

Impervious Surface in the Richmond Region

November 14, 2005

Town of
 Ashland
Counties of
 Charles City
 Chesterfield
 Goochland
 Hanover
 Henrico
 New Kent
 Powhatan
City of
 Richmond



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Richmond Regional Planning District Commission

Planning district commissions make government more efficient and effective through coordinated planning and program analysis. Virginia's General Assembly created planning districts in 1968 under the authority of the *Virginia Area Development Act* - revised as the *Regional Cooperation Act* in 1995 - "to promote orderly and efficient development of the physical, social and economic elements of the districts." Through planning district commissions, now 21 in number, local governments solve mutual problems which cross boundary lines and obtain expertise from professional staffs and advice on making the most of scarce taxpayer dollars through intergovernmental cooperation.

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Mapping Impervious Surface in the Richmond Region with Ortho imagery

Introduction

The Richmond Regional Planning District Commission (RRPDC) conducted a regional study on impervious area for the FY2005 Coastal Grant project funded by National Oceanic and Atmospheric Administration (NOAA) through Virginia Department of Environmental Quality (VADEQ). This study calculated the total land area and relative increase in impervious surface from 1994 to 2002. National studies show that impervious surfaces are indicators of the quality of water resources as they measure the impacts of land development on aquatic systems. Illustrations and examples of calculating and mapping imperviousness are provided below.

Impervious surfaces and water resources

For the purposes of this study, impervious surfaces include roads, parking lots, built footprints, and other similar impermeable surfaces usually associated with urban and suburban landscapes. An increase in impervious surface area affects, among other things, the hydrologic cycle and as a result, water resources. Such effects may include: increased flooding and stream bank erosion, degraded aquatic habitat, reduced groundwater recharge, additional pollutants entering the river from storm water runoff, and reduction in healthy water supply.

Process

Data Sources

Ortho imagery is ortho rectified digital aerial photographs known as digital ortho quarter quads (DOQQ). Ortho imagery supports various geographic information analysis and mapping applications. It is used to develop and revise transportation, cadastral, and land use/land cover information. Federal, state, and county agencies use ortho imagery as a base map for wetlands, soil, land parcel, farm-field boundary, forest inventory, and other natural resources mapping, analysis, and planning applications.

This study relies upon the visual comparison of digital ortho imagery data from one year to another (1994 and 2002) to identify areas of change within the Richmond region. Ideally, all of the data sets should be generated using the same standards and methods of ortho imagery with simply a difference in the year of photography. Therefore, the user would only need to compare the original data to the updated data to identify areas of change in polygon boundaries and/or types of impervious surfaces (i.e., roads, parking lot, structures) denoted as use codes.

In this study, changes occurred between the 1994 and 2002 ortho imagery due to advances in technology, changes in base imagery quality, resolution, and data sources. Because of these improvements, a more detailed impervious surface inventory was conducted with the 2002 imagery. The user needs to be aware of these differences and their significance while using the layers as a trend analysis tool.

The 1994 DOQQs are the property of the United States Geological Society (USGS) who allows Radford University permission to distribute the data. The 1994 DOQQs were used as a baseline to obtain an historical perspective for this project. The black-and-white and color-infrared photographs were taken at a 1:12,000-scale, quarter-quadrangle centered, and 1-meter pixel resolution. They are projected in Universal Transverse Mercator, NAD 83.

The 2002 DOQQs used in this study are from the Virginia Base Mapping Project (VBMP) and were obtained from the Virginia Geographical Information Network (VGIN) agency. This set of DOQQs were flown and processed in the late winter/early spring of 2002 by VARGIS, a Virginia-based firm. The DOQQs were produced in full color, leaf-off, digital ortho-photography for the entire land base of Virginia. The imagery was developed at one of 3 scales: 1:4,800 scale (2' resolution) in rural areas; 1:2,400 scale (1' resolution) in urban and suburban areas; and 1:1,200 scale (1/2' resolution) in areas where localities chose the option to purchase higher accuracy product.

