GROWTH AREA EXISTING CONDITIONS
HYDROLOGY STUDY
HINESBURG, VERMONT

JANUARY 2012

MMI #4726-01

Prepared for:

Town of Hinesburg, Vermont

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EXECUTIVE SUMMARY

Existing conditions hydrology modeling of the LaPlatte River Watershed has been completed for the Town of Hinesburg, Vermont, with special focus on the Village Growth Area and upstream contributing areas. The hydrology model has created a baseline for addressing stormwater runoff in the Town. Low-impact design and proper stormwater handling can be planned and designed starting with the existing conditions hydrology model. For example, the model can help identify priority treatment areas where existing development is causing excessive stormwater runoff relative to other areas in the watershed. Results of this analysis can guide where development takes place and how it can be best implemented to protect water resources. The modeling can also be used to develop regulations for future development that explicitly considers stormwater treatment. A proactive approach to stormwater treatment is essential for smart growth that both protects water quality and reduces flood and erosion risks.

Existing conditions hydrographs were modeled showing the flow, volume, and timing during a range of floods. Runoff patterns, both volume and peak discharge, follow watershed land use trends that can generally be described as developed with high runoff in the Village Growth Area, forested with lower runoff to the east, and agricultural with moderate runoff to the west. Hydrographs showed a trend of higher peak discharge values occurring earlier in the storm in the agricultural lands with clay soils in the western section of town compared to forested subwatersheds in the eastern part of town. The six subwatersheds contributing the highest peak runoff and the highest runoff depth are located in and immediately upstream of the Village Growth Area.

A buildout scenario was modeled where land use was modified to reflect a theoretical full development condition based on current zoning regulations and likely developable land. Full buildout increased runoff peak flow rate and volume throughout the watershed for all modeled storm events. For example, the first flush of runoