

***Refining Impervious Surface
Mapping in the Richmond Region***

— Phase II —

October 13, 2006

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

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Phase II Refining Impervious Surface Mapping of the Richmond Region

Introduction

The Richmond Regional Planning District Commission (RRPDC) continued to study impervious surface area at the regional level for the FY 06 Coastal Grant project funded by National Oceanic and Atmospheric Administration (NOAA) through Virginia Coastal Zone Management Program (VACZM). This document details Phase II of the impervious surface mapping project. It was an effort to improve the methodology and results of Phase I, conducted during FY 05. The goal of Phase I was to digitize and calculate the relative increase in impervious surface from 1994 to 2002. The baseline for the comparison was the digitization of the 1994 color infrared orthophotography.

For the purposes of this study, impervious surfaces include roads, parking lots, building 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.

Background

Phase I

Phase I began with the intent to measure the change in impervious surfaces in the Richmond Region between 1994 and 2002. The imagery used for the 1994 baseline came from the United States Geological Society (USGS) color infrared Digital Orthophotography Quarter Quads (DOQQs). The 2002 imagery was a high resolution orthophotography product developed by Virginia Geographic Information Network (VGIN) under their Virginia Base Mapping Program (VBMP). The comparison of the digitized data from each of these years was the basis for measuring the change.

The digitization of the impervious surface polygons on the 1994 and 2002 VBMP orthophotography was conducted using the Geographic Information Systems (GIS) software known as ArcGIS. When available, staff started with locality-created information such as building footprints and parking lots. A database was established for the impervious surface features. For localities with a building footprint layer, existing data was used as a starting point. In some cases, localities had not prepared an existing building footprint layer, so a layer was created by digitizing structures visible in the orthophotography. Information about the newly digitized polygons was placed into the database attribute table. The polygons were classified as either existing in 1994 orthoimagery or constructed between 1994-2002.

In comparison, there were degrees of inaccuracy between the 1994 and the 2002 polygon delineations due to resolution quality of the two orthophotographic sources and differences in the data projections. The color aerial photography used to capture the 2002 data provided the user more detailed and accurate delineations than was possible when using the 1994 color infrared DOQQs. Using the road and structure polygons, the impervious area was calculated for both 1994 and 2002. Maps were prepared as a visual tool illustrating the change in regional impervious surface.

For a more detailed methodology of Phase I, please refer to Mapping Impervious Surface in the Richmond Region with Ortho Imagery at www.richmondregional.org.

Phase II

Phase II of this project was conducted between January and September 2006. The goal of Phase II was to improve the accuracy of the existing building polygons, capture driveways, improve classifications of polygons by using a standard classification system in the four rural jurisdictions, and improve the road layer, region-wide, to reflect the difference in road widths between rural and urban/suburban jurisdictions. It was decided that a similar analysis using 1994 orthophotography would be less valuable due to the lower resolution and quality of the DOQQ's.

A final step was to identify inconsistencies due to varying techniques of individual technicians compiling the project. Separate technicians analyzed and coded impervious areas differently in Phase I which resulted in polygons having different configurations and impervious use codes. Methodology was reassessed and use codes were corrected to reflect a comparable category and a more generalized use code. Use codes included, but were not limited to, buildings (residential, commercial, and industrial), airports, driveways, parking lots, pools, and tennis courts. Map 1 is a close-up example of the newly digitized driveways (yellow) and improved categories reflecting pools (blue) and tennis courts (green). The building polygons (orange) more closely reflect the actual building footprints.

The refinement to the Phase I methodology resulted in very similar calculations at the regional level, but greatly differing calculations at the county/city level. Discussion of the results for each jurisdiction follows in the results section. New maps of the four rural jurisdictions are also included.

Methodology - Road Surfaces

VDOT-Maintained Roads:

The RRPDC obtained GIS data from VDOT that included data on surface width measurements. By creating a new field in the existing data table, staff was able to calculate a general road width for the different road types. The width was determined by staff by dividing the surface width measurement field in half. Staff used the "Buffer by Field" tool from the ArcGIS program to create a polygon and to calculate the impervious surface of the roads maintained by VDOT. A

quality control check of the data revealed the road buffer polygon to be an accurate reflection of road widths.