Procedure

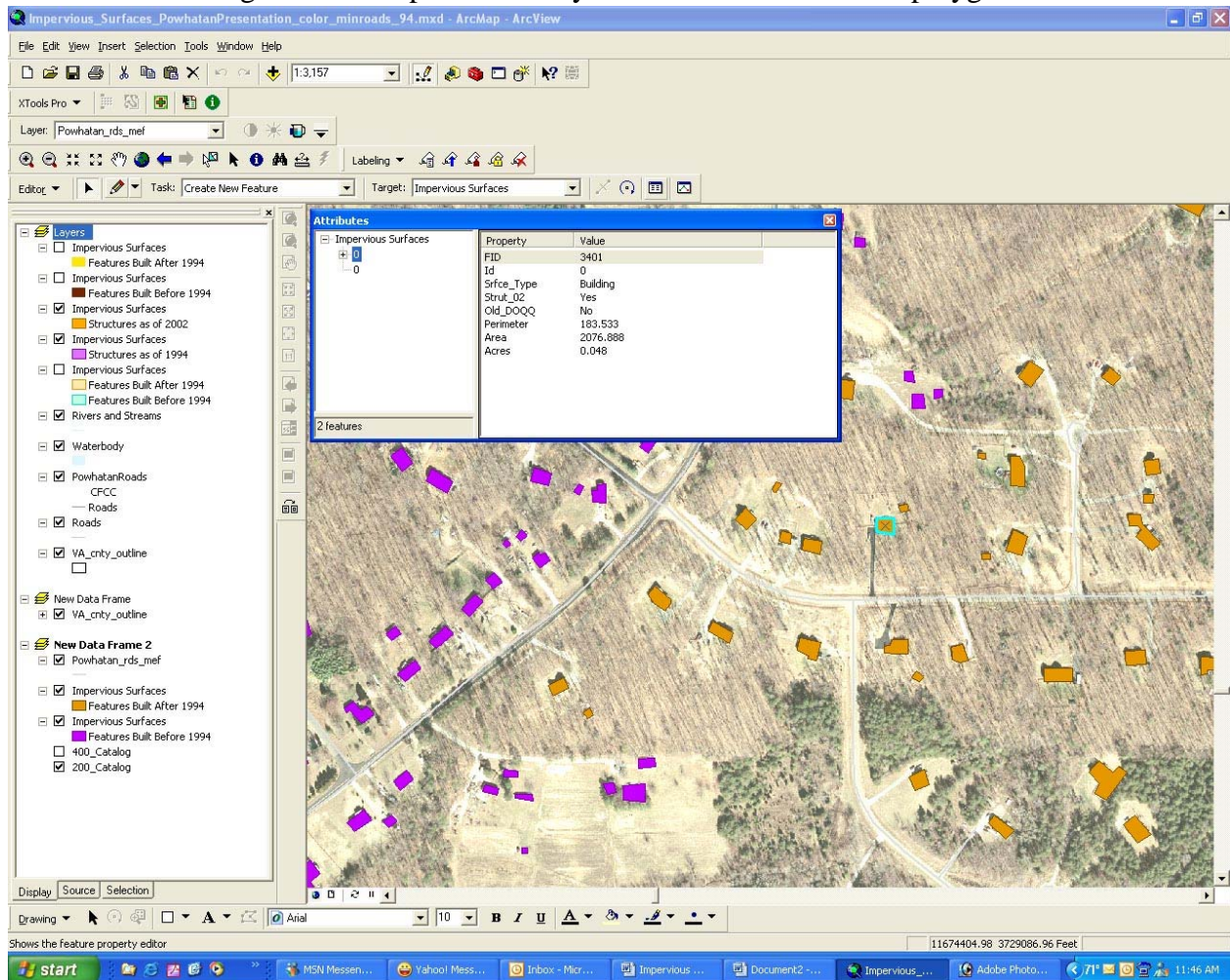
The establishment of the impervious surface polygons on the 1994 and 2002 DOQQs was determined using the geographic information systems (GIS) software known as ArcGIS. Various layers of information were brought together for this project to overlay on the DOQQ imagery. Some of these layers included roads, streams/waterbodies, and when available, locality-specific information such as building footprints and parking lots. A database was established for the impervious surface features. The RRPDC staff input information about the polygons into fields in the database attribute table.

