Impervious Cover Analysis and Stormwater Planning for Lewis Creek Watershed Towns: Hinesburg and Charlotte, VT

June 2005

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Funded by
Vermont Agency of Commerce and Community Development
Municipal Planning Grant FY04
Consortium: Hinesburg & Charlotte, VT

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ACKNOWLEDGEMENTS

Funding for this project was provided by a Municipal Planning Grant, awarded by the Agency of Commerce and Community Development.

The project was greatly aided by input from the following Steering Committee members:

- Alex Weinhagen, Town Planner, Hinesburg
- Dean Block, Town Planner, Charlotte
- Marty Illick, Director of Lewis Creek Association
- Michele Maresca, Chittenden County Regional Planning Commission
- Kevin Behm, Addison County Regional Planning Commission

Additional support was provided by several individuals, including Andrea Morgante, Hinesburg; Nell Fraser and Jim Donovan, Charlotte; Greg Brown, Melanie Rubinson, Pamela Brangan, and Brad Rawson, CCRPC.

C. L. Davis Consulting Associates, Inc. of Middlebury – Weybridge, VT (CLDCA) assisted in this effort as a sub-contractor providing Geographic Information System (GIS), build out analysis and software development services.

South Mountain Research and Consulting assumes sole responsibility for this report, along with any recommendations and opinions expressed.

1.0 INTRODUCTION

Hinesburg and Charlotte are concerned about present and future consequences of impervious surfaces in the towns, resulting from increased development, and the implications for stormwater management. While neighboring towns to the north are presently in a reactionary mode, addressing stormwater issues in urbanized settings, Hinesburg and Charlotte are well positioned to plan for development that is more compatible with natural systems.

This project involved estimating impervious cover, on a watershed scale, across the two towns (see Figure 1). Impervious estimates were then evaluated alongside results of GIS-based build-out analyses to identify potential impacts to receiving waters under future development. Evaluation results will be used by the towns to plan for development that minimizes impacts to water quality and reduces future costs associated with stormwater–related consequences to receiving river and lake systems.

The project was also pursued to stimulate community planning across town boundaries. Watershed groups (Lewis Creek Association, LaPlatte River Partnership) can facilitate this planning across municipal boundaries, and stakeholders can apply results of this study to various watershed and channel management objectives.

Hinesburg and Charlotte are concerned that ultimate build out under current zoning regulations could result in aggregate percent imperviousness that exceeds water quality thresholds. The towns could then be faced with increased expenses associated with damage to infrastructure, degradation of water quality, and mobilization of sediment and phosphorus to receiving waters.

At present, neither Hinesburg nor Charlotte has a stormwater ordinance. Certain industrial projects and larger commercial or residential projects will require State stormwater management permits. However, based on past development patterns, it is expected that much of the future development in the towns will be single-family dwellings on smaller acreage lots (1 to 10+ acres). A substantial percentage of these residential development projects will not fall under State or Federal oversight requiring stormwater management structures or practices.

Based on a preliminary, ultimate build out presented to each town by Lewis Creek Association in the summer of 2002, Hinesburg and Charlotte were aware that future development could more than double the number of residential structures in their respective towns under current zoning. Lewis Creek Association assisted the two towns in making application to the Agency of Commerce and Community Development for funding to conduct an evaluation of impervious cover and to prepare more detailed build outs.

Review of the percent impervious calculations alongside the refined build out results for the towns has helped to visualize the impacts of expected low-density upland and riparian development on the hydrologic and geomorphic conditions of receiving waters. Also under this Municipal Planning Grant, the Charlotte Planning Commission and Lewis Creek Association worked with consultants to enhance their town's build out with scenarios considering: (1) alternate planning and zoning approaches (e.g., changing minimum acreage in zoning districts, adding density to downtown or village districts); and (2) natural systems (e.g., natural communities, wildlife corridors, riparian corridors).

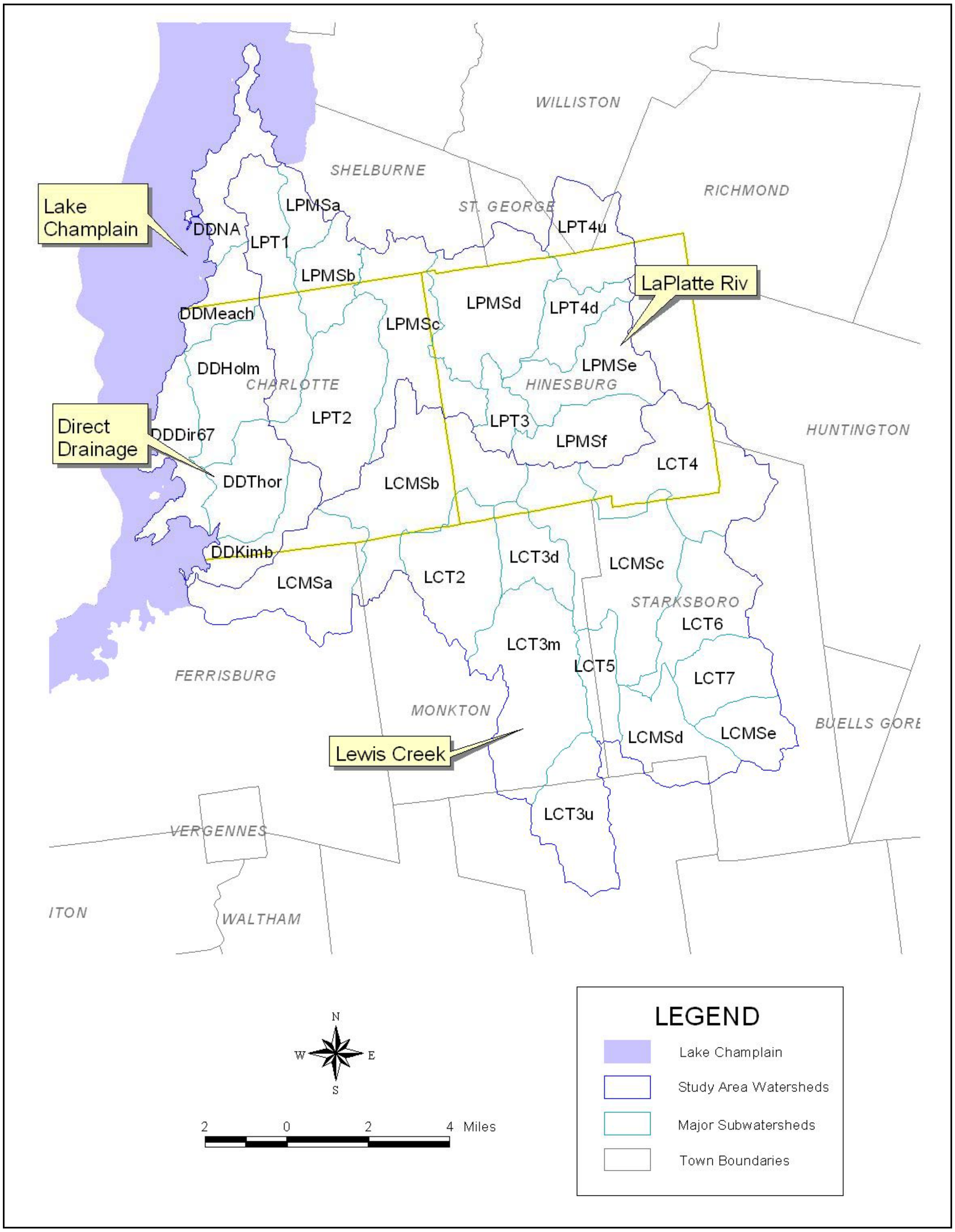


Figure 1. Study Area Watersheds
Principal Towns (Hinesburg & Charlotte) outlined in yellow.

Secondary benefits of this project have included the following:

- Percent imperviousness was estimated for portions of four adjoining in Chittenden County towns (Shelburne, Williston, St. George, Richmond) and four adjoining Addison Counties (Starksboro, Monkton, Ferrisburgh, Bristol) in those portions of watersheds which overlap the boundaries with Hinesburg and Charlotte;

- An extension to the ArcView® Geographic Information System (GIS) software was developed. This extension can assist the user in determining the percent impervious within watershed using available Land Cover/Land Use (LcLu) data. The percent impervious values will reflect the percent impervious values as of the date of the LcLu data. Refer to Appendix C.

- With funding from the Center for Rural Studies, additional capabilities were incorporated into the Addison County Community Build Out Analysis extension (ACBOA) to ArcView®. Among the added features is the ability to perform a very basic build out for commercial and industrial districts. Hinesburg and Charlotte were used to test the new enhancements to the extension.

2.0 BACKGROUND

Several research efforts have established positive correlations between increasing urbanization and decreasing water quality, stream stability, and habitat conditions (Hammer, 1977; Booth, 1990; EPA, 1997; Jacobson et al, 2001). Often the percentage of impervious surface in watersheds is cited as a key indicator of development intensity, and estimates of impervious percentage in watersheds are promoted as a tool to predict physical, biological and chemical impacts to stream channels (Schueler, 1994; Arnold & Gibbons, 1996). Impervious cover is an index of watershed development that serves as a proxy for all of the watershed and channel stressors that typically accompany development and lead to water quality, stream stability, and aquatic habitat impacts.

Various thresholds of impervious surface percentage have been developed for specific management objectives and geographic regions. Impervious thresholds often applied in the context of watershed planning are those defined in the Impervious Cover Model (Schueler, 1994; Center for Watershed Protection, 1998; Giannotti & Prisloe, 1998). Impervious thresholds of 10% and 25% are used to broadly categorize sub-watersheds into three different management units.

- For watersheds with greater than 25% impervious cover, the ***Non-Supporting*** category predicts that many or most of the indices of stream quality can be expected to have a ranking of poor. Streams in this category would be expected to display significant streambank erosion, loss of morphological and habitat diversity, degraded water quality and reduced diversity of aquatic species (CWP, 1998).
- Watersheds with between 10 and 25% impervious cover are categorized as ***Impacted***, and indicators are predicted to be in the fair to good range. Some impacts would be expected including channel erosion, and biological and habitat degradation. Loss of species diversity would be anticipated, with those species most sensitive to disturbances being absent or underrepresented.
- Those watersheds with less than 10% impervious cover would be classified as ***Sensitive***. Some impacts might be expected, but overall water quality, stream stability, habitat quality, and species diversity would be expected to be in good to excellent condition.

These thresholds are not black and white; rather they are intended to reflect a gradual transition point between one category of predicted impact to the next. Any given stream system with a given impervious cover may not exhibit the predicted condition. In fact, recent research (summarized in CWP, 2003) has indicated that stream quality impacts are much more variable in watersheds with impervious cover in the 0 to 10% range. There is considerable scatter of quality indicators among watersheds with impervious cover in this range. Impacts range from negligible to substantial (excellent to poor quality), and may vary considerably by geographic region, and by parameter.

In a study of Vermont watersheds, Center for Watershed Protection (CWP) developed a statistical correlation between stream channel enlargement / instability and percent imperviousness (CWP *et al.,* 1999). The study evaluated 24 reaches located in eight Vermont watersheds. The sub-watersheds defined for the reaches varied in area from 0.5 square mile to 24 square miles; and the total percent imperviousness ranged from 1 to 22%.

Alluvial streams were found to demonstrate evidence of geomorphic stress when the impervious value calculated was 2% or more. Active adjustment of channel form was observed for impervious values exceeding 9%. Increases in percent imperviousness were also statistically correlated to decreases in biological diversity and overall macro-invertebrate health in Vermont receiving waters (CWP, 2000a).

It is important to recognize the following limitations with regard to percent impervious estimates and their application to watershed and channel management programs:

- Impervious estimates are indicators only, and should not be viewed as absolute values. Significant variability can exist in the methods used to develop impervious estimates.
- Data sets used to calculate imperviousness should be reviewed carefully with regard to their impact on the calculations of impervious cover. These data sets will likely establish inherent limitations on the ability to calculate impervious cover due to age, scale, resolution, accuracy, etc.
- Application of the Impervious Cover Model to a particular stream network only suggests the ***potential*** for degraded stream quality. Field-truthing is required to evaluate actual water quality, habitat status, and stream stability.
- Depending on unique attributes of a channel setting (including channel gradient; presence of grade controls such as exposed bedrock; size and cohesiveness of streambank and streambed sediments; degree and type of streambank vegetation; age of watershed development; etc.) upstream and up-watershed impervious surfaces may or may not cause the expected degree of channel enlargement.
- Impervious cover (development in a watershed) is only one of several cumulative and overlapping watershed and channel stressors that may result in channel disequilibrium and systemic instabilities. Other stressors include channelization, dredging, floodplain encroachments, berming, armoring, and undersized crossing structures.
- Most impervious cover estimates do not adequately account for the potential mitigating effects of various watershed treatments, such as stormwater detention or infiltration measures; vegetated riparian buffers; low-impact design options for new development (e.g., green roofs, pervious pavements, etc.). As time passes, and these stormwater management and low-impact design methods are incorporated into local planning and zoning mechanisms, impervious surfaces will likely become less of a direct indicator of stream quality.
- The Impervious Cover Model has been tested in, and is therefore applicable to, the Northeast, Mid-Atlantic, Southeast, Upper Midwest and Pacific Northwest regions of the United States.

In addition, the following definitions should be introduced at this point: Total Impervious Cover; Effective Impervious Cover; and Equivalent Impervious Cover.

Total Impervious Cover in a watershed includes all those surfaces which effectively prevent rainfall or runoff from infiltrating through the ground surface into the underlying soils and sediments. Examples of impervious surfaces include paved roads, rooftops, decks, and parking areas.

Effective Impervious Cover refers to that subset of Total Impervious Cover identified in a watershed that are actually connected to the receiving stream channel network. For example, a gazebo located in the middle of a meadow is an impervious surface. Rainfall sheets off the roof and does not infiltrate the soils immediately beneath the structure. However, this rainfall will be directed to the ground at the drip edge of the structure and seep into the underlying soils near this point. Technically, those impervious surfaces which are not immediately adjacent to a stream channel, or which are not connected to the nearby stream channel by a series of impervious surfaces (e.g., paved area to storm drain to stormwater outfall at the river's edge), should not be counted.

A distinction should be made between Effective Impervious Cover (hydraulically and hydrologically connected to the receiving streams) and Total Impervious Cover. However, since such a distinction requires more intensive field efforts and records research to determine, most methods currently utilize a tally of Total Impervious Cover. This study of Charlotte and Hinesburg watersheds measured Total Impervious Cover, and did not directly address Effective Impervious Cover.

Equivalent Impervious Cover recognizes that some urbanized land surfaces have been disturbed and compacted to the degree that their capacity to absorb rainfall and runoff has been reduced. Examples include lawn surfaces that have been landscaped, golf courses, town greens, and logging clearings. Typically, projects at the watershed scale do not take into account these surfaces, due to the difficulty in identifying them and quantifying the degree of equivalent imperviousness. This study of Charlotte and Hinesburg watersheds did not address Equivalent Impervious Cover directly.

Despite these acknowledged limitations, impervious estimates serve as a valuable planning tool applied at the regional (watershed) scale. Impervious estimates can be compared, one watershed to another, to identify and prioritize various management strategies. Similarly, impervious values can be used for trend analysis of land cover/land use conditions in the same watershed through time. In either case, it is important to use consistent methods from one estimate to the next, so that an "apples to apples" comparison is being made.

To address the potential for increases in impervious surface with future development, detailed build out analyses were conducted in this project for Hinesburg and Charlotte using the *Addison Community Build Out Analysis* software (an extension to ArcView® 3.x). For the Town of Charlotte, three build out scenarios were defined to enable consideration of natural resources. In addition, since the Study Area watersheds overlapped into adjacent Chittenden County and Addison County towns, a basic zoning-based estimate of build out was performed for the towns bordering Hinesburg and Charlotte.

Watershed boundaries were used to review the build out results in an effort to determine possible implications on impervious conditions; and to assist in formulating planning and zoning recommendations.

3.0 IMPERVIOUS SURFACE ANALYSIS

Impervious surface analysis was conducted for Study Area watersheds overlapping the Principal Towns, Hinesburg and Charlotte, under existing conditions. The available source data for this analysis (land cover / land use data derived from satellite imagery) was dated circa 1993. Therefore, "existing conditions" in this context represents a "snap-shot" in time from imagery captured circa 1993.

3.1 Methodology

There are several ways to estimate impervious surfaces. The *Rapid Watershed Planning Handbook* (CWP, 1998) provides an overview of possible methods. Generally, utility and accuracy of methods increases with increasing application of time and resources (Figure 2).

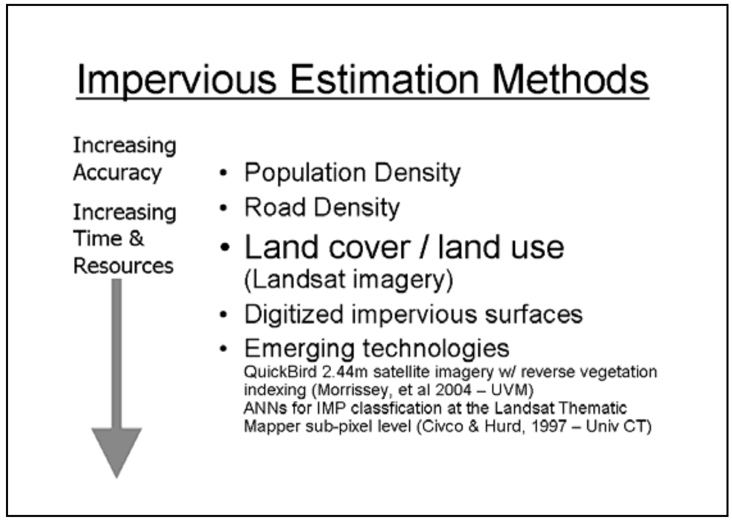


Figure 2. Impervious Estimation Methods

This project utilized the land cover / land use data, given:

- the largely rural character of the Principal Towns (i.e., relatively small percentages of actual impervious surface);
- the availability of standardized land cover / land use data for the entire State of Vermont, enabling a similar methodology (detailed in Appendix B) to be used for the other 200 or more rural towns in Vermont; (Note: digitized impervious cover was available for small portions of the Study Area in Charlotte (Pease, 2004; Pease 1997). However, digitizing impervious cover for the remaining Study Area was beyond the scope of this study);
- the project goals of using impervious values for prioritizing watershed management and municipal planning activities (at a broad scale - not requiring rigorous, resource-intensive impervious estimation methods);
- the compatibility of this method with the available budget.

3.2 Study Area Watersheds and Delineation of Major Sub-watersheds for Estimation of Percent Imperviousness

Each of the Study Area watersheds was divided into sub-watersheds for the estimation of percent imperviousness. Details of this watershed delineation procedure are summarized in Appendix A. Study Area sub-watersheds are illustrated with respect to town boundaries in Figure 1. The study area is comprised of the LaPlatte River and Lewis Creek watersheds, as well as the collection of smaller tributaries and westward-draining slopes collectively identified as the Direct Drainage to Lake Champlain (Figure 1).

- The LaPlatte River watershed is approximately 53 square miles in area, and drains portions of the towns of Charlotte, Hinesburg, and Shelburne, as well as small areas of St. George, Williston and Richmond.

- The Lewis Creek watershed drains an 81-square-mile area located in the towns of Bristol, Starksboro, Monkton, Huntington, Hinesburg, Charlotte, and Ferrisburg, in Addison and Chittenden Counties.

- The Direct Drainage to Lake Champlain watershed is a 23.5-square-mile area comprised of smaller streams and direct drainage to Shelburne Bay and the broad lake. Direct Drainage overlaps the towns of Ferrisburg, Charlotte and Shelburne in Addison and Chittenden Counties.

3.3 Summary of Land Cover / Land Use Statistics by Watershed and by Principal Town

A summary of land cover / land use for the Principal Towns is provided in Table 1 and illustrated graphically in Figure 3 (based on Millette, 1997; source dates of 1991/1993). The distribution and proportions of Developed and Transportation categories are similar in the two towns. Agricultural and forested land covers dominate in both towns; Charlotte has more agriculture than forest, while Hinesburg has the reverse pattern.

