stream layer. streetcl_03.shp for road layer. Pavement03.shp used for impervious cover data. Saluda_14.shp and Enoree_14.shp used for site map. Watershed area for each site delineated and clipped in ArcMap. Individual sites on Figure 1 plotted from GPS longitude/latitude readings.

Booth, D.B., et al., 2005, Urban Impacts on Physical Stream Condition: Effects of Spatial Scale, Connectivity, and Longitudal Trends, Journal of the American Water Resources Association, pp. 565-580.

Rose, Seth, et al., 2001, Effects of Urbanization on Streamflow in the Atlanta Area (GA, USA): a comparative hydrological approach, Hydrological Processes, vol. 15, pp. 1441-1457.

Schueler, T, 1994, The Importance of Imperviousness, Watershed Protection Techniques, vol 1, no. 3.

Results and Discussion

Incision ratio, bankfull width, and bankfull depth were all compared to the ratio of road crossings to stream order. This dimensionless ratio of number of road crossings to the order of stream was calculated to capture the direct storm water inputs into streams and how the effects of these inputs on stream morphology dissipate with increasing stream order. A higher stream order number means that there are other smaller tributaries contributing to it upstream, which means that the higher the stream order, the higher the amount of flow. Streams with a low stream order are more susceptible to higher incision ratio's as the number of road crossing (storm water inputs) increases (Figure 2). The correlation between incision ratio and the stream order ratio was 0.677, which was statistically significant. Bankfull depths ranged from .17m to .61m and had a non-significant negative correlation (r=-0.354, p=0.29) with the stream order ratio (Figure 3). This relationship present for bankfull widths, which ranged from 1.81m to 6.30m, had a negative correlation but statistically not significant (r=-0.427, p=0.19) (Figure 4). Both relationships between bankfull measurements and the stream order ratio were not statistically significant. Overall, developing relationships between physical stream measurements in urban areas and the road connectivity of a stream network creates more correlated results for incision ratio than when comparing incision ratio to impervious cover percentage. However, the lack of relationship between bankfull width and depth is present when comparing it to road connectivity metrics as well as impervious cover percentage. This is most likely due to the dynamic nature of streams. One storm event could erode a bank upstream, which is deposited downstream, and this makes the bankfull width and depth measurements very susceptible to change.