Build-Out Analysis in GIS as a Planning Tool With a Demonstration for Roanoke County, Virginia

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Abstract

The objectives of this paper are to explain what build-out analysis is and how localities can integrate it into their planning regimen. In addition, I will demonstrate a build-out analysis tailored to Roanoke County, Virginia, in order to calculate the fiscal impact of its current zoning ordinance at complete build-out. I conclude with recommendations for Roanoke County, other uses of build-out analysis and conclusions about this tool.

The purpose of a build-out analysis is to show a locality what land is available for development, how much development can occur and at what densities, and what consequences may result when complete build-out of available land occurs according to the zoning ordinance. A build-out analysis can reflect changes in the zoning ordinance to illustrate the effects of those changes on future resources. A build-out analysis can also help quantify the costs of growth.

Original build-out analyses were done by hand and relied on mathematical formulas. Now, build-out analyses are becoming more popular, feasible and dynamic with advances in computers and developments in geographic information system (GIS) software. While mathematical formulas still produce the quantitative measures of build out, GIS can provide visual representation and spatial specificity, as well as some of the quantitative measures.

The first part of this paper describes the process of conducting a build-out analysis. The second part uses a modified process to illustrate how to tailor build-out analysis to a real location. This location is Roanoke County, which is experiencing growth demands in its low- to medium-density residential zoning districts.

It appears from my analysis that Roanoke County can withstand another century of growth in these zoning districts before it reaches build-out, if the smallest lot sizes are applied. If larger lots are used, build-out will occur faster. From my analysis, it appears that small-lot zoning would cost the County more initially but may ultimately preserve more of the things that citizens value, as described in the goals of the 1998 Community Plan. Measures need to be taken at present to prepare for the growth allowed by the County's 1992 Zoning Ordinance.

Dedication

This work is dedicated to my family. The inspiration I derive from those who have passed and those now present is immeasurable.

I praise God for the opportunities He has given me. I rely daily on His guidance, strength and grace. In the search for knowledge is the realization that the only truth is found in faith.

"For I know the plans I have for you," declares the Lord,
"plans to prosper you and not to harm you,
plans to give you hope and a future.
Then you will call upon me and come and pray to me,
and I will listen to you.
You will seek me and find me
when you seek me with all your heart.
I will be found by you."
Jeremiah 29:11-14a

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To my grandmother, Alice Bragg, for listening as if this was all very important in the overall scheme of the world,

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And to my husband, my love, Richard, for being my cheerleader, my stability and my best friend, and for believing in my idea of returning to school.

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Chapter 1: Planning and Build-Out Analysis

Planning Tools

The primary tool for urban planning is land use controls. These controls are implemented through zoning. Zoning dictates where certain types of development are permitted by segregating a locality into different zones. Each zone has guidelines for the type of land use and the density of buildings (So and Getzels, 1988). Zoning regulations in ordinances can also specify details such as lighting and landscape requirements, including how much of the land must remain open or unimproved. Zoning can be effective for protecting certain noxious land uses from affecting other adjacent uses.

In addition to the types of development, zoning can also dictate how much development can occur. It is hard for a locality to envision its future density and plan for it when the land is currently undeveloped. Governments and residents may desire to protect the undeveloped, open land and associated rural character, thinking that zoning will work to achieve that protection.

Sprawl may happen quickly and then it is too late to adjust the zoning ordinance accordingly. One response to rapid development is to increase the lot sizes required for development in the zoning ordinance. The intent is to keep lots larger in order to keep more land visually open. However, this type of zoning uses more land more quickly and mostly for only one-home residential parcels that do not leave land open for agriculture, wildlife, and other rural and recreational uses (Lacy, 1992).

In response to the difficulty of envisioning a developed future, planners have a tool available to help them illustrate to the community the anticipated growth that a zoning ordinance allows. Build-out analysis is this tool. After using build-out analysis, a community can see if its vision for the future can be achieved with current regulations.

Build-Out Analysis

A build-out analysis is an impact assessment of the current zoning criteria of a locality. Localities can use the analysis as a snapshot, worse-case scenario tool for planning. The build-out analysis can assist local governments by showing what growth the locality will allow in the future under current zoning designations. Localities can use the information generated in a build-out analysis to estimate the financial effects on government services and infrastructure that will be required to meet the growth demands.

A build-out analysis works using existing zoning criteria and applies these criteria to individual undeveloped or under-developed parcels. The analysis illustrates the number of buildings or units that can be built in each zoning district in a locality in the future. Population figures and other subsequent estimates can be derived from the number of potential units.

Planners and others can do build-out analyses for all zoning designations in a locality, including residential, commercial, industrial, business, agricultural, preservation and others as defined from the zoning ordinance. Some analyses go so far as to illustrate possible building placement and footprints on each parcel to help visualize expected design when more than one structure can be built on a given parcel or in a development.

Build-out analysis is a two-phase process, a spatial, or visual, phase and a numeric phase. Analysts can conduct these by hand or by computer. Analyses done by hand use hand-drawn overlays and mathematical calculations. Analyses conducted by computer use GIS software to complete the visual phase, and spreadsheets or other computational software to conduct the mathematic phase. (However, some mathematical functions can be done in the GIS.) When done by computer, the first part of the analysis uses digital data layers to create overlays, like the overlays done by hand. The second part uses mathematical formulas and tables generated from the first part to derive actual numbers of building units. I present details of this computer process in the Methodology and Data section.

One important factor to note in build-out analysis is that time does not need to be a factor. The future of a community is shown in the analyses. This future can be an agreed-upon estimate based on tested demographic projections or this future may be the furthest point in time when a community has achieved its maximum size but is still the same geographic entity, hence build out. Analyses can be done for established points in time as decided by those involved in the process. For some communities, it is helpful to mark milestones in time such as 5, 20, and 50 years and at complete community development (Lacy, 1992).

Brief History of Build-Out Analysis

Build-out analysis is a relatively new technical term for "cumulative impact assessment" (Kaiser, et al, 1995). This type of assessment uses an aggregation of different data overlaid one upon another to produce a multi-layered, composite image. Build-out can work the same way or can produce a reduced image left by subtracting different overlays. The result is the same in either technique, that being the quantifiable, numeric measurement of the impact of an action or set of actions in a defined area.

The initial work on build-out analysis is the Manual of Build-Out Analysis from the Center for Rural Massachusetts. This document describes the steps to create manual individual overlays of information to produce "mapped and tabular information that shows visually what a landscape *could* look like, and numerically what the resulting population *could* be" (Lacy, 1992). This Manual clearly lays out this two-fold nature of build-out analysis and how to proceed.

Massachusetts is leading the way in the computerized process as well. The Massachusetts Executive Office of Environmental Affairs completed a statewide build-out analysis in 2002 and made it interactively available on the Internet for citizens to use in their communities (2002b). I base my build-out demonstration on the methodology laid out in this recent influential work.

Methodology for a Computer-Generated Build-Out Analysis

Build-out analyses can be as simple or as complex as a locality needs them to be. No matter the complexity, there are basic elements inherent to all. Zoning information forms the basis for any analysis. This information is available in the zoning designations and associated lot requirements found in the target zoning ordinance. The person doing the analysis needs the zoning maps that accompany the ordinance. Individual parcel information is also necessary. It is helpful if both the zoning and parcel information are available digitally for use in a GIS.

The analyst must know land use restrictions for each zoning district or overlay area. These may include floodplain development restrictions and guidelines; wetland regulations (assuming these differ from state and federal regulations); soil type limitations; slope development restrictions; the existence of conservation easements; and the presence of rare, threatened, endangered or sensitive species, if the locality has overlay restrictions.

The analyst will subtract all of the land use restrictions from the total amount of land available for construction on a given parcel. By reducing the amount of land available, a more realistic picture of development becomes clear. It is then possible to apply zoning lot requirements to this reduced land amount to estimate the number of buildings or units allowed on a parcel, given its unique parameters. The following discussion describes how to conduct a build-out analysis, in general.

Part I: Spatial Processes

1. *Determine locality needs.* Determine the needs of the locality for attempting a build-out analysis. Prioritize the factors to be assessed. Identify reasons for the analysis. For example, will the analysis illustrate effects on utility infrastructure, the increase in population, the number of additional school-age children, the total loss of agricultural land to residential development, or other effects?

2. *Define analysis area.* Decide which areas of the locality will be studied, or if the whole area of the locality is to be studied.

3. *Decide level of detail or scale.* Decide the level of detail (or scale) at which to conduct the analysis. There are detailed, moderate and coarse levels based on available parcel data, or based on time available to do the study, whichever is the more limiting factor (Amengual, 2001).

   The site-design level (micro scale) of analysis is the most detailed level and creates a site design for every parcel in the analysis area. This time-intensive exercise allows the analyst to generate a rough site plan for each parcel in order to account for actual physical constraints and zoning requirements. This level produces the most accurate numbers from which to draw conclusions.

   One could also undertake a more moderate approach (intermediate scale) for each parcel, which does not account for actual constraints. This approach estimates constraints using parameters that are applied equally across the study area. Although not as exact as the site design level of estimation, this approach may be realistic and technically accurate, given time and data availability. I describe in more detail and apply the moderate approach in this paper.

   The land use or zoning district level is the grossest level of build-out. When time and data do not permit either of the more "exact" techniques described above, this level of development estimation may suffice. This type of analysis is extremely dependent on the expected use of the products. The zoning district is most likely not specific enough to help a locality know where development can occur because all areas of the locality are combined into zoning districts, not area-specific parcels (Amengual, 2001).

Any of these levels of detail can be ultimately combined to produce an analysis at the regional or state level (macro scale). When this is done, build-out analysis can provide a broader view of planning for a wide range of constituents.

4. *Choose period.* Decide what period the analysis will illustrate. Will the analysis reflect incremental periods in a community's build-out, such as 10-year intervals, or will it illustrate the community at complete build-out?

5. *Choose multipliers.* Decide which numeric values to use in effect estimation. For example, what factor will the analyst use to estimate additional students; what are current costs to the locality for services that will be studied? The values determined here become multipliers once total units are estimated (Step 15).

6. *Collect supporting data layers.* Acquire the current zoning ordinance, zoning map, subdivision ordinance, and any overlay district ordinances such as those for flood or historic resources. If necessary, consider which zoning districts are applicable to the study and use only those. These features serve as the basis for what are constraints to development.

7. *Assemble parcel data.* Acquire parcel data. This can be an extremely detailed process if the data is not available digitally or accurately. In the absence of parcel data, a zoning district-level analysis may be the method of choice. Aerial photographs, hard copy parcel data and site visits may augment when digital data is not available. If so, it will take time for digitization.

Part II: Numeric Processes

8. *Determine gross parcel area.* Determine the physical area of the parcels in acres and/or square feet (gross buildable area). Most likely, square footage is the proper unit in which to work. If feet are used, multiply acreage by 43,560 feet to get square feet.

9. *Define constraints.* Determine the layers that are either absolute or partial constraints to development. Areas that are absolute constraints cannot be built upon. These constraints may include conservation easements or other land use restrictions. Areas of absolute constraint are removed totally from available gross buildable area and are not figured at all for development.

Partial constraints do not inhibit development on the whole parcel but reduce the amount of area by a percentage depending on the constraining factor and the percentage assigned to it (Massachusetts Executive Office of Environmental Affairs, 2002a). Partial constraint layers may be utility easements, natural factors including steep slopes, floodplains, or wetlands, or existing development and public ownership (Lacy, 1992).

10. *Determine how much land will be removed for each constraint.* Decide how much each partial constraint layer will reduce the area of the parcels. For example, the location of a floodplain on a parcel may remove a percentage of land from development, depending on local regulations. These constraint layers will differ according to locality regulations, individual parcel characteristics, and constraint layer characteristics.

11. *Subtract constraints from net area.* Subtract the estimated areas of constraint from the total amount initially determined available (Step 8) to get net buildable area, or potentially developable land, or net usable land area (Massachusetts Executive Office of Environmental Affairs, 2002a).

12. *Subtract zoning restrictions.* Apply zoning restrictions to each parcel, including minimum lot sizes, frontages, allowances for water and sewer and road rights of way, and any other development requirements. Availability of public facilities may be a determining factor in lot requirements.

13. *Determine units per parcel.* After removing the area for these requirements, divide the minimum lot area into the available land, i.e., net buildable area (I will illustrate this step below). The resulting number from this step is the number of units allowed per parcel.

14. *Sum units.* Sum the number of units for each parcel for all parcels to get total allowable units for the area that was defined in Step 2.

15. *Estimate effects.* Use the total unit number to estimate population, school-age children, potential tax revenue, per capita expenses for the locality, cost to provide services such as water and sewer, and many other fiscally-related estimates. Use the values from Step 5 to determine these estimates, which are the ultimate purpose of the analysis.

This process appears more complicated than it is without examples of what I mean. Therefore, I will next apply the process to Roanoke County to help clarify the steps.

Chapter 2: Build-Out Analysis Demonstration – Roanoke County, Virginia

Background Information and Demographics

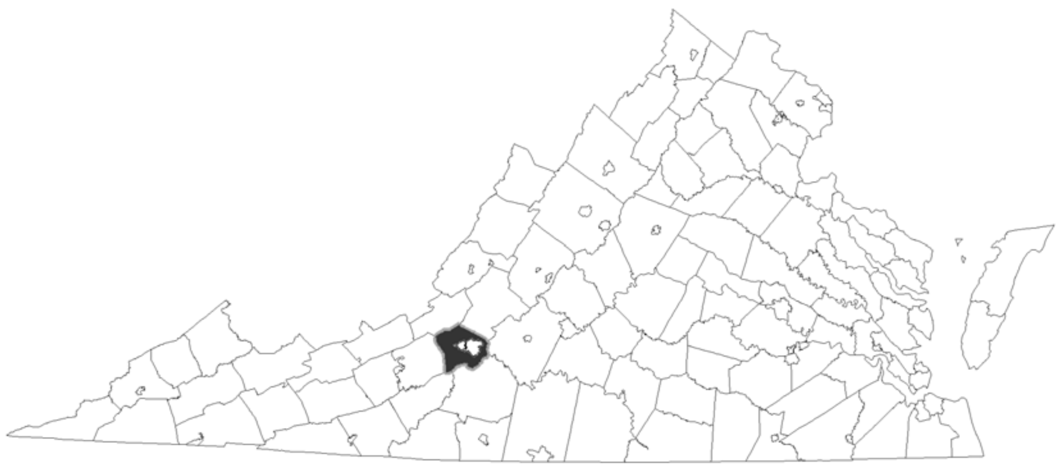


Figure 1: Roanoke County, Virginia (dark area)

Roanoke County is located in southwest Virginia, approximately 320 miles from the state capitol of Richmond, and 400 miles from Washington D.C. The County is comprised of 251 square miles, or 160,640 acres (United States, 2000).

There is one incorporated town within the boundaries of Roanoke County, the Town of Vinton. Roanoke County and Vinton share tax revenues and certain government services, yet operate with separate governing bodies.

The independent cities of Roanoke and Salem are also located within the County boundary. There is no revenue or service sharing agreement. The governments operate separately from one another.

There are five magisterial districts within the County. Each district has representation on the five-member Board of Supervisors. The Board is responsible for appointing the County Administrator, who oversees daily government operations, including County departments.