Table 1. Land cover / Land Use Summary for Charlotte and Hinesburg

		Charlotte		Hinesburg	
LcLu Category	Includes LcLu Codes	Approx. Extent of Category in Study Area (ac)	Approx. Percent of Category in Study Area (%)	Approx. Extent of Category in Study Area (ac)	Approx. Percent of Category in Study Area (%)
Water	5	1,222	4.6%	1,045	4.8%
Wetlands	61, 62	770	2.9%	924	4.2%
Brush / Transitional / Barren	3, 7	82	0.3%	61	0.3%
Forest	41, 42, 43	7,637	28.9%	10,428	47.5%
Agriculture	22, 24, 211, 212	13,645	51.7%	6,365	29.0%
Developed	11, 12, 13, 17	1,781	6.7%	2,238	10.2%
Transportation / Utilities	14	1,279	4.8%	897	4.1%

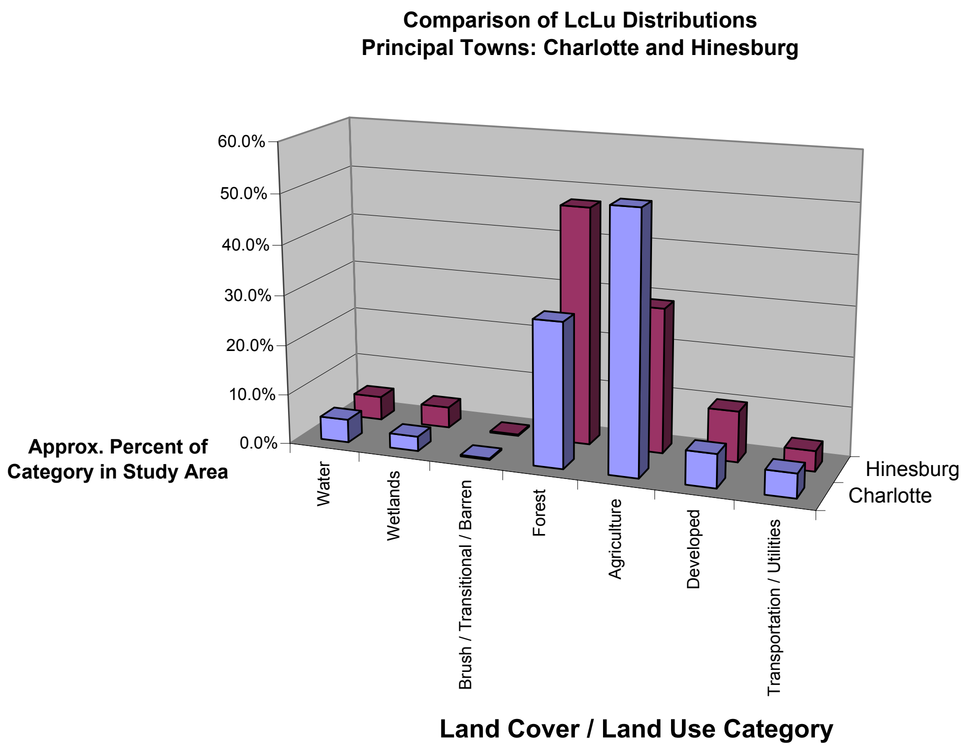


Figure 3. Summary of Land Cover / Land Use for Charlotte and Hinesburg

Land cover can also be compared watershed to watershed (Table 2). Lewis Creek is less developed than the other watersheds, lacking the degree of density of its village centers that is characteristic of village areas present in LaPlatte (Shelburne village, Hinesburg village) and Direct Drainage (Thompson's Point, Charlotte village). Particularly the upper Lewis Creek watershed is heavily dominated by forest cover. The LaPlatte and Direct Drainage watersheds show less forest cover and an increasing predominance of agricultural land covers**.**

Table 2. Summary of Land Cover / Land Use by Study Area Watersheds

Land Cover / Land Use				
LcLu Group	includes Category Codes:	Lewis Creek	LaPlatte	Dir Drainage
Water	5	5.0%	5.2%	3.4%
Wetlands	61, 62	6.1%	4.4%	0.0%
Brush/Transit/Barren	3, 7	0.3%	0.4%	0.1%
Forested	41, 42, 43	57.4%	35.6%	29.8%
Agricultural	22, 24, 211, 212	26.0%	38.7%	51.8%
Developed	11, 12, 13,17	1.8%	10.9%	8.0%
Transportation/Utilities	14	3.3%	4.8%	6.9%

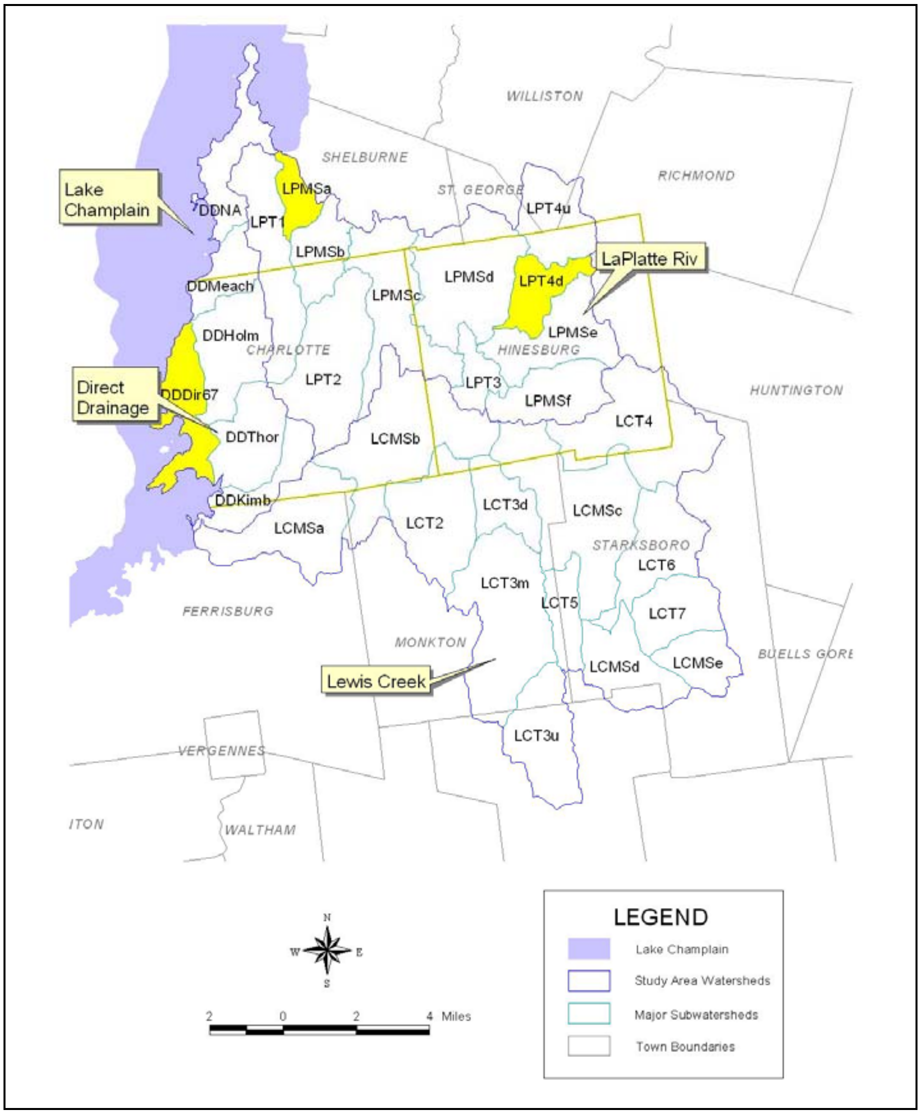
3.4 Summary of Percent Imperviousness by Watershed

Area-Weighted Imperviousness was calculated for each of the Study Area major sub-watersheds based on land cover / land use data. Details of the methods are summarized in Appendix B. Results are illustrated in Figure 4. Sub-watersheds with the highest percent imperviousness (% IMP) are highlighted:

- LPMSa in the LaPlatte River watershed is coincident with the village area of Shelburne;
- LPT4d in the LaPlatte River tributary of Patrick Brook (T4) is coincident with much of the village center of Hinesburg; and
- DDDir67 in the Direct Drainage watershed includes the higher-density seasonal and fulltime residences along Thompson's Point and Cedar Beach.

While transportation networks represent a relatively small total area within each town, they have a significant influence on the Area-Weighted Imperviousness in Study Area watersheds, since the impervious coefficient applied is 100% (see Appendix B).

Also, while Effective Impervious Cover was not accounted for separately from Total Impervious Cover in this study, it is important to note that road and driveway networks and their associated road-side ditch networks tend to be more directly connected to river and stream networks than rooftop impervious surfaces.



Direct Drainage

Subshed	% IMP
DDDir67	6
DDHolm	4
DDKimb	5
DDMeach	4
DDNA	4
DDThor	4

Lewis Creek

Subshed	% IMP
LCMSa	3
LCMSb	3
LCMSc	2
LCMSd	2
LCMSe	1
LCT2	3
LCT3d	3
LCT3m	2
LCT3u	1
LCT4	2
LCT5	<1
LCT6	2
LCT7	1

LaPlatte River

Subshed	% IMP
LPMSa	8
LPMSb	5
LPMSc	4
LPMSd	4
LPMSe	4
LPMSf	3
LPT1	5
LPT2	3
LPT3	3
LPT4d	7
LPT4u	3

Figure 4. Area-Weighted Percent Imperviousness for Study Area Sub-watersheds. (Highest Impervious Sub-watersheds highlighted).

4.0 FUTURE DEVELOPMENT

To assess the influence of future development on impervious conditions in the Study Area watersheds spanning each of the Principal Towns, build out analyses were conducted. The LaPlatte River, Lewis Creek and Direct Drainage watersheds do not conform to the political boundaries of towns. Thus, major sub-watersheds for which imperviousness was estimated extend beyond the Principal Town boundaries into adjacent towns in Chittenden and Addison Counties. Estimates were therefore made to address future development in the Principal Towns, as well as the immediately adjacent towns.

For Hinesburg and Charlotte, a detailed build out analysis was conducted using the *Addison Community Buildout Analysis* software (ACBOA, an extension to ArcView® 3.x). Results for Hinesburg are summarized in Appendix D; and results for Charlotte are contained in Appendix E. A maximum-potential, zoning-based build out was performed for towns adjacent to Charlotte and Hinesburg, to obtain a coarse estimate of potential development densities in portions of the sub-watersheds that overlapped into those adjacent towns. Results of this maximum build out are presented in Appendix F.

Build out results are intended for planning purposes only - for application at a regional scale (e.g., town-wide , watershed-wide). Build out results should not be evaluated at the parcel or sub-parcel level.

4.1 Detailed Build Out Analyses for Hinesburg and Charlotte

Previous build outs had been conducted for both Charlotte and Hinesburg in 2003 by CCRPC using a regional build-out analysis (RBA) process (Spitz & Stone Environmental, 2003). These build outs were performed to evaluate future development on a County scale and to review consistency of predicted development patterns with regional and town plans.

Original data sets, zoning information, and certain constraint assumptions utilized in the CCRPC RBA for each of the Principal Towns were utilized as the basis for running a build out analysis using the ACBOA software. The results of the RBA and ACBOA build out analyses were then compared and presented to the project Steering Committee. The results obtained from the ACBOA build out closely matched the results from the RBA.

Certain basic assumptions varied between the two methods:

- A "Build Factor" was employed in the RBA to remove a certain percentage of land area from density calculations. This area was to provide for setbacks, infrastructure development, etc. No such factor was employed in the ACBOA approach.

- A three-to-one factor was employed in the RBA. This effectively stated that a parcel must be at least three times the size of the minimum required lot size for the zoning district in order to be subdivided. No such restriction was imposed in the ACBOA approach.

The above variations were discussed with the member of the Principal Towns on the Steering Committee with the consensus being that the ACBOA approach more closely reflected the reality of development in these towns. The ACBOA approach was subsequently used in performing build out analysis for various scenarios.

4.1.1 Zoning District Characteristics of Principal Towns

Zoning Districts for Hinesburg and Charlotte are illustrated in Figure 5. Zoning district areas and characteristics are summarized in Tables 3 and 4, respectively.

Hinesburg and Charlotte have similar distributions of commercial / industrial / village areas versus rural / agricultural areas in their zoning districts. In Hinesburg, the commercial/ industrial / village areas are concentrated in one area at the current downtown center, except for the Hinesburg Sand & Gravel quarry area in the southeastern corner of the town, which is zoned Industrial. Charlotte's commercial/industrial/village uses are concentrated in the "West Village" area near the Route 7 and Ferry Road intersection and in the "East Village" area near the Hinesburg Road / Spear Street intersection. The "Rt. 7 Industrial Park" in the southwest portion of Charlotte is still zoned Industrial; however, this area was converted to a conserved status in 2004 (Illick, 2005).

In general, existing zoning regulations permit higher development densities in Hinesburg than in Charlotte. Agricultural and Rural Residential districts in Hinesburg, comprising 95% of the total town area, are designated at 2-acre to 3-acre zoning. In Charlotte, Rural and Conservation districts, comprising 93% of the total town area, are designated at 5-acre minimum zoning.

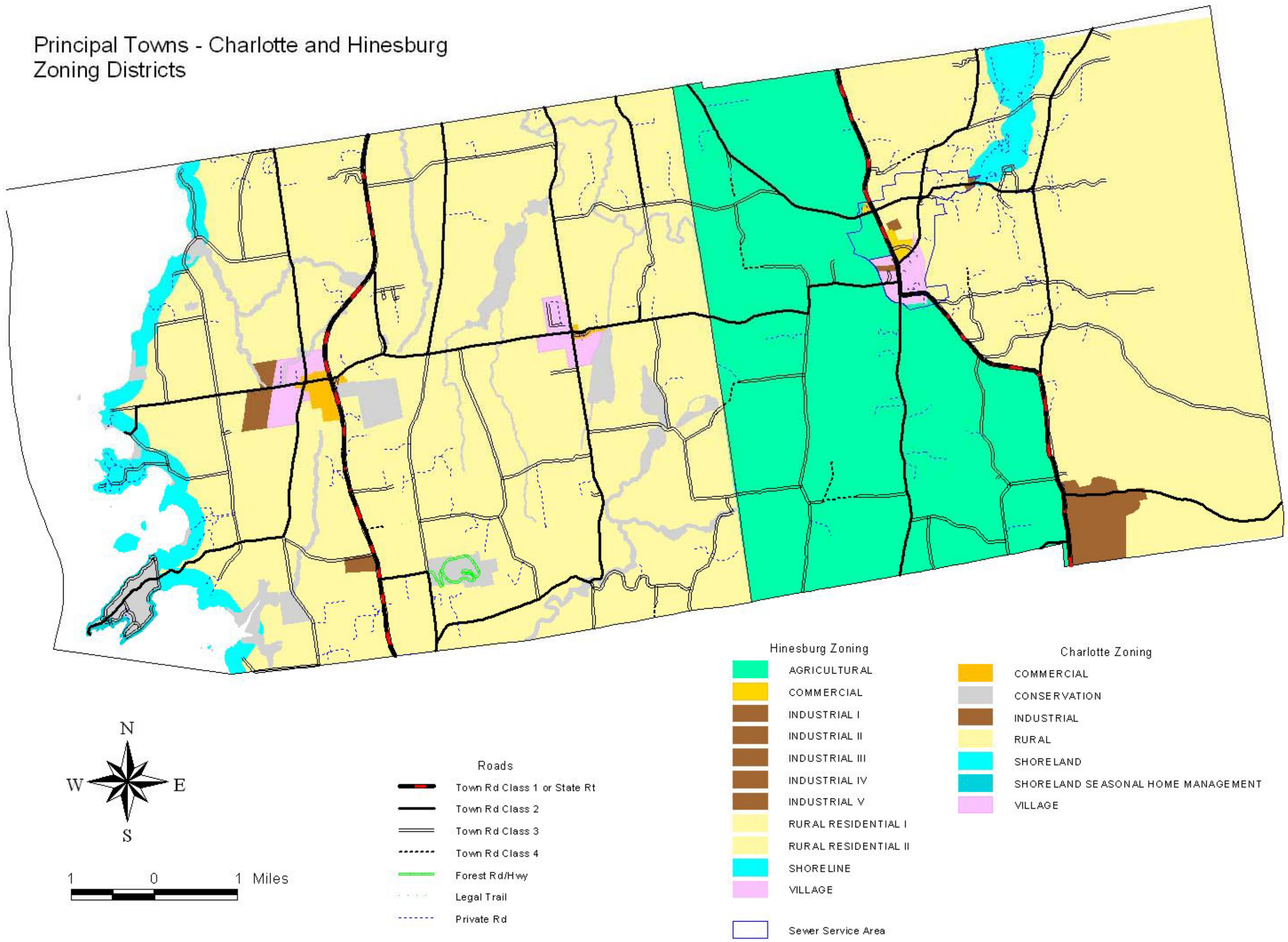


Figure 5. Illustration of Zoning Districts, Hinesburg and Charlotte

Table 3. Town of Hinesburg Zoning District Areas.

Zoning District *Miniumum Acreage*		Area (acres)	**Total Area (acres)**	**Total Area (sq mi)**	**Percent of Total Town Area (%)**
Agricultural			11,186	17.5	44.0%
2 Ac					
Commercial			52	0.1	0.2%
0.46 Ac	*(a)*	*8*			
0.46 Ac	*(b)*	*44*			
Industrial			489	0.8	1.9%
0.92 Ac	*I*	*461*			
0.92 Ac	*II*	*8*			
0.92 Ac	*III*	*10*			
0.92 Ac	*IV*	*1*			
0.92 Ac	*V*	*9*			
Rural Residential			13,007	20.3	51.1%
3 Ac	*I*	*3,880*			
3 Ac	*II*	*9,127*			
Shoreline			515	0.8	2.0%
3 Ac					
Village			192	0.3	0.8%
0.33 Ac	*(a)*	*174*			
0.33 Ac	*(b)*	*18*			
		TOTAL:	25,441	39.8	

Note: Minimum acreage for Rural Residential I is 1 acre in the Sewer Service Area (see Figure 5).

Table 4. Town of Charlotte Zoning District Areas.

Zoning District *Minimum Acreage **		Area (acres)	Total Area (acres)	Total Area (sq mi)	Percent of Total Town Area (%)
Commercial			147	0.2	0.6%
*5 Ac (1 Ac) **	*East Village*	*20*			
*5 Ac (1 Ac) **	*West Village*	*127*			
Conservation			2,214	3.5	8.3%
5 Ac					
Industrial			162	0.3	0.6%
*5 Ac (1 Ac) **	*Rt. 7 Industrial Pk (conserved 2004)*	*43*			
*5 Ac (1 Ac) **	*West Village*	*119*			
Rural			22,493	35.1	84.8%
5 Ac					
Shoreland			1,034	1.6	3.9%
5 Ac					
Shoreland Seasonal			64	0.1	0.2%
5 Ac					
Village			416	0.7	1.6%
*5 Ac (1 Ac) **	*East Village*	*202*			
*5 Ac (1 Ac) **	*West Village*	*214*			
		TOTAL:	26,530	41.5	

** Note: Residential Use (Non-residential Use) in Mixed Use District*

4.1.2 Build Out Results

Build out results for Hinesburg and Charlotte are summarized in Table 5. Detailed results are provided in Appendices D and E, respectively. Plate-size maps accompanying these results are on file at the respective town offices. Results are provided for both residential build out and commercial build out.

A basic build out ("Basic BO" in Table 5) was performed for each town, which simply considered the minimum acreage requirements under current zoning to determine numbers of potential new units, in addition to existing development (from E911 data). Areas of roads and water, public parcels such as cemeteries, and conserved parcels were removed as undevelopable under these basic build outs. Results of such a basic build out, however, tend to overstate potential development, since none of the typical constraints to development are considered, such as presence of wetlands or slow-draining soils.

A refined build out ("Refined BO" in Table 5) was performed for each town which considered a suite of natural resource constraints identified in consultation with the Steering Committee members from the two towns, Lewis Creek Association, ACRPC and CCRPC. Constraints included suitability of soils for residential on-site waste disposal systems (under the 2002 Vermont Environmental Protection Rules); prime ag soils; State-wide soils (Charlotte only); wetlands; surface water buffers; steep slopes; natural communities and wildlife habitats; FEMA-FIRM floodplains and wellhead protection areas (Hinesburg only).

Charlotte then prepared three alternate build out scenarios which considered: (1) increased development density in its Village districts; (2) changes to the assumptions about the degree of constraint represented by unsuitable soils; and (3) enhanced protections for surface water buffers.

Hinesburg

As summarized in Table 5 (and Appendix D), the residential units in Hinesburg would be expected to more than triple under maximum build out. A potential 3,375 units would be added to the 1,586 existing units, for a total of approximately 4,961 units town-wide. This build out considers current zoning allowances, existence of the Sewer Service Area, and the estimated natural resource constraints.

At build out, a total estimated 122 acres of commercial/industrial development (including building footprint and parking areas) would be expected in the Commercial and Industrial zoning districts of Hinesburg.

Charlotte

As summarized in Table 5 (and Appendix E), a potential 1,001 residential units would be expected in addition to the 1,543 existing residential units in Charlotte, considering current zoning allowances and estimated natural resource constraints. The majority of these potential units are estimated to occur in the Rural zoning district (approximately 899, or 90%). A total of approximately 12 potential units (or 1%) are estimated to be added in the Village district (both West Village and East Village).

At build out, a total estimated 23 acres of commercial/industrial development (including building footprint and parking areas) would be expected in the Commercial and Industrial zoning districts of Charlotte. Note that while the "Rt. 7 Industrial Park" in the southwest portion of Charlotte is still zoned Industrial, this area was converted to a conserved status in 2004 (Illick, 2005). As a consequence, no potential buildings or parking areas resulted from the commercial / industrial build out in the Rt. 7 Industrial Park area (see Appendix E).

Table 5. Summary of Build Out Results: Principal Towns

Buildout Results	**Charlotte**	**Hinesburg**
Basic BO	Road and water portions of parcels removed. Conserved parcels removed.	
Residential BO *Residential Development in all applicable Zoning Districts*	4557 units *1543 existing + 3014 pot.*	9546 units *1584 existing + 7962 pot.*
Commercial / Industrial BO *Sum of Commercial Dev in Commercial Districts, Industrial Dev in Indust Districts - Bldg Footprint and Parking Area*	85 Acres	393 Acres
Refined BO	Constraints applied for Slopes >25%, Wetlands and Wetland Buffer Areas, Wildlife, Prime Ag and Statewide Soils, Septic Suitability of Soils (new rules), and Surface Water Buffers.	Constraints applied for prime ag soils, and septic suitability (new rules), slopes >20% & >8%, FEMA-FIRM floodplain, Wellhead Protection Areas and Development Isolation Zones, Wetlands, buffered (75ft) surface waters, natural communities, deer wintering areas. Sewer Service Area Included.
Residential BO	2544 units *1543 existing + 1001 pot.*	4961 units *1586 existing + 3375 pot.*
Commercial / Industrial BO	23 Acres	122 Acres

4.1.3 Comparison of Build Out Results: Principal Towns

At present, Hinesburg and Charlotte have similar numbers of existing structures town-wide. The aerial extent of their zoning districts in commercial / industrial use versus residential / agricultural use is also similar (see Figure 5). Yet, Table 5 indicates a much greater potential for growth in Hinesburg than in Charlotte based on current zoning for each town. This fact is likely attributed to two main reasons:

1) Hinesburg zoning regulations generally permit greater development densities than Charlotte (see Tables 3 and 4, respectively), and the future availability of the Sewer Service Area contributes significantly to this potential for growth.

2) Generally, the natural resources considered in the Hinesburg build out are lesser in aerial extent and lesser in degree of constraint than those considered in the Charlotte build out. The "All Constraints" maps available in large size for each Town indicate that development in nearly 100% of Charlotte is anticipated to be affected by some level of constraint. Whereas, in Hinesburg, there are significant areas not impacted to any degree by the natural resource constraints, at least those considered under the build out detailed in Appendix D.

4.1.4 Summary of Build Out Scenario Results: Charlotte

Alternate build out scenarios were identified by a Charlotte Working Group consisting of: Dean Block, Jim Donovan, and Nell Fraser from Charlotte; Marty Illick from Lewis Creek Association; and Kristen Underwood of South Mountain Research & Consulting.

Details of build out runs under the following three scenarios are presented in Appendix E, and are summarized in Table 6.

- Scenario 1 – Evaluate influence of increased village district density;
- Scenario 2 – Evaluate assumptions about "developability" of unsuitable soils;
- Scenario 3 – Remove development potential for 75-foot surface water buffers.

For purposes of evaluating Scenarios, only the Residential BO results were reviewed, since Commercial and Industrial districts in Charlotte represent approximately 309 acres in area, or only 1.2% of the total town area of 26,530 acres (see Table 4).