Locality-Maintained Roads:

The City of Richmond and Henrico County maintain their own roads and are not included in the VDOT database. These jurisdictions also have a highly developed GIS and have accurate road polygons. The pre-existing road polygons from Richmond City and Henrico County were used to calculate road surface. The 2006 digital road layer from Henrico County was checked against 2002 orthophotography to remove roads in subdivisions constructed since 2002. Richmond City's roads were not reviewed to remove roads constructed since 2002, because the city is largely built out and roads constructed since 2002, if any, would be a minimal contribution to the overall impervious surfaces calculation.

Driveways, Private Roads, and Parking Lots:

VGIN created a database of "ancillary" road centerlines digitized from the same 2002 Virginia Base Mapping Program (VBMP) orthophotography as used in phases I and II of this impervious surface project. VGIN defines the ancillary features as roads, trails, and driveways over 200 feet in length and that are not named or addressed. Private roads, trails, and driveways are typically found to have a width of about 10 feet. Therefore, these roads were buffered at five feet (from the centerline) for the entire region. Driveways shorter than 200 feet were captured and coded manually during the Quality Assurance/Quality Control (QA/QC) process at a scale of 1:2,500. Driveways that had not been captured in Phase I were also captured.

The attribute field, "Structure Type", contains descriptive use codes allowing structures such as "driveway" to be selected. The driveway polygons were then calculated with the other transportation and roads surfaces to determine the impervious surface statistics for the roadways. Polygons that were originally coded as "industrial" or "commercial" and included both structure and parking lot were separated into one of two distinct shapes and coded as either "structure" or "parking lot."

Conclusion:

Buffering the roads individually, as opposed to the uniform buffer applied to roads in Phase I, dramatically changed the impervious surface calculations for each jurisdiction. In some localities, the uniform buffer overestimated the amount of impervious surface by nearly 300 percent. Map 2 is an example with the road buffers shown with the driveway and structure polygons. Note the accuracy of the road width buffer and the precise matching of driveway vertices and edges to road layer edges.

Methodology - Structures

Staff not only spent time on the road surfaces but also reviewed and compared the 1994 and 2002 structures to ensure that all polygons were coded as either existing in 1994

orthophotography or constructed between 1994-2002. At the same time, staff reassessed the use code for each structure for consistency among the data and re-digitized the structure footprints.

For all areas that underwent QA/QC, the Phase I structure layer was inspected at 1:2,500 scale. The attribute field, "Structure Type," contains descriptive use codes allowing structures such as "building," "tennis court," or "pool" to be selected. Structures that had not been captured in the original study were also captured. Polygons that were originally coded as "industrial" or "commercial" and included both structure and parking lot were separated into one of two distinct shapes, and coded as either "structure" or "parking lot."

Results

Regional Results

With refinements in the project methodology and more complete transportation data in Phase II, the staff at the RRPDC was able to determine that there was an overestimation of the regional impervious surface in Phase I. The most notable change was a 0.25 percent reduction in overall calculated impervious surface. The QA/QC and methodology improvements resulted in a 22 percent decrease in total structures impervious surface and a 3.8 percent increase in total transportation impervious surface. Both Phase I and Phase II were conducted using the same 2002 orthophotography, so this is not a change in impervious surface over time but rather an improvement of the original Phase I measurements.

Maps 3 and 4 illustrate the distribution of structures and transportation surfaces in the region. Please note that for mapping purposes, Map 3 includes only structures and main roads and does not include VBMP ancillary roads as discussed above. Map 4 includes only the buffered road surfaces.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for the region.

<u>TOTAL RICHMOND REGION</u>	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
Total Structures	35,580.48	55.59	29,103.00	45.47
Total Transportation Surfaces	42,343.92	66.16	44,038.00	68.22
<i>Ancillary Roads</i>			<i>7,325.00</i>	<i>11.45</i>
<i>Main Roads</i>			<i>25,507.00</i>	<i>39.85</i>
<i>Driveways</i>			<i>3,849.00</i>	<i>6.01</i>
<i>Parking</i>			<i>6,980.00</i>	<i>10.91</i>
Total Impervious Surface	77,924.40	121.76	73,141.00	113.69
Total Land Area	1,404,677	2194.81	1,404,677	2194.81
<i>Percent of Region that is Impervious</i>	5.55%		5.21%	

Rural Localities

Charles City County

The difference between Phase I and Phase II data calculations of the 2002 impervious surfaces in Charles City County is quite significant. This difference stems mostly from the improved road surface methodology. In buffering the roads at the same width region-wide, Phase I overestimated the amount of impervious surface for VDOT maintained roads within this county. Roads in rural areas are very narrow when compared with roads in suburban or urban areas. The “road surfaces” category acreage was 1.74 square miles greater in Phase I, even when considering the driveways and ancillary roads that were added as a part of Phase II. The difference in structure acreage is attributed to QA/QC that captured missed structures, multiple structures within one polygon, redefining the use codes in the structures database, and improved digitization methods. The overall impervious surface calculation decreased by 1.35 percent.