The RRPDC staff overlaid the roads and waterbodies with the 2002 DOQQ layer. A polygon was drawn around each feature and the attribute table was updated with the new information (see Figure 1). Any structure present in 2002 was placed under a field named DOQQ02. These steps were repeated until all nine localities in the region were complete.

The 2002 ortho imagery was used first because the ortho-photography resolution was sharper and data, similar in timeframe, on impervious surface features was provided by several localities including the City of Richmond, and the counties of Charles City, Chesterfield, Henrico and Hanover. The RRPDC then supplemented this information by additional digitization and categorization of use codes. The remaining localities - Goochland, New Kent, and Powhatan were digitized directly from the ortho-photography by the RRPDC.

To complete the historical perspective of the regional growth between 1994 and 2002, the RRPDC staff continued the review by comparing the 1994 ortho-photography impervious surface features to the newly digitized 2002 impervious surface layer. In comparison, there were degrees of inaccuracy between the 1994 digital image and the 2002 polygon delineations due to the resolution quality of the two sources and differences in the projections. The color aerial photography used to capture the 2002 data allowed the user more detailed and accurate delineations than was possible when using the 1994 color infrared DOQQs. Since this may result in incorrect impervious surface change analysis, many of the 1994 polygon boundary use codes were adjusted to conform to the more accurate 2002 imagery. Each impervious area

Figure 1: Example of data layers and attribute table for polygons



present as of 1994 was denoted in the DOQQ94 field and a representative polygon layer for the 1994 ortho imagery was created.

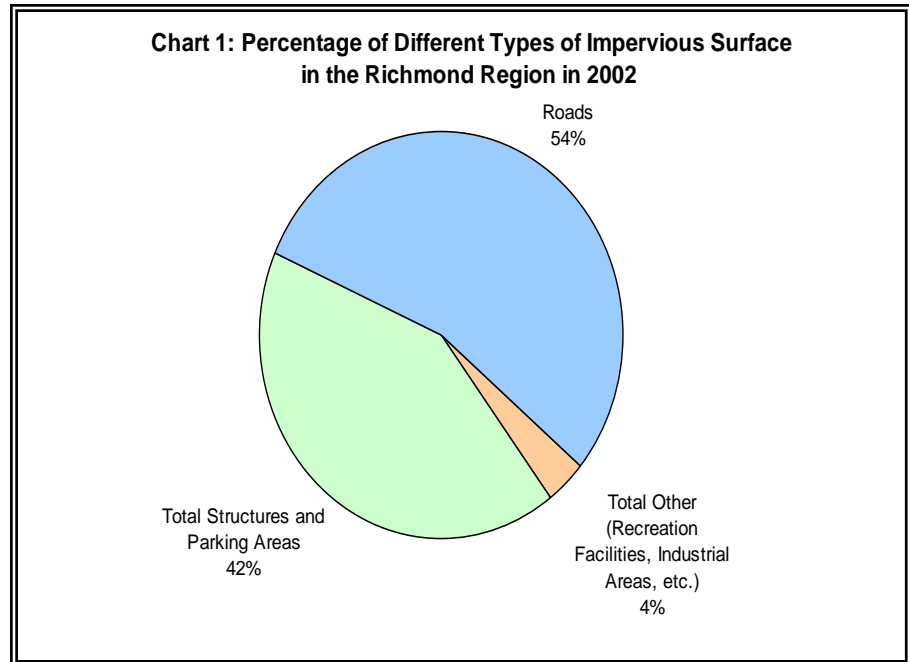
A final step in comparing 1994 and 2002 imagery was to identify inconsistencies due to varying technique of individual technicians compiling the project. Separate technicians analyzed and coded impervious areas differently which resulted in polygons having different configurations and impervious use codes. Methodology was reassessed and codes were corrected to reflect a comparable category and a more generalized code. This work is still in progress for phase II of the project.

After the mapping and database work was complete, analysis was run by locality and region to determine the percentage of change in total impervious surface between 1994 and 2002. Figure 2 shows an example of the total percent of impervious surface in 1994 and 2002 on a county level.

Results

Results of the research for the two sets of impervious surface are summarized below. It should be noted that these results are preliminary. The RRPDC staff is currently incorporating additional data including population, land use, and watersheds into research that will lead to an update of the impervious surface project, phase II.

In 2002, there was a total of 5.55 percent, or 122 square miles of impervious surface in the Richmond region. The 66 square miles of roads accounted for a larger portion than the 56 square miles of structures, parking, and other impervious areas (other impervious areas are considered quarries, recreational facilities, industrial areas, etc.). Chart 1 shows the percentage of each category of impervious surface in the region in 2002.



Between 1994 and 2002, the area of impervious surface, excluding roads, grew by 14.33 percent in the Richmond region. In the eight years between 1994 and 2002, the Richmond region's impervious surface grew at a rate 400 percent faster than the rate at which the region grew from when it was first settled in the 1600s until 1994.

Data for structures, parking areas, and other impervious surfaces, excluding roads, was collected for both 1994 and 2002 for eight localities in the Richmond region. Of these localities, the City of Richmond had the highest percentage of total impervious surface in both 1994 (30.74%) and in 2002 (31.24%), but the lowest relative increase in impervious surface over the eight years (2.48%).

Compared to the other rural localities, Charles City (11.61%) had a relatively low increase in impervious surface between 1994 and 2002. The three other rural counties of New Kent (26.61%), Powhatan (25.47%), and Goochland (20.71%) had similar relative increases in impervious surface over the eight years between 1994 and 2002.

The data indicated that the suburban counties of Chesterfield (20.31%), Henrico (13.83%), and Hanover (20.24%) had less percent increase but a greater amount of impervious area than most of the rural counties.

Note that in phase I of this project, data for impervious area of roads were calculated but not separated between 1994 and 2002. Therefore, roads were excluded when calculating percentage of growth. Phase II will contain calculations for the road feature.

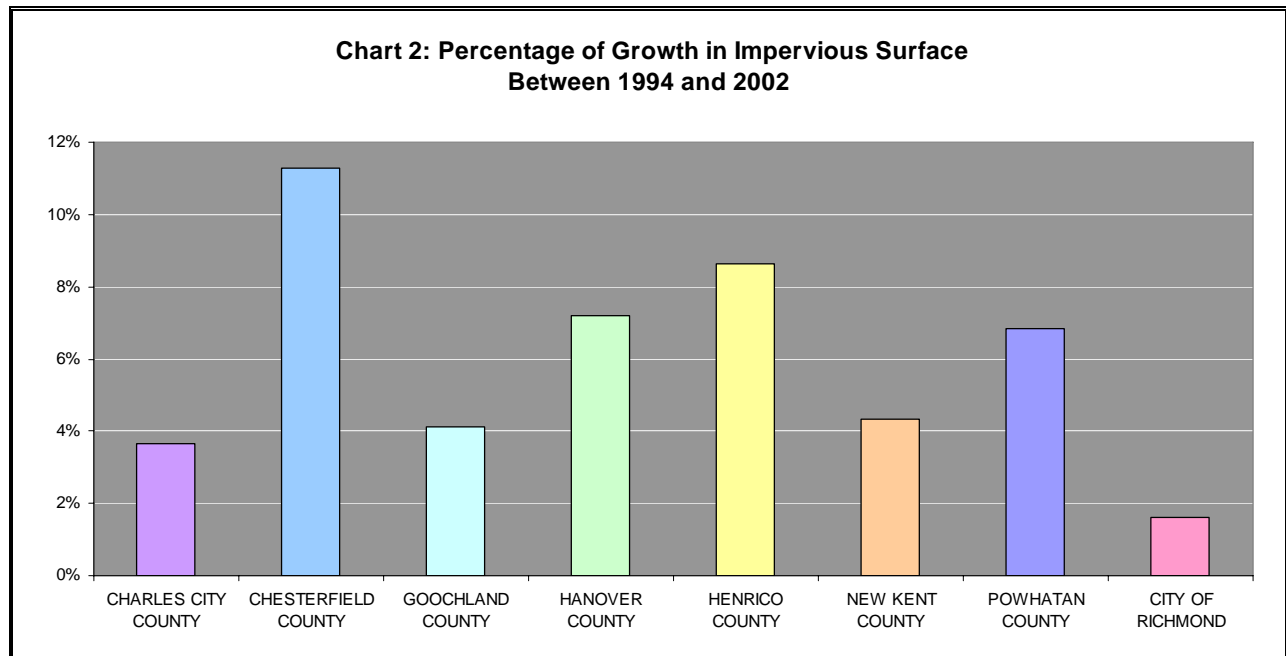
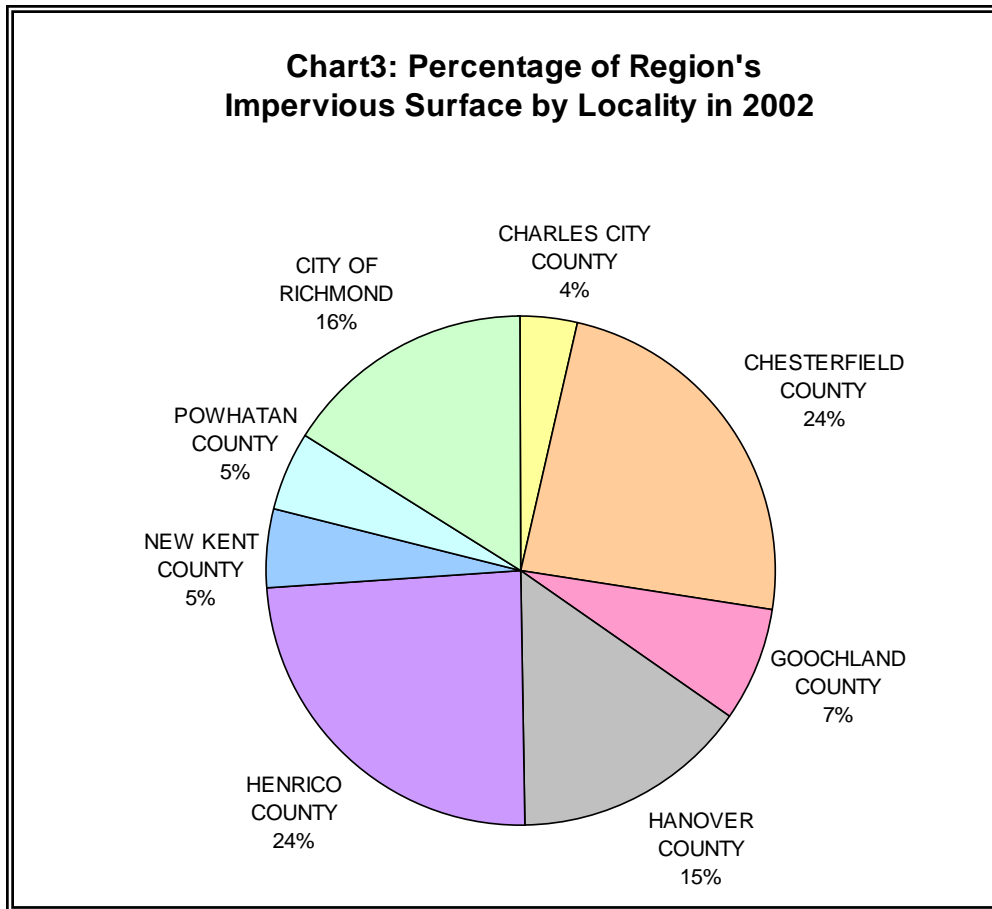


Chart 2 shows the percent age of growth in impervious surface for each of the eight localities for which data was collected in both 1994 and 2002.

In 2002, Henrico County had the greatest area of impervious surface in the region with 30 square miles (12.20 percent of the county, 24 percent of the total region). Chesterfield County (29 square miles of the county, 24 percent of the region), the City of Richmond (20 square miles of the city and 16 percent of the region), and Hanover County (18 square miles of the county, 15 percent of the region) all had a larger area of impervious surface than New Kent County (six square miles of the county, five percent of the region), Powhatan County (six square miles of the county, five percent of the region), Goochland County (nine square miles of the county, seven square miles of the region), and Charles City County (five square miles of the county, four square miles of the region). (See Chart 3.)