The Department of Community Development houses the Planning and Zoning Division, led by a Chief Planner. The division is responsible for carrying out duties that further the work laid out in the Community Plan and accompanying zoning ordinance. The division also provides expert guidance to the Administrator, Planning Commission and Board of Supervisors.

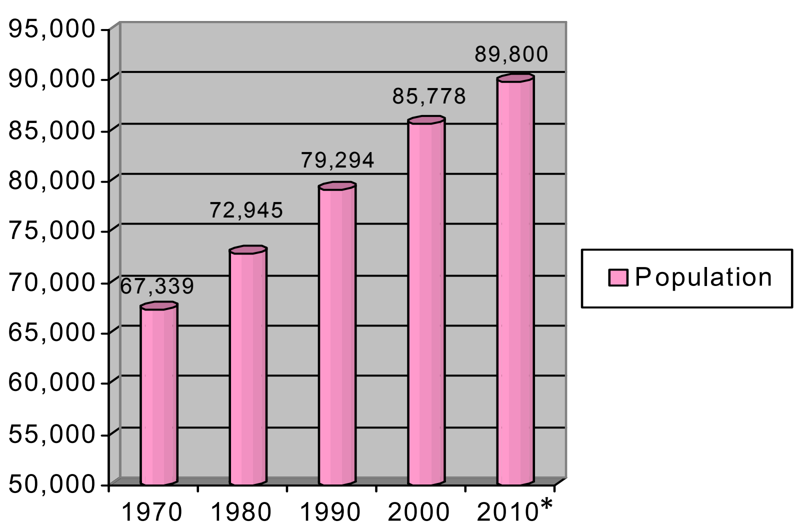
The 1998 Community Plan that guides the County envisioned goals to the year 2010. The citizen-based work for this Plan began in 1995 and culminated in the 1998 Plan. This Community Plan serves as the Comprehensive Plan for Roanoke County. It is due to be reviewed in 2003 as part of the five-year comprehensive plan review process mandated by Virginia statute § 15.2-2230 (Code of Virginia, accessed 2003).

The current Community Plan divides the county into 12 planning areas. Each of these areas has issues, concerns and goals specific to them. However, there are overarching goals for the county as a whole that came about in the citizen participation from 1995 to 1998. These goals are discussed later in this paper to illustrate the need for build-out analysis in Roanoke County.

The Planning Commission of Roanoke County is an integral part of the Community Plan implementation and any updates. This five-member group (corresponding to the five magisterial districts) is responsible for presenting and making recommendations for proposed changes to the Plan and other land use changes as they arise to the Board of Supervisors.

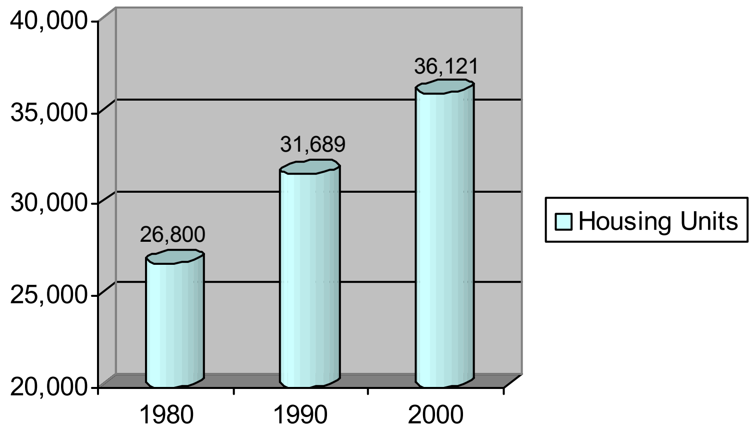
All of the entities discussed above work in conjunction to help the County and its citizens prepare for the future. At present, population figures from 1970 to 2010 indicate a trend for steady growth in the future of Roanoke County (Figure 2, compiled from Weldon Cooper, 2003b and * Virginia Employment Commission, 2003.) Housing unit construction is also rising steadily in response to population growth (Figure 3, compiled from Weldon Cooper, 2003b and United States Census, 2000).

Figure 2: Population Figures for Roanoke County, 1970-2010



The citizens of Roanoke County recognize the need for preparing for the County's future. Residents are concerned about the specters of rampant growth and poorly-planned development. The 1998 Community Plan set high goals from citizen comments relating to growth and development, as excerpted below.

Figure 3: Housing Unit Figures for Roanoke County, 1980-2000



- Encourage the development and re-development of lands served by public utilities while discouraging through zoning ordinance revisions the development of lands without these services.

- Act proactively to manage growth. Encourage and direct growth toward those areas of the County that can support it with the appropriate and necessary infrastructure, facilities and services and discourage development where the infrastructure and transportation system cannot support it.

- Encourage land use development patterns that reflect community values and desires. Discourage land consumptive development patterns.

- Recognize that in order to discourage sprawl and protect rural lands and natural resources, some reasonable increase in housing density may be necessary as infill development and re-development occurs.

- Recognize the impact that large residential developments have on community facilities, including schools, parks and police and fire services. Consider the use of impact fees and proffers to offset some of these costs.

- Prevent or discourage land development that will destroy the County's valuable natural resources including ridgelines, mountains, floodplains, wetlands, scenic vistas and water quality. Develop incentives that will make this policy more palatable.

- Use creative and flexible site design techniques to protect natural resources while allowing reasonable densities.

- Recognize that County citizens desire and support economic growth, even in close proximity to their neighborhoods, when the developments are carefully designed, the buildings have aesthetically pleasing and site appropriate architecture, and creative site design elements that are sensitive to surrounding neighborhoods, are utilized.

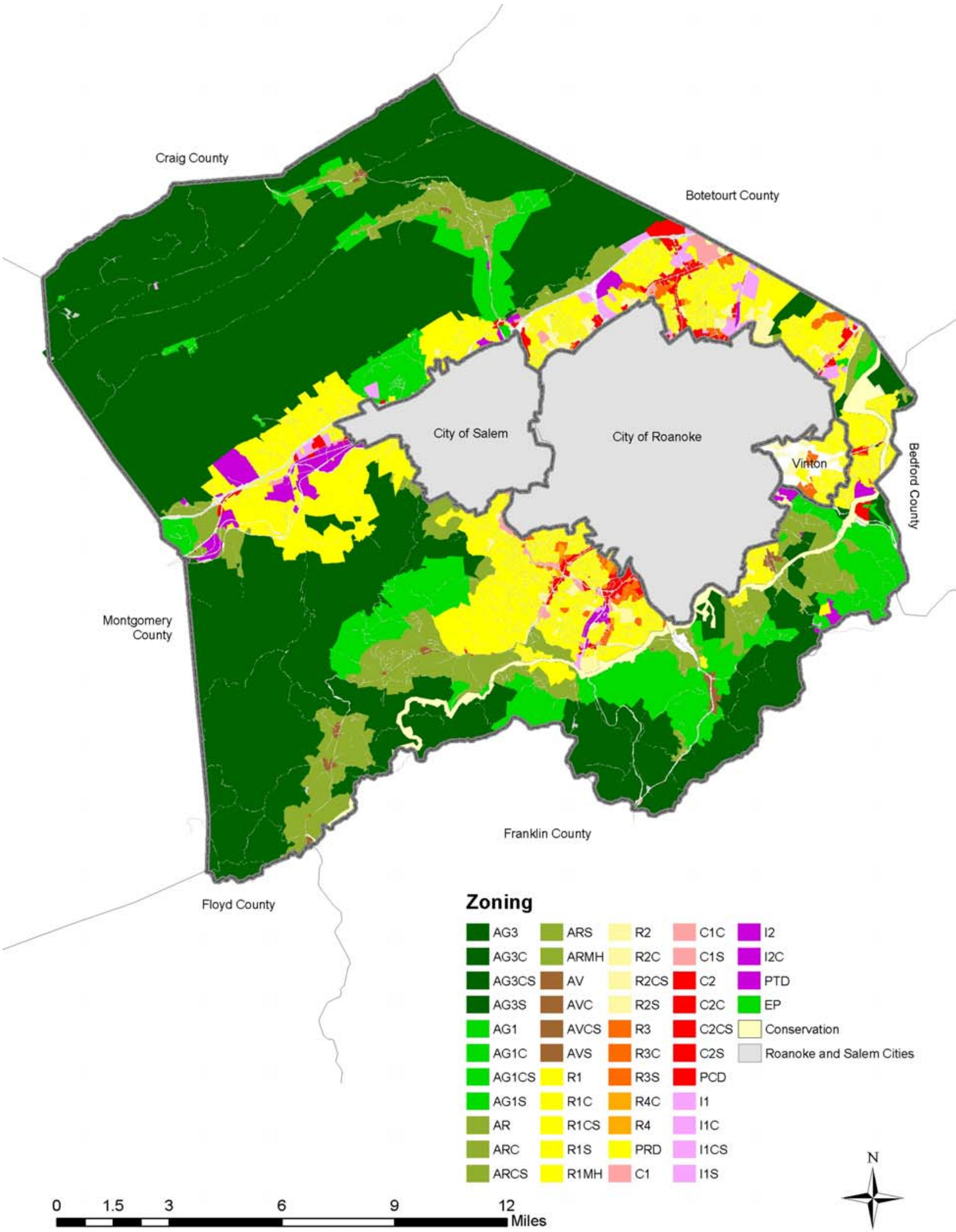
- Recognize that the scenic beauty of the Roanoke County area is an essential ingredient in the tourist experience. Support efforts to preserve and protect these valuable natural resource features.

The primary tool for achieving many of these goals is the zoning ordinance. There are 25 zoning districts in the 1992 Zoning Ordinance. These include the standard district designations for residential, commercial, industrial and agriculture as well as numerous overlay districts to supplement the standard zones (Figure 4).

Build-out analysis can be employed as a technique in Roanoke County to examine in detail how the zoning ordinance may affect the above goals and vision. Roanoke County has specific needs in using the data generated in a build-out analysis. The County is most interested in the impact of residential development within the R-1 and R-2 zoning districts, not in commercial, industrial or any agricultural districts at this time.

The result of quantifying the impact of development in Roanoke County is to understand the effects this added development will have on the costs of providing water and sewer infrastructure, school capacity and road capacity associated with residential development. To meet this end, the build-out analysis I conducted is a scaled-down version of the analysis methodology I described in Chapter 1 but follows the same sequential steps using the parcel-level, moderate estimation method. Specific instructions for how to complete the analysis in ArcGIS 8.1 are included as the Appendix.

Figure 4: Roanoke County Zoning (1992)



Applying Build-Out Methodology to Roanoke County

Assumptions for a Build-Out Analysis for Roanoke County

I apply a number of assumptions in my analysis for Roanoke County. The assumptions are described in the following paragraphs, as well as in subsequent discussions.

Level of Detail

I analyzed only low density (R-1) and medium density (R-2) residential districts, which entails only single-family houses. My work illustrates only development allowed by right, or what could occur without special use permits, variances or adjacent lot assemblage. There is too much conjecture required to estimate what special use permits or variances would be applied for by developers so I do not consider these here.

I am conducting a moderate parcel-level analysis, not a site-design level analysis because of time constraints. Therefore, I do not consider actual lot road frontage required for each development at this time, or specific building footprints or placement. However, the 25% estimation method I will discuss in the specific formula section does factor in the minimum 60-foot road frontage requirement of the R-1 and R-2 zoning districts.

Time

Time intervals are not considered. I conducted the analysis for complete build-out with no assumption of when that may be. My analysis illustrates complete build-out as opposed to an incremental analysis at defined time intervals. I am not able to determine when development will occur because that is dependent on many factors, primarily personal choice and economic growth, which I do not take into consideration here. However, the ultimate date of build-out can be roughly estimated and I do so in the conclusion section for Roanoke County.

The parcel data used is from December 31, 2002. I arbitrarily chose a time to provide a snapshot of development for only that point in time. The County could use updated databases as they become available. As new developments occur, the real estate database should reflect the removal of developable land.

Multipliers

Multipliers for my analysis come from existing sources. I estimated additional public school students by applying a multiplier of 0.665 to estimated housing units (Burchell, et al, 1994). The average household size from the 2000 Census is 2.41 people (United States). The cost to the County for installing public water and sewer is $4,690 per unit (Scheid, 2003). Some of this cost is passed to the developer or owner.

Constraints Considered but not Included

My analysis is a worst-case scenario of development in the future; therefore, I have considered very little to be constraints to development. Since the County is primarily interested in the effects of development in zoning districts R-1 and R-2, land not zoned as such was not included in my analysis. Industrial and commercial zoning, multi-family residential zoning, all agricultural zoning districts, conservation easements, and publicly-held lands including federal, state and local lands, were not included (Figure 5).

In addition to the R-1 and R-2 tailoring, I modified other aspects of a typical build-out analysis described in Chapter 2 as it relates to land use restrictions. Roanoke County is in a unique position in relation to floodplains and steep slopes. Floodplains are not constraints in the county because they are often wide and can be built in with certain provisions as described in the "Floodplain Overlay District" of the zoning ordinance (Scheid, 2003). Regulations exist but do not often apply. Under the regulations, landowners can build on the floodway fringe but not in the floodway.

In reference to slope, even though there are areas in the county that can be classified as "steep slopes," these areas can still be built upon with current road and building technology. The proper equipment can overcome road construction obstacles, the greatest deterrent to developing these lands (Scheid, 2003). In reality, however, areas of steep slope may not be developed to the maximum extent possible as in less steep areas. I did not reduce the amount of development allowed in steep slope areas, as one should in build-out analysis, since I did not identify these areas.

Other land-use restrictions such as soil, wetlands and sensitive species are not prohibitions to construction in Roanoke County for the following reasons. All soils in the county are suitable for development and are therefore not limiting. An area may not be suitable for on-site sewer systems, but public water and sewer could ultimately service it. Proper construction techniques can mitigate soil erosion on steep slopes. Section 404 of the Clean Water Act provides regulation for wetlands through the Army Corps of Engineers. The County relies on these regulations and permit processes without its own additional overlay zoning. As far as rare plant and animal species are concerned, the County has no additional protection beyond federal laws, which do not inhibit private development, generally speaking.

Proximity to existing public water and sewer is not a factor. I assumed public sewer and water would be available in order to use the minimum lot size of 7,200 square feet.

Constraints to Development in Roanoke County

Two factors are constraints to development in Roanoke County. Existing development and zoning are the two constraints I address in my demonstration. Areas already developed are constraints because no additional development can occur while the current structures exist. Zoning is a constraint because it separates the types and amounts of development allowed in given zoning districts.

In addition to these two constraints, I separated parcels into two divisions, vacant and underutilized, and performed the build-out analysis for both. I used a minimum acreage cut-off for each division. For vacant parcels, the minimum acreage I included in the analysis was greater than two acres. The two-acre vacant lot minimum is an arbitrary figure. Lots two acres and smaller in size are not included in the analysis. Two acres can accommodate approximately 10 units. There are approximately 3,856 parcels that are two acres or smaller, which could produce 9,804 units. These units are not counted in this analysis.

I defined "underutilized" as parcels not developed to their full potential, based on acreage. I applied this definition to parcels with an existing building on five or more acres for minimum acreage. The major difference in estimating development for the two divisions is that I subtracted one acre from the 5-acre built parcels to account for existing structures and ingress/egress before estimating the number of allowed units. One acre is an arbitrary figure. The vacant and underutilized parcels became "developable land" (Figure 6).