Many large manufacturing or industrial sites were captured as large polygons extending beyond the building footprint to include the parking areas in Phase I. These polygons were re-digitized and re-categorized to capture the individual building footprints and parking areas within the sites during Phase II.

Map 5 shows the distribution of impervious surfaces related to structures and roads for Charles City County. The higher level of impervious surface is reflected by a much higher proportion of structures (shown in purple) in the western half of the county.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Charles City County.

<i>CHARLES CITY COUNTY</i>	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
Structures	884.39	1.38	236.00	0.37
Transportation Surfaces	2,034.00	3.18	919.00	1.44
<i>Ancillary Roads</i>			<i>397.00</i>	<i>0.62</i>
<i>Driveways</i>			<i>91.00</i>	<i>0.14</i>
<i>Main Roads</i>			<i>392.00</i>	<i>0.61</i>
<i>Parking</i>			<i>39.00</i>	<i>0.06</i>
Total Impervious Surface	2,918.39	4.56	1,155.00	1.80
Total Land Area	130,984.46	204.66	130,984.46	204.66
<i>Percent of County that is Impervious</i>	2.23%		0.88%	

Goochland County

QA/QC and methodology improvements made a large difference between Phase I and Phase II data calculations of the 2002 impervious surfaces in Goochland County. This difference stems mostly from the improved road methodology. In buffering the roads at the same width region-wide, Phase I overestimated the amount of impervious surface for VDOT maintained roads within this county. Roads in rural areas are very narrow when compared with roads in suburban or urban areas. The “road surfaces” category acreage was 4.28 square miles greater in Phase I, even when considering the driveways and ancillary roads that were added as a part of Phase II. The difference in structure acreage is attributed to QA/QC that captured missed structures, multiple structures within one polygon, redefining the use codes in the structures database, and improved digitization methods. The overall impervious surface percentage decreased by 1.57 percent.

Many homes in Goochland County are quite large and are surrounded by outbuildings and large paved parking areas. In Phase I, polygons encompassing the entire site were captured. In many cases, houses with irregular footprints were digitized as a square, resulting in an overestimation of impervious surface due to structures. These polygons were re-digitized and re-categorized to capture the individual building footprints and driveways/parking areas within the sites during Phase II.

Map 6 shows the distribution of impervious surfaces related to structures and road surfaces in Goochland County. The higher level of impervious surface is reflected by a much higher pattern of village development in the middle of the county along Route 6 and the encroaching suburban growth patterns in the far eastern edge of the county.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Goochland County.

	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
<i>GOOCHLAND COUNTY</i>				
Structures	1,066.89	1.67	931.00	1.45
Transportation Surfaces	4,526.81	7.07	1,786.00	2.79
<i>Ancillary Roads</i>			384.00	0.60
<i>Driveways</i>			251.00	0.39
<i>Main Roads</i>			1,151.00	1.80
<i>Parking</i>			**	**
Total Impervious Surface	5,593.70	8.74	2,717.00	4.25
Total Land Area	183,154.68	286.18	183,154.68	286.18
<i>Percent of County that is Impervious</i>	3.05%		1.48%	

** This category has not been calculated for the jurisdiction yet and is included in other categories.

New Kent County

QA/QC and methodology improvements made a large difference between Phase I and Phase II data calculations of the 2002 impervious surfaces in New Kent County. This difference stems mostly from the improved road methodology. In buffering the roads at the same width region-wide, Phase I overestimated the amount of impervious surface for VDOT maintained roads within this county. Roads in rural areas are very narrow when compared with roads in suburban or urban areas. The “road surfaces” category was 3.2 square miles less than Phase I, even when considering the driveways and ancillary roads that were added as a part of Phase II. The difference in structure acreage is attributed to QA/QC that captured missed structures, multiple structures within one polygon, redefining the use codes in the structures database, and improved digitization methods. The total impervious surface calculations were reduced by 1.4 percent.

Map 7 shows the distribution of impervious surfaces related to structures and road surfaces in New Kent County. The higher level of impervious surface is reflected by several areas of suburban development in the south and west portion of the county, as well as south of Route 60 near the Chickahominy River.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for New Kent County.

<u>NEW KENT COUNTY</u>	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
Structures	590.84	0.92	584.00	0.91
Transportation Surfaces	3,200.94	5.00	1,200.00	1.88
<i>Ancillary Roads</i>			<i>344.00</i>	<i>0.54</i>
<i>Driveways</i>			<i>38.00</i>	<i>0.06</i>
<i>Main Roads</i>			<i>818.00</i>	<i>1.28</i>
<i>Parking</i>			**	**
Total Impervious Surface	3,791.78	5.92	1,784.00	2.79
Total Land Area	142,984.72	223.41	142,984.72	223.41
Percent of County that is Impervious	2.65%		1.25%	

** This category has not been calculated for the jurisdiction yet and is included in other categories.

Powhatan County

QA/QC and methodology improvements made a large difference between Phase I and Phase II data calculations of the 2002 impervious surfaces in Powhatan County. This difference stems mostly from the improved road methodology. In buffering the roads at the same width region-wide, Phase I overestimated the amount of impervious surface for VDOT maintained roads within this county. Roads in rural areas are very narrow when compared with roads in suburban or urban areas. The “road surfaces” category acreage was 1.21 square miles greater in Phase I, even when considering the driveways and ancillary roads that were added as a part of Phase II. The difference in structure acreage is attributed to QA/QC that captured missed structures, multiple structures within one polygon, redefining the use codes in the structures database, and improved digitization methods. The total impervious surface calculations were reduced by .52 percent.

Map 8 shows the distribution of impervious surfaces related to structures and road surfaces in Powhatan County. The higher level of impervious surface is reflected by several areas of suburban developments north of Route 60 near the middle of the county. Near the James River in the western portion of the county, there is a higher level of transportation related impervious surface than structure related.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Powhatan County.

	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
<i>POWHATAN COUNTY</i>				
Structures	1,012.69	1.58	908.00	1.42
Transportation Surfaces	3,014.68	4.71	2,242.00	3.50
<i>Ancillary Roads</i>			<i>1,099.00</i>	<i>1.72</i>
<i>Driveways</i>			<i>236.00</i>	<i>0.37</i>
<i>Main Roads</i>			<i>843.00</i>	<i>1.32</i>
<i>Parking</i>			<i>64.00</i>	<i>0.10</i>
Total Impervious Surface	4,027.37	6.29	3,150.00	4.92
Total Land Area	169,107.56	264.23	169,107.56	264.23
<i>Percent of County that is Impervious</i>	2.38%		1.86%	

** This category has not been calculated for the jurisdiction yet and is included in other categories.

Other Localities in the Region

Chesterfield County

Chesterfield County was not one of the four jurisdictions included in Phase II of this project. However, there was a change in calculated road surfaces due to the improvement in road buffering methodology. In Phase I, a regional road buffer utilizing a uniform width of five feet region-wide was used to calculate impervious surface related to roads. Although 2.58 square miles of ancillary roads excluded from Phase I calculations were added to the road surface subtotals, the overall road surfaces calculation decreased by 3.69 square miles. This resulted in a decrease of .83 percent in total impervious surface calculation.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Chesterfield County.

CHESTERFIELD COUNTY	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
Structures	9,204.00	14.38	9,224.00	14.41
Transportation Surfaces	9,235.00	14.43	6,874.00	10.74
<i>Ancillary Roads</i>			<i>1,653.00</i>	<i>2.58</i>
<i>Driveways</i>			**	**
<i>Main Roads</i>			<i>5,221.00</i>	<i>8.16</i>
<i>Parking</i>			**	**
Total Impervious Surface	18,439.00	28.81	16,098.00	25.15
Total Land Area	279,642.85	436.94	279,642.85	436.94
Percent of County that is Impervious	6.59%		5.76%	

** This category has not been calculated for the jurisdiction yet and is included in other categories.

Hanover County

Hanover County was not one of the four jurisdictions included in Phase II of this project. Staff, however, did refine the structure polygons in the highly populated Mechanicsville area of the county. This led to an improvement in polygon accuracy and a change in impervious surface calculations attributed to structures.

Differences were found in the calculated road surfaces due to the improvement in road buffering methodology. In Phase I, a regional road buffer utilizing a uniform width of five feet region-wide was used to calculate impervious surface related to roads. Although square miles of ancillary roads not included in Phase I calculations were added to the road surfaces subtotals, the overall road surfaces calculation decreased by 4.97 square miles. This resulted in a decrease of 1.01 percent in total impervious surface calculation.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Hanover County.

	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
<i>HANOVER COUNTY</i>				
Structures	3,881.21	6.06	3,981.00	6.22
Transportation Surfaces	7,812.54	12.21	4,636.00	7.24
<i>Ancillary Roads</i>			1,693.00	2.65
<i>Driveways</i>			329.00	0.51
<i>Main Roads</i>			2,614.00	4.08
<i>Parking</i>			**	**
Total Impervious Surface	11,693.75	18.27	8,617.00	13.46
Total Land Area	303,395.35	474.06	303,395.35	474.06
<i>Percent of County that is Impervious</i>	3.85%		2.84%	

Henrico County

Henrico County was not one of the four jurisdictions included in Phase II of this project. In Phase II, only actual structures were counted in the structure category, but improved data layers allowed staff to separate out parking and driveway layers to be included in road surfaces subtotals. This, and the use of Henrico County’s road polygon layer, led to a change in calculated road surfaces. In Phase I, a regional road buffer utilizing a uniform width of five feet region-wide was used to calculate impervious surface related to roads.

Henrico County has several areas of development in various regions of the county. Because Henrico County maintains its own roads, the ancillary roads were not included in Phase I calculations. Including the ancillary roads, recategorization of driveways and parking surfaces from the general “structures” field into transportation surfaces, and the improved road buffering methodology, 14.82 square miles of impervious surface were added to the road surfaces subtotals in Phase II. The improvement in methodology, categorization, and data sources resulted in an increase of 8.1 square miles in total impervious surface calculation.

The chart shown below describes the data collected in both studies and how the statistics changed with the improved methodology and transportation data for Henrico County.

<i>HENRICO COUNTY</i>	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
Structures	10,888.30	17.01	6,586.00	10.29
Transportation Surfaces	8,074.20	12.62	17,561.00	27.44
<i>Ancillary Roads</i>			930.00	1.45
<i>Driveways</i>			3,178.00	4.97
<i>Main Roads</i>			9,456.00	14.78
<i>Parking</i>			3,997.00	6.25
Total Impervious Surface	18,962.50	29.63	24,147.00	37.73
Total Land Area	155,396.24	242.81	155,396.24	242.81
<i>Percent of County that is Impervious</i>	12.20%		15.54%	

*** This category has not been calculated for the jurisdiction yet and is included in other categories.*

Richmond City

Richmond City was not one of the four jurisdictions included in the Phase II of this project. In Phase II, only actual structures were counted in the structure category, and improved data layers allowed staff to separate parking and driveway/ancillary road layers to be included in road surfaces subtotals. This, and the use of Richmond City’s road polygon layer, led to changes in calculated transportation surfaces. In Phase I, a regional road buffer utilizing a uniform width of five feet was used to calculate impervious surface related to roads.

Richmond City has comparatively high levels of development in most neighborhoods. The ancillary roads were not included in Phase I calculations; however, Richmond City GIS data did include these and classified them as driveways. Although calculated with all other transportation surfaces in phase I, when separated into specific categories, driveways and ancillary roads contributed 1.29 square miles of impervious surface to the road surfaces subtotals. The improvement in methodology, categorization, and data sources resulted in an increase of 7.43 percent in total impervious surface.

	Phase I Data		Phase II Data	
	Acres	Square Miles	Acres	Square Miles
CITY OF RICHMOND				
Structures	8,052.16	12.58	6,653.00	10.40
Transportation Surfaces	4,445.75	6.95	8,820.00	13.78
<i>Parking</i>			2,983.00	4.66
<i>Ancillary Roads</i>			825.00	1.29
<i>Main Roads</i>			5,012.00	7.83
<i>Driveways</i>			**	**
Total Impervious Surface	12,497.91	19.53	15,473.00	24.18
Total Land Area	40,010.71	62.52	40,010.71	62.52
Percent of County that is Impervious	31.24%		38.67%	

** This category has not been calculated for the jurisdiction yet and is included in other categories.