Maps of each locality and of the region are attached. Each map shows impervious structures for 1994 and 2002. A chart is attached comparing each localities' impervious area in square footage, acres, and square miles for 1994 and 2002. It shows the percentage of the county that is impervious (including roads) and the percentage of growth (excluding roads).

Chart3: Percentage of Region's Impervious Surface by Locality in 2002



Phase II

According to T. R. Schueler¹, an expert in the study of impervious area, watersheds become impacted when over 10 percent of the watershed is covered with impervious surface. Schueler goes on to say that if over 25 percent of a watershed is covered with impervious surface, the watershed becomes degraded.

The Richmond region is located within the James River and York River watersheds, both of which flow into the Chesapeake Bay. The Chickahominy, Appomattox, and Swift Creek watersheds are all sub-watersheds to the James River. The Pamunkey River watershed is also partly in the Richmond region and is a sub-watershed of the York River.

As part of phase II of this project, the RRPDC will study these watersheds and sub-watersheds to determine how much impervious surface coverage exists in each. Phase II will also assess growth trends of impervious surface and how close the watersheds in the Richmond region are to being impacted or degraded by this coverage.

As well as defining data by watershed, phase II will include population and land use comparisons and census growth trends. Road features will be further defined and separated by year built. Phase II will also include continued QA/QC and reassessment of coding consistencies.

Sources:

Sleavin, William J. Measuring Impervious Surfaces for Non-point Source Pollution Modeling. University of Connecticut. 2000.

Cappiella, K. and K. Brown. 2001. Land Use and Impervious Cover in the Chesapeake Bay Region. *Watershed Protection Techniques*, 3(4): 835-840

¹ Schueler, T.R. 1994. The Importance of Imperviousness. *Watershed Protection Techniques*. 1(3): 100-111 or <http://www.stormwatercenter.net/Practice/1-Importance%20of%20Imperviousness.pdf>

Impervious Surface in the Richmond Region Summary

	1994			2002			Percent Growth (Excluding Roads)
	Square Feet	Acres	Square Miles	Square Feet	Acres	Square Miles	
<u>CHARLES CITY COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	11,303,861	259.50	0.41	11,851,661	272.08	0.43	11.61%
Total Structures and Parking Areas	22,746,020	522.18	0.82	26,672,135	612.31	0.96	
Roads*	88,630,661	2,034.68	3.18	88,630,661	2,034.68	3.18	
Total Impervious Surface	122,680,542	2,816.36	4.40	127,154,457	2,919.06	4.56	
Total Land Area	5,705,682,941	130,984.46	204.66	5,705,682,941	130,984.46	204.66	
Percent of County that is Impervious	2.15%			2.23%			
<u>CHESTERFIELD COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	6,427,520	147.56	0.23	7,899,606	181.35	0.28	20.31%
Total Structures and Parking Areas	313,102,994	7,187.86	11.23	393,046,236	9,023.10	14.10	
Roads*	402,315,368	9,235.89	14.43	402,315,368	9,235.89	14.43	
Total Impervious Surface	721,845,882	16,571.30	25.89	803,261,210	18,440.34	28.81	
Total Land Area	12,181,242,546	279,642.85	436.94	12,181,242,546	279,642.85	436.94	
Percent of County that is Impervious	5.93%			6.59%			
<u>GOOCHLAND COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	1,606,758	36.89	0.06	2,042,639	46.89	0.07	20.71%
Total Structures and Parking Areas	35,247,329	809.17	1.26	44,437,796	1,020.15	1.59	
Roads*	197,187,844	4,526.81	7.07	197,187,844	4,526.81	7.07	
Total Impervious Surface	234,041,931	5,372.86	8.40	243,668,279	5,593.85	8.74	
Total Land Area	7,978,217,915	183,154.68	286.18	7,978,217,915	183,154.68	286.18	
Percent of County that is Impervious	2.93%			3.05%			
<u>HANOVER COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	4,258,426	97.76	0.15	6,751,098	154.98	0.24	20.24%
Total Structures and Parking Areas	130,581,990	2,997.75	4.68	162,314,597	3,726.23	5.82	
Roads*	340,314,242	7,812.54	12.2	340,314,242	7,812.54	12.21	
Total Impervious Surface	475,154,658.00	10,908.05	17.04	509,379,937	11,693.75	18.27	
Total Land Area	13,215,901,446	303,395.35	474.1	13,215,901,446	303,395.35	474.06	
Percent of County that is Impervious	3.60%			3.85%			
<u>HENRICO COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	13,806,332	316.95	0.50	25,105,490	576.34	0.90	13.83%
Total Structures and Parking Areas	394,900,966	9,065.68	14.17	449,188,917	10,311.96	16.11	
Roads*	351,712,152	8,074.20	12.62	351,712,152	8,074.20	12.62	
Total Impervious Surface	760,419,450	17,456.83	27.28	826,006,559	18,962.50	29.63	
Total Land Area	6,769,060,013	155,396.24	242.81	6,769,060,013	155,396.24	242.81	
Percent of County that is Impervious	11.23%			12.20%			