Figure 5: R-1 and R-2 Zoning Districts in Roanoke County

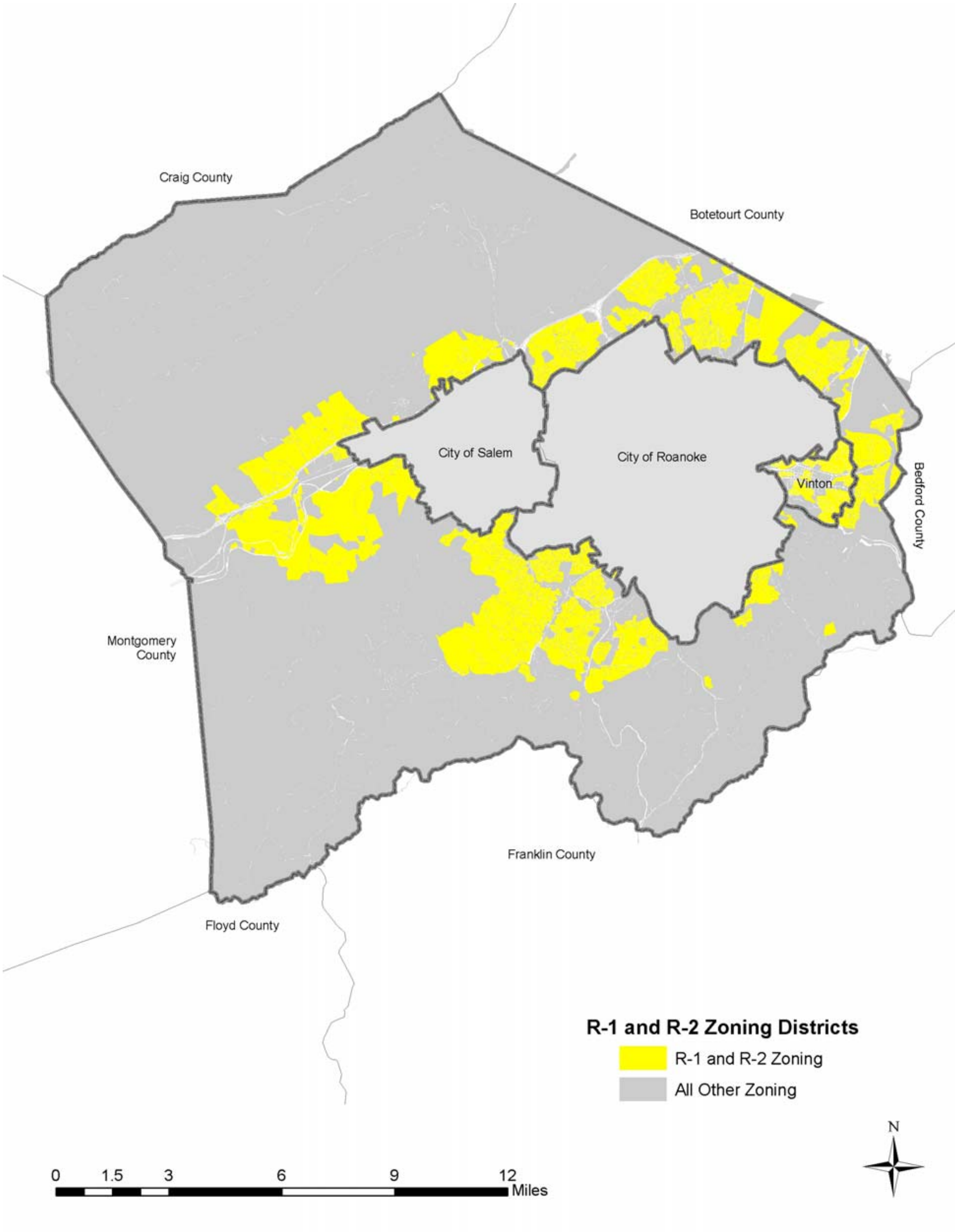
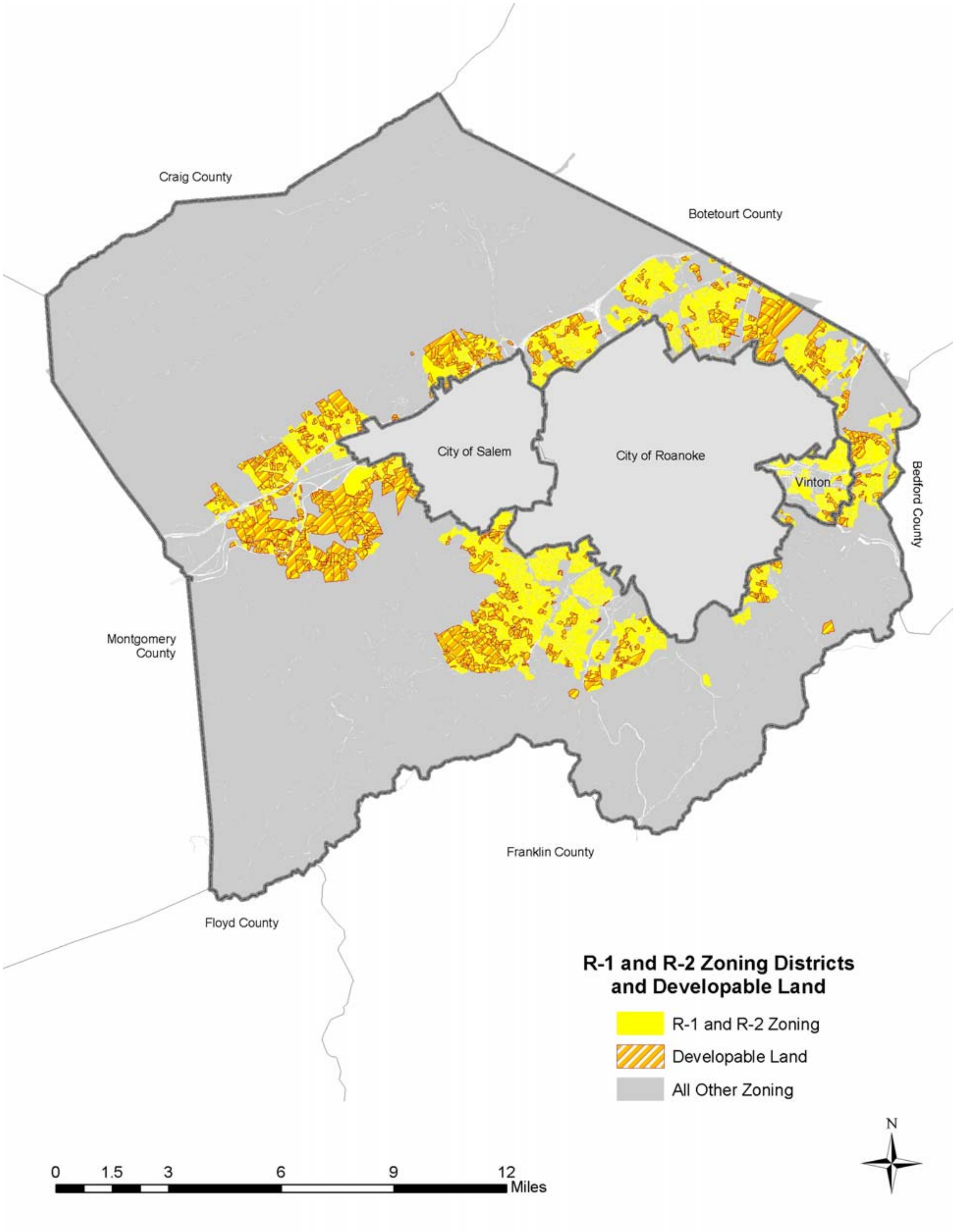


Figure 6: Developable Land Zoned R-1 and R-2 in Roanoke County



Specific Formulas

Determining Net Lot Area Available for Development

I used the minimum lot size allowed by the County zoning ordinance under the assumption that public water and sewer would be available in order to achieve the greatest building density. The minimum size for parcels in R-1 and R-2 is 7,200 square feet with 60 feet of frontage on publicly owned and maintained roads (Roanoke County Zoning Ordinance, 1992). It is hard to determine the road frontage aspect at this time by speculating the location of future roads in areas not yet developed. The second formula I use below should account for this as well as odd lots. I converted the calculated acreage received from the County real estate database into square footage by multiplying the acreage by 43,560 feet to get gross developable area.

Area Reduction Factors

After estimating the amount of gross area available on a parcel, I determined the amount of area to subtract for roads, stormwater management and, in a second formula iteration, odd lot sizes. As part of determining the available land estimate, I subtracted one acre for existing structures on underutilized parcels five acres or greater.

I generated two housing unit estimates from different area reduction methods for the above factors. The first estimate only accounted for the removal of land for roads and stormwater management. I used the number **17.5%** for these two factors because it was an average of 15% and 20%, a range currently used by the Roanoke County Department of Planning (Scheid, 2003).

The second estimate accounted for roads and sewer and water, as well as the removal of land due to odd lots and included the more specific road width right-of-way requirement. This second estimation method was adapted from the 2002 Massachusetts build-out example, which used 10% for odd lot sizes and a specific right-of-way figure. I tailored the Massachusetts formula to Roanoke County by using an average road right-of-way of 44 feet (VDOT, 1996), the County's 60-foot lot width requirement and 7,200 square foot minimum lot size. In this second formula, I removed **25%** from available parcel area, creating an amount that was approximately 8% more conservative than the first estimate, which did not account for specific lot requirements or odd lots. The second formula used to generate the percent of land to remove was:

a) 22 [1/2 of VDOT 44-foot road right-of-way] x 60 [zoning road frontage requirement] = 1,320 feet

b) 1,320 + 7,200 [lot size for zoning districts] = 8,520 feet

c) **1,320 / 8,520 = 15.5% + 10% [odd lots] = 25% rounded multiplier for second iteration**

Having estimated the overall area available for development, I estimated the area remaining after removing 17.5% and 25% of land for infrastructure and odd lots that may occur. I did this with the following formulas:

1) Gross buildable square footage area – 17.5%
   or
   Gross buildable square footage area x 0.825 [100 – 17.5 = 82.5]
2) Gross buildable square footage area – 25%
   or
   Gross buildable square footage area x 0.75 [100 – 25 = 75]

Generating Unit Estimates

I then used the figures generated from the above formulas for each parcel and divided each figure by 7,200 square feet for the two zoning district requirements to estimate the number of units allowed on each parcel. The number of units that resulted is the basis for all other estimates including water and sewer demand, school attendance and vehicle trips.

To illustrate, using the first estimation method, the calculations for a ten-acre, vacant parcel would be:

1. Gross square footage available: 10 acres x 43,560 feet = 435,600 square feet
2. Net square footage available: 435,600 – 17.5% [or 435,600 x 0.825] = 359,370
3. Number of units: 359,370 / 7,200 = **49.9 units**

Using the second, slightly more specific, method, the calculations for a ten-acre, vacant parcel would be:

1. Gross square footage available: 10 acres x 43,560 feet = 435,600 square feet
2. Net square footage available: 435,600 – 25% [or 435,600 x 0.75] = 326,700
3. Number of units: 326,700 / 7,200 = **45.2 units**

The same calculations would apply for a parcel of five acres or more that is not vacant. However, to follow my methodology, one should subtract 43,560 square feet from the number generated in the first step (gross buildable area) for existing buildings and access. I applied this methodology to the Roanoke County build-out analysis and describe details below. The estimates generated from this analysis are summarized in Table 1 on the following page.

Applying Formulas to Get Estimates for Roanoke County

New Housing Unit Estimates

Using the above calculation for Roanoke County, the total numbers of new lots, or single-family building units, are:

17.5% Reduction	
From vacant lots larger than 2 acres	28,138
From 5 acre or larger lots with a building	19,746
Total Units or New Lots Allowed	**47,884**
25% Reduction	
From vacant lots larger than 2 acres	25,568
From 5 acre or larger lots with a building	17,948
Total Units or New Lots Allowed	**43,516**

Table 1: Summary of Build-Out Analysis Results

Acres Available For Development	9,914
HOUSING UNITS	
Total at 17.5%	47,884
Total at 25%	43,516
POPULATION (units x 2.41)	
Total at 17.5%	115,400
Total at 25%	104,874
STUDENTS (units x 0.665)	
Total at 17.5%	31,843
Total at 25%	28,938
STUDENT COSTS (students x $3,784)	
Total at 17.5%	$120,493,382
Total at 25%	$109,501,922
WATER & SEWER COSTS (units x $4,690)	
Total at 17.5%	$224,575,960
Total at 25%	$204,090,040
VEHICLE TRIPS (units x 10)	
Total at 17.5%	478,840
Total at 25%	435,160

Population Estimate

The number of new single-family housing units forms the basis for population estimates as well as school-age children. The 2000 Census offers an average number of persons per household of 2.41, which is the multiplier I used to estimate population (United States, 2003). For the new housing estimate of 47,884 units, the population estimate is **115,400** people. For the new housing estimate of 43,516 units, the resulting population estimate is **104,874** people.

Public School Student Estimation

The method used to estimate the future additional students in the public school system is to apply a multiplier to the number of estimated units. I used the multiplier suggested by Burchell, et al (1994) of 0.665 children ages 5-18 per 3-bedroom single-family unit. With this multiplier, the addition of 47,884 or 43,516 units would theoretically generate **31,843** and **28,938** children ages 5-18. I discuss the increased costs to the County in "Effects to Roanoke County Resources".

Comparing demographic multipliers specific to Roanoke County can generate student multipliers that are more "precise" when compared with actual historical numbers. Such a multiplier has not been developed for the County so the use of this technique is beyond the scope of this paper. An ideal method of estimation would be to determine the number of students actually added by a new development project and apply these actual numbers to other proposed development.

Public Water and Sewer Demand Estimation

Water and sewer infrastructure effects will result from the estimated number of new housing units, 47,884 or 43,516. These estimates have direct cost implications to Roanoke County and I discuss them in the "Effects to Roanoke County Resources" section that follows.

Vehicle Trip Generation Estimate

As with the other above estimates, I determined the number of vehicle trips generated per day from the basic estimation of housing units. A standard formula used by Roanoke County to estimate daily trips is to multiply the number of new units by 10 vehicle trips (VT) (Scheid, 2003).

The total numbers of vehicle trips per day for the potential additional units in Roanoke County are as follows:

17.5% Reduction	
From vacant lots larger than 2 acres	281,380
From 5 acre or larger lots with a building	197,460
Total Additional Vehicle Trips	**478,840**
25% Reduction	
From vacant lots larger than 2 acres	255,680
From 5 acre or larger lots with a building	179 480
Total Additional Vehicle Trips	**435,160**

Effects on Roanoke County Resources

I measured the effects to Roanoke County for both the 17.5% estimation method and the 25% estimation method in order to show differing scenarios in more detail. Table 2 summarizes significant increases in housing units, population, and student numbers and student education costs predicted at build-out for the 17.5% reduction method, the estimate method used by the County. These values can be added to current known numbers (2000-2003) for the entire county to produce future estimates at build-out.