Scenario 1 – Evaluate influence of increased density in village district

To evaluate an increased development density in the village areas of Charlotte, a 1-acre minimum was substituted for the 5-acre minimum in the Village zoning district of Charlotte; all other districts remained at a 5-acre minimum (see Table 4). The Village zoning district (consisting of both the East Village and West Village areas) represents approximately 416 acres in total area, or 1.6% of the total town area of 26,530 acres. The West Village occupies the DDHolm sub-watershed in Direct Drainage, while the East Village is located in LPT2 sub-watershed of the LaPlatte River.

Approximately 64 residential units are gained town-wide under Scenario 1, as compared to the Refined BO results (see Table 6). Under Refined BO, 12 potential units are added to the 95 existing units, while under Scenario 1, 76 potential units are added to the 95 existing units in this Village district. All structures gained were located in the Village District, as expected (see Appendix E).

Under Scenario 1, the number of residential structures in the Village District would nearly double from 95 to a total of 171. These increased density effects would impact the DDHolm and LPT2 sub-watersheds, concentrated at the areas of "West Village" and "East Village", respectively. Low impact development choices and effective stormwater mitigation structures and practices could minimize the potential effects of this localized, increase in development density and associated impervious surfaces.

Table 6. Summary of Build Out Scenario Results: Charlotte.

Scenario Results	Residential BO	Comments
Refined BO	Constraints applied for Slopes >25%, Wetlands and Wetland Buffer Areas, Wildlife, Prime Ag and Statewide Soils, Septic Suitability of Soils (new rules), and Surface Water Buffers	
	2544 units *1543 existing + 1001 pot.*	
Scenario 1	1-acre minimum zoning substituted for 5-acre minimum in Village Districts. All other districts remain at 5-acre minimum.	
Evaluate influence of increased village district density	2608 units *1543 existing + 1065 pot.*	64 residential units are gained in Village Districts. These increased development density effects would impact the DDHolm and LPT2 major subsheds, concentrated at the areas of West Village and East Village, respectively.
Scenario 2	Assumed 80% developability of Class IV, V, and VI soils utilized in the Refined BO (and Scenarios 1 and 3) is replaced with a conservative assumption of 10% developability.	
Evaluate assumptions about "developability" of Class IV, V, and VI soils (new septic rules)	2272 units *1543 existing + 729 pot.*	A loss of approximately 272 structures is noted by comparison of Scenario 2 results to Refined BO results, or 27% of the total estimated potential units under Refined BO. The majority of these losses are exhibited in the Rural, Conservation, and Shoreland districts.
Scenario 3	Remove development potential for areas within surface water 75-foot buffers (do not allow these areas to count toward density requirements)	
Evaluate enhanced protection for established riparian buffers.	2472 units *1543 existing + 929 pot.*	A loss of approximately 72 structures is noted by comparison of Scenario 3 results to Refined BO results, or 7% of the total estimated potential units under Refined BO. The majority of these losses are exhibited in the Rural, Conservation, and Shoreland districts.

Scenario 2 - Evaluate assumptions about "developability" of unsuitable soils

Following adoption of the 2002 Vermont Environmental Protection Rules (VTDEC Wastewater Management Division, 2002), suitability of soils for residential on-site sewage disposal was reclassified in the table of Top 20 parameters associated with NRCS state-wide soil coverage published by the Natural Resources Conservation Service (NRCS, 2003).

- **Class I - Well suited** – includes soil mapping units classified with moderate to rapid permeability and limited slopes.
- **Class II - Moderately suited** – includes soil mapping units classified with various combinations of slow to rapid permeabilities; limited to moderate slopes; moderate depth to bedrock or seasonal high water table; and/or flooding limitations.

- **Class III - Marginally suited** - includes soil mapping units classified with various combinations of limited to moderate slopes; marginal depths to bedrock or seasonal high water table; and other limitations due to flooding or depth to bedrock and/or seasonal high water table.
- **Class IV - Not suited**, due to excessive wetness, steepness of slope, limited depth to bedrock, and or slow permeability.
- **Class V - Not rated** – includes miscellaneous soil mapping units which have been disturbed by human land uses (filled, excavated, re-graded) and units which are mapped as water.

Under build outs for both Hinesburg and Charlotte, Class I, II, and III soils were assumed to be 100% developable (i.e., no restriction or constraint on development with respect to septic suitability of soils). Based on patterns of development observed across the individual towns, Charlotte and Hinesburg representatives chose different assumptions for those soils mapped as Class IV and V. While these soils are classified by NRCS as "not suited" and "not rated", respectively, the minimum mapping unit for these soils is 3 acres. Experience shows that small subareas of these soil mapping units can have marginally-suited to well-suited soils within them. Identification of pockets of suitable soils during onsite evaluations and use of innovative septic designs permitted under the new Environmental Protection Rules frequently result in unconstrained or minimally constrained development occurring in areas mapped as not suited for onsite sewage disposal.

Under the Refined BO, Hinesburg chose to consider Class IV and V soils as 10% developable, allowing for a limited degree of development to occur on these soils. In contrast, Charlotte chose to consider these soils as 80% developable, since they see a greater degree of development occurring in their town in those areas mapped as "not suited".

Under Scenario 2 for Charlotte, the assumed 80% developability of these unsuitable soils utilized in the Refined BO (and in Scenarios 1 and 3), was replaced with a conservative assumption of 10% developability, to evaluate the significance of this assumption on overall build out results. The sensitivity of build out results to this parameter was expected to be significant, given the considerable aerial extent of Class IV and V soils in the town of Charlotte (Figure 6). (Note: Figure 6 also includes small areas of unknown class soils.
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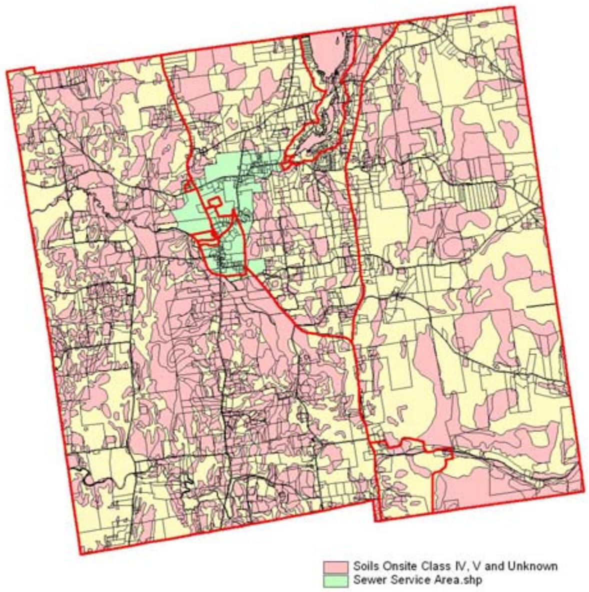
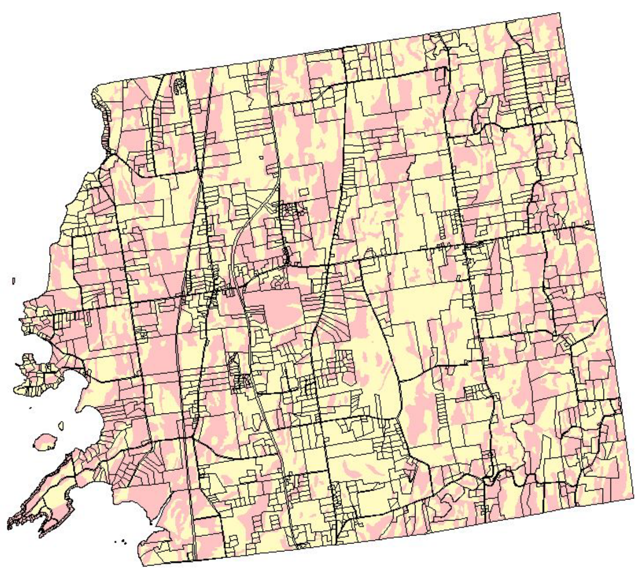
As summarized in Table 6, approximately 272 structures are "lost" town-wide under Scenario 2, as compared to the Refined BO results. The majority of these "losses" are exhibited in the zoning districts comprising the three highest total acreages in the town: Rural, Conservation, and Shoreland (see Table 4). A loss of 272 structures under Scenario 2 represents approximately 27% of the total estimated potential structures under the Refined BO.

Scenario 2 results indicate that the estimation of the "developability" of Class IV and V soils is significant to the calculation of potential build out. Further study to refine this estimate would improve the accuracy of build out predictions. In all likelihood the actual "developability" lies somewhere between 80% and 10%, and potential residential units are some approximate number between 1,001 and 729. Town of Charlotte representatives report that this value is closer to 80% based on local experience.



Hinesburg



Charlotte

Figure 6. Aerial extent of Class IV and V soils in Hinesburg and Charlotte.

Scenario 3 – Remove development potential for 75-foot surface water buffers.

In Scenario 3, Charlotte considered an added measure of protection for its surface waters. Current zoning requires a 75-foot setback of structures from streams/ rivers. Therefore, under the Refined BO, no structures were permitted to be placed within the areas representing buffered surface waters. The area could, however, count toward density requirements governed by the relevant zoning district. In Scenario 3, the area represented by these buffered streams was not allowed to count toward density requirements in parcel-based build out. As a result, approximately 72 structures were lost town-wide under Scenario 3, as compared to the Refined BO results. All of these "losses" occurred in the zoning districts comprising the three highest total acreages in the town: Rural, Conservation, and Shoreland. These 72 structures under Scenario 3 represented approximately 7% of the total estimated potential structures under the Refined BO. Thus, removing development potential for areas within surface water 75-foot buffers was determined to result in a significant reduction in potential units at build out.

This scenario represents a more stringent level of protection for Charlotte's surface waters, over simple structure setbacks. Such a choice would improve water quality by lessening development densities near the buffer along stream channels in the Rural, Conservation, and Shoreland districts. This improved public value should be evaluated in light of the potential costs to riparian landowners in terms of loss of use.

It is interesting to note that the number of structures lost to town-wide development under Scenario 3 is similar to the number of structures gained in the Village districts under Scenario 1.

4.1.5 Predicted Development Relative to Major Sub-watersheds

Predicted build out from the above analyses can be evaluated within the boundaries of the major sub-watersheds on the Plate-size maps of build out results which accompany this study (on file at the respective town offices). Expected distributions of potential new structures are illustrated in a generalized way on project maps. Point locations of new structures are approximate only, and should not be relied upon for parcel-scale evaluation or planning. However, the cross-town and cross-watershed distribution pattern of development densities visualized by these build out results can help to prioritize municipal planning and watershed management activities in the two towns.

Hinesburg

Under the Refined BO results for Hinesburg, residential development would appear to be fairly evenly distributed town-wide, across the major Sub-watersheds, with the exception of the village area. Greater increases in development density at build out would be expected within the Sewer Service Area, in which 1-acre minimum zoning is permitted in the Rural Residential I district. The Sewer Service Area straddles sub-watersheds LPT4d at the downstream extent of the Patrick Brook, and LPMSe and LPMSd along the main stem of the LaPlatte River.

At build out, an estimated 122 acres of commercial/industrial development (including building footprint and parking areas) would be expected in the Commercial and Industrial zoning districts town-wide. Two of the three commercial/industrial zoning districts are located in the same sub-watersheds noted above: LPT4d, LPMSe and LPMSd in the LaPlatte River watershed. The third commercial/industrial district is coincident with the Hinesburg Sand & Gravel quarry in LCT4, along the Hollow Brook tributary to Lewis Creek.

Charlotte

Under the Refined BO results for Charlotte, residential development would appear to be fairly evenly distributed town-wide, across the major sub-watersheds - even in DDHolm and LPT2, containing the West Village and East Village areas, respectively. This result is likely due in part to zoning densities assumed for the village areas in the detailed build out, as well as to constraints posed by natural resources. While the Charlotte zoning regulations allow for non-residential uses at higher densities (1-acre minimum zoning) in the Village district (and in the Commercial and Industrial districts; see Table 4), the Refined BO assumed residential use (5-acre minimum zoning) in these mixed-use districts. This 5-acre minimum zoning is consistent across other zoning districts. A visual representation of higher-densities in the Village district can be viewed in the large-scale mapping for results of build out Scenario 1.

The estimated 23 acres of commercial/industrial development (including building footprint and parking areas) expected in the Commercial and Industrial zoning districts of West Village and East Village would be located in sub-watersheds DDHolm and LPT2, respectively.

4.2 Zoning-based Maximum Build Out Analyses for Study Area Towns

The Study Area watersheds overlap portions of seven Chittenden County towns (Charlotte, Hinesburg, Williston, Richmond, Huntington, Shelburne, and St. George) and four Addison County towns (Bristol, Ferrisburg, Monkton, and Starksboro). A zoning-based maximum build out was performed for the Study Area portions of each of these 11 towns to support a review of estimated development densities at build out across the Study Area. This zoning-based maximum build out did not take into consideration: (1) existing development within the towns that may or may not conform to densities specified under current zoning; (2) natural resource constraints to development (e.g., limiting soils, wetlands); or (3) societal constraints to development (e.g., conserved parcels, public parcels). This method was intended as a rapid way for watershed communities to: (1) observe the expected influence of cross-town and cross-district zoning choices on future development density patterns across the Study Area; and (2) prioritize watershed management and municipal planning activities in the context of stormwater planning.

Results of the zoning-based maximum build out are presented in Appendix F, and are summarized in Table 7. Current zoning district configurations, and minimum acreage requirements under each zoning district category, were compiled for the eleven Study Area towns (see Appendix F). The eleven towns were "clipped" to the Study Area major sub-watersheds, and an approximate number of structures at build out in each of the sub-watersheds was determined based on the minimum lot sizes specified per zoning district in each sub-watershed-clipped area of the 11 towns. An average developed area of 0.4 acre was applied to each structure, to determine the approximate developed area in each sub-watershed at maximum build out. A development density for each Sub-watershed was then calculated as the percent of sub-watershed developed (Table 7). (Note: The value of 0.4 acre was derived from an analysis of vector-based delineations of "developed area" in the Lewis Creek watershed (Capen, 2003). Details of this analysis are available upon request. No distinction was made in the average developed area of structures in residential versus commercial/industrial districts. A different value of average-developed-area-per-structure would likely result from a different land cover / land use data source or from analysis in a different geographic region of Vermont. The important result from this analysis is the ***relative*** difference of development densities between sub-watersheds crossing municipal boundaries).

Table 7. Estimated Development Densities at Maximum Build Out based on Current Zoning in Eleven Study Area Towns

Subshed	Average Lot Size (acres)	No. Units	Developed Area (acres)	Subshed Area (square miles)	Percent Subshed Developed
LCT7	24.8	95	38	3.7	2%
LCT5	24.4	65	26	2.4	2%
LCT6	21.8	153	61	5.2	2%
LCT3u	19.3	180	72	5.4	2%
LCMSe	18.2	98	39	2.8	2%
LCMSd	15.8	189	76	4.7	3%
LCT3m	11.4	554	222	9.9	4%
LCMSc	11.3	622	249	10.9	4%
LCT3d	9.6	202	81	3.0	4%
LCMSa	8.1	561	224	7.1	5%
LCT4	8.1	726	290	9.2	5%
LCT2	7.7	522	209	6.3	5%
DDKimb	5.3	385	154	3.2	8%
DDDir67	5.0	512	205	4.0	8%
DDMeach	5.0	323	129	2.5	8%
DDThor	5.0	571	228	4.5	8%
LPT2	5.0	1019	408	8.0	8%
DDHolm	5.0	699	280	5.5	8%
DDNA	4.6	516	206	3.8	8%
LPT1	4.4	892	357	6.2	9%
LPMSc	4.4	1051	420	7.2	9%
LCMSb	4.3	1559	624	10.5	9%
LPMSb	3.4	595	238	3.2	12%
LPMSd	2.6	2102	841	8.5	16%
LPT4u	2.4	1153	461	4.3	17%
LPMSf	2.3	1149	460	4.2	17%
LPMSe	2.1	1617	647	5.3	19%
LPMSa	2.0	510	204	1.6	20%
LPT3	2.0	603	241	1.9	20%
LPT4d	1.5	1199	480	2.8	27%

Each major sub-watershed may overlap multiple zoning districts (sometimes from different towns) with varying minimum lot sizes. An average minimum lot size was calculated for each major sub-watershed as a whole (Table 7). In sub-watersheds like Lewis Creek's LCT7, the average lot size can be quite large, where Starksboro's Forestry and Conservation zoning district (25-acre minimum) dominates. In contrast, a small average lot size is evident for many of the LaPlatte sub-watersheds (e.g., LPT3, LPT4d) located in Hinesburg, where minimum lot sizes of 2 to 3 acres dominate.

As suggested by Kevin Behm of ACRPC, the average minimum lot size might serve as an indicator of approximate development densities at maximum build out. Generally speaking, development densities increase with decreasing average lot size. As displayed in Figure 7, an exponential relationship is suggested.

The development densities across the Study Area are illustrated graphically in Figure 8. Drainage densities were classified into arbitrary Low (1% to 5%), Medium (6% to 10%), and High (> 10%) categories. Figure 8 highlights those sub-watersheds overlapping towns (or zoning districts within towns) that allow for higher development densities (i.e., lower minimum lot sizes). These results can be used by watershed communities to identify where impervious surface

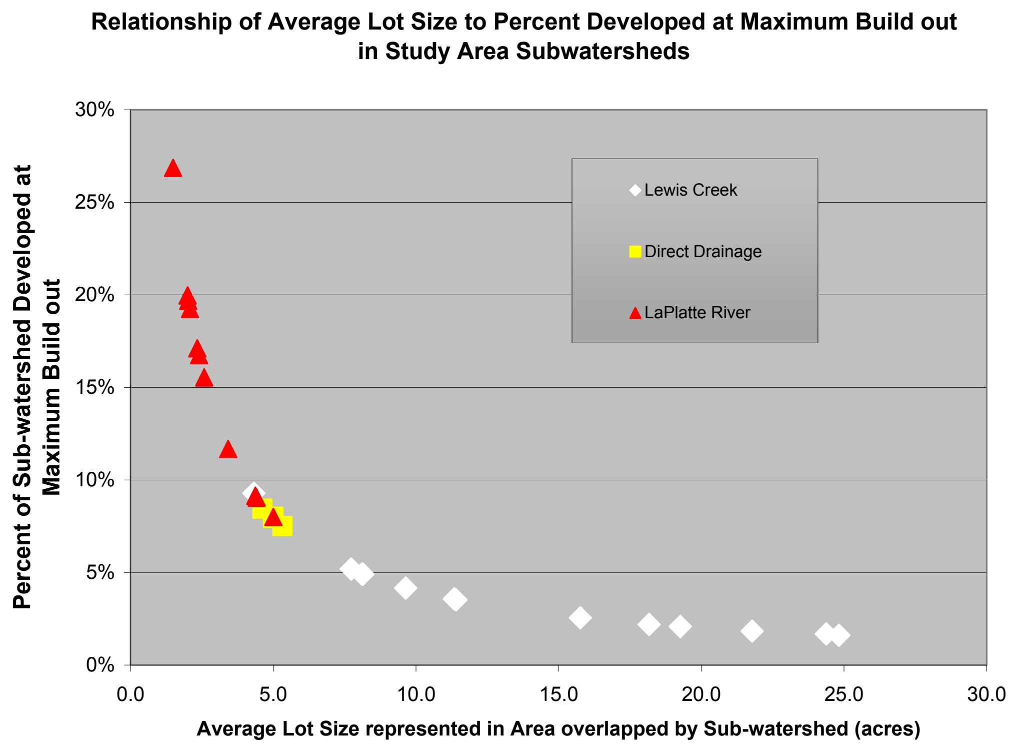


Figure 7.

impacts from future development might be more prevalent, based solely on the current distribution of zoning requirements across the Study Area.

Figure 7 and Figure 8 illustrate that Lewis Creek watersheds, in general, would be expected to exhibit lower development densities at maximum build out than the other Study Area watersheds. One exception to this generalization would be sub-watershed LCMSb which overlaps into Charlotte and Hinesburg, where higher development densities are permitted by zoning as compared to the other Lewis Creek towns of Monkton and Starksboro. Direct Drainage sub-watersheds exhibit moderate development densities at maximum build out. While, LaPlatte River sub-watersheds would be expected to exhibit the highest development densities at maximum build out under current zoning.

There are limitations of this zoning-based method of determining expected development densities at maximum build out. First, the method does not address development that may exist today at higher densities than would be permitted under current zoning. Thus, the method may underestimate development density at build out in the affected sub-watersheds. For example, DDDir67 in Charlotte, encompassing the Thompson's Point and Cedar Beach areas, would be predicted to have a moderate development density, based solely on allowed densities under current zoning. Contrary to this expectation, DDDir67 was identified as one of the three sub-watersheds across the entire Study Area with highest estimated imperviousness, based on current (1993) land cover/ land use (Section 3.4, Figure 4).

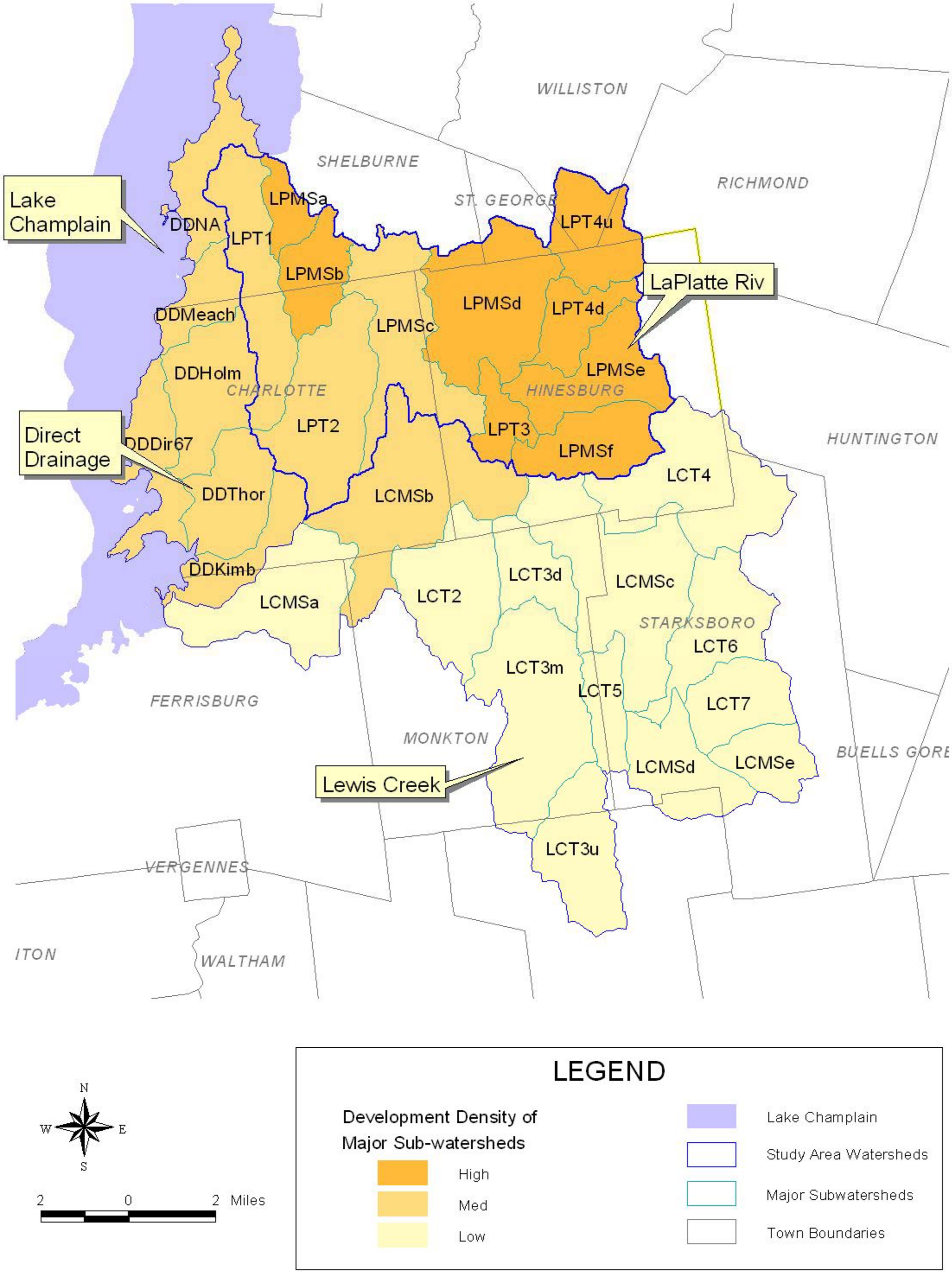


Figure 8. Zoning-derived estimates of Development Density at Maximum Build Out in Study Area Major Sub-watersheds.

Consistent with expectations, the other two sub-watersheds with highest percent imperviousness (LPT4d and LPMSa; see Figure 4) were predicted to have high development densities at maximum build out, based on zoning alone. These watersheds are located coincident with village areas in Hinesburg and Shelburne, respectively, where zoning regulations permit higher densities. Observed development patterns, (based on 1993 land cover/ land use data sets) are thus consistent with current zoning in these sub-watersheds.

A second limitation to using the zoning-based method of determining expected development densities at maximum build out is that this method does not consider the natural resource constraints to development (such as limiting soils or wetlands). Nor does the method address societal factors that would render certain parcels un-developable, such as presence of cemeteries or other publicly-owned parcels, and publicly or privately conserved parcels or easements. These factors can vary considerably across the landscape and from town to town and will affect development densities in ways not captured in the basic zoning-based method presented here.

Finally, a third limitation to using the zoning-based derived maximum development densities to infer possible increases in impervious surfaces, is that this method does not adequately address the increased density of road and driveway networks (and other transportation / utility networks) that would accompany development. These factors are difficult to predict, and yet they are expected to have a significant influence on the overall determination of impervious surfaces and potential impacts to water quality (see Appendix B).

5.0 DISCUSSION AND CONCLUSIONS

5.1 Comparison of Impervious Estimates to the Impervious Cover Model

As summarized in Section 3.4, the current (1993) area-weighted imperviousness for Study Area sub-watersheds ranged from less than 1% (LCT5; upland watershed along Hogback Mountain spanning Monkton and Starksboro in Lewis Creek) to a maximum of 8% (LPMSa; Shelburne Village in the LaPlatte River watershed). As compared to the thresholds of the Impervious Cover Model (CWP, 1998), all the Study Area watersheds would currently be in the Sensitive range (less than 10%). Recent research indicates that Impervious Cover (IC) alone, at percentages below the 10% threshold, is a less effective predictor of stream quality. "…[T]he influence of IC in the one to 10% range is relatively weak compared to other potential watershed factors, such as percent forest cover, riparian continuity, historical land use, soils, agriculture,…Consequently, watershed managers should never rely on IC alone to classify and manage streams in watersheds with less than 10% IC" (CWP, 2003, p.6).

For lightly developed watersheds such as the Study Area, it has been suggested that stream quality is optimized by both minimizing impervious surfaces and conserving mature forest cover (CWP, 2003). The non-"developed" land uses represented largely by agricultural cropland and pasture, golf courses and recreational fields may impart an Equivalent Percent Impervious value related to the removal of forest vegetation and soil compaction from grading and the repetitive use of heavy machinery. As discussed in an earlier section (Section 2.0) the Equivalent Percent Impervious values are not adequately captured in the regional scale impervious estimating method used in this study. Based on studies of Northwestern US watersheds, Booth (1991) suggests that forest cover greater than 65% should be maintained along with minimizing impervious surfaces to maintain stream quality. Figure 9 illustrates percent forest cover in the Study Area major sub-watersheds relative to percent imperviousness.

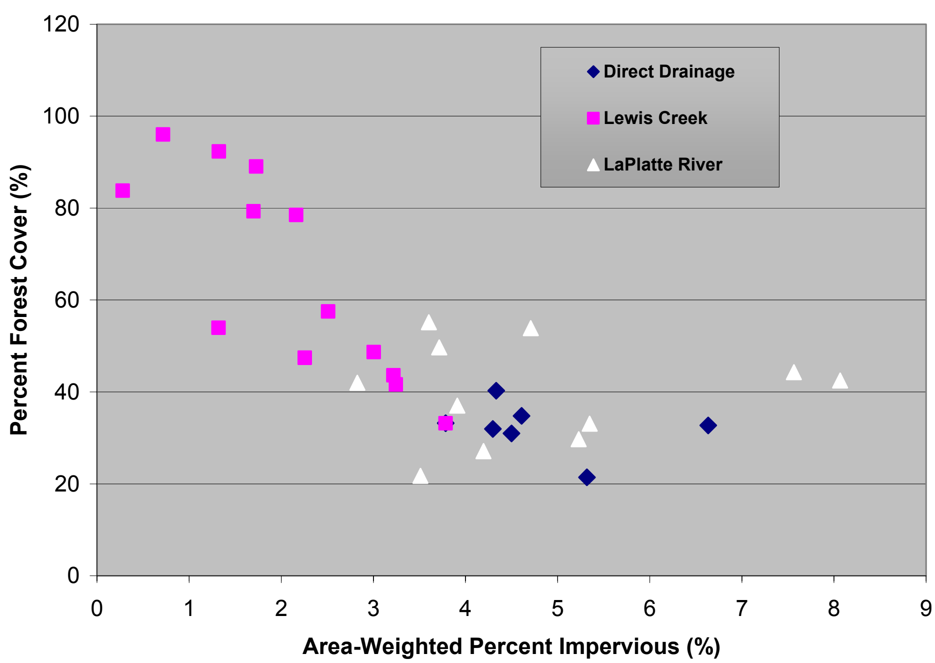


Figure 9. Relationship of Forest Cover to Total Watershed Percent Impervious

A majority of the major sub-watersheds in the Study Area have forest ranging from less than 60% to as low as 20% based on the 1993 land cover / land use data. Development over the last 12 years has likely further reduced these percentages in some sub-watersheds. Lewis Creek is the least developed of the three Study Area watersheds and increases in percent impervious appear strongly correlated with decreasing forest cover. However, in the Direct Drainage and LaPlatte River watersheds where there are larger percentages of agricultural land cover/ land use (see Table 2), impervious percentage is not strongly correlated to the inverse of forest cover. Based on Booth's recommendations for Northwestern streams, degraded stream quality could be expected in Study Area sub-watersheds of the LaPlatte River, Direct Drainage and lower Lewis Creek even at percent impervious values below 10%. Collection and review of water quality and geomorphic data for these waterways would be warranted to evaluate for these potential impacts.

Less research is available for evaluating the influence of riparian continuity on overall quality of receiving streams. Center for Watershed Protection (2003) defines riparian continuity as "the proportion of the perennial stream network in a sub-watershed that has a fixed width of mature streamside forest". CWP cites various sources that report positive correlations between diversity of fish and macroinvertebrates to high degrees of riparian continuity (Horner *et al*., 2001; May *et al*., 1997; Roth *et al*., 1998).

5.2 Future Percent Impervious Estimates

A new set of state-wide land cover / land use data is scheduled for development in the next few years. This data set can be run using the same method presented here (Appendix B) to update impervious predictions for the Study Area, and enable trend analysis (assuming that the same scale, methodology and classifications are used in creating any new Land Cover/Land Use data sets).

In the meantime, Charlotte and Hinesburg can look to nearby urban centers in Chittenden and Rutland County watersheds for expected magnitude of impervious percents under higher-density development (Table 8).

Table 8. Estimated percent impervious in Vermont urban areas

Watershed	Location	Drainage Area (mi^2)	Impervious Surf. Area (%)	Ortho Year	Data Source
Muddy Brook	Williston	20.9	3.9	1996	a
Allen Brook	Williston	11.3	5.5	1996	a
Indian	Colchester / Essex	11.8	6.3	1996	a
Sunderland	Colchester / Essex	5.3	11.4	1996	a
Potash Brook	So. Burlington / Burlington	7.4	17.8	1996	a
Centennial	Burlington	1.4	25.1	1996	a
Englesby	Burlington	0.8	19.9	1996	a
Morehouse	Winooski	0.5	13.6	1996	a
Bartlett Brook	South Burlington	1.5	16.9	1996	a
Tenney Brook	Rutland Town / City	4.4	6	1994	b
Moon Brook	Rutland Town / City	5.3	13	1994	b
Lower Stevens	St. Albans	6.9	13	1995	b

Sources: (a) Pease, 1997; (b) CWP, 1999

The increased peak flows, flow frequency and flow volumes in receiving stream channels generated by untreated stormwater runoff in these urbanizing watersheds leads to wider and deeper channels. Based on data from Vermont, Maryland, and Texas, alluvial channels can be expected to double in width and depth at impervious values exceeding 20% and triple at values exceeding 30% (CWP, 2000b). These physical changes to channels resulting from increased (untreated or inadequately treated) stormwater runoff can result in excess sedimentation in downstream reaches, loss of cropland, and risks to infrastructure including bridge or culvert crossing structures, roads, and buildings. Other impacts of increased stormwater runoff include: (1) reduced infiltration leading to lower groundwater elevations; (2) increased temperatures of streams from the introduction of pavement-heated runoff; (3) increases in dissolved and sediment-related toxins in receiving waters, including oils and greases, heavy metals, nutrients, bacteria, etc.; (4) degraded aquatic habitats; and (5) reduced biodiversity of aquatic and riparian habitats (USEPA, 1983).

As noted previously, the simplified method of assessing Total Impervious Cover with respect to thresholds of the Impervious Cover Model does not account for the mitigating effects of stormwater treatments. Presumably, the degree of Effective Impervious Cover (only that portion of impervious cover hydraulically connected to the receiving stream networks) would decrease as society implements various alternatives such as stormwater treatment options, low-impact development designs, and adoption or expansion of vegetated riparian buffers.

It is possible that Total Impervious Cover estimated for current or future years would overestimate potential impacts on receiving waters, if such watershed treatment options have been successfully and comprehensively applied in the intervening time period. To reduce impervious surface impacts of future development, Hinesburg and Charlotte could consider planning and zoning mechanisms at the local level to complement the Act 250 and Stormwater Management Rule requirements for larger developments.

5.3 Evaluation relative to Water Quality

While impervious cover estimates in the Study Area sub-watersheds ranged from only 1% to 8%, water quality impacts in the Study Area have been documented.

5.3.1 LaPlatte River watershed

The State of Vermont has listed the following LaPlatte River sections as impaired due to Fecal coliform impacts likely resulting from agricultural runoff and streambank erosion (VTDEC WQD, 2004a):

- LaPlatte River main stem approximately 10.5 miles from the mouth upstream to Hinesburg (LPMSa, LPMSb, and LPMSc) – Fecal coliform, agricultural runoff
- Mud Hollow Brook from mouth to river mile 3 (LPT2, downstream portion) – Fecal coliform, runoff and streambank erosion

In addition, LaPlatte River mouth (LPMSa) is listed on Part C for further assessment of nutrient impacts, specifically phosphorous loading (VTDEC WQD, 2004b).

Water quality monitoring from the Summer months of 2004 (LaPlatte Watershed Partnership and Champlain Water District, 2005) indicates impacts from phosphorus, *E.coli*, and turbidity in the LaPlatte River watershed:

- Phosphorus exceeding the lake-based standard of 0.014 mg/L was detected in all sample stations on the LaPlatte River main stem (LPMSa to LPMSf); McCabe's Brook (LPT1), Mud Hollow Brook (LPT2), and the un-named tributary (LPT3), and some stations along Patrick Brook (LPT4). While there is no in-stream standard for Total Phosphorous, these concentrations can be expected to contribute to nutrient-enrichment and progressive eutrophication in Shelburne Bay.

- *E.coli* (from agricultural runoff and potentially sewage discharge) exceeded the State water quality standard in moderate to high flows in the LaPlatte main stem sample stations (LPMSa to LPMSf), McCabe's Brook (LPT1), Mud Hollow Brook (LPT2), Patrick Brook (LPT4), and the un-named tributary (LPT3).

- The State standard for turbidity (25 NTU) was exceeded during high flows in August 2004 at sample stations along the lower main stem of the LaPlatte (LPMSa to LPMSd), along McCabe's Brook (LPT1), and along Mud Hollow Brook (LPT2). During low flow conditions through the summer months, the turbidity standard was not exceeded except at some localized sample stations, apparently in response to point sources of sediment including construction runoff and sewage outfall.

5.3.2 Lewis Creek

The State of Vermont has listed the following Lewis Creek sections as impaired due to *E. coli* impacts likely resulting from agricultural runoff (VTDEC WQD, 2004a):

- Lewis Creek main stem, 12.3 miles from Lower Covered Bridge upstream to footbridge (LCMSb, LCMSc) – *E. coli*, agricultural runoff
- Pond Brook from confluence with Lewis Creek upstream approximately 1.5 miles (LCT3d) - *E. coli*, agricultural runoff

In addition, the following river sections are listed on Part C for further assessment of nutrient and *E. coli* impacts from agricultural runoff, riparian disturbances, and land development (VTDEC WQD, 2004b):

- Lewis Creek mouth (LCMSa) – phosphorous loading
- Lewis Creek river mile 7.5 to 16.6 (LCMSb and downstream portion of LCMSc)

Historic water quality sampling (1992 to 2004) by the Lewis Creek Association has identified phosphorus and *E. coli*, impacts in Lewis Creek, as well as sedimentation from unstable stream reaches and road / culvert maintenance practices (ACRWC, 2005). *E.coli* is consistently above State water quality standards at sampling stations located in Major Sub-watersheds LCMSa, LCMSb, and LCMSc (monitored from 1997-2004). More recent (2003-2004) monitoring initiated in Pond Brook tributary (LCT3d) has also noted *E.coli* concentrations well above standards. Total Phosphorus concentrations have consistently been above levels which would suggest nutrient-enrichment in sampling sites from LCMSa, LCMSb, and LCMSc (1992-2004) and in LCT3d (2003-2004). No in-stream water quality standard exists for Total Phosphorus, at present. Stormwater runoff is a direct contributor to these water quality impacts. Stormwater management measures undertaken by the Lewis Creek watershed communities, including Hinesburg and Charlotte, will serve to reduce these water quality impacts over the longterm.

5.3.3 Direct Drainage

Direct Drainage waterways within the Study Area are not listed as impaired. However, these surface waters are small in size and dispersed across the "watershed", and the authors are not aware of any State or citizen monitoring efforts ongoing in these streams. Based on the estimated impervious values for these major sub-watersheds (ranging from 4% to 6%) and given the above described nutrient, pathogen and sediment impacts to Lewis Creek sub-watersheds (ranging from 2% to 3% impervious) and LaPlatte River sub-watersheds (ranging from 3% to 8% impervious), water quality impacts would be expected in the Direct Drainage streams.

5.4 Evaluation relative to Geomorphic Assessments

While impervious cover estimates in the Study Area sub-watersheds ranged from only 1% to 8%, channel enlargement and streambank erosion have been documented in the Study Area.

The degree of channel enlargement and streambank erosion associated with increased imperviousness and stormwater runoff can be determined through comprehensive geomorphic assessments. The State of Vermont has developed protocols for phased geomorphic assessments (VTANR, 2004) with the objectives of: (1) minimizing fluvial erosion hazard losses; (2) improving water quality; and (3) improving aquatic and riparian habitats. Geomorphic assessments are also promoted in the context of All-Hazards Mitigation plans recently adopted by Addison County and Chittenden County towns.

5.4.1 LaPlatte River watershed

A Phase 1 Stream Geomorphic Assessment has been completed for the LaPlatte River watershed (LaPlatte Watershed Partnership, 2005) following VTANR protocols (VTANR, 2004). Limited Phase 2 Geomorphic Assessments have also been completed for reaches along Patrick Brook (LPT4; 7% IMP) and the LaPlatte main stem (LPMSe and LPMSd, each 4% IMP) in the Hinesburg village center area (Godfrey, 2005). Phase 2 assessments in these reaches indicates geomorphic conditions ranging from good to poor.

Reaches in fair to poor condition are exhibiting active lateral adjustments (widening and planform adjustment) and vertical adjustments (incising and aggrading) in response to development-related stressors including reduced riparian buffers, historic channelization, armoring, berming, floodplain encroachment, dams, undersized bridge crossings, and recent conversion of agricultural and forested lands to residential and commercial use (Godfrey, 2005). Reaches in adjustment are particularly sensitive to future development-related stressors including increased stormwater runoff, floodplain encroachments, and increasing road and crossing structure density.

5.4.2 Lewis Creek

Geomorphic assessments conducted to date in the Lewis Creek indicate reaches ranging from Good to Poor geomorphic condition (VTDEC, 2001; VTDEC, 2003). These Lewis Creek reaches are located near the southern extents of the two Principal Towns, Hinesburg and Charlotte. Reaches in fair to poor condition are exhibiting active lateral and vertical adjustments in response to development-related stressors including reduced riparian buffers, historic channelization and armoring, floodplain encroachment, undersized bridge crossings, and conversion of agricultural and forested lands to residential and commercial use. Reaches in adjustment are particularly sensitive to future development-related stressors including increased stormwater runoff, floodplain encroachments, and increasing road and crossing structure density.

5.4.3 Direct Drainage

Direct Drainage waterways within the Study Area have not been assessed for geomorphic condition, to the Study Team's knowledge. Based on the estimated impervious values for these Major Sub-watersheds (ranging from 4% to 6%) and given the above described geomorphic conditions of Lewis Creek sub-watersheds (ranging from 2% to 3% impervious) and LaPlatte River sub-watersheds (ranging from 3% to 8% impervious), channel adjustments would be expected in the Direct Drainage streams.

6.0 RECOMMENDATIONS

The following recommendations are offered for Hinesburg and Charlotte relative to watershed and channel management, community planning, and stormwater management. General project recommendations summarized from feedback at the final Steering Committee meeting are also presented in Section 6.4.

6.1 Watershed and Channel Management

a) Focus geomorphic and water quality assessments particularly in those watersheds with highest % IMP. When future trend data are available, track more closely those watersheds that show the most change. Watersheds with lower % IMP are candidates for conservation efforts along waterways. Watersheds with higher % IMP are candidates for targeted geomorphic field assessments, and prioritized water quality monitoring (phosphorus, stormwater contaminants).

b) Evaluate the positioning of watersheds relative to Charlotte and Hinesburg's proposed growth centers and zoning districts that permit higher densities of development.

c) Use geomorphic and water quality data to identify strategic sediment and phosphorus attenuation locations along the river networks. These areas, particularly those with wetlands contiguous to the channel, can be identified for their potential role in mitigating for cumulative, upstream stormwater impacts.

d) The Town of Charlotte should consider baseline water quality testing in the streams of the Direct Drainage watershed which have not been monitored on any consistent basis to date (i.e., Kimball Brook, Holmes Creek, Pringle Brook, and Thorpe Brook).

e) The Town of Charlotte should consider sponsoring baseline geomorphic assessments of the Direct Drainage streams which have not been assessed to date. Geomorphic assessment work will inform science-based riparian buffer widths and fluvial erosion hazard corridors for mitigating erosion hazards, improving water quality, and improving and sustaining aquatic and terrestrial habitats. Assessment work near the Town's growth centers (East Village and West Village) and in the network of receiving streams from these areas should be prioritized.

f) The Town of Hinesburg should continue supporting geomorphic assessments along the LaPlatte River network near the village growth center, and consider development of geomorphically-informed riparian buffers (town-wide) and fluvial erosion hazard corridors through the village center.

g) Continue to maintain buffers in undisturbed states. The naturally, vegetated, undisturbed buffer area provides a holding area for dissipation of flood flows, infiltration and treatment of stormwaters, and recharge of stormwaters to groundwater. The filtering role of the naturally vegetation buffer improves water quality. Riparian vegetation continuity along the river networks is important in maintaining overall aquatic and terrestrial habitats and biodiversity.

h) Continue inter-town and inter-county collaborations for acquisition of water quality and geomorphic data, as these watersheds cross municipal boundaries.

6.2 Community Planning

a) Continue to delineate & map natural resources including local wetlands, riparian areas, natural communities, wildlife corridors. These GIS coverages can be incorporated into build out scenarios for consideration of the natural systems alongside development to achieve ecologically and economically sustainable growth.

b) Continue with build out scenarios that will inform possible zoning changes and general town planning. The Addison Community Build Out Analysis software facilitates the development of build out scenarios.

c) Update and validate GIS coverages for improved accuracy & ease of continued build out scenarios; communicate with other data generators (VCGI, ACRPC, CCRPC, UVM Spatial Analysis Lab; LCBP). (e.g., field-verify E911 structure locations, address different parcel source data sets for Conserved coverages).

d) Use build out tool to evaluate clustered development/ open space concepts, and trade development rights for protection of natural systems that will function to assimilate increased sediment and water loading from impacts of floodplain encroachments, increased impervious surfaces, and stormwater runoff.

e) Continue inter-town discussions of planning and stormwater management objectives, as development within adjacent towns will influence (imperviousness) water quality and channel stability in a given town.

6.3 Stormwater Management

a) Consider Low Impact Design features and their incorporation into local planning and zoning mechanisms – e.g., clustered developments, reduced road widths, reduced sidewalk coverage, more green space, porous pavements, disconnected impervious surfaces. (www.lowimpactdesign.org; www.cwp.org)

b) Hinesburg and Charlotte could consider planning and zoning mechanisms at the local level to complement the Act 250 and Stormwater Management Rule requirements for larger developments.

c) Undertake transportation planning to optimize future road and driveway networks – most efficiency/safety for least density of roads.

d) Adopt road maintenance practices that minimize sedimentation to the rivers (Better Back Roads).

e) Adopt new driveway standards that minimize sedimentation and stormwater flows to the town/State roads and adjacent rivers/streams (Better Back Roads).

f) Size future culverts and bridges to pass bankfull and higher flows without constriction; consider future development in (and resultant stormwater flows from) the upstream watersheds when replacing or installing new structures.

6.4 General Project Recommendations

Based on discussions during project Steering Committee meetings, the following additional recommendations were articulated:

a) Evaluate possible use of the CCRPC Decision Support Software to predict future road / driveway networks for the Study Area and merge the resultant (probably vector-based) transportation data set with LcLu data to update IMP % estimates. This idea was floated as a way to address the hard-to-predict increases in density of road/driveway networks that would be expected to accompany future build out - acknowledging that the road surfaces account for the majority of the area-weighted percent imperviousness in our watersheds. (Melanie Rubinson, CCRPC)

b) Lobby the Lake Champlain Basin Program (LCBP) and other relevant stakeholders to collect the LcLu datasets using consistent methods and with increased frequency to enable Charlotte & Hinesburg to conduct repeated percent imperviousness estimates and trend analyses for our watersheds. Maintain close communications with LCBP so that they are aware how the Towns are using this data and can understand the need for consistent and frequent data sets. Find out more (from LCBP) about the LcLu data sets which are currently in the works: (1) short-term LcLu (due 2006) for purposes of updating Phosphorus export models; and (2) longer-term LcLu data acquisition (2008 or 2009?) that apparently will be similar in nature to the 1993 LandSat-derived data set that was used in this project. What will be the Scale? How will LcLu categories be assigned, and collapsed? etc. (Alex Weinhagen, Town of Hinesburg; Kevin Behm, ACRPC)

c) Acknowledge the following project outcome: The value of local data sets to town planning has been highlighted for all participants. The project has increased awareness of the interdependence of planning tasks – between ACRPC & CCRPC; town to town; and towns to regional data managers such as VGCI, LCBP, etc.

d) Recommend need for further study relating to how impervious effects will accumulate from upstream to downstream in a river network. This study has focused on LcLu impacts within the boundaries of individual sub-watersheds only (Chris Davis). Ongoing research at the University of Connecticut, among other places, is reported to be addressing this cumulative effect (Prisloe, Lei, & Hurd, 2001).

e) This study highlights the value/need of allocating limited resources to preventative, proactive strategies in watersheds like ours that are not yet impacted to the degree that we see in the greater Burlington area. Currently, most of the resources (e.g., under Clean & Clear) appear to be going to already-impacted watersheds (Alex Weinhagen, Town of Hinesburg).

f) From a research perspective, it would be helpful to develop State-wide data sets evaluating the relationship of percent imperviousness to geomorphic condition and water quality. With standardized percent imperviousness estimating approaches, and perhaps leveraging the growing geomorphic databases (VTDEC River Management Section), stronger correlations could be drawn and perhaps thresholds developed (Alex Weinhagen, Town of Hinesburg).

g) In Charlotte and Hinesburg, more education and outreach should be planned in the short term for local reps to the Planning and Conservation commissions to share these concepts of stormwater / impervious impacts on our waterways and present project results. In the fall, a day-long or several-hour workshop could be organized to review planning options and Low Impact Development designs that would reduce impervious surfaces. (*Following this recommendation, a project presentation was hosted by the Hinesburg Conservation Commission on 23 May 2005. Additional presentations to the Hinesburg Planning Commission and Selectboard and to the Charlotte Planning Commission are being coordinated as follow-on efforts to this project*).

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Impervious Cover Analysis and Stormwater Planning for Lewis Creek Watershed Towns: Hinesburg and Charlotte, VT

June 2005

Appendix A: Delineation of Study Area Watersheds

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A.1 INTRODUCTION

Study Area watersheds overlapping the Principal Towns included the LaPlatte River, the Lewis Creek, as well as the collection of smaller tributaries and westward-draining slopes collectively identified as the Direct Drainage to Lake Champlain (Figure A.1). Original plans to include the Huntington River watershed in the eastern third of the Town of Hinesburg were revised as a result of a reduced project budget.

To estimate percent imperviousness, these watersheds were divided into major sub-watersheds. Reach-based sub-watershed delineations were available for the LaPlatte River and Lewis Creek as a result of recent Phase 1 Stream Geomorphic Assessment work following VT Agency of Natural Resources protocols (VTANR, 2003). These formed the basis for major sub-watersheds identified in the LaPlatte River and Lewis Creek watersheds. Sub-watersheds for the Direct Drainage were newly delineated during this project.

A.2 DELINEATION OF MAJOR SUBWATERSHEDS

To the extent practical, the following conventions (CWP, 2001; CWP, 1998) guided the delineation of major sub-watersheds for assessment of imperviousness:

- Delineation of major sub-watersheds between 1 and 10 square miles in area, keeping the areas as consistent in size as possible across the watershed;
- Creation of major sub-watersheds which have largely similar land uses;
- Termination of major sub-watersheds at or near the downstream end of major water bodies (e.g., Bristol Pond)
- Downstream termination of major sub-watersheds at or near the point of existing gaging stations (e.g., LCT6 at Historic USGS Gage Station #4282700)

A.2.1 LaPlatte River

LaPlatte River watershed is approximately 53 square miles in area, and drains portions of the towns of Charlotte, Hinesburg, Shelburne, and St. George as well as small areas of Williston and Richmond.

Major sub-watersheds for analysis of percent imperviousness in this study were compiled from reach-based sub-watersheds defined by the LaPlatte Watershed Partnership (Godfrey, 2003) during completion of a Phase 1 Stream Geomorphic Assessment (LaPlatte River Partnership, 2005). The LaPlatte watershed was delineated into 48 reaches. Nineteen reaches were identified along the main stem. Twenty-nine additional reaches were defined along principal tributaries to the main stem. The reach-based sub-watershed data layer was reviewed to identify logical groupings for the assessment of percent imperviousness. Major sub-watersheds were established as follows (see also Figure A.1):

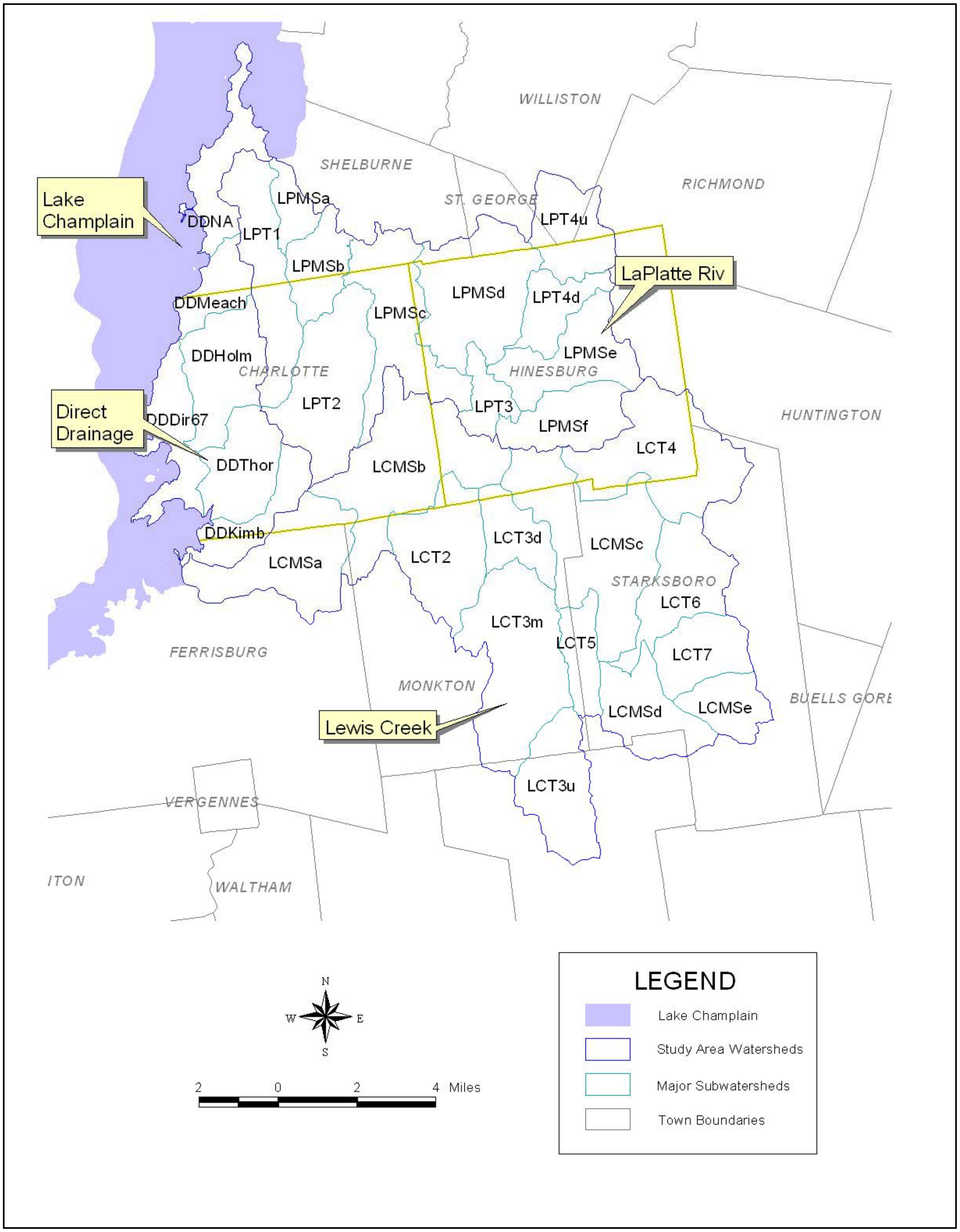

Figure A.1 Study Area Watersheds

Table A.1
Identification of Major Sub-watersheds Used to Calculate Percent Imperviousness
LaPlatte River Watershed

Major Subwatershed	Code	Geomorphic Reach & Tributary Identification [a]	Area (sq. mi.)
McCabe Brook	**LPT1**	Corresponds to **T1** tributary identified in Phase 1 Stream Geomorphic Assessment; Reaches T1.01 – T1.08	6.2
Mud Hollow Brook (also Bingham Brook and Un-named Trib to Mud Hollow)	**LPT2**	**T2** tributary: Reaches T2.01 – T2.06; T2S1.01-T2S1.02; T2S2.01-T2S2.02	8.0
Un-named tributary	**LPT3**	**T3** tributary: Reaches T3.01 – T3.03	1.9
Patrick Brook - upstream	**LPT4u**	**T4** tributary: Reaches T4.06 – T4.08	4.3
Patrick Brook - downstream	**LPT4d**	**T4** tributary: Reaches T4.01 – T4.05	2.8
Mainstem	**LPMSf**	Reaches M19, M18, M17	4.2
Mainstem	**LPMSe**	Reach M16	5.3
Mainstem	**LPMSd**	Reaches M15, M14, M13, M12	8.5
Mainstem	**LPMSc**	Reaches M11, M10, M09	7.2
Mainstem	**LPMSb**	Reaches M08, M07, M06, M05	3.2
Mainstem	**LPMSa**	Reaches M04, M03, M02, M01	1.6

A.2.2 Lewis Creek

Lewis Creek drains an 81-square-mile watershed located in the towns of Bristol, Starksboro, Monkton, Hinesburg, Charlotte, and Ferrisburg, in Addison and Chittenden Counties. Current land use in the basin is largely agricultural, forested, and rural residential. Development centers currently include the village of Starksboro, Monkton Ridge, Cedar Lake, North Ferrisburg and the commercial / residential properties built up along Rt. 7 north of Ferrisburg village.

Phase 1 geomorphic assessment data exists for the Lewis Creek watershed (VTDEC, 2001; VTDEC, 2003). The reach-based sub-watershed data layer was reviewed to identify logical groupings for the assessment of percent imperviousness. Major sub-watersheds were established as follows (see also Figure A.1):

Table A.2
Identification of Major Subsheds Utilized to Calculate Percent Imperviousness
Lewis Creek Watershed

Major Subwatershed	Code	Geomorphic Reach & Tributary Identification [a]	Area (sq. mi.)
Cedar Lake	**LCT2**	Corresponds to **T2** tributary identified in Phase 1 Stream Geomorphic Assessment; Reaches T2.01 – T2.06	6.3
Pond Brook - upstream	**LCT3u**	**T3** tributary: Reaches T3.07, T3.06, T3.05	5.4
Pond Brook - midstream	**LCT3m**	**T3** tributary: Reaches T3.04, T3.03	9.8
Pond Brook - downstream	**LCT3d**	**T3** tributary: Reaches T3.02, T3.01	3.0
Hollow Brook	**LCT4**	**T4** tributary; Reaches T4.01 – T4.07	9.2

Hogback Brook	**LCT5**	**T5** tributary: Reaches T5.01 – T5.05	2.4
Headwater Tributary	**LCT7**	**T7** tributary: Reaches T7.01 – T7.02	3.7
Headwater Tributary 2	**LCT6**	**T6** tributary (not reach delineated); Historic USGS Gage Station 04282700 (1963-1974) [b]	5.2
Main Stem	**LCMSe**	Reaches M25, M24	2.8
Main Stem	**LCMSd**	Reaches M23, M22, M21, M20	4.6
Main Stem	**LCMSc**	Reaches M19, M18, M17, M16, M15, M14, M13	10.9
Main Stem	**LCMSb**	Reaches M12, M12.5, M11, M10c, M10ab, M09, M08	10.5
Main Stem	**LCMSa**	Reaches M07, M06, M05, M04, M03, M02, M01	7.1

A.2.3 Direct Drainage

The Direct Drainage to Lake Champlain is a 23.5-square-mile area comprised of smaller streams and direct drainage to Shelburn Bay and the broad lake. Direct Drainage overlaps the towns of Ferrisburg, Charlotte and Shelburne in Addison and Chittenden Counties. With reference to topographic base maps, orthophotos, and 1:5000 surface waters, major sub-watersheds in Direct Drainage were delineated in ArcView® using the Stream Geomorphic Assessment Tool (SGAT) (v.2; VTANR, 2003).

Table A.3
Identification of Major Subwatersheds Utilized to Calculate Percent Imperviousness
Direct Drainage to Lake Champlain

Major Subwatershed	Code	Description	Area (sq. mi.)
Thorpe Brook	**DDThor**	Thorpe Brook, including three mapped tributaries, draining to Town Farm Bay south of Thompson's Point	4.5
Meach Cove	**DDMeach**	Unnamed stream draining to Meach Cove and direct drainage from vicinity of Hill Point	2.5
Kimball Brook	**DDKimb**	Kimball Brook draining from Mount Philo to Town Farm Bay south of Thompson's Point	3.2
Holmes	**DDHolm**	Holmes Creek, including Pringle Brook and two unnamed tributaries, draining from village of Charlotte to Hill Bay	5.5
Direct Drainage 6 & 7	**DDDir67**	Drainage from land west of Lake Rd including Thompsons Point to Town Farm Bay, Converse Bay, McNeil Cove and points north	2.8
Direct Drainage	**DDNA**	These subwatersheds are to the north of Direct Drainage 6 & 7 and are not a part of this Study Area; Duck Pond outlet and direct drainage from Shelburne Point to Shelburne Bay and the Broad Lake	3.8

A.2.4 Merge into Study Area watershed coverage

Once the major sub-watersheds had been delineated within each watershed, they were merged together using XTools®, an ArcView® 3.x extension. Along with the merge, several processing steps were performed to create consistent attributes and to ensure topologically correct outer boundaries of the three watersheds.

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Impervious Cover Analysis and Stormwater Planning for Lewis Creek Watershed Towns: Hinesburg and Charlotte, VT

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Appendix B: Calculation of Area-Weighted Imperviousness

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B.1 INTRODUCTION

This appendix provides details of the impervious estimation method for the Study Area major sub-watersheds. Area-weighted impervious cover was estimated for each major sub-watershed by applying various impervious coefficients to land cover / land use categories represented in each sub-watershed. Methods generally followed those outlined in the *Rapid Watershed Planning Handbook* (CWP, 1998) to derive impervious estimates that are applicable to watershed-scale planning and management objectives. Please refer to the study report for additional discussion of method assumptions and limitations.

B.2 METHODOLOGY

The overall methods applied are outlined as follows:

- Develop a separate vector-based coverage of transportation and surface waters by buffering linear features based on assumed widths.
- Modify the LcLu data set to dissolve out raster-based roads and water and assign adjacent LcLu designation (Spatial Analyst, Kevin Behm, ACRPC).
- "Burn" buffered surface waters and buffered roads into the modified LcLu coverage.
- Clip modified state-wide land cover / land use data to the Study Area major sub-watersheds.
- Assign Impervious Coefficient to each separate LcLu code.
- Calculate area-weighted percent imperviousness per watershed

The following sections provide details of each step of the procedure. Impervious calculations utilized the *Watershed Impervious Analysis* tool (C.L. Davis Consulting Associates, Ltd.), an ArcView® 3.x extension. Documentation for this tool is provided in Appendix C.

B.2.1 Land Cover / Land Use Data

The source of land cover / land use data utilized in this study was the *Landcover / Landuse for Vermont and Lake Champlain Basin* available from the Vermont Center for Geographic Information, www.vcgi.org (LandLandcov_LCLU, edition 2003, downloaded 15 May 2003). This is a raster data set, developed through pixel-based classification of LANDSAT Thematic Mapper Imagery with source dates of 1991 to 1993. There is a 2-acre minimum mapping unit with a resultant grid cell size of 25-meters square, and a reported 86% accuracy. Further details of this land cover / land use data set are available at: http://www.vcgi.org/metadata/LandLandcov_LCLU.htm.

While the VT and Lake Champlain Basin Landcover/ Landuse (LcLu) data coverage has certain limitations due to its age (approximately 12 years outdated), accuracy, and resolution. However, it was the only standardized land cover /land use data set available state-wide,

Two other land cover data sets were reviewed under this study. A Capen land cover classification vector coverage covered only the Lewis Creek watershed (Capen, 2000). Chittenden County Landuse data (LandLanduse_CCLANDUSE00 - VCGI, 2000) is a parcel-based vector coverage. Neither data set was used in the end, as neither one provided common coverage for the complete Study Area. Also, the CCRPC parcel-based land use data set was too broad in scale for the intended use, and of unreported accuracy.

A goal of this project was to identify a methodology that could be applied by other rural communities like Charlotte and Hinesburg. As a result, the only option available was the 1993 state-wide coverage available via VCGI. This data set was deemed of adequate accuracy, resolution, and age for the intended data use of watershed-level planning.

Classification of the LcLu data follows methods of Anderson, *et al.*, 1976. Approximately 17 LcLu categories appear to be regularly used at least in the Champlain Valley geographic region (Table B.1). For purposes of impervious surface estimating, these 17 categories were further consolidated into broad groups of water, wetlands, brush/transitional/barren, forest, agricultural, developed and transportation/utilities. Development contains residential, commercial, industrial, and other urban. In these rural communities at present, the commercial and industrial developments are small enough in total area, and disperse enough in character, that all of these LcLu were grouped as one.

Table B.1 Grouping of Land Cover / Land Use Categories for Assignment of Impervious Coefficients

Land Cover / Land Use		
Category	**Code**	**Group**
Open Water	5	Water
Forested Wetland	61	Wetland
Non-forested Wetland	62	
Brush / Transitional	3	Brush/ Transit/Barren
Barren Land	7	
Deciduous Forest	41	Forest
Coniferous Forest	42	
Mixed Forest	43	
Agricultural – Hay/Pasture	212	Agriculture
Agricultural - Row Crop	211	
Orchard/Tree Farm	22	
Other Agricultural Land	24	
Residential	11	Developed
Commercial	12	
Industrial	13	
Other Urban	17	
Utilities (electric transmission)	540	Utilities
Railroads	520	
Transportation (Roads)	500	Transportation
Transportation (Driveways)	501	

By way of illustration, the Study Area watersheds have the following distributions of land cover / land use in these broad categories (Table B.2)

Table B.2 Distribution of Land Cover / Land Use in Study Area watersheds.

Land Cover / Land Use				
LcLu Group	**includes Category Codes:**	**Lewis Creek**	**LaPlatte**	**Dir Drainage**
Water	5	5.0%	5.2%	3.4%
Wetlands	61, 62	6.1%	4.4%	0.0%
Brush/Transit/Barren	3, 7	0.3%	0.4%	0.1%
Forested	41, 42, 43	57.4%	35.6%	29.8%
Agricultural	22, 24, 211, 212	26.0%	38.7%	51.8%
Developed	11, 12, 13,17	1.8%	10.9%	8.0%
Transportation/Utilities	14	3.3%	4.8%	6.9%

B.2.2 Evaluate Transportation/Utilities Coverage and Influence on Overall Watershed Imperviousness

In rural watersheds, the majority of impervious surfaces are contributed by the road and driveway networks. A sensitivity analysis was conducted to quantify the possible influence of road networks in the Study Area. This analysis assumed variable impervious coefficients of 100%, 50% and 0% for LcLu code 14 (Transportation/ Utilities category of the Land Cover / Land Use for VT and the Lake Champlain Basin). Resulting test values of area-weighted imperviousness for the major sub-watersheds varied substantially, by as much as 9 percentage points, or nearly the whole range of 0-10% imperviousness which defines the Sensitive category in the Impervious Cover Model (Table B.3).

Variability of the estimated impervious values in the above sensitivity analysis was greater in those sub-watersheds where the area of transportation accounted for a higher percentage of the total watershed area (e.g., DDDir67, DDMeach, LPMSa). This variability is related to how the transportation land covers are represented in the raster-based LcLu coverage. As can be seen from Figure B.1, the raster (pixel-based) representation of roads overestimates actual road surface area, especially for areas with a greater percentage of the narrower road classes and driveways.