Impervious Surface in the Richmond Region Summary: Page 2

	1994			2002			Percent Growth (Excluding Roads)
	Square Feet	Acres	Square Miles	Square Feet	Acres	Square Miles	
<u>NEW KENT COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	1,348,192	30.95	0.05	1,592,686	36.56	0.06	26.61%
Total Structures and Parking Areas	17,540,471	402.67	0.63	24,144,462	554.28	0.87	
Roads*	139,432,946	3,200.94	5.00	139,432,946	3,200.94	5.00	
Total Impervious Surface	158,321,610	3,634.56	5.68	165,170,094	3,791.78	5.92	
Total Land Area	6,228,414,341	142,984.72	223.41	6,228,414,341	142,984.72	223.41	
Percent of County that is Impervious	2.54%			2.65%			
<u>POWHATAN COUNTY</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	1,720,188	39.49	0.06	3,018,658	71.35	0.11	25.47%
Total Structures and Parking Areas	31,157,598	715.28	1.12	41,004,747	941.34	1.47	
Roads*	131,319,461	3,014.68	4.71	131,319,461	3,014.68	4.71	
Total Impervious Surface	164,197,247	3,769.45	5.89	175,342,866	4,027.37	6.29	
Total Land Area	7,366,325,110	169,107.56	264.23	7,366,325,110	169,107.56	264.23	
Percent of County that is Impervious	2.23%			2.38%			
<u>CITY OF RICHMOND</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	66,530,926	1,527.34	2.39	66,550,881	1,527.80	2.39	2.48%
Total Structures and Parking Areas	275,523,682	6,325.15	9.88	284,201,319	6,524.36	10.19	
Roads*	193,656,870	4,445.75	6.95	193,656,870	4,445.75	6.95	
Total Impervious Surface	535,711,478	12,298.24	19.22	544,409,070	12,497.91	19.53	
Total Land Area	1,742,866,363	40,010.71	62.52	1,742,866,363	40,010.71	62.52	
Percent of County that is Impervious	30.74%			31.24%			
<u>TOTAL RICHMOND REGION</u>							
Total Other (Recreation Facilities, Industrial Areas, etc.)	107,002,202	2,456.43	3.84	124,812,718	2,867.36	4.48	14.33%
Total Structures and Parking Areas	1,220,801,050	28,025.74	43.79	1,425,010,210	32,713.73	51.12	
Roads*	1,844,569,544	42,345.49	66.16	1,844,569,544	42,345.49	66.16	
Total Impervious Surface	3,172,372,797	72,827.66	113.79	3,394,392,472	77,926.58	121.76	
Total Land Area	61,187,710,674	1,404,677	2,194.81	61,187,710,674	1,404,677	2,194.81	
Percent of County that is Impervious	5.18%			5.55%			

*This category has not been compared to the aerial photography in 1994 or in 2002. The area for this category has been calculated from 2000 Tiger road files.