Table 2: Comparison of Current and Future Figures from the Build-Out Analysis

HOUSING UNITS	
2000	36,121
Total at Build-out (17.5%)	84,005
POPULATION	
2000 (United States, 2003)	85,778
Total at Build-out (17.5%)	201,178
STUDENTS	
2003	14,009
Total at Build-out (17.5%)	45,852
STUDENT COSTS TO COUNTY	
2003	$52,311,049
Total at Build-out (17.5%)	$172,804,431
WATER AND SEWER USAGE	
2001 (gallons/day)	4,966,488
Total at Build-out (17.5%)	12,432,740

Estimates for water and sewer costs, and vehicle trips were included in Table 1. Current total County expenditures for new water and sewer are known only on a per-unit basis, thus, they are not quantified by cost in Table 2. I do not know actual countywide vehicle trips at this time in order to produce future totals in the table.

<u>Housing Unit and Population Estimates</u>

The estimated increase in housing units and population will create the need for additional public services such as fire, rescue and police protection, recreational opportunities, libraries, the judicial system, and health and welfare in those areas most affected by proposed development. Table 3 shows current costs to the County (Roanoke County, 2001). Applying per capita costs to population figures produces the large numbers shown in the table (2001 dollars). The per capita costs will be higher at build-out, given future inflation and other factors.

The build-out analysis illustrates three key areas likely to experience the most growth in the County. These are west county (Catawba Magisterial District), south county (Windsor Hills and Cave Spring Magisterial Districts), and northeast (Hollins Magisterial District) (Figure 7).

Figure 7: Developable Land by Magisterial District

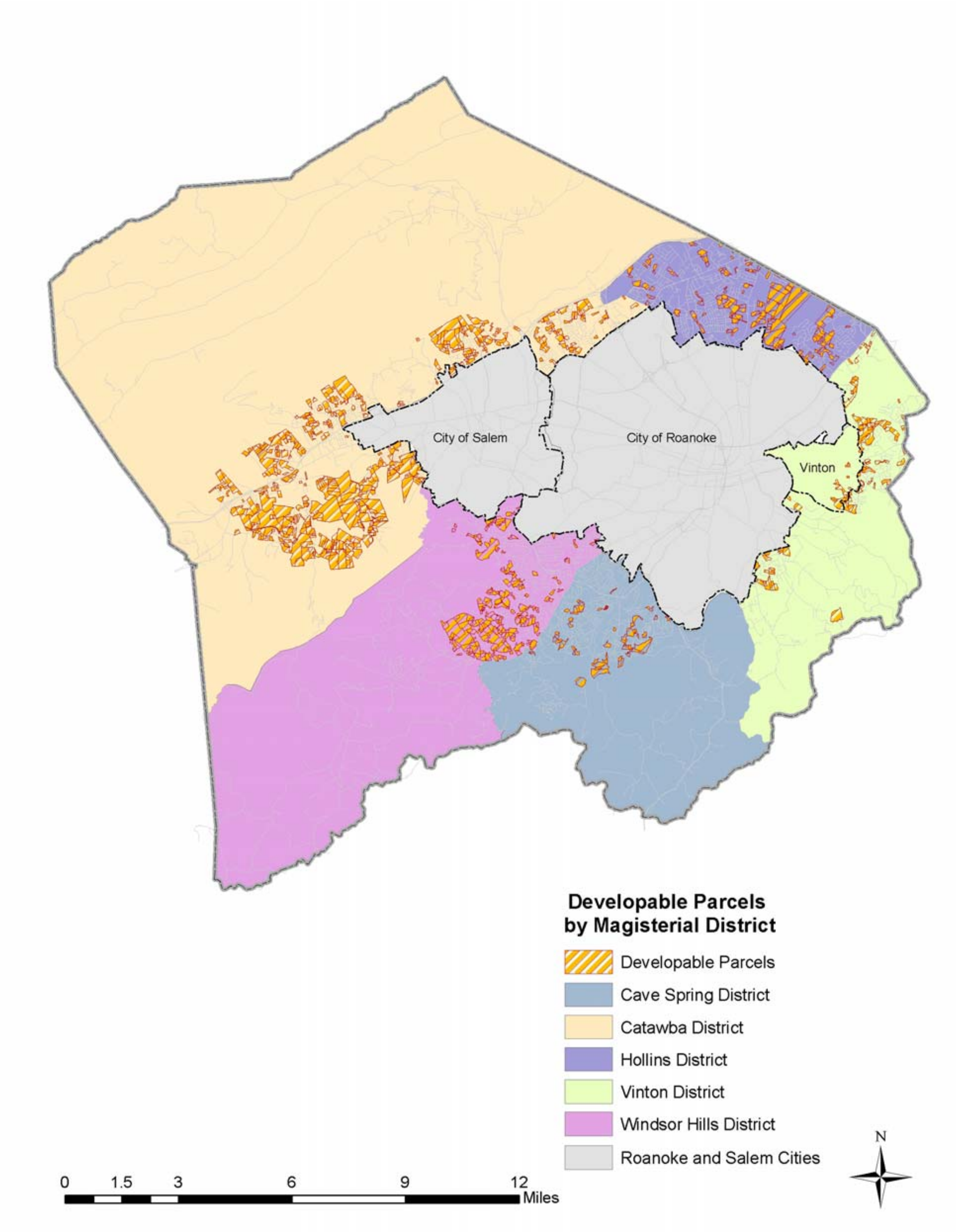


Table 3. Expenditures (2001) by Roanoke County Government Applied to Current and Future Populations

Service	Per Capita Expenditure	2000 Population	Build-Out Population Only (17.5%)	Total Build-Out Population (2000 + 17.5% BO)
		85,778	115,400	201,178
Community Development	$20	$1,715,560	$2,308,000	$4,023,560
Education	$1,151	$98,730,478	$132,825,400	$231,555,878
General Gov't Administration	$66	$5,661,348	$7,616,400	$13,277,748
Health & Welfare	$118	$10,121,804	$13,617,200	$23,739,004
Judicial	$33	$2,830,674	$3,808,200	$6,638,874
Parks, Recreation, & Cultural	$61	$5,232,458	$7,039,400	$12,271,858
Public Safety	$264	$22,645,392	$30,465,600	$53,110,992
Public Works	$134	$11,494,252	$15,463,600	$26,957,852
Total Expenditures	**$1,847**	**$158,431,966**	**$213,143,800**	**$371,575,766**

Additional housing units will also generate additional tax revenue from real estate taxes, personal property taxes, utility license taxes, and phone and cable service taxes. I do not estimate projected revenue from property taxes because I do not estimate the property value of the potential housing units or number of additional vehicles per unit. The current real estate tax rate in the County is $1.12/$100. The current vehicle license tax is $20 per vehicle (Roanoke County, 2001). These rates can be applied to the projected home values and vehicle-per-household estimates if these figures become available, perhaps from known average values. Utility, phone and cable taxes are dependent on personal preference and related to the number of these resources present at each property. It is difficult to estimate the potential tax revenues from these sources with limited data.

School Enrollment – Costs and Physical Capacity

The per-unit multiplier of 0.665 children per unit (discussed in the previous estimate section) generates numbers of children between ages 5 and 18. For this paper, I will assume all additional children would be in the public school system, not enrolled in private schools or home schooled.

Public education costs per student are readily available. For 2001-2002, the total education cost per student was $7,100, of which the County paid $3,784 (53%) (Roanoke County Schools, 2003). Applying this amount to the new student numbers (31,843 and 28,938), the total annual additional cost in 2003 dollars would be $266,084,306 and $205,460,794. Of this total cost, additional cost to the County would be **$120,493,382** and **$109,501,922** (2003 dollars).

The 27 schools in Roanoke County (not including the regional Career Center) have a total enrollment of 14,291 students from January 2003 (Roanoke County Schools). The total capacity for these schools is 13,358. The difference between these numbers indicates schools are 933 students over capacity at this time. The problem of over capacity in the schools will intensify over time. I was not able to assign estimated student numbers to specific education levels due to overlap in middle and high school attendance zones with elementary schools. Therefore, I grouped estimated numbers by elementary school zones, which are unique, in Table 4.

Table 4: Number of New Students at Build-Out in Roanoke County by Elementary School Zone

	New Students at Build-out	
Elementary School Zone	**17.5%**	**25%**
Glenvar	12,811	10,495
Back Creek	2,873	2,415
Bonsack	2,590	2,003
Fort Lewis	2,606	2,067
Mountain View	2,091	1,722
Glen Cove	2,030	1,663
Cave Spring	1,476	1,226
W.E. Cundiff	1,369	1,075
Penn Forest	1,263	986
Oak Grove	959	816
Mount Pleasant	676	585
Burlington	570	487
Herman L. Horn	308	253
Mason's Cove	118	92
Green Valley	10	7
Clearbrook	0	0
Bent Mountain	0	0

The potential for growth is not evenly distributed. This growth would burden certain school districts more (this analysis does not take into account proposed redistricting scenarios). Glenvar Elementary School zone in west county would be most affected by growth, and could have 12,811 or 10,495 additional students at complete build-out. Roanoke County school zones would experience increases in student numbers as shown in Table 4. Figure 8 visually represents these increased numbers by elementary school zone. Conversely, Clearbrook and Bent Mountain Elementary School zones would have no increase in student numbers at build-out.

Public Water and Sewer Demand

The estimated numbers of new units in Roanoke County discussed in the "New Housing Unit Estimate" section would generate the need for additional water and sewer infrastructure. The current per-unit cost to the County to provide water and sewer is $4,690, with $2,690 used for water and $2,000 for sewer (Scheid, 2003). For 47,884 units, this translates to a cost of **$224,575,960** for the County. Using the 25% reduction estimate, 43,516 units would cost the County **$204,090,040** for water and sewer at buildout. All figures are in 2003 dollars.

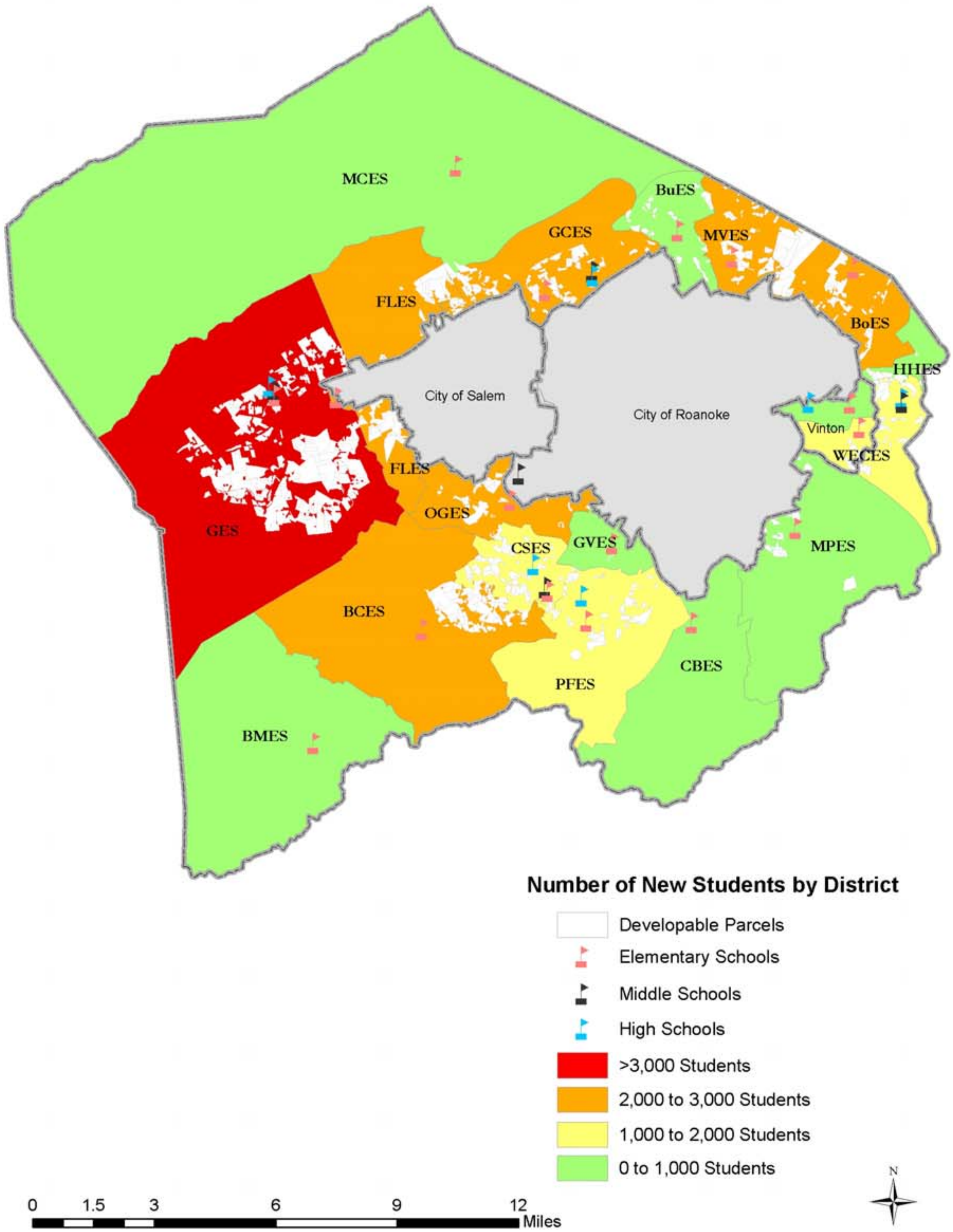
Current average daily water and sewer use in residential units is 148 gallons per unit, or 5,345,908 gallons per day for the 36,121 units in the county (Roanoke County, 2001). Applying the gallon/unit figure to the number of new units indicates an estimated usage of **7,086,832** gallons per day for the new units alone and **12,432,740** gallons per day for all units in the county at build out.

Additional water and sewer demand will also produce the need for additional treatment plants. Appropriate sites will need to be selected, purchased, developed, and maintained, adding further cost to the County. I do not quantify these costs here.

Vehicle Trip Generation and Road Capacity

The vehicle trip generation figures produced by the build-out analysis can be applied to road capacity. In order to do this, one must know what roads will be accepting additional vehicle trips. This is a tedious process if there are many primary, secondary and local roads in the traffic system because vehicle estimates must be obtained for all roads affected by growth in areas served by the system.

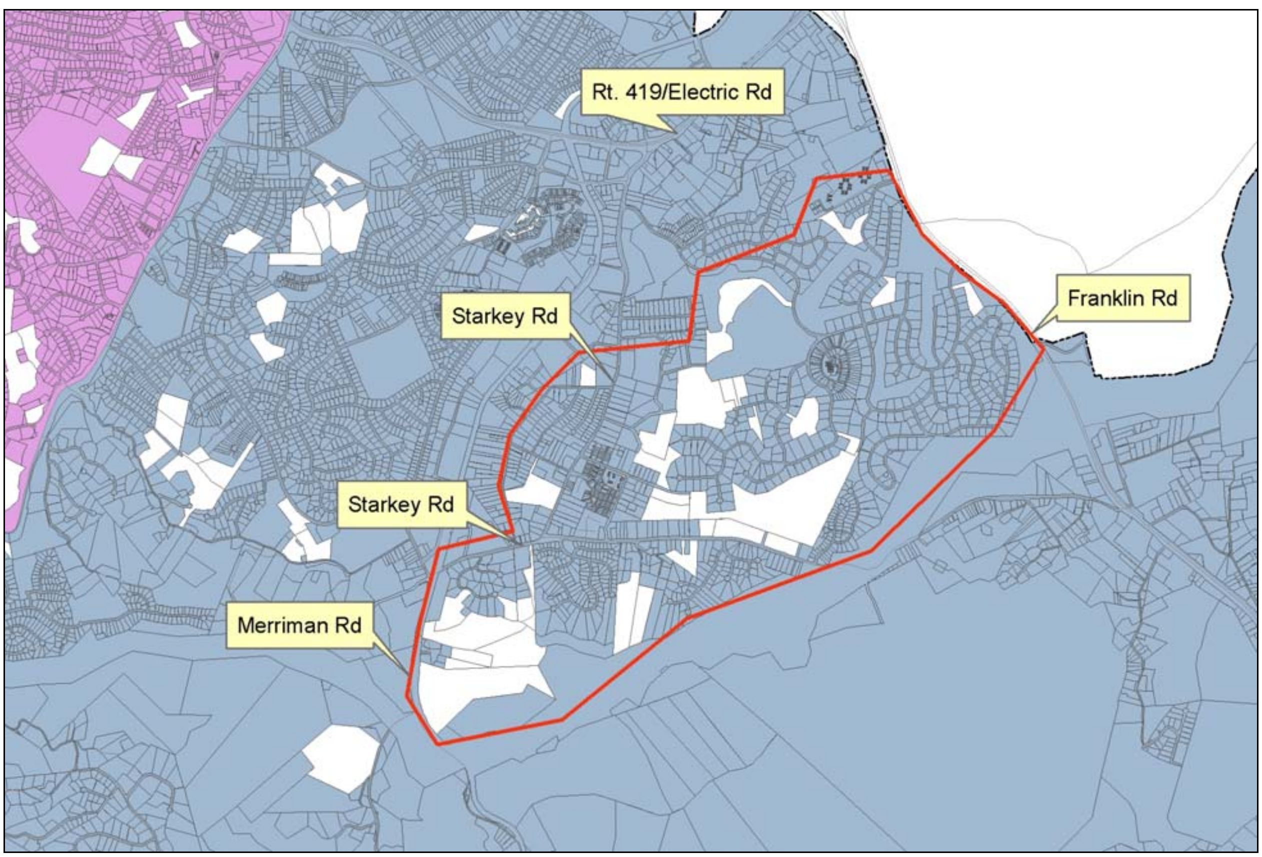
Figure 8: Developable Land and the Number of New Students by Elementary School Zone



Other factors contribute to determining road capacity. These factors include level of service and construction issues. There is consequently no set formula for determining road capacity (Varney, 2003). Due to the multi-faceted nature of estimating road capacity, I have not conducted a full road capacity analysis for the entire county to draw accurate capacity conclusions.

However, as an example, I have compiled the number of additional vehicle trips in one southern section of the county to illustrate the first step in road capacity formulation. The graphic below (Figure 9) is from the Cave Spring Magisterial District. The area within the red line delineates developable parcels (in white) bounded by Merriman, Starkey, Electric (Route 419), and Franklin roads. For this example, I am assuming that most of the parcels will be accessing Electric Road via Starkey Road. The number of housing units estimated at build-out within this defined area is 1,448. Using the factor of 10 vehicle trips per unit per day, these units could generate 14,480 vehicle trips per day. This amount would add exponentially when vehicles from other developments ultimately reach Electric Road/Route 419, which is already a heavily traveled, major thoroughfare within the county.

Figure 9: Example Area Defined for Determining New Housing Units for Road Capacity



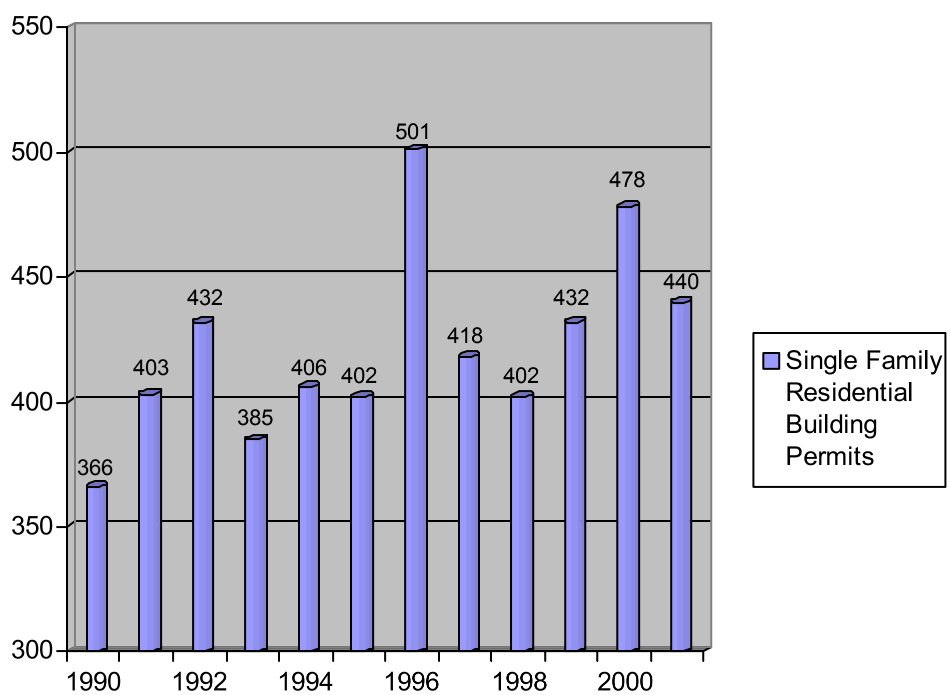
Quantifying the effects of additional development in Roanoke County is useful in planning for future infrastructure and public services, as discussed previously. However, such an exercise is merely academic without understanding if the process truly works when factors change. A sensitivity analysis using different development factors can measure the responsiveness of the analysis to changes in zoning ordinances and development regulations. The sensitivity analysis for this demonstration is located on page 42, following the conclusions and recommendations section.

Conclusions for Roanoke County

Roanoke County is ripe for development, not only in residentially-zoned areas but also in agriculturally-zoned districts. I believe, in its current form, that the zoning ordinance can achieve most of the goals of the Community Plan listed previously in zoning districts R-1 and R-2. This assumes no further re-zonings in other districts to R-1 or R-2, or utilization only of lands currently included in these two zoning districts.

Trends in single-family residential building permits over the last decade indicate a fluctuating pattern of steady growth (Figure 10) (Weldon Cooper Center, 2003a). The number of permits over this time range from a low of 366 in 1990 to a high of 501 in 1996. For that period, there were 5,072 permits for an average of 423 per year. Following this trend, future housing growth in Roanoke County should continue to increase with occasional dips and swells that relatively correspond to market pressure. In the document, I estimate approximately 45,000 new units (an approximation between 47,884 and 43,516) must be added to reach complete build-out. If 423 units are added each year based on the current trend, build-out will be achieved in 106 years (45,000 units/423 units per year = 106 years). This number supports my belief that Roanoke County can continue to grow successfully for another century without changing its zoning ordinance.

Figure 10: Single Family Residential Building Permits, 1990-2001



If the smallest minimum lot sizes are not applied to development, build-out will occur far sooner. To illustrate, there are only 9,914 acres available for development from this build-out analysis. If developable lots of R-1 and R-2 zoning in Roanoke County are developed with one unit per acre, build-out will be achieved in 23 years, not the 100 years previously discussed (9,914/423).

More specifically, the current Roanoke County minimum lot size in these two districts (with private water and sewer) is 0.75 acre. If all 9,914 acres of available land were developed to this standard, 13,219 new units could be accommodated. Build-out in this density would occur in 31 years (13,219/423 = 31). Although cheaper for the County concerning water, sewer, school and public service costs, it may ultimately mean the quicker conversion of available land in other zoning districts when R-1 and R-2 lands are completely developed. These other districts may best be suited for uses other than development, such as agricultural or forest lands.

Small-lot zoning may initially cost the County more but these costs may be partially recouped through the development fees, property tax revenue and other tax revenues associated with development and an increased tax base. Larger-lot zoning is the true worse case scenario, from a land consumption perspective. From the above illustration, it appears that small-lot zoning would cost the County more initially but may ultimately preserve more of the things that citizens value, as described from the goals of the Community Plan. It bears repeating the pertinent goals here:

- Encourage the development and re-development of lands served by public utilities while discouraging through zoning ordinance revisions the development of lands without these services.
- Act proactively to manage growth. Encourage and direct growth toward those areas of the County that can support it with the appropriate and necessary infrastructure, facilities and services and discourage development where the infrastructure and transportation system cannot support it.
- Encourage land use development patterns that reflect community values and desires. Discourage land consumptive development patterns.
- Recognize that in order to discourage sprawl and protect rural lands and natural resources, some reasonable increase in housing density may be necessary as infill development and re-development occurs.
- Recognize the impact that large residential developments have on community facilities, including schools, parks and police and fire services. Consider the use of impact fees and proffers to offset some of these costs.

Recommendations for Roanoke County

1. Consider providing the necessary infrastructure to encourage more compact, clustered growth in these zoning districts.

2. The County cannot reduce maximum lot sizes but it can provide the infrastructure necessary to accommodate the application of the smallest minimum lot sizes, i.e. 7,200 square feet versus 0.75 acres.

3. Do not rezone land not currently zoned as R-1 or R-2 for single-family residential development.

4. Conduct additional, more extensive build-out analyses. These could be generated from community-based assumptions. Additional analyses could be conducted for other areas and different zones, especially those agricultural zones most susceptible to conversion to higher-density residential uses. These analyses can also be site specific as warranted.

5. Using the results of this analysis and others, the County Planning Department can proactively ask County residents and the County Board of Supervisors if this amount of development is what they want. Present the findings to citizens for their reaction and to generate discussion. This is what Massachusetts did with their statewide build-out analysis. If the scenario shown in the county analysis is not what citizens desire, determine development goals and reassess the current zoning ordinance. Study other zoning ordinances for guidance to see what has worked for similar localities.

6. Conduct a site-design level build-out analysis for areas in the county most affected by development in this current analysis, i.e. western and south county. Use partial constraints to development not considered for this analysis in a more precise build-out analysis. Include floodplains and slope in the more precise analysis.

7. The County should investigate the implementation of urban growth boundaries and associated guidelines.

8. Roanoke County should investigate a citizen education campaign with the Virginia Outdoors Foundation, the Western Virginia Land Trust (mentioned in the 1998 Community Plan), the Nature Conservancy, the Trust for Public Land and other land conservation organizations to

encourage citizens to preserve and/or conserve their land. This would involve the allocation of funds for educational purposes. Funds to begin such an initiative may be available through federal or other grants, as well as general County expenditures. Such funding should be seen as an investment in the future quality of life in Roanoke County. Doing so could tie planning in with attracting economic development, which in turn could fund planning efforts that would help position the County to provide the necessary infrastructure for build-out.

9. Require viewshed analysis as part of any development application process for properties within designated viewshed areas, including and especially the Blue Ridge Parkway.

10. Work with landscape architects from the Parkway to draft realistic development goals for areas adjacent to or in view of the Parkway. Finding the balance between private property rights and public welfare is delicate work, especially with current pressure from large-scale developers.

11. Update any build-out analyses as new, large developments remove developable land.

12. Consider conducting the build-out analysis for all vacant parcels up to and including two acres in order to fully account for the effects of the estimated 9,804 units mentioned previously, which are not considered here.

Sensitivity Analysis for the Roanoke County Demonstration

How sensitive are the formulas in this analysis to fluctuations in the percent of land removed from development? More appropriately, what would change if zoning district requirements changed the amount of land available or removed from development? The following discussion indicates that the percent used to reduce land from development (net buildable land) does have an effect on the estimates generated in a build-out analysis. Doubling the percentage of land removed from 15% to 30% produces 8,689 fewer units, or approximately 21% fewer units (Table 5). The difference for unit generation and other estimates is not equally proportionate to land reduction, i.e. doubling land removal does not produce half as many units.

Table 5: Sensitivity Analysis for 15%, 17.5%, 25% and 30% Reduction in Available Land

ESTIMATES	15%	17.5%	25%	30%
> 2-acre vacant	28,974	28,138	25,568	23,875
> 5-acre built (underutilized)	20,347	19,746	17,948	16,757
Total Units at Build-out	49,321	47,884	43,516	40,632
Population	118,864	115,400	104,874	97,923
Students	32,798	31,843	28,938	27,020
Student Costs to Gov't	$124,109,392	$120,493,382	$109,501,922	$102,244,740
Water and Sewer Costs	$231,315,490	$224,575,960	$204,090,040	$190,564,080
Vehicle Trips/day	493,210	478,840	435,160	406,320

Understanding the responsiveness to change in a build-out analysis is one factor for creating a system of checks and balances in the process. Poor sensitivity to alterations in regulation may be one limitation to build-out analysis. Build-out analysis is not an exact science but more closely related to an art form. As such, there must be certain assumptions, as previously discussed, and there are limitations and uncertainty.

Limitations, Uncertainty and Issues Not Addressed

There are limitations, uncertainty and issues that are not addressed in this build-out analysis demonstration due to time constraints and data availability. In addition, an analyst must be prepared for the unexpected. I found that there were discrepancies in the data and decisions to be made when data does not fall neatly into pre-assigned categories.

As mentioned previously, there are 3,856 parcels that are two acres or smaller, which could produce 9,804 units. These units are not counted in this analysis. The omission of these units will underestimate the total effects of build-out in this analysis. Re-conducting an analysis to include these figures may be a worthwhile future exercise if it is necessary to include this parameter.

The incorporated Town of Vinton was included in this analysis using the zoning district designations assigned in the County's real estate database. The Town has its own zoning ordinance but provides this data to the County. The County GIS Department is responsible for all mapping for the Town of Vinton. I did not compare the two zoning ordinances but used the County designation since it was available digitally in the database I used. However, the inclusion of Vinton added 470 (17.5%) and 427 (25%) new units to the build-out analysis estimate. This adds 1133 (17.5%) and 1029 (25%) additional people as well as 753 (17.5%) and 684 (25%) new students to the counts.

As mentioned, I did not undertake a complete road capacity estimation. Nonetheless, the process I described for determining vehicle trips can be continued for all roads in consultation with the Virginia Department of Transportation.

The resultant estimates I reached for land available for development at complete build-out are not ground-truthed but could be refined with current aerial photography or ground investigation. Another way to tailor this process is to do a parcel-level analysis using more detailed base data and actual site designs for parcels. However, other factors such as the possibility of assembling adjacent developable parcels must be considered. This adds additional variables to a site-design level analysis and creates a more complicated process.

My analysis is limited in the expression of time. I do not discuss the date of build-out here, except to say it is the point at which all currently developable parcels are developed. Specific periods may be defined with additional, more precise data in subsequent analyses.

The multiplier I used to estimate children ages 5-18 (0.665) is dated (1994) and not specific to Roanoke County. In addition, an analyst should apply an acceptable adjuster to the resulting estimates to separate public schools from other education providers, such as private school attendance and home-school students.

Uncertainty – Discrepancies in Data

In my demonstration, I found there are parcels with no zoning designation. These parcels accounted for 81 acres throughout the county, or 407 additional lots (17.5% method) and 370 additional lots (25% method), if they were in R-1 or R-2 districts. Such a dilemma is inherent to the data and to be expected in build-out analysis. However, these discrepancies must be acknowledged and dealt with, as necessary to the process.

In my analysis, there was some parcel overlap across school districts. Two parcels fell across two elementary school districts. Since I could not separate the parcels at this time without knowing how they may be developed, I placed the parts of the parcels that were smallest into the count of the district that had the larger proportion of the parcel. The numbers of units were negligible and should not affect student estimates for school zones. I chose to put one parcel (9.1 acres) completely into the Cave Spring zone. This added 46 (17.5%) or 34 lots (25%). I placed the other parcel (35.9 acres) into the Glen Cove zone. This added 174 (17.5%) or 158 lots (25%). This decision placed Glen Cove in the 2,000-3,000 additional students range.

Two parcels listed as vacant in the land use category have building valuations. One, a 3.7-acre parcel, added 18 (17.5%) and 16 lots (25%). The other, a 40-acre parcel, added 198 (17.5%) and 180 lots (25%). Ideally, this second parcel would have been counted in the 5-acre underutilized division with one acre removed for existing structures. However, I do not feel the numbers produced by either of these discrepancies flaws the total number count.

One cemetery appeared as vacant in the R-1 zone district. This 2.1-acre parcel added 11 (17.5%) and 10 lots (25%) to the total unit count. These numbers should preferably be subtracted out of the total.

I included a 6-acre mobile home park in the unit estimate because it appeared as vacant in the County database. This parcel produced 31 (17.5%) and 28 lots (25%). As with the above discrepancies, I do not think these numbers significantly affect the overall outcome but I do not remove them. This parcel is technically developable, although I do not account for other mobile home parks besides this one, since others did not appear as vacant.

Limitations and uncertainty must be identified and dealt with in any build-out analysis. If they cannot be satisfactorily resolved, they must be reported, at the least. I have attempted to do that here.

Other Uses of Build-Out Analysis in Roanoke County

Roanoke County and other localities can use build-out analysis to achieve a variety of additional assessments. Development affects all aspects of our communities from quality of life to the natural environment. Understanding the effects can help us all better plan for the future of the community and its resources.

Application to Other Zoning Districts

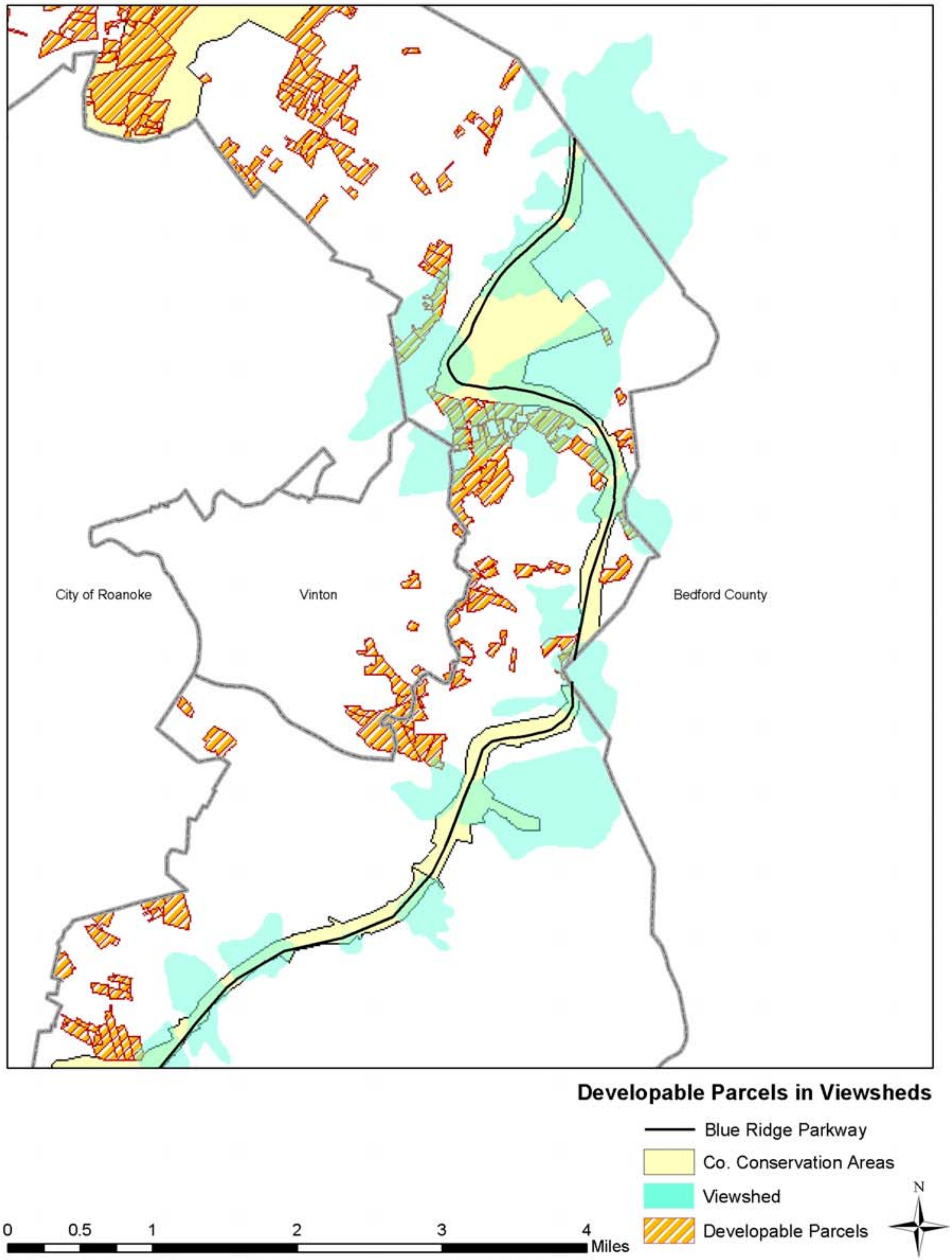
Build-out analysis can illustrate the future growth of all zoning districts for an area in order to aid in the planning process for all types of development. My demonstration for Roanoke County illustrates a specific application for build-out. One could apply a build-out analysis for all zoning districts in the County or locality, if desired. Build-out analysis is most useful in rural areas to show the amount of agricultural land available for conversion and development. So much of the remaining undeveloped land in Roanoke County is currently zoned for agricultural or rural residential uses. Illustrating these zoning districts at build-out may produce staggering numbers and indicate a truly worst-case scenario for government-provided resources and realizing the loss to open space.

Illustration of Viewshed Effects

Development affects visual features of the land as well as the physical features. Viewsheds are areas visible from a particular point or points of observation. Viewshed protection is a controversial issue among landowners, developers, and citizens, planning commissions, planners and Boards of Supervisors. Such protection pits "acknowledging that ridgelines and views of them are a valuable natural resources" against "excessive government control over landowners' rights", as reported in adjacent Botetourt County (Barlow, 2003).

The 1998 Roanoke County Community Plan places a high priority on ridgelines and scenic vistas, comparable to the prioritization of natural resource protection (see previously-mentioned goals in 3.1). Build-out analysis can be used to show which areas of development will be within identified viewshed areas prioritized for possible protection (Figure 11). The addition of a viewshed layer to the build-out analysis is easy to do in a GIS and can be quite persuasive when shown to the citizens that wish to protect the scenic vistas. The hard sell then becomes how to draft an ordinance that has teeth to protect the viewsheds in question and is acceptable to landowners and developers. This task of selling an ordinance becomes harder when viewsheds cross jurisdictions.

Figure 11: Sample Viewshed Analysis with Developable Land in Eastern Roanoke County



Viewshed preservation is especially important in planning for the Blue Ridge Parkway. Property next to the Parkway is extremely valuable and desirable in the development market. New development near and adjacent to the Parkway is increasing at a high rate as a result. However, development along the Parkway and within view of the overlooks adversely affects the National Park Service's goal of keeping the Parkway a "scenic drive" (National Park Service, 2003). In fact, Scenic America designated the Parkway through Roanoke County as a "last chance landscape" for 2002-2003 in its annual list of "endangered American landscapes" (Scenic America, 2003).

Investigating Impacts of Construction in Floodplains

Localities, including Roanoke County, can use build-out analysis in GIS to illustrate areas of FEMA-mapped floodplains in order to help write enforceable ordinances to protect citizens. Measuring the cumulative effects of floodplain construction may be a more appropriate use of build-out analysis. Downstream impacts from upstream flooding can be quantified in a GIS. Localities could then use this information to plan for regional flooding issues, especially relating to stormwater management.

Estimating Tree Cover and Critical Wildlife Habitat Loss

A build-out analysis can include natural resources such as tree cover, vegetation, riparian areas, over-wintering wildlife habitat and any other habitat parameters as constraint layers. After including these resources as layers, it would be possible to quantify losses from development or other environmental changes that may be anticipated over time with projected development.

It is possible to use the tree cover loss analysis to draw conclusions about loss of habitat since tree cover is so closely related to many critical wildlife habitats. This use of build-out analysis would be particularly relevant for habitat determined to be critical for endangered species management or for use in drafting local critical habitat designation regulations.

Other Fiscal Analyses

Roanoke County can estimate many more fiscal impacts from a build-out analysis. The County can estimate the amount of tax revenue generated from new development by using figures for local tax revenue ($65,970,661 in 2001) from real estate assessment ($1.12/$100) and personal property tax estimates ($3.50/$100). The County could estimate the cost of additional public services such as the cost of public safety ($264/person) and fees to provide parks and recreational services ($61/person) (2001 numbers; sample shown in Table 4).

Chapter 3: Conclusions for Build-Out Analysis

Build-out analysis is a planning tool available to localities to help illustrate the effectiveness of its zoning ordinance and development regulations. Original build-out analyses were done by hand. The application of geographic information systems to this once manual process provides a scalable, flexible, and adaptable tool that can be easily updated as necessary. Analyses can be done more quickly in GIS than by using manually-drawn overlays, as once was done. This allows for timely changes and faster results.

Build-out analysis is available for use by local and regional planning offices, GIS or engineering departments under planner guidance, local governing bodies, planning commissions, citizens, and anyone who wants to know what development can occur in the community in the future. The limiting factors in conducting build-out analyses in GIS are the availability of the software and the knowledge of how to use it.

It may be beneficial for localities to work with a regional planning organization, or higher-level planning organization, to conduct the analyses so that there is consistent methodology across jurisdictions to aid in regional planning efforts. It would be wise for neighboring localities to get together, once they decide to conduct an analysis, and determine a protocol for consistency in order to make results comparable across the localities.

The build-out analysis done at the state level in Massachusetts is the ideal scenario for using the analysis in planning. Professionals with specific, reproducible instructions conducted the project. There was consistency across communities in the state so each locality knew how it compared to others around it. The state made the information produced in the analysis available to the people in the communities, both on the Internet and through public presentations. This open planning process put the power in the hands of the people to help them decide what was best for their communities and how they would like to see development occur.

In Virginia, planning is done at the local level with the use of the comprehensive plan and accompanying zoning map. This puts the burden of responsibility on local governments to study and understand the ramifications of their planning decisions. It is for this reason that build-out analysis can be so helpful to localities. I chose to demonstrate this for Roanoke County. Build-out analysis can appear difficult and complicated without a practical demonstration to show that it can actually be done fairly simply with the right equipment and proper formulas.

In conducting build-out analysis in a GIS, it is imperative to have information available digitally. If information is not available digitally, the analyst will spend the greatest amount of analysis time on getting the data in the necessary format. However, once the data is in a database, the analysis becomes very simple to perform. The process then becomes a matter of maintaining the database with up-to-date, accurate data. The greatest amount of time and money for build-out analysis occurs up front. After that, staff time allocated for the analysis should decrease.

Time is the defining difference between manual build-out analysis and analysis done in a GIS. Staff time will hardly ever decrease with manual analysis due to the time required to re-create the manual overlays when changes occur or when assumptions change. It is more simple to re-run an analysis in GIS when parameters change than to re-draw the changed layers by hand.

In order to conduct a basic build-out analysis in GIS, there are several critical digital data layers. These layers include: parcel information in tabular form, parcel information in spatial form (polygons) to allow for visualization of data, current zoning designations, data that indicates where existing development is, floodplain and floodway data, other water layers, slope (which can be derived from contours), school district boundaries, and roads.

In order to do additional or more specific analyses, different data layers will be required. These may include critical wildlife habitat areas, conservation zones, easements, locations of utilities, locations of sewer and water treatment plants, or designated riparian areas, depending on the type of analysis to be conducted.

It is necessary for the analyst to have data for the multipliers that will be used in the subsequent formulas. These multipliers can be derived specifically for the locality or standard multipliers may be equally appropriate. The use of multipliers will be determined by the level of specificity desired.

Build-out analysis is an exceptionally useful tool in planning that can illustrate a zoning ordinance. Build-out analysis is a feasible estimation technique that localities can use to understand the ramifications of current planning policy. It provides planners, governments and citizens with an illustration of what could be possible for development in the future.

Whether done by hand or in a GIS, analysts should tailor build-out analyses to the needs of the community that intends to use it. It is very important for a locality to understand the goals and intended uses of such an analysis before beginning one to make sure the results are usable and defensible. The locality can then change the parameters of the analysis to reflect changes in zoning and development regulations. By changing parameters, localities can better understand and anticipate the interaction between zoning and the effects of development. From the results of build-out analysis, the community may decide to change its regulations or keep them as they are. Build-out analysis in GIS makes illustrating community change more palatable.

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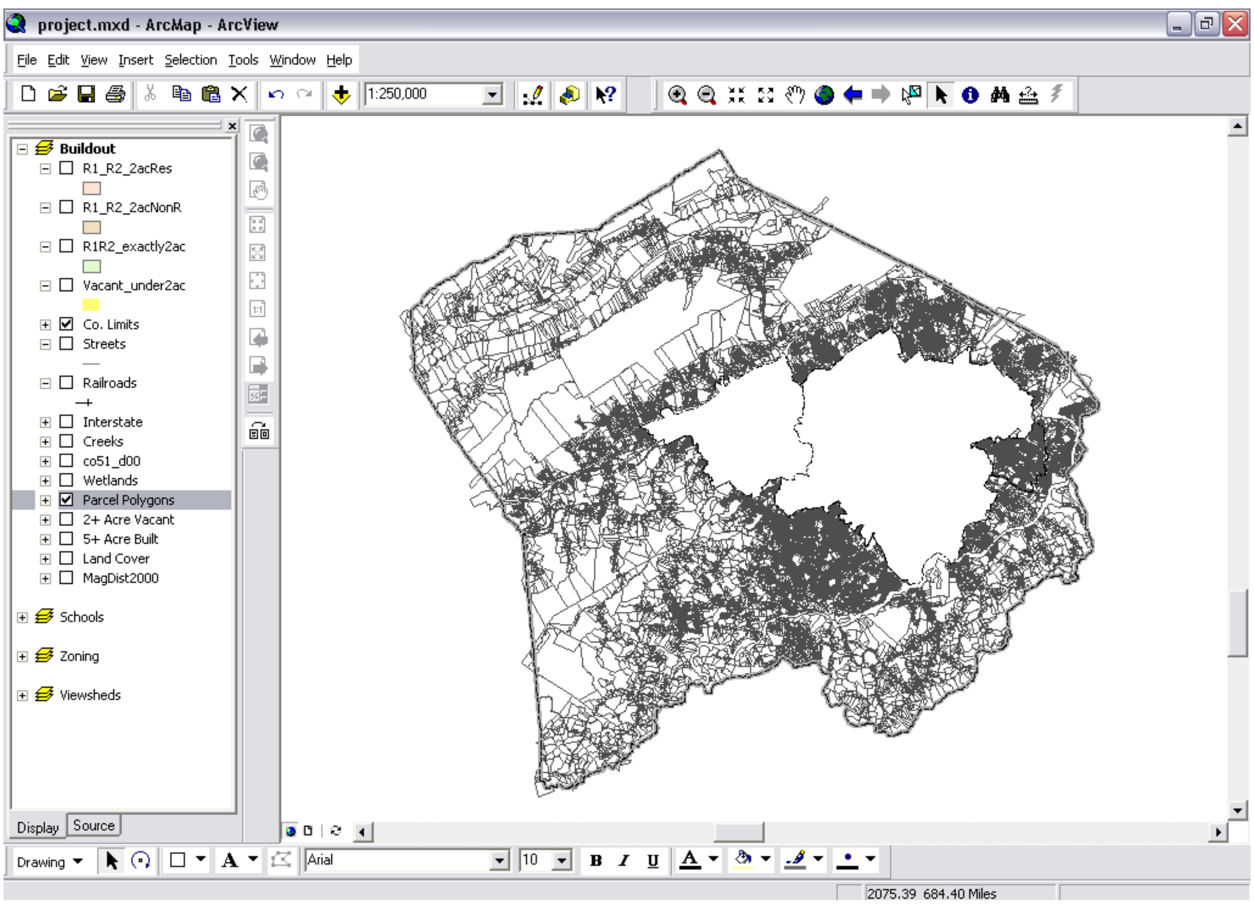
Appendix

Detailed Process for Build-Out Analysis in ArcGIS Version 8.1

Acquire Data

I acquired data from the Roanoke County GIS department from the real estate tax database. This database contains the name and address of the owner, zoning designation, land use model code (in two separate fields as well as one combined field), land and building values separately, and acreage calculated from deed acreage (I am not clear on how calculated acreage was devised from deed acreage). This data was in shapefile format (.shp) with associated database file (.dbf) so I was able to use polygon as well as tabular data (Figure A1).

Figure A1: All County Parcels in ArcGIS



Separate Parcels

a) Zoning district segregation

When I started, there were 43,796 individual parcels. After using "open attribute table" to get into the database file within ArcGIS, I used "select by attributes" to "create a new selection" of the database file based on the "zoning" field for codes R1 and R2 (as well as all sub-districts) [formula: "ZONING" = "R1" or "ZONING" = "R2"; repeat for all sub-districts of R1 and R2] (Figure A2). In the Map Layout, I selected Data/Export Data for the selected attributes in the Table of Contents and saved this as a new shapefile (Figure A3). This left 27,336 parcels.

Figure A2: Selecting Attributes in ArcGIS

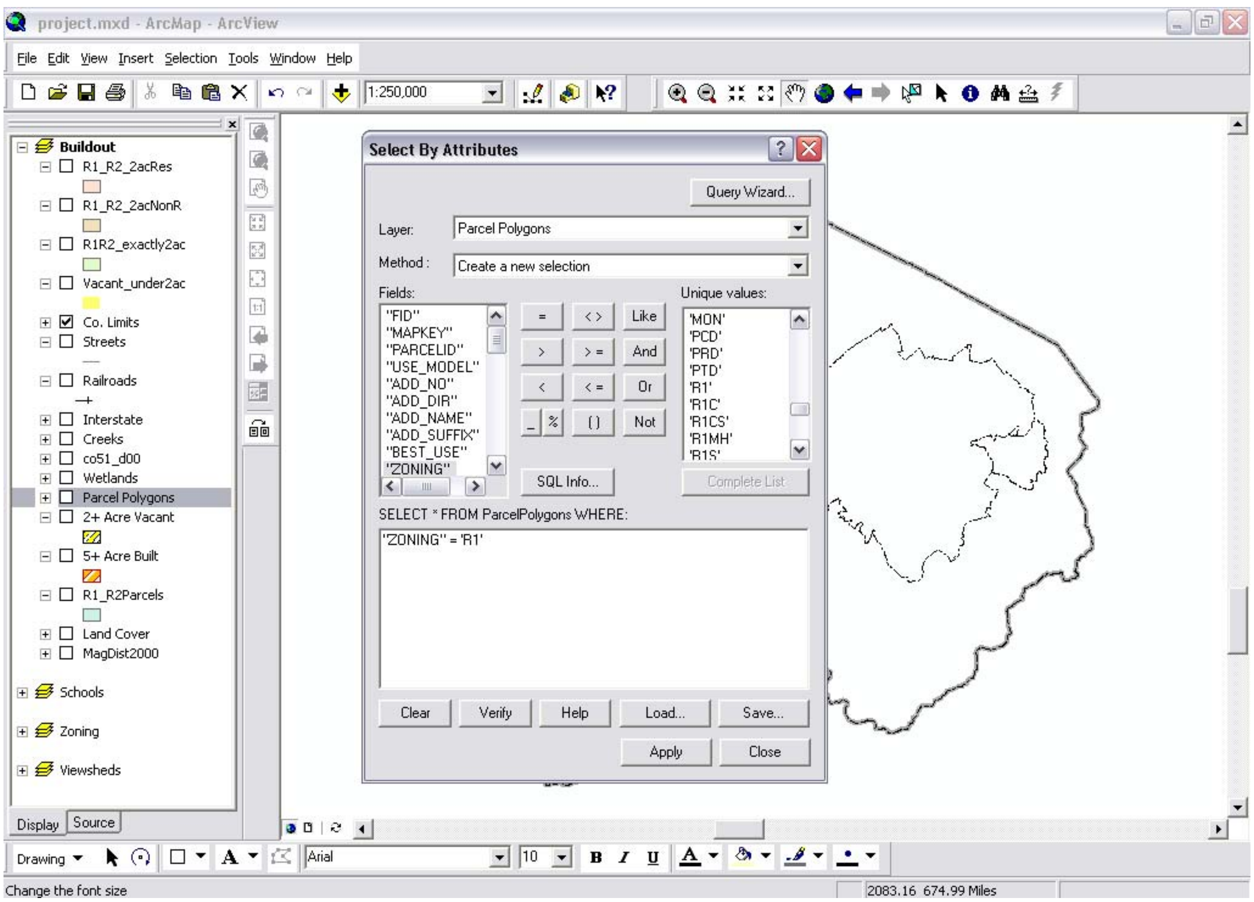
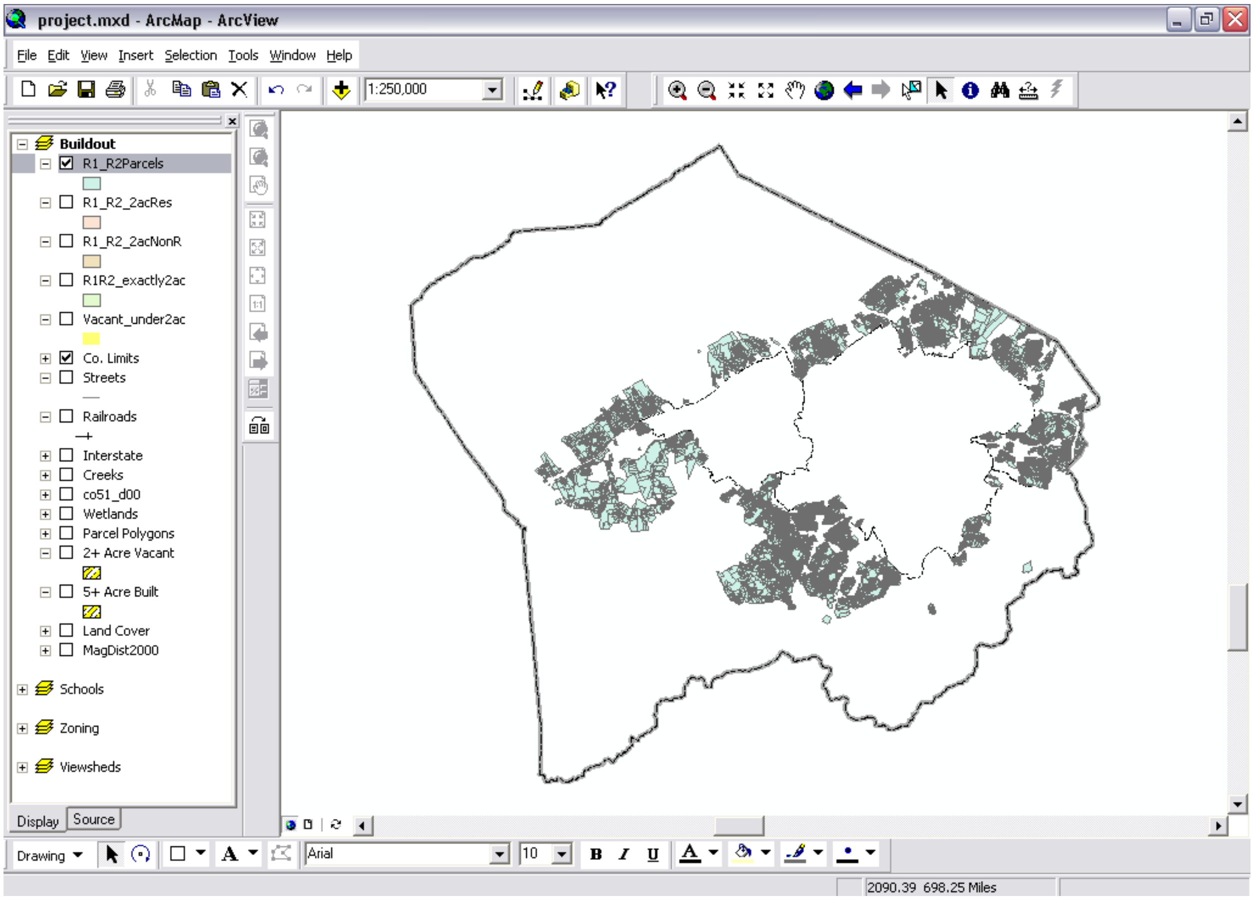


Figure A3: Parcels Zoned R-1 and R-2 (all sub-districts included)



b) Two-acre vacant parcels

My analysis focused on two divisions of land within zoning districts R-1 and R-2. I isolated these two divisions according to arbitrary acreage cut offs. These cut offs are vacant parcels greater than two acres, and parcels five-acres and greater with a structure on them.

I isolated all parcels within zones R1 and R2 over two acres with the "select by attributes" function for the calculated acreage field [formula: "CALCACRE">2]. In the Map Layout, I selected Data/Export Data for the selected attributes in the Table of Contents and saved this as a new shapefile. This left 1,720 parcels.

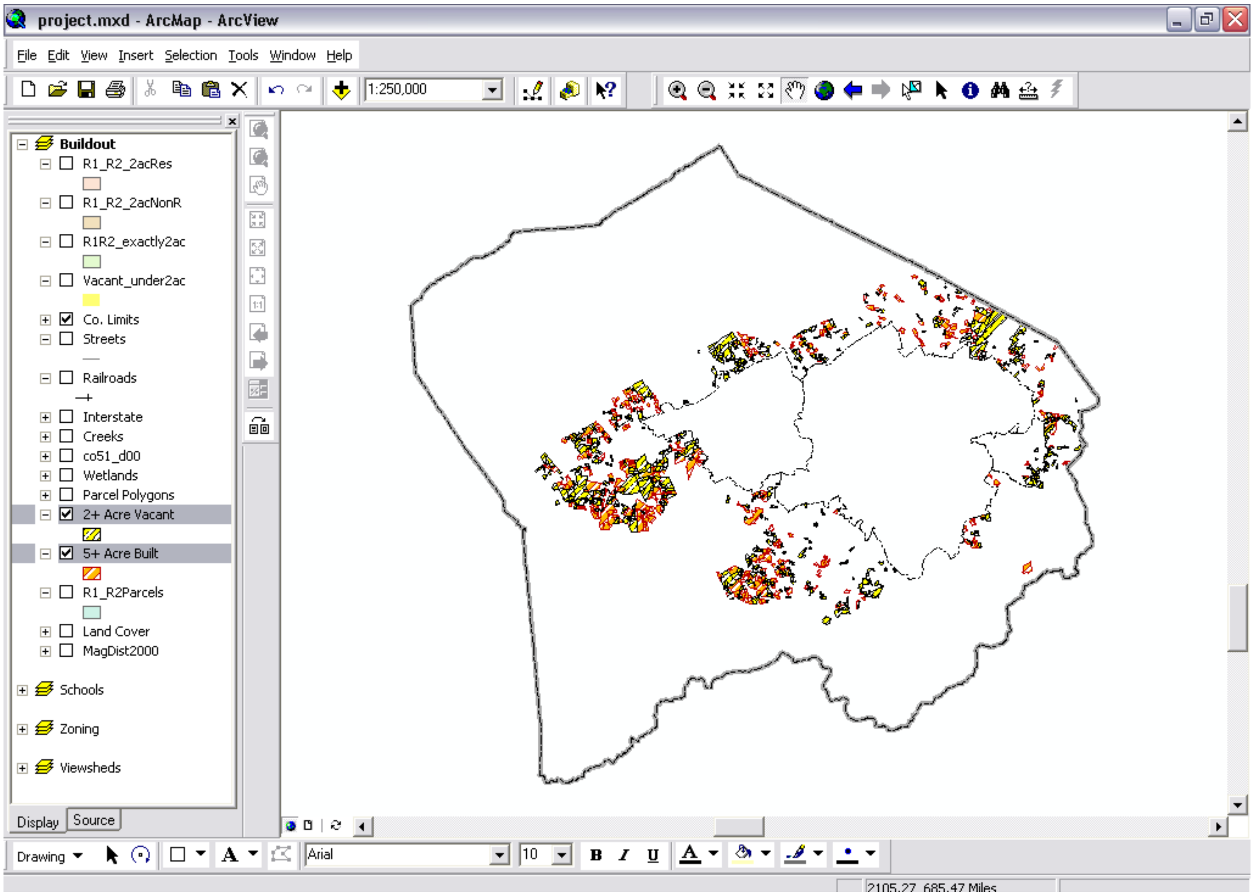
I then had to find which of these parcels were in residential use and vacant. I did this from the above step with "select by attributes" function for land use model code less than 6201 and model code equal to '00', the designation for "vacant" [formula: "USE_MODEL" <= "6201" AND "MODEL"='00']. "6201" is the combined "use" and "model" fields in the database file for residential use, both vacant and occupied land. Residential uses in Roanoke County are coded with values less than 62; vacant parcels have a model of '00'. This step could be executed using either the separate "use" or "model" fields. In Data View, I selected Data/Export Data for the selected attributes in the Table of Contents and saved this as a new shapefile. This step left 544 parcels that were in R1 or R2 zones, greater than two acres in size and designated for residential use on land that is currently vacant. You must know the code for residential use and vacant parcel designation to isolate vacant residential parcels in this way.

c) Five-acre parcels with a structure on them

In order to find parcels five acres and greater with a structure on them, I used the following steps similar to b). After separating parcels in all R1 and R2 districts as above, I used "select by attributes" for all parcels five acres and greater [formula: "CALCACRE">=5]. In the Map Layout, I selected Data/Export Data for the selected attributes in the Table of Contents and saved this as a new shapefile (Figure A4). There were 571 parcels from this step.

Then, I isolated parcels with "model" designation of greater than '00', meaning not vacant, with the "select by attributes" function [formula: "MODEL">'00']. In Data View, I selected Data/Export Data for the selected attributes in the Table of Contents and saved this as a new shapefile. 322 parcels remained after this step. Note: check to make sure there is a building on the parcel, either by field survey, aerial photo, or by checking the building value field is present in the database file.

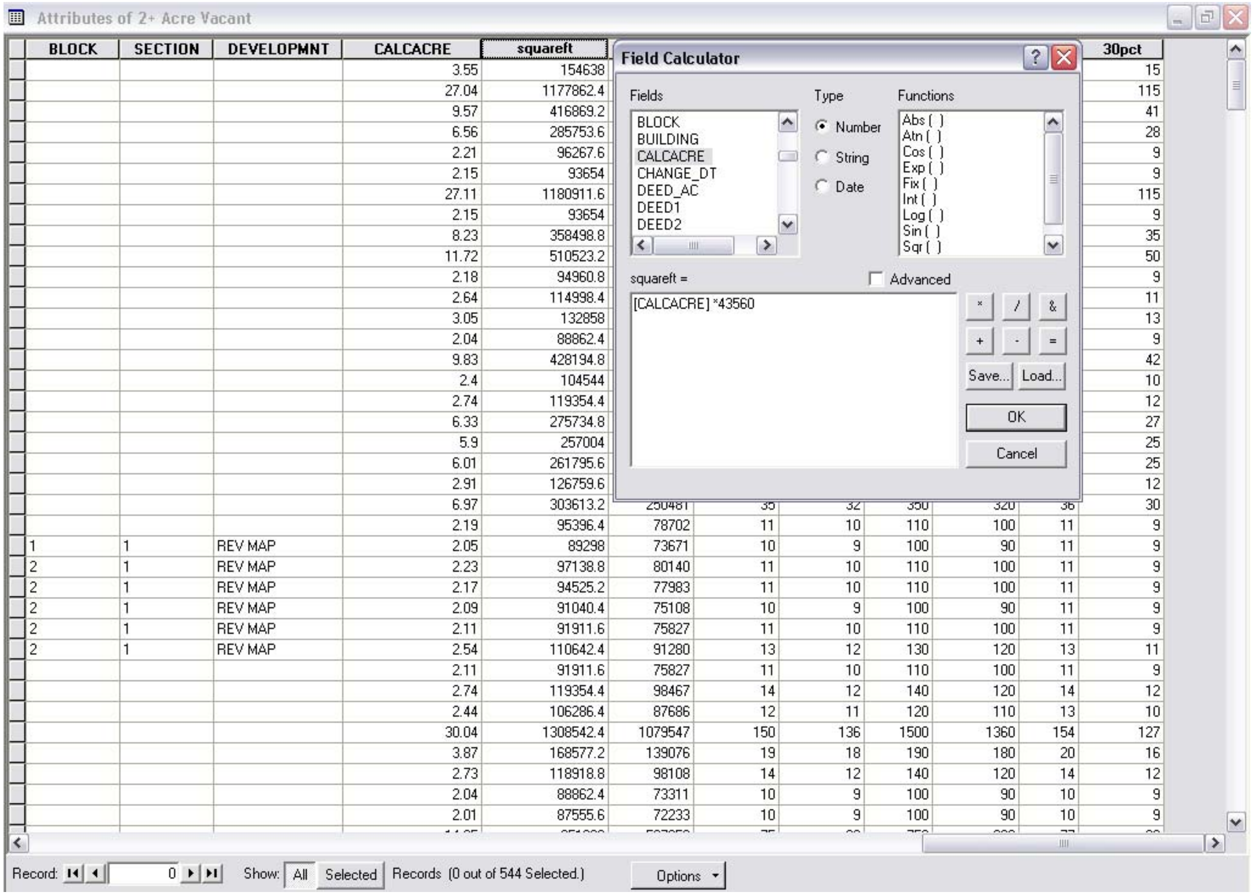
Figure A4: Vacant Parcels 2+ Acres and Parcels 5 Acres and Greater with an Existing Structure



<u>Calculating available gross square footage</u>

In my analysis, I convert acreage into square footage in order to apply the square footage requirements of the zoning ordinance. This is a simple mathematical procedure done in the attribute table of shapefiles in ArcGIS. It is necessary to "Add Field…" with the proper type defined (either short or long integer selected) and precision set (for decimals). Once the necessary fields have been added, it is wiser to begin the calculations after activating the Editor feature for the table. I multiplied the calculated acreage from the County's database file by 43,560 feet to get square footage in the "Calculate Values" operation window [right-click on the target field name and select "Calculate Values"; formula: "CALCACRE"*43560] (Figure A5).

Figure A5: Calculating Gross Square Footage from Acreage



In my analysis, I arbitrarily chose to remove one acre from the 5-acre and greater parcels to account for existing structures. I determined net buildable area in one step by subtracting 43,560 feet (=one acre) [formula: ("CALCACRE" * 43560) – 43560].

Calculating net buildable area (net square footage)

The gross square footage from the previous step is not used directly in formulating the number of possible units from the database files associated with the newly exported shapefiles. Square footage must be adjusted for the removal of area for roads, odd lots, stormwater management, and other environmental constraints. Again, add a new field with the proper numeric features. Calculate values using the square footage from above multiplied by the remaining percentage of land **not** removed [formula: "SQFOOT" * 0.825]. For example, if 17.5% is to be removed from gross available land, the converse of this is the land that will be available, or 82.5% (100% - 17.5%). The same is true if 25% is to be removed; 75% will remain as the multiplier to get net square footage (100% - 25%).

I conducted the analysis twice. The first time I used 17.5% land removal and the second time I used 25% removal, as shown above.

Determining the number of units in ArcGIS

Calculations for the number of possible units from the net square footage can be calculated in ArcGIS. This is also done in the attributes table of the target shapefile. One must know the lot size specified in the applicable zoning ordinance district for this step. It is necessary to "Add Field…" with the proper type defined (either short or long integer selected) and precision set. Calculate the value for possible units by dividing net area by the minimum square footage allowed by zoning [formula: "NETAREA"/7200]. These units can be totaled in ArcGIS at this point or later for application to subsequent statistics.

Determine other statistics in ArcGIS

There are two ways to generate statistics in ArcGIS. If you need to know numbers for each parcel individually, use the descriptions immediately below. If you only need to know final, summary numbers, use the step described in d) below.

a) Population: Determine the proper multiplier to estimate population from the number of estimated new units. I used 2.41 from 2000 Census data for Roanoke County. Add a field. Calculate the value for population using the multiplier [formula: "UNITS" * 2.41].

b) Students: Determine the proper multiplier to estimate new additional students from the number of estimated new units. I used 0.665 from the Urban Land Institute. Add a field. Calculate the value for students using the multiplier [formula: "UNITS" * 0.665].

c) Vehicle Trip Generation: Determine the proper multiplier to estimate new vehicle trips possible for the number of estimated new units. I used 10 because the County uses this figure. The state department of transportation may have a different number depending on the locality. Add a field. Calculate the value for trips using the multiplier [formula: "UNITS" * 10].

I conducted the sensitivity analysis in ArcGIS using the formula from step 4 and substituting desired percentages for area removal. For example, for 15% land removal, I used "SQFOOT" * 0.85 and for 30% land removal, I used "SQFOOT" * 0.70 (Figure A6).

Figure A6: Calculations Done in ArcGIS

Attributes of 2+ Acre Vacant

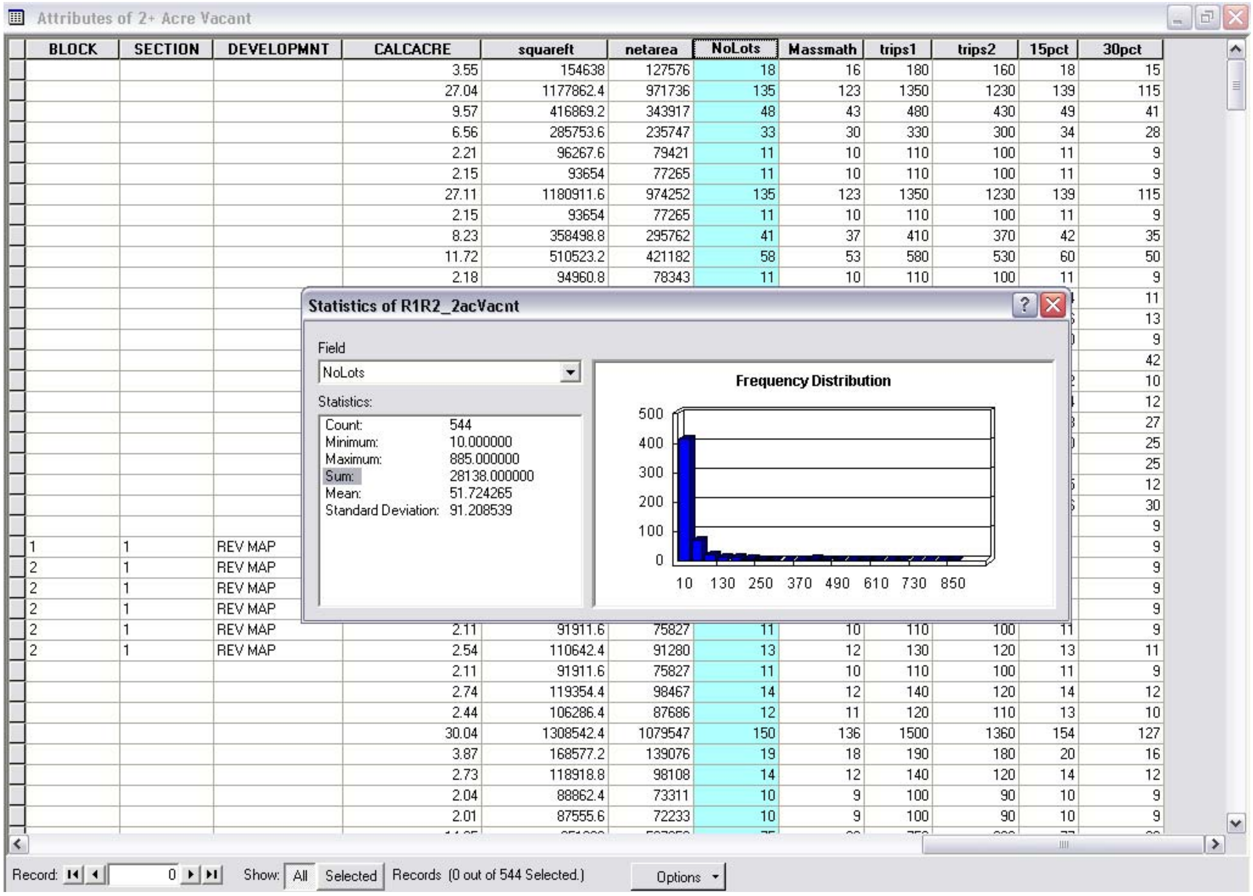
BLOCK	SECTION	DEVELOPMNT	CALCACRE	squareft	netarea	NoLots	Massmath	trips1	trips2	15pct	30pct
			3.55	154638	127576	18	16	180	160	18	15
			27.04	1177862.4	971736	135	123	1350	1230	139	115
			9.57	416869.2	343917	48	43	480	430	49	41
			6.56	285753.6	235747	33	30	330	300	34	28
			2.21	96267.6	79421	11	10	110	100	11	9
			2.15	93654	77265	11	10	110	100	11	9
			27.11	1180911.6	974252	135	123	1350	1230	139	115
			2.15	93654	77265	11	10	110	100	11	9
			8.23	358498.8	295762	41	37	410	370	42	35
			11.72	510523.2	421182	58	53	580	530	60	50
			2.18	94960.8	78343	11	10	110	100	11	9
			2.64	114998.4	94874	13	12	130	120	14	11
			3.05	132858	109608	15	14	150	140	16	13
			2.04	88862.4	73311	10	9	100	90	10	9
			9.83	428194.8	353261	49	45	490	450	51	42
			2.4	104544	86249	12	11	120	110	12	10
			2.74	119354.4	98467	14	12	140	120	14	12
			6.33	275734.8	227481	32	29	320	290	33	27
			5.9	257004	212028	29	27	290	270	30	25
			6.01	261795.6	215981	30	27	300	270	31	25
			2.91	126759.6	104577	15	13	150	130	15	12
			6.97	303613.2	250481	35	32	350	320	36	30
			2.19	95396.4	78702	11	10	110	100	11	9
1	1	REV MAP	2.05	89298	73671	10	9	100	90	11	9
2	1	REV MAP	2.23	97138.8	80140	11	10	110	100	11	9
2	1	REV MAP	2.17	94525.2	77983	11	10	110	100	11	9
2	1	REV MAP	2.09	91040.4	75108	10	9	100	90	11	9
2	1	REV MAP	2.11	91911.6	75827	11	10	110	100	11	9
2	1	REV MAP	2.54	110642.4	91280	13	12	130	120	13	11
			2.11	91911.6	75827	11	10	110	100	11	9
			2.74	119354.4	98467	14	12	140	120	14	12
			2.44	106286.4	87686	12	11	120	110	13	10
			30.04	1308542.4	1079547	150	136	1500	1360	154	127
			3.87	168577.2	139076	19	18	190	180	20	16
			2.73	118918.8	98108	14	12	140	120	14	12
			2.04	88862.4	73311	10	9	100	90	10	9
			2.01	87555.6	72233	10	9	100	90	10	9

Record: 0 Show: All Selected Records (0 out of 544 Selected.) Options

d) Summarize statistics: When these statistics have all been calculated, they can be summarized simply in ArcGIS. Right-click on the field of interest in the attribute table and select "Statistics". The resulting box will have a line for "Sum" (Figure A7). This is the sum of all numbers in the chosen field. This will produce a single number, not a number per parcel. Use the "Statistics" function as above to get the total number of new units. Multiply this number by the selected multiplier on a calculator.

These statistics can also be generated in Excel by multiplying the results of the unit estimates with the multipliers for each parcel. The results of the field must first be "Summarized", however, saved and opened as a .dbf file in Excel.

Figure A7: Using the Statistics Function in ArcGIS to Summarize Unit Estimates



Vita

Mary A. Zirkle was born in Roanoke, Virginia to a mother of exceptional strength and understanding of the world. Mary was influenced greatly by her family as she grew. She was inspired by the beauty of God's creation to pursue studies in biology as an undergraduate. Her professional career led her to the field of planning and subsequent pursuit of an advanced degree in the subject. Her hope for the future involves professional success that makes a positive contribution to the well-being of others and the natural environment. She hopes people will ultimately remember her not so much for positions held but for contributions made.