An analysis was conducted to compare the area for Transportation/Utilities represented in the LcLu (raster-based) data set and an area created using vector-based data. This was performed for each Major Sub-watershed. The LcLu Code 14 Transportation/Utilities includes roads, electric transmission lines, and railroads in the Study Area. Therefore to create a vector-based data set of Transportation / Utilities, centerline data for roads, railroads and electric transmission lines were downloaded from VCGI. Road, railroad, and electric transmission centerline data (VCGI, 2004) were then buffered to create the assumed widths noted in Table B.4. Driveways are generally not included in LcLu Code 14 (see for example, the driveways represented at the top of Figure B.1); however, this is not consistently the case.

The ratio of vector-based transportation (buffered road/utility center lines) coverage to raster-based coverage for the Study Area as a whole was approximately 0.33 (geometric mean). This vector to raster ratio varied by sub-watershed from a minimum of 0.15 to a maximum of 0.43, depending on: (1) the density of transportation in each watershed; (2) the distribution of road classes represented in each watershed; (3) the degree of development that may have occurred between 1993 (the approximate source date for the LcLu Code 14 coverage) and 2004 (the source date for the vector-based centerline data); and (4) the fact that occasionally the raster-based LcLu Code 14 coverage includes driveways, while buffered driveways were purposely excluded from the vector coverage developed for this evaluation.

Table B.3 Sensitivity Analysis to Examine the Influence of Transportation/Utilities LcLu Category on Watershed Impervious Estimates

				Area-Weighted % Imperviousness of Major Subshed Under Various Assumptions of % Imperviousness for Transportation LcLu Code 14		
Major Subshed	Total Area of Transportation LcLu Code 14 (sq mi)	Total Area of Major Subshed (sq mi)	Percent of Major Subshed Occupied by Transportation LcLu Code 14	Assumed 100 % Imperviousness for Transportation LcLu Code	Assumed 50 % Imperviousness for Transportation LcLu Code	Assumed 00 % Imperviousness for Transportation LcLu Code
PRIMARYID	**N14**	**TOTAL**		**TOTAL_100**	**TOTAL_50**	**TOTAL_0**
DDDir67	0.328	4.008	8.2%	9.00	4.91	0.82
DDHolm	0.318	5.458	5.8%	6.92	4.00	1.08
DDKimb	0.197	3.199	6.1%	7.40	4.33	1.26
DDMeach	0.213	2.522	8.4%	9.46	5.24	1.03
DDNA	0.306	3.783	8.1%	9.04	5.00	0.95
DDThor	0.258	4.458	5.8%	6.89	3.99	1.09
LCMSa	0.307	7.133	4.3%	5.33	3.17	1.02
LCMSb	0.429	10.504	4.1%	4.95	2.91	0.87
LCMSc	0.338	10.876	3.1%	3.73	2.18	0.62
LCMSd	0.139	4.649	3.0%	3.29	1.80	0.30
LCMSe	0.074	2.775	2.7%	2.74	1.41	0.08
LCT2	0.319	6.299	5.1%	5.69	3.16	0.63
LCT3d	0.111	3.045	3.7%	4.45	2.62	0.79
LCT3m	0.314	9.854	3.2%	3.77	2.17	0.58
LCT3u	0.125	5.394	2.3%	2.69	1.53	0.38
LCT4	0.279	9.216	3.0%	3.25	1.74	0.23
LCT5	0.008	2.419	0.3%	0.48	0.31	0.14
LCT6	0.195	5.194	3.8%	3.86	1.98	0.11
LCT7	0.078	3.692	2.1%	2.13	1.07	0.02
LPMSa	0.152	1.619	9.4%	9.64	4.94	0.24
LPMSb	0.177	3.186	5.5%	6.45	3.68	0.91
LPMSc	0.269	7.173	3.7%	4.80	2.92	1.05
LPMSd	0.340	8.446	4.0%	4.82	2.81	0.79
LPMSe	0.251	5.248	4.8%	5.20	2.81	0.43
LPMSf	0.151	4.200	3.6%	4.07	2.27	0.47
LPT1	0.470	6.164	7.6%	8.61	4.79	0.98
LPT2	0.278	7.961	3.5%	4.68	2.93	1.19
LPT3	0.068	1.886	3.6%	4.36	2.54	0.73
LPT4d	0.183	2.790	6.6%	6.78	3.50	0.22
LPT4u	0.212	4.291	4.9%	5.35	2.88	0.42
Total	**6.885**	**157.439**	**4.4%**	**5.05**	**2.87**	**0.68**

Notes:
LcLu from VCGI State-wide coverage.
Remaining LcLu Categories (other than Transportation) had Assigned Percent Impervious
values consistent with CWP, 1999 EXCEPT that Developed (~ 11 + 12 + 13 + 17) = 0 %
0 % = 3, 5, 7, 41, 42, 43, 61, 62
0 % = 11, 12, 13, 17
2 % = 22, 24, 211, 212

Generally speaking, for the upland more rural watersheds with low road densities and mostly narrower Class 2, 3, and 4 roads, the raster-based Transportation coverage in the state-wide land cover land use would more significantly overestimate the area of road surfaces. The area-weighted imperviousness estimated for these more rural watersheds would thus be overestimated.

The way in which surface waters are classified in the raster-based LcLu coverage posed additional concerns. Similar to roads, the raster-based (pixilated) representation of linear streams and river channels in the LcLu Code 5 coverage would be expected to overestimate the area of waters in the Study Area watersheds. As a consequence, impervious values calculated from this raster-base coverage could underestimate the imperviousness in an area where surface waters were classified immediately adjacent to developed or agricultural areas with measurable imperviousness.

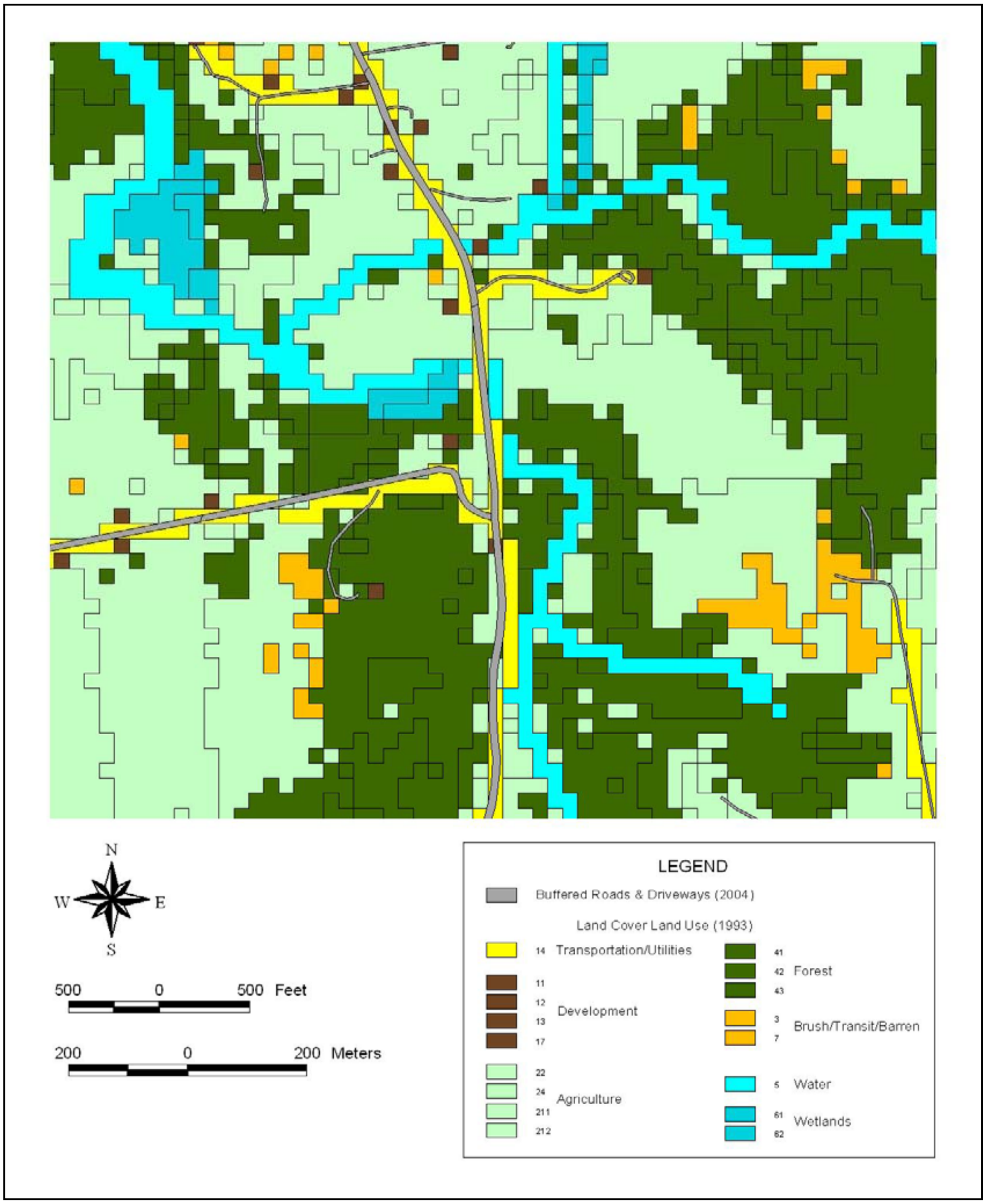

Figure B.1
Illustration of differences between Transportation (14) raster-based LcLu coverage and buffered E911 road and driveway center line vector-based coverage.

Given the above concerns, the Project Steering Committee determined that a vector-based treatment was warranted for the transportation/utilities and surface water land cover / land use categories.

B.2.3 Revised Treatment of Transportation / Utilities and Surface Waters

Kevin Behm, Addison County Regional Planning Commission, used the Spatial Analyst extension to ArcView® to remove the transportation and surface waters from the LcLu coverage. Subsequently transportation was created by buffering road, driveway and electric transmission centerlines. The buffer distances were obtained from a separate table that enables one to define road, shoulder and ditch widths by class of road. Surface waters were obtained from surface water coverages available from VCGI with linear features buffered by 7.5 feet.

The resulting polygonal transportation/utility and surface water features were then incorporated into the LcLu coverage; thus, replacing the raster-based equivalents. A brief summary of data processing steps follows:

1. Study Area LcLu data was modified to dissolve out transportation/utilities (14) and water (5) and assign adjacent LcLu designation (Spatial Analyst, Kevin Behm, ACRPC).

2. Create buffered vector data sets for transportation, utilities, and surface waters.
   a. Linear surface waters (NHD, 1:5000) were buffered by 7.5 feet (for a total width of 15 ft);
   b. Polygonal surface waters (NHD, 1:5000) were represented as is;
   c. Driveways (E911 centerline coverage downloaded from VCGI) were buffered by 7 ft (for a total width of 14 ft);
   d. Roads (E911 centerline coverage downloaded from VCGI) were buffered by class to result in the total of assumed road surface width, shoulder width, and ditch width values summarized in Table B.4.

3. Buffered roads, driveways, and surface waters were then "burned in" to the modified LcLu coverage from Step 1.

4. Vector coverages were re-attributed with LcLu classifications: surface waters (both buffered channels and polygonal surface waters) retained the original Water LcLu Code of 5; roads and driveways were arbitrarily assigned LcLu codes of 500 and 501, respectively.

Table B.4 Buffer Values by Class Used to Create Buffered Road and Driveway Center Lines

LcLu Class	Road Class	Road Type	Surface Width (ft)	Shoulder Width (ft)	Ditch Width (ft)	Total Buffered Width (ft)
500	2	Town Class 2 Road	27	6	6	39
	3	Town Class 3 Road	27	0	6	33
	4	Town Class 4 Road	27	0	6	33
	5	State Forest Highway	27	0	4	31
	7	Legal Trail	3	0	0	3
	9	Private (Display) Road	14	0	0	14
	30	VT Highways	32	6	6	44
	40	US Highways	32	6	6	44
	96	Discontinued Road	14	0	0	14
	99	Unknown (Private?) Road	14	0	0	14
501	N/A	Driveway (Pvt, from E911 driveways)	14	0	0	14

B.2.4 Union Modified Land Cover/Land Use Data with Major Subwatersheds.

A union was performed between the modified land use / land cover data and the Study Area major sub-watersheds layer to quantify and summarize land cover statistics by sub-watershed.

B.2.5 Assignment of Impervious Coefficients to Land Cover / Land Use Categories

The following imperviousness coefficients were assigned to each of the land cover / land use categories. These values are largely consistent with those utilized in impervious cover studies in similar low-density rural Northeast watersheds (CWP, 1998; USDA, 2000).

Table B.5 Assignment of Impervious Coefficients

Land Cover / Land Use			Impervious Coefficient (%)	Data Source
Category	Code	Group		
Open Water	5	Water	0	a
Forested Wetland	61	Wetland	0	a
Non-forested Wetland	62			
Brush / Transitional	3	Brush/ Transit/Barren	0	a
Barren Land	7			
Deciduous Forest	41	Forest	0	a
Coniferous Forest	42			
Mixed Forest	43			
Agricultural – Hay/Pasture	212	Agriculture	2	a
Agricultural - Row Crop	211			
Orchard/Tree Farm	22			
Other Agricultural Land	24			
Residential	11	Developed	10	a, b, c
Commercial	12			
Industrial	13			
Other Urban	17			
Transportation (Roads)	500	Roads	100	a
Transportation (Driveways)	501	Driveways	100	a

References:
a (CWP, et al, 1999) – from eight Vermont watersheds, ranging in area from 3.2 to 24 square miles, in a mix of rural to urban settings
b (USDA, circa 2000) – New England regional estimates
c (CWP, 1998; p.6.7) – summary of estimates from five study sites across the US

Electric transmission lines and railroads were not assessed in this estimate of percent impervious. Only 7 of the 30 Study Area sub-watersheds contained Railroad corridors (assumed buffered width of 23 feet based on remote sensing measurement of a rail line in Charlotte). Areas of railroads in these 7 watersheds ranged from 0.04% to 0.46% of the total sub-watershed area. Eleven (11) of the 30 Study Area sub-watersheds contained electric transmission lines (assumed buffered width of 26 feet based on pacing of a typical line in Hinesburg). Areas of electric transmission lines in these 11 watersheds ranged from 0.007% to 0.53% of the total sub-watershed areas. Given an impervious coefficient of 2% assumed for electric transmission lines and 50% for railroad lines, these utilities were estimated not to have a significant effect on overall area-weighted impervious calculations for the major sub-watersheds.

The full width of the road surface, road shoulder and road ditches for the roads coverage was assigned a 100% impervious value in this estimate of impervious surface. (No shoulders or ditches were assumed for driveways). This assumption may tend to overestimate actual impervious surface for Class 2, 3, 4, 5, 30, and 40 roads that have shoulders and/or ditches. However, since Equivalent Impervious Surface values were not readily available, these shoulder and ditch areas were assigned a 100% impervious coefficient to capture the reduction of infiltration capacity as a result of grading, use of fill materials and compaction.

B.2.6 Calculation of Area-Weighted Imperviousness

Area-weighted percent imperviousness was calculated for each of the Study Area major sub-watersheds. In general terms, the calculation of area-weighted imperviousness can be described by the following example.

Figure B.2 illustrates a hypothetical watershed with a mix of land cover / land use categories. The entire box represents the total area of the watershed, and the relative size of each land cover/land use box represents the area of that land cover / land use category relative to the total area of the watershed. To calculate an area-weighted impervious value for the entire watershed, the impervious coefficients for each land cover/ land use category (represented by values in the circles) are applied using the following formula.

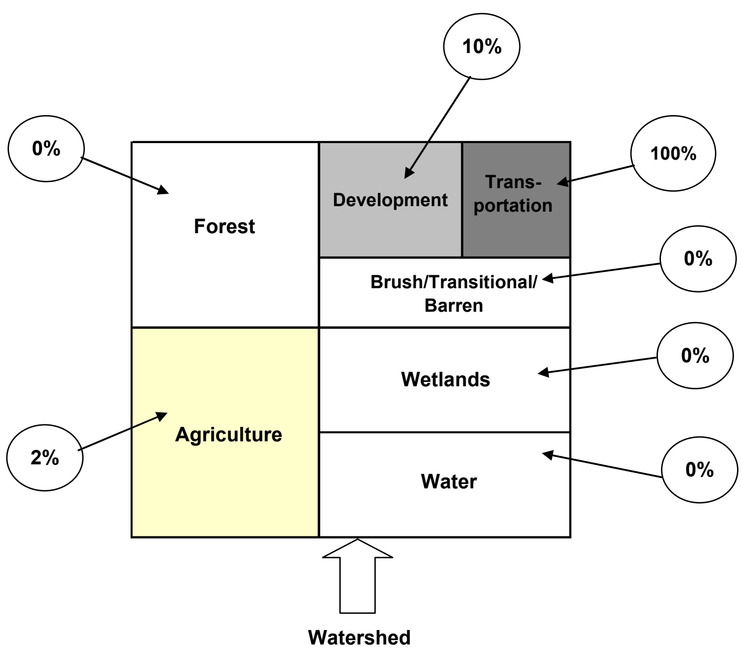

Figure B.2 Calculation of Area-Weighted Imperviousness for Hypothetical Watershed

$$AWIMP_{wshd} = \frac{A_{trans} * I_{trans}}{A_{wshd}} + \frac{A_{dev} * I_{dev}}{A_{wshd}} + \frac{A_{for} * I_{for}}{A_{wshd}} + \frac{A_{ag} * I_{ag}}{A_{wshd}} + \frac{A_{wat} * I_{wat}}{A_{wshd}} + \frac{A_{btb} * I_{btb}}{A_{wshd}}$$

Where,

AW-IMP $_{wshd}$ = the area-weighted impervious value for the watershed

A $_{wshd}$ = the area of the watershed (square miles)

A $_{trans}$ = the area of **transportation** LcLu in the watershed
A $_{dev}$ = the area of **developed** LcLu in the watershed
A $_{for}$ = the area of **forested** LcLu in the watershed
A $_{ag}$ = the area of **agricultural** LcLu in the watershed
A $_{wat}$ = the area of **water/wetlands** LcLu in the watershed
A $_{btb}$ = the area of **brush**/**transitional**/**barren** LcLu in the watershed

I $_{trans}$ = the impervious coefficient for **transportation** LcLu
I $_{dev}$ = the impervious coefficient for **developed** LcLu
I $_{for}$ = the impervious coefficient for **forested** LcLu, and so on….

B.3 RESULTS

Area-weighted impervious values (%) calculated by the above methodology for each of the Study Area major sub-watersheds are summarized in Table B.6.

B.4 AUTOMATION OF IMPERVIOUS CALCULATION

A *Watershed Impervious Analysis* tool (ArcView® 3.x extension) was developed by C.L. Davis Consulting Associates, Ltd. of Weybridge, VT under this Municipal Planning Grant (see Appendix C). This tool automates the above-described calculation of impervious surface based on user-specified land cover/land use data sets and impervious coefficients.

Note that the *Watershed Impervious Analysis* extension developed under this project (Appendix C) provides an automated tool for buffering road, driveway, railroad, and electric transmission centerlines following user-specified buffer values. Data pre-processing by individuals knowledgeable of GIS systems is required to identify and attribute the vector coverages of surface waters, roads, driveways, railroads, and utility lines for a given Study Area. Spatial Analyst is required to dissolve out the transportation/utility and surface water coverages and re-attribute these pixels with adjacent LcLu classifications.

Table B.6 Impervious Cover in Major Sub-watersheds (1993)

Major Subwatershed	Code	Geomorphic Reach & Tributary Identification	AW-IMP (%)
LaPlatte River Watershed			
McCabe Brook	**LPT1**	Corresponds to **T1** tributary identified in Phase 1 Stream Geomorphic Assessment; Reaches T1.01 – T1.08	5
Mud Hollow Brook (also Bingham Brook and Un-named Trib to Mud Hollow)	**LPT2**	**T2** tributary: Reaches T2.01 – T2.06; T2S1.01-T2S1.02; T2S2.01-T2S2.02	3
Un-named tributary	**LPT3**	**T3** tributary: Reaches T3.01 – T3.03	3
Patrick Brook - upstream	**LPT4u**	**T4** tributary: Reaches T4.06 – T4.08	3
Patrick Brook - downstream	**LPT4d**	**T4** tributary: Reaches T4.01 – T4.05	7
Mainstem	**LPMSf**	Reaches M19, M18, M17	3
Mainstem	**LPMSe**	Reach M16	4
Mainstem	**LPMSd**	Reaches M15, M14, M13, M12	4
Mainstem	**LPMSc**	Reaches M11, M10, M09	4
Mainstem	**LPMSb**	Reaches M08, M07, M06, M05	5
Mainstem	**LPMSa**	Reaches M04, M03, M02, M01	8
Lewis Creek Watershed			
Cedar Lake	**LCT2**	Corresponds to **T2** tributary; Reaches T2.01 – T2.06	3
Pond Brook - upstream	**LCT3u**	**T3** tributary: Reaches T3.07, T3.06, T3.05	1
Pond Brook - midstream	**LCT3m**	**T3** tributary: Reaches T3.04, T3.03	2
Pond Brook - downstream	**LCT3d**	**T3** tributary: Reaches T3.02, T3.01	3
Hollow Brook	**LCT4**	**T4** tributary; Reaches T4.01 – T4.07	2
Hogback Brook	**LCT5**	**T5** tributary: Reaches T5.01 – T5.05	<1
Headwater Tributary	**LCT7**	**T7** tributary: Reaches T7.01 – T7.02	1
Headwater Tributary 2	**LCT6**	**T6** tributary (not reach delineated);	2
Main Stem	**LCMSe**	Reaches M25, M24	1
Main Stem	**LCMSd**	Reaches M23, M22, M21, M20	2
Main Stem	**LCMSc**	Reaches M19, M18, M17, M16, M15, M14, M13	2
Main Stem	**LCMSb**	Reaches M12, M12.5, M11, M10c, M10ab, M09, M08	3
Main Stem	**LCMSa**	Reaches M07, M06, M05, M04, M03, M02, M01	3
Direct Drainage Watershed			
Thorpe Brook	**DDThor**	Thorpe Brook, including three mapped tributaries, draining to Town Farm Bay south of Thompson's Point	4
Meach Cove	**DDMeach**	Unnamed stream draining to Meach Cove and direct drainage from vicinity of Hill Point	4
Kimball Brook	**DDKimb**	Kimball Brook draining from Mount Philo to Town Farm Bay south of Thompson's Point	5
Holmes	**DDHolm**	Holmes Creek, including Pringle Brook and two unnamed tributaries, draining from village of Charlotte to Hill Bay	4
Direct Drainage 6 & 7	**DDDir67**	Drainage from land west of Lake Rd including Thompson's Point to Town Farm Bay, Converse Bay, McNeil Cove and points north	6
Direct Drainage	**DDNA**	These subwatersheds are to the north of Direct Drainage 6 & 7 and are not a part of this Study Area; Duck Pond outlet and direct drainage from Shelburne Point to Shelburne Bay and the Broad Lake	4

B.5 REFERENCES

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer, 1976, *A Land Use and Land Cover Classification System for Use With Remote Sensor Data*. US Geological Survey Professional Paper 964. Washington D.C., Department of the Interior.

Capen, D.E., L. Osborn, S. MacFaden (Spatial Analysis Laboratory, UVM) and R. Sims (NRCS), 2000, *Mapping Wildlife Habitat in the Lewis Creek Watershed*.

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Center for Watershed Protection, Aquafor Beech, Ltd., Lori Barg, and Robert Kort, September 1999, *Watershed Hydrology Protection and Flood Mitigation Project, Phase II – Technical Analysis: Stream Geomorphic Assessment.* Prepared for Vermont Geological Survey, Waterbury, VT. http://www.anr.state.vt.us/geology/pdfdocs/phaseIIcomplete.pdf

USDA, circa 2000, *Norwalk River Basin GIS Mapping Fact Sheet*, Natural Resources Conservation Service New England Interdisciplinary Resource Technical Team, Storrs, CT.

Vermont Center for Geographic Information, www.vcgi.org
LandLandcov_LCLU, 2004 – Landcover/Landuse for VT and Lake Champlain Basin
EmergencyE911_RDS, 2004 – E911 Road center lines from 1:5000 orthophotos and GPS
EmergencyE911_DW, 2004 – Driveways captured for E911 use

Impervious Cover Analysis and Stormwater Planning for Lewis Creek Watershed Towns: Hinesburg and Charlotte, VT

June 2005

Appendix C: Watershed Impervious Analysis Tool: An ArcView® 3.x extension

***C. L. Davis Consulting Associates, Ltd*.**

ArcView[TM] Dialogs and Reference Tables
Used for Impervious Surface Calculations

Installation

The extension named BOImpVerA5.avx must be copied to the EXT32 sub-directory under the directory in which ArcView® 3.2+ has been installed. If you are not sure where that directory is located, use the operating system to search for "files and folders" and enter EXT32 as the name to be searched for.

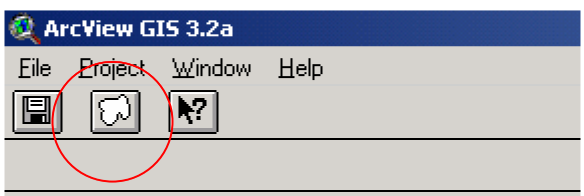
> Note: ArcView® is a registered trademark of Environmental Systems Research Institute, Inc. of Redlands, California (ESRI).

Loading the Extension

To access the extension, perform the following steps:

1. Start up ArcView.
2. Save the ArcView project to a directory of your choosing.
3. Click on the ***File*** menu.
4. Click on ***Extensions***.
5. Scroll down the list of *extensions* to ArcView until you see an entry labeled "*Watershed Impervious Analysis (V5)*".
6. Click on the check box to the left of the entry for (5) until a check mark appears.
7. Click on the ***Ok*** button. You will be returned to ArcView.

After following the above steps, a button (similar to a pond) will appear on the ArcView button bar (see figure below). This button will only be present when the ArcView Project window or a View window is active.



Clicking on that button will take you to the main dialog for the extension.

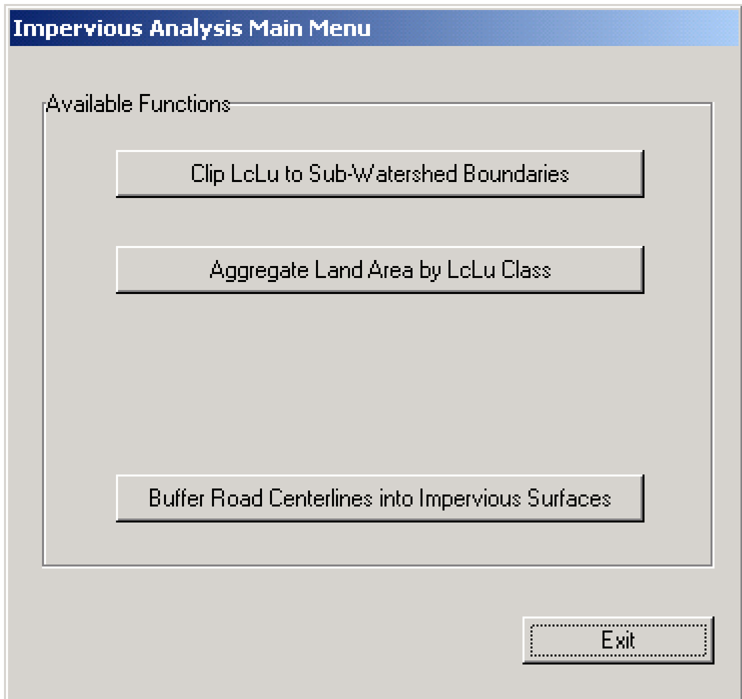
WARNING

This extension has not undergone rigorous testing and has been used in a very limited extent. As a result, ***<u>use this extension at your own risk.</u>*** ***<u>Use any results generated by the extension with caution and take the time to verify them.</u>***

All geographic data sets used by this extension must be in ArcView shape file format and must be in a consistent geographic projection and coordinate system.

Main Dialog

Access to the functions is from the main dialog shown below:



The first button "*Clip LcLu to Sub-Watershed Boundaries*" performs a Union similar to that available via the *Geoprocessing Wizard* available from ESRI. The only difference is the control of what attributes get passed on to the output theme.

The second button "*Aggregate Land Area by LcLu Class*" performs a cross-tabulation of the data in the theme resulting from the Union (first operation).

The last button "*Buffer Road Centerlines into Impervious Surfaces*" allows one to "ceate"road Right-of-Ways (ROWs) from a road centerline geographic file and a *reference* dBase table named RdPctImp.dbf.

Note: When the extension is accessed by clicking on the button described earlier, an initialization procedure is performed prior to the display of the main dialog shown above. This procedure includes the following:

- Determines if the ArcView project has been saved. If not, then an error message is issued and access to the functions on the Main dialog is prevented.
- Determines if subdirectories named "*ShapeFiles*" and "*Tables*" exist under the directory in which the ArcView project is located. If they do not exist, they are created.
- Determines if the dBase table named "SysUnits.dbf" has been added to the ArcView project. If not an error message is issued and access to the functions on the Main dialog is prevented.

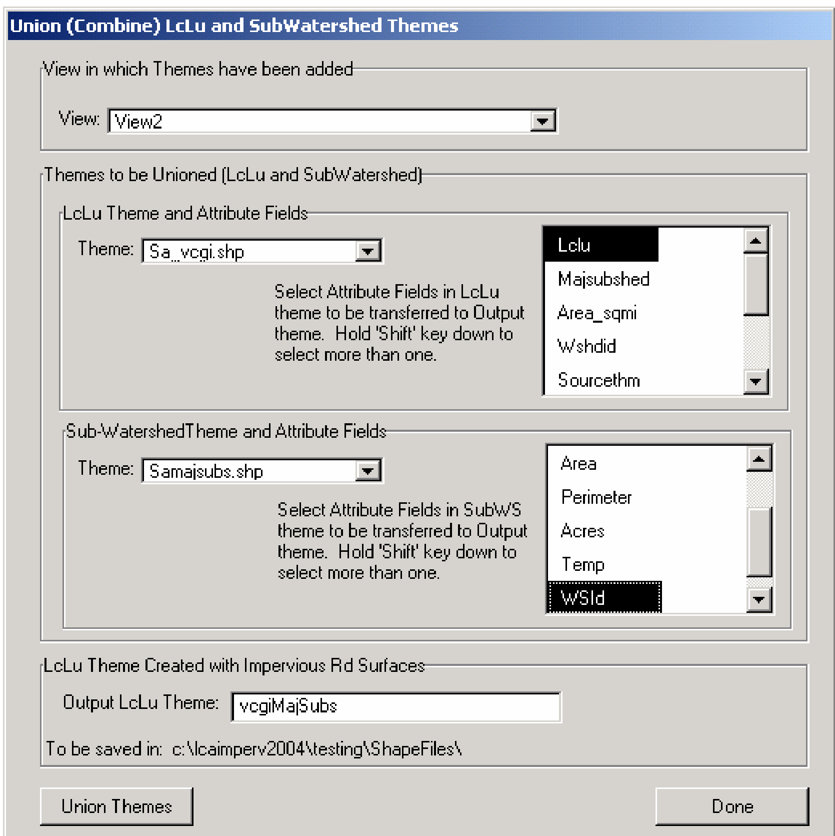
If no errors are detected, access to the functions on the Main dialog is permitted.

Union (Combine) LcLu and Sub-Watershed Themes

This dialog provides the ability to perform a *Union* between the LcLu and Sub-Watershed themes. The *Union* process subdivides any LcLu areas that cross a sub-watershed boundary. The user selects the attribute fields that are to be transferred from each of the source themes to the resulting theme. In addition, an attribute field named *LcLuArea* is added and populated with the area of each polygon. This enables (in a subsequent step) areas by LcLu class to be aggregated to the sub-watershed level.

> **Note:** Calculation of the field *LcLuArea* requires use of a reference dBase table named *SysUnits.dbf*. This table is described in the next section.

Each record in the resulting theme will have an attribute field named "*LcLuArea*" containing the area of the associated polygon in square miles.



__At a minimum, an LcLu classification field from the LcLu theme and a watershed identifier field must be transferred to the output theme in order to use the subsequent step.__ In the figure above, the *LcLu* field contains the Land Use classification in the LcLu theme; and the *WSId* field contains the sub-watershed identifier in the sub-watershed theme.

The output theme, named by the user, will be saved in the *ShapeFiles* sub-directory under the directory in which the ArcView project file is located.

SysUnits.dbf Table

The *SysUnits.Dbf* table is used in the processing step *Union (Combine) LcLu and Sub-Watershed Themes* described earlier. The table enables the user to define the coordinate units for the *Views* and for any distances or areas to be calculated. The factors to convert from the view units to those selected for distance and area are included in this table. This table must be manually maintained.

MAP	DISTANCE	AREA	MAPTODIST	ZEROVALUE	MAPTOAREA
Meters	Feet	sq. Miles	3.28083333	0.001000000000	0.000000386101

Fields are:

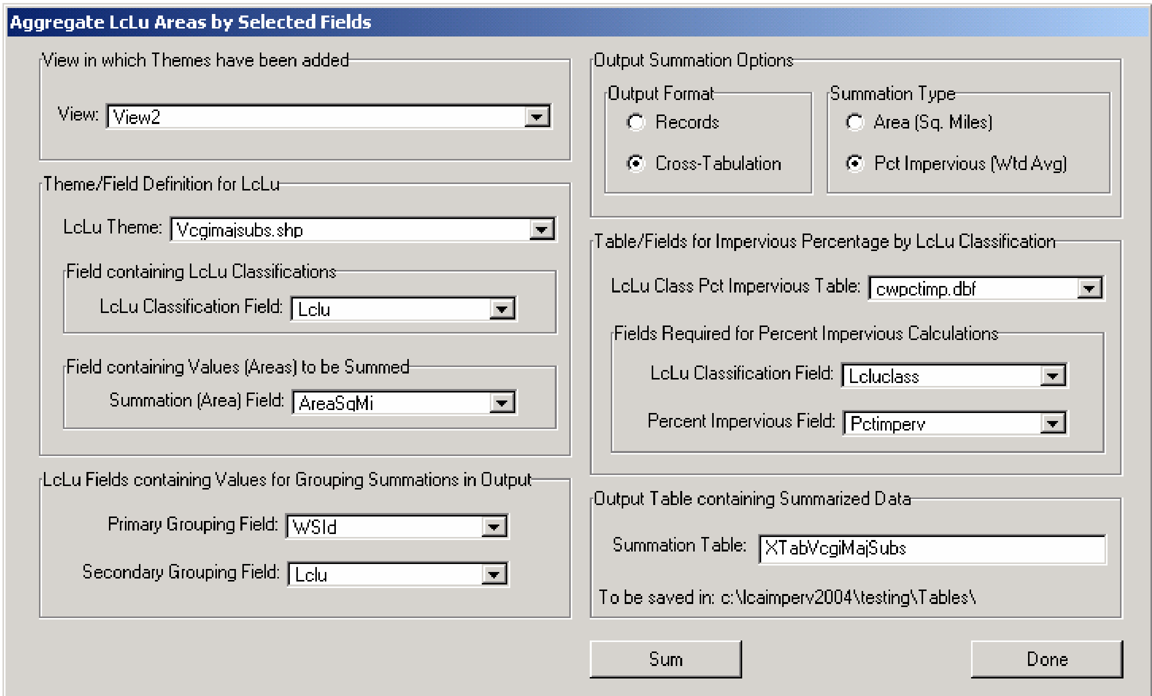
Map – Map Units set in ArcView View Property dialog. Units must be consistent with the coordinate units of the data (themes). In Vermont, data is available in the Vermont State Plane Coordinate System, NAD 83 with units in **Meters**.
Distance – Units to be used for any distances to be calculated within the software.
Area – Units to be used for any areas to be calculated within the software.
MapToDist – Factor used to convert from ***Map*** units to the ***Distance*** units. In the above table, 1 meter (Map) is equal to 3.28083333 feet (Distance)
ZeroValue – Value to be used for testing for the equivalence of zero in numerical testing. Specifically, for values which are to be positive, any value less than 0.001 will be treated as zero.
MapToArea – Factor used to convert from ***Map*** units (squared) to the ***Area*** units. In the above table 1 square meter (Map area) is equal to 0.000000386101 square miles (Area).

Use caution in modifying this table. Do not modify the value for ZeroValue as this will affect logic within the extension. All other parameters must be consistent.

This table must be named "SysUnits.dbf" and must have been added to the Tables GUI prior to using the extension. If this table is not present in the Tables GUI, an error message will be issued and access to the functions is prevented.

Aggregate LcLu Areas by Selected Fields

The processing associated with the following dialog permits one to create various summation levels and output formats for the areas associated with the LcLu Class. This dialog is illustrated below.



__There are numerous possibilities for creating summations; and not all combinations have been tested. As a result, take the time to experiment and VERIFY the results before using any results produced in this step.__

To use the dialog, first select the View containing the theme to be processed.

Next, select the LcLu theme for which areas are to be aggregated. This dialog is intended to work with the theme created from the previous function "*Union (Combine) LcLu and Sub-Watershed Themes*". As a result, the theme to be selected here would normally be the theme created by that step.

Once the theme has been selected, the attribute fields for the selected theme will be listed in the remaining four controls on the left hand side of the dialog:

- **LcLu Classification Field** -- contains the Land Use classification code associated with a record (polygon) in the theme.
- **Summation (Area) Field** – contains the area for the record (polygon) which is to be summed. If the theme selected for the LcLu theme (above) was created by the prior step "*Union (Combine) LcLu and Sub-Watershed Themes*", then this field would normally be named "*LcLuArea*".
- **Primary Grouping Field**
- **Secondary Grouping Field**

The *Primary* and *Secondary* fields define the parameters for the areas to be summarized. These fields are selected in the lower portion of the left-hand column. In the figure shown earlier, the summation fields are the sub-watershed identifier (*WSId*) and the LcLu Classification code (*LcLu*).

It is important to note that neither, one or both of the *Primary* and *Secondary* fields be defined. If neither is defined (i.e. left as "Not Selected"), then the output will be one record containing one field with the summation of the areas contained in the field identified for *Summation (Area) Field*.

> Note: Only fields of character type or numeric type with no decimal places can be selected for a *Primary* or *Secondary* field.

The format of the output table is identified in the top portion of the right-hand column in the *radio button* areas labeled as *Output Format* and *Summation Type*.

When the *Output Format* is *Records*, one record will be entered into the output table for each unique combination of the primary (*WSId*) and secondary (*LcLu*) grouping fields. The *sum of the Areas* or the *weighted average of the Percent Impervious* will be included in each record (as identified in the corresponding radio button for *Summation Type*).

When the *Output Format* is *Cross-tabulation*, one record will be entered into the output table for each unique value for the secondary (*LcLu*) grouping field. In that record, a field will be included for each unique value for the primary (*WSId*) grouping field. The *sum of the Areas* or the *weighted average of the Percent Impervious* will be entered as the value for each field (as identified in the corresponding radio button for *Summation Type*). A sample of a portion of a *cross-tabulation* output table is included on page 8.

If the *Pct Impervious (Wtd Avg)* option for *Summation Type* is selected, the user must identify the reference dBase table containing the percent impervious value associated with each *LcLu Classification*. This table must have already been added to the ArcView Tables GUI. A sample of this table is included on the next page.

Reference table for LcLu Percent Impervious Values for LcLu Classes

The records in the table on the following page are used to assign a percent impervious value to each *LcLu class* in the processing associated with the preceding dialog. This table is a dBase table named "CWPctImp.dbf". To use this table, it must have been added to the ArcView Tables GUI.

When the radio button labeled Pct Impervious (Wtd Avg) is selected, then one can select the table in the drop-down list for *LcLu Class Pct Impervious Table*. Once the table is selected, then the fields can be established. The *LcLu Classification Field* must be set to *LcLuClass*; and the *Percent Impervious Field* must be set to *PctImperv*. Other tables (and field names) can be used as long as one field identifies the LcLu classification values used in the theme identified for *LcLu Theme* on the dialog. The other field must contain percentage (whole numbers, e.g. 80 and not 0.80) impervious values associated with the corresponding LcLu class.

Refer to the next page for an example of the table.

LcLu	Percent	Descriptions			Included in		
Class	Imperv	Capen	SMRC	VCGI	Capen SMRC	SMRC MPG	VCGIS
3	0			Brush or Transitional between open and forested			X
5	0			Water			X
7	0			Barren Land			X
11	10			Residential			X
12	10			Commercial, Services & Institutional			X
13	10			Industrial			X
14	100			Transportation, Communication & Utilities			X
17	10			Outdoor & Other Urban & Built-up Land			X
22	2	Agricultural - Orchard/Tree Farm		Orchards, bush fruits, vineyards & ornamental	X		X
24	0			Other Agricultural land			X
30	0	Transitional - Shrub/Overgrown Field			X		
41	0	Deciduous Forest - Upland		Broadleaf Forest (generally deciduous)	X		X
42	0	Coniferous Forest - Upland		Coniferous Forest (generally evergreen)	X		X
43	0	Mixed Forest - Upland		Mixed Coniferous-Broadleaf Forest	X		X
50	0	Open Water			X		
61	0			Forested Wetland			X
62	0			Non-forested Wetland			X
63	0	Wetland - Emergent			X		
64	0	Wetland - Scrub/shrub			X		
65	0	Wetland - Forested			X		
100	10	Developed			X		
211	2	Agricultural - Row Crop		Row Crops (not including orchards & berries)	X		X
212	2	Agricultural - Hayfield/Pasture/Abandon ed Field		Hay/Rotation/Perman ent Pasture	X		X
500	100		Roads			xx	
501	100		Driveway			xx	
520	50		Railroads			xx	
540	2		Electric Transmission			xx	

Sample Cross Tabulation

The following table is a sample cross-tabulation created via the preceding dialog. In the table, areas are summarized by the LcLu Class (rows) and the major sub-watershed (columns). (Note that numerous columns have been omitted.)

		Major Sub_Watersheds					
LCLU Class	**Total Of AREASQMI**	**DDDir67**	**DDHolm**	**DDKimb**	**DDMeach**	**DDNA**	**DDThor**
0	0.1299574	0.02331719	0	0.00863745	0.00587642	0.01665242	0.00143185
3	0.3528729	0.00482626	0.00675674	0.00324535	0.0019305		0.00627414
5	7.95150593	0.02115813	0.24656245	0.11984706	0.0610903	0.09851295	0.21940435
7	0.11679335						
11	7.48502592	0.70567519	0.3385644	0.13306883	0.10796079	0.15625346	0.22564599
12	0.46586236	0.02273075	0.01464258	0.00485882	0.00241578	0.02500267	0.00921489
13	0.43017955		0.02726848	0.00072394			
14	6.88521369	0.32766655	0.31837848	0.19658509	0.21251342	0.30592043	0.25844318
17	0.71034385		0.00120655	0.08507137	0.00024131	0.00248547	0.00024131
22	0.03137079						0.0139962
24	2.37560333	0.28859494	0.4555573	0.13372807	0.13526906	0.13171795	0.35598168
41	35.33740055	0.63935869	0.84287534	0.23800756	0.50850469	0.65942689	0.62182454
42	11.19689151	0.22730283	0.07065705	0.13968406	0.03970355	0.29419991	0.19499278
43	25.62225879	0.40630551	0.63654069	0.26592232	0.28757035	0.43760204	0.48766632
61	3.79020236						
62	3.46437545						
211	20.81304951	0.66470078	1.10427088	0.66104887	0.3247154	0.44163885	0.818019
212	30.41988922	0.69984699	1.39469296	1.21697005	0.83970928	1.23048481	1.24613986

In the corresponding dBase table from which the above was extracted, each row represents a record and each column represents a field. The names of the fields are created using the values of a field in the source theme. In the above case, the sub-watershed identifiers are used as the field names, e.g. DDDir67, DDHolm, DDKimb, DDMeach, DDNA and DDThor.

If the values used to create the fields are numeric, then each field name will be preceded by the letter "N". This is required because numeric values cannot be used as field names in ArcView. This is illustrated in the following table where a single watershed with an identifier of "**1**" was used to create a cross-tabulation with the LcLu classes. Each LcLu class is a row (record) and lists the sum of the area for the watershed under column N1 and the total for all watersheds. (Since there is only a single watershed, the total is the same as that for the watershed with an identifier of "**1**", column "N1".))

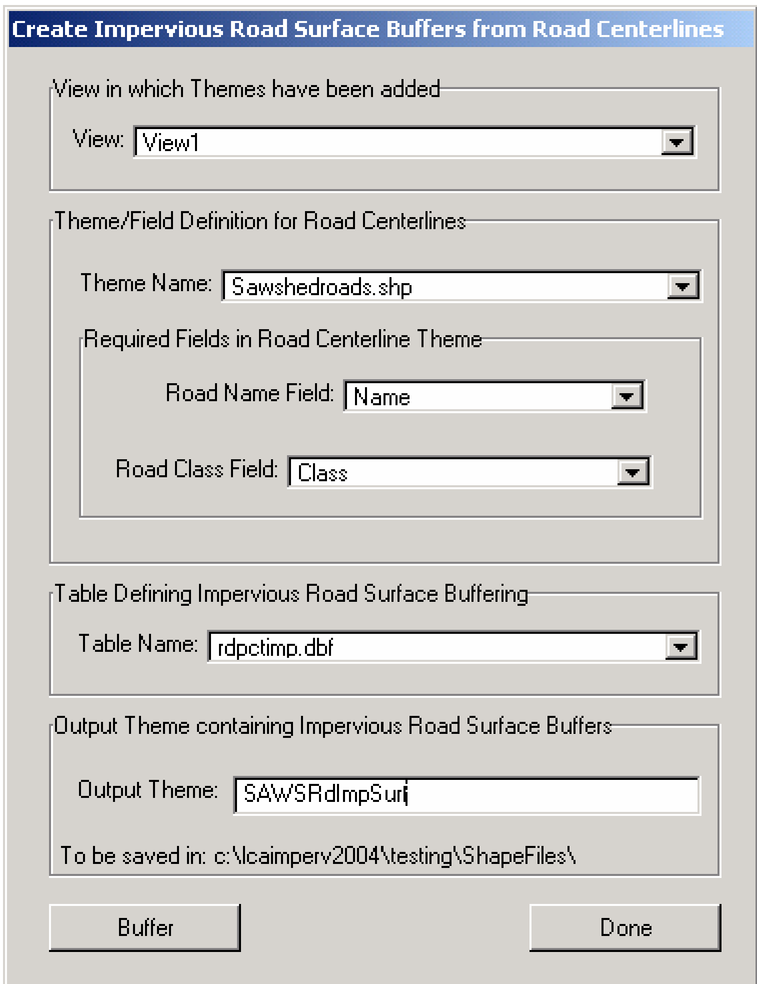
LCLU	**N1**	**TOTAL**
11	0.00011603	0.00011603
14	0.00007629	0.00007629
41	0.01068565	0.01068565
42	0.00120476	0.00120476
43	0.00482977	0.00482977
61	0.00020558	0.00020558
211	0.00032455	0.00032455
212	0.00110488	0.00110488
0	0.01854751	0.01854751

Create Impervious Road Surface Buffers from Road Centerlines

The processing associated with this dialog will create buffers around road centerlines. These buffers will be used to represent the impervious surfaces associated with the road.

The impervious surface will be composed of a road surface (paved or gravel), shoulders and ditch. All of the road centerline features (polylines) associated with a given road name and class are merged together prior to buffering. Upon completion of buffering, the overlapping portions are removed in accordance with a hierarchy established in the reference table identified on the dialog.

The reference table is described on the following pages.



RdPctImp.dbf – Reference table used for defining impervious road surface by road class. A sample table is shown following the field definitions.

Class -- Road class (borrowed from VCGI)
Priority -- Since road classes are not in numerical order of "importance", this field is used to assign a relative priority, where interstates are "1" and legal trails or non-roads are assigned "13". This field is used to determine from which road buffer the overlap is removed at points of intersection. Specifically, the overlap area is removed from the buffer containing the higher numerical value for priorities.
RoadType -- General description of class (borrowed from VCGI)
SurfWidth -- Width (in feet) of the road surface.
ShldWidth -- Width (in feet) of the road shoulders. If road is paved, included paved portion of shoulders in field SurfWidth", remaining shoulder width would be in this field.
DtchWidth -- Width (in feet) of the road ditch.
SurfImpPct -- Impervious Percentage to be associated with the road surface.
ShldImpPct --Impervious Percentage to be associated with the road shoulder.
DtchImpPct -- Impervious Percentage to be associated with the road ditch.

				Widths			Impervious Percent	
Priority	**Class**	**RoadType**	**Surface**	**Shoulder**	**Ditch**	**Surface**	**Shoulder**	**Ditch**
1	50	Interstate	0	0	0	100	60	60
1	51	Interstate (North bound)	0	0	0	100	60	60
1	52	Interstate (South bound)	0	0	0	100	60	60
1	53	Interstate (East bound)	0	0	0	100	60	60
1	54	Interstate (West bound)	0	0	0	100	60	60
1	55	Interstate Ent/Exit, Approach.	0	0	0	100	60	60
1	56	Interstate (Emeregency U-turn)	0	0	0	100	60	60
1	57	Interstate (Rest Area)	0	0	0	100	60	60
1	58	Interstate (Not Used)	0	0	0	100	60	60
1	59	Interstate (Other, Weigh Station, Maint.)	0	0	0	100	60	60
1	86	Proposed Interstate	0	0	0	100	60	60
1	87	Proposed Ramp: Interstate	0	0	0	100	60	60
2	40	US Highways	32	6	6	100	60	60
2	41	US Highways (North bound)	32	6	6	100	60	60
2	42	US Highways (South bound)	32	6	6	100	60	60
2	43	US Highways (East bound)	32	6	6	100	60	60
2	44	US Highways (West bound)	32	6	6	100	60	60
2	45	US Highways Ent/Exit, Approach.	32	6	6	100	60	60
2	46	US Highways (Emeregency U-turn)	32	6	6	100	60	60
2	47	US Highways (Rest Area)	32	6	6	100	60	60
2	48	US Highways (Not Used)	32	6	6	100	60	60
2	49	US Highways (Other, Weigh Station, Maint.)	32	6	6	100	60	60
2	85	Proposed US Highway	32	6	6	100	60	60
3	30	VT Highways	32	6	6	100	60	60
3	31	VT Highways (North bound)	32	6	6	100	60	60
3	32	VT Highways (South bound)	32	6	6	100	60	60
3	33	VT Highways (East bound)	32	6	6	100	60	60
3	34	VT Highways (West bound)	32	6	6	100	60	60
3	35	VT Highways Ent/Exit, Approach.	32	6	6	100	60	60
3	36	VT Highways (Emeregency U-turn)	32	6	6	100	60	60
3	37	VT Highways (Rest Area)	32	6	6	100	60	60
3	38	VT Highways (Not Used)	32	6	6	100	60	60
3	39	VT Highways (Other, Weigh Station, Maint.)	32	6	6	100	60	60

(Continued)

			Widths			Impervious Percent		
Priority	**Class**	**RoadType**	**Surface**	**Shoulder**	**Ditch**	**Surface**	**Shoulder**	**Ditch**
3	84	Proposed VT Highway	32	6	6	100	60	60
4	1	Town Class 1 Road	32	6	6	100	60	60
4	10	Class 1 (Not Used)	32	6	6	100	60	60
4	11	Class 1 (North bound)	32	6	6	100	60	60
4	12	Class 1 (South bound)	32	6	6	100	60	60
4	13	Class 1 (East bound)	32	6	6	100	60	60
4	14	Class 1 (West bound)	32	6	6	100	60	60
4	15	Class 1 Ent/Exit, Approach.	32	6	6	100	60	60
4	16	Class 1 (Emeregency U-turn)	32	6	6	100	60	60
4	17	Class 1 (Rest Area)	32	6	6	100	60	60
4	18	Class 1 (Not Used)	32	6	6	100	60	60
4	19	Class 1 (Other, Weigh Station, Maint.)	32	6	6	100	60	60
4	81	Proposed Class 1 Town Rd	32	6	6	100	60	60
4	88	Proposed Ramp: non-Interstate	32	6	6	100	60	60
5	2	Town Class 2 Road	27	6	6	100	40	40
5	20	Class 2 (Not Used)	27	6	6	100	40	40
5	21	Class 2 (North bound)	27	6	6	100	40	40
5	22	Class 2 (South bound)	27	6	6	100	40	40
5	23	Class 2 (East bound)	27	6	6	100	40	40
5	24	Class 2 (West bound)	27	6	6	100	40	40
5	25	Class 2 Ent/Exit, Approach.	27	6	6	100	40	40
5	26	Class 2 (Emeregency U-turn)	27	6	6	100	40	40
5	27	Class 2 (Rest Area)	27	6	6	100	40	40
5	28	Class 2 (Not Used)	27	6	6	100	40	40
5	29	Class 2 (Other, Weigh Station, Maint.)	27	6	6	100	40	40
5	82	Proposed Class 2 Town Rd	27	6	6	100	40	40
6	3	Town Class 3 Road	27	0	6	100	40	40
6	83	Proposed Class 3 Town Rd	27	0	6	100	40	40
6	93	Public Rd (class ?)	27	0	6	100	40	40
7	5	State Forest Highway	27	0	4	100	40	40
7	6	National Forest Highway	27	0	4	100	40	40
8	4	Town Class 4 Road	27	0	6	100	40	40
9	92	Military (No Public Access)	27	0	6	100	40	40
10	8	Private (No Display) Road	14	0	0	100	40	40
10	9	Private (Display) Road	14	0	0	100	40	40
10	89	Proposed Private Rd	14	0	0	100	40	40
10	99	Unknown (Private?) Road	14	0	0	100	40	40
11	91	Driveway (Pvt, not-named)	14	0	0	100	40	40
11	501	Driveway (Pvt, from E911 driveways)	14	0	0	100	40	40
12	95	Under Special Review (temporary)	27	0	0	100	40	40
20	520	Railroads	23	0	0	50	0	0
40	540	Electric Transmission	26	0	0	2	0	0
99	7	Legal Trail	3	0	0	0	0	0
99	96	Discontinued Road	14	0	0	0	0	0
99	97	Not Used	0	0	0	0	0	0
99	98	Not Considered a road	0	0	0	0	0	0

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Appendix D: Hinesburg Build Out Results

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ATTACHMENTS

Buildout Analysis Tables

Maps (on file at Town offices)

D.1 Refined Build Out (BO) Results

Build out results for Hinesburg are summarized in the attached tables and on large-scale maps maintained at the Town of Hinesburg municipal offices. Build outs were performed using the *Addison Community Buildout Analysis* software (ACBOA, an extension to ArcView® 3.x). Please refer to the ACBOA Users Manual for details of the methodology. Build out analysis was performed by C. L. Davis Consulting Associates, Inc. of Middlebury – Weybridge, VT (CLDCA).

D.1.a Residential

In addition to the estimated 1,586 existing residential units in Hinesburg, approximately 3,375 potential residential units would be expected at maximum build out under current zoning allowances, given the presence of the Sewer Service Area depicted on attached maps, and in consideration of the natural resource constraints detailed in the attached tables and maps.

D.1.b Commercial / Industrial

For purposes of this study, the calculated Potential Footprint (PTFTPRNT) and Potential Parking Area (PTPRKAREA) fields of the Commercial/Industrial build out results tables are summed to represent the approximate area of impervious surface at full build out. For the Hinesburg Refined BO these are estimated as:

Commercial:	23 Acres
Industrial:	99 Acres
Total:	122 Acres

D.1.c Comparison to Basic BO Results

Comparison of the Basic BO results to the Refined BO results highlights the influence of estimated constraints on final BO. From a residential BO perspective, ***potential*** residential units were decreased from approximately 7,962 to 3,375 by the application of anticipated constraints to build out.

D.1.d Comparison to Previous BO Efforts

The CCRPC Regional Build-out Analysis (RBA) completed in 2003 estimated approximately 2,323 potential residential units at the fully built-out condition for Hinesburg (Spitz & Stone Environmental, 2003). As best as could be achieved, the Project Team simulated assumptions used in the CCRPC RBA. A Preliminary BO prepared for Alex Wienhagen (Town of Hinesburg) in October of 2004 using the ACBOA software, predicted an estimated 2,801 potential residential units under maximum build out for Hinesburg.

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ATTACHMENTS

Buildout Analysis Tables

Maps (on file at Town offices)

E.1 Refined Build Out (BO) Results

Build out results for Charlotte are summarized in the attached tables and on Plate-size maps maintained at the Town of Charlotte municipal offices. Build outs were performed using the *Addison Community Buildout Analysis* software (ACBOA, an extension to ArcView® 3.x). Please refer to the ACBOA Users Manual for details of the methodology.

Build out analysis was performed by C. L. Davis Consulting Associates, Inc. of Middlebury – Weybridge, VT (CLDCA). Alternate build out scenarios were identified by a Charlotte Working Group consisting of: Dean Block, Jim Donovan, and Nell Fraser from Charlotte; Marty Illick from Lewis Creek Association; and Kristen Underwood of South Mountain Research & Consulting.

E.1.a Residential

In addition to the estimated 1,543 existing residential units in Charlotte, approximately 1,001 potential residential units would be expected at maximum build out under current zoning allowances and in consideration of the natural resource constraints detailed in the attached tables and maps.

E.1.b Commercial / Industrial

For purposes of this study, the calculated Potential Footprint (PTFTPRNT) and Potential Parking Area (PTPRKAREA) fields of the Commercial/Industrial build out results tables are summed to represent the approximate area of impervious surface at full build out. For the Charlotte Refined BO these are estimated as:

Commercial:	8 Acres
Industrial:	15 Acres
Total:	23 Acres

Commercial districts are located in LPT2 (East Village) and DDHolm (West Village) major sub-watersheds. Industrial districts are located in DDHolm (West Village) and DDThor (Rt. 7 Industrial Park) major sub-watersheds. However, while the “Rt. 7 Industrial Park” area is still zoned Industrial, this area was converted to a conserved status in 2004 (Illick, 2005). No potential buildings or parking areas resulted from the commercial / industrial build out in the Rt. 7 Industrial Park (Appendix E).

E.1.c Comparison to Basic BO Results

Comparison of the Basic BO results to the Refined BO results highlights the influence of estimated constraints on final BO. From a residential BO perspective, ***potential*** residential units were decreased from approximately 3,014 to 1,001 by the application of anticipated constraints to build out.

E.1.d Comparison to Previous BO Efforts

The CCRPC Regional Build-out Analysis (RBA) completed in 2003 estimated approximately 909 potential residential units at the fully built-out condition for Charlotte (Spitz & Stone Environmental, 2003). As best as could be achieved, the Project Team simulated assumptions used in the CCRPC RBA. A Preliminary BO prepared for the Steering Committee in September

2004 using the ACBOA software, predicted an estimated 1,181 potential residential units under maximum build out for Charlotte.

E.2 Scenarios

Alternate build out scenarios were identified by a Charlotte Working Group consisting of: Dean Block, Jim Donovan, and Nell Fraser from Charlotte; Marty Illick from Lewis Creek Association; and Kristen Underwood of South Mountain Research & Consulting.

Details of the build out runs under the following three scenarios are presented in the attached tables and maps. For purposes of evaluating Scenarios, only the Residential BO results were reviewed, since Commercial and Industrial districts in Charlotte represent approximately 309 acres in area, or only 1.2% of the total town area of 26,530 acres.

An outline of the three build out runs is presented in Table E.1.

E.2.1 Scenario 1 - Evaluate influence of increased density in village district

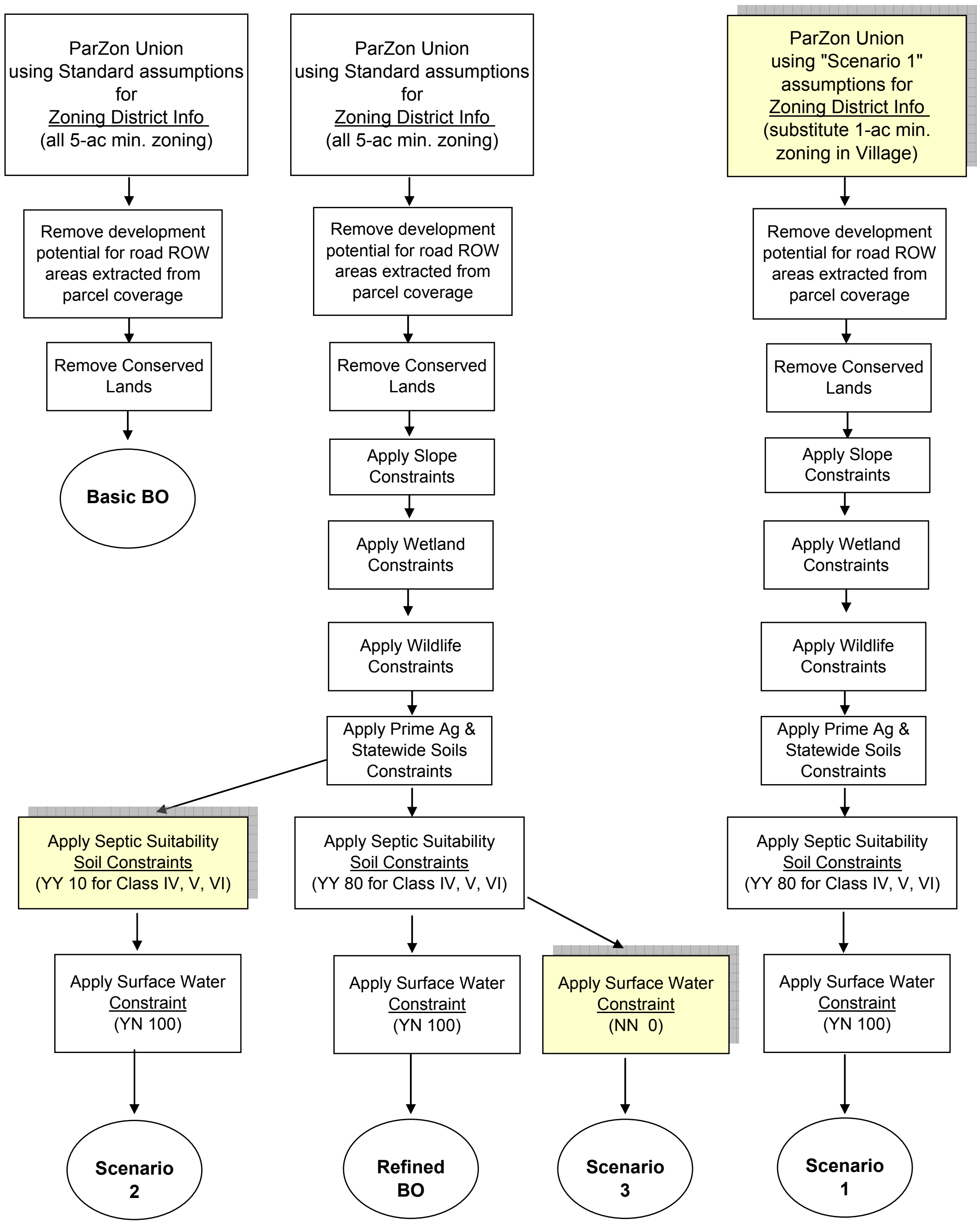
To evaluate an increased development density in the village areas of Charlotte, a 1-acre minimum was substituted for the 5-acre minimum in the Village zoning district of Charlotte; all other districts remained at a 5-acre minimum. Village District (East Village and West Village) represents approximate 416 acres in area, or 1.6% of the total town area of 26,530 acres. Village Districts occupy the DDHolm (West Village) and LPT2 (East Village) major subwatersheds.

Compare results of REFINED BO to results of SCENARIO 1

Residential BO: Total approximate number of structures at BO under Scenario 1 = 2608 (1065 potential + 1543 existing). Approximately 64 residential units are gained townwide under Scenario 1, as compared to the Refined BO results. Under Refined BO, 12 potential units are added to the 95 existing units, while under Scenario 1, 76 potential units are added to the 95 existing units. All structures gained are located in the Village District, as expected.

Conclusion: Under Scenario 1, the number of residential structures in the Village District would nearly double. These increased density effects would impact the DDHolm and LPT2 major subsheds, concentrated at the areas of "West Village" and "East Village", respectively. Low impact development choices and effective stormwater mitigation structures and practices could minimize the effects of this localized, increase in development density.

Table E.1. Outline of Charlotte Build Out Scenarios



E.2.2 Scenario 2 - Evaluate assumptions about "developability" of Class IV and V soils

An assumed 80% developability of these soils utilized in the Refined BO (and in Scenarios 1 and 3), is replaced with a conservative assumption of 10% developability, to evaluate the significance of this assumption on overall build out results. The sensitivity of build out results to this parameter is expected to be significant given the considerable aerial extent of Class IV and V soils in the Town of Charlotte.

Compare results of REFINED BO to results of SCENARIO 2

Residential BO: Total approximate number of structures at BO under Scenario 2 = 2272 (729 potential + 1543 existing). Approximately 272 structures are "lost" town-wide under Scenario 2, as compared to the Refined BO results. The majority of these "losses" are exhibited in the zoning districts comprising the three highest total acreages in the town: Rural, Conservation, and Shoreland. A loss of 272 structures under Scenario 2 represents approximately 27% of the total estimated potential structures under the Refined BO.

Conclusion: Estimation of the "developability" of Class IV and V soils is significant in the calculation of potential BO and in the estimated effects on increased development density on water quality. Further study to refine this estimate would improve the accuracy of BO predictions. In all likelihood the actual "developability" lies somewhere between 80% and 10%, and potential residential units are some approximate number between 1,001 and 729. Town of Charlotte representatives report that this value is closer to 80% based on local experience.

E.2.3 Scenario 3 – Remove development potential for areas within surface water 75-foot buffers.

Compare results of REFINED BO to results of SCENARIO 3

Residential BO: Total approximate number of structures at BO under Scenario 3 = 2472 (929 potential + 1543 existing). Approximately 72 structures are lost townwide under Scenario 3, as compared to the Refined BO results. All of these "losses" are exhibited in the zoning districts comprising the three highest total acreages in the town: Rural, Conservation, and Shoreland. A loss of 72 structures under Scenario 2 represents approximately 7% of the total estimated potential structures under the Refined BO.

Conclusion: Removing development potential for areas within surface water 75-foot buffers results in a significant reduction in potential units at BO. This scenario represents a more stringent level of protection for Charlotte's surface waters, over simple structure setbacks. Such a choice would improve water quality by lessening development densities near the buffer along stream channels in the Rural, Conservation, and Shoreland districts. This improved public value should be evaluated in light of the potential costs to riparian landowners in terms of loss of use.

Note that Scenario 3 includes an assumption of 80% developability on Class IV, V, and VI soils. If actual developability is some value less than 80%, it is possible that, for a given parcel, a loss of structure incurred as a result of preventing stream buffers from counting toward density would coincide with a loss incurred as a result of more conservative assumptions about developability of Class IV, V, and VI soils. In other words, Scenarios 2 and 3 are unique and results cannot be simply be added together to determine the composite impact of both Scenarios on BO.

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Appendix F:
Zoning-based Maximum Build Out Results

***C. L. Davis Consulting Associates, Ltd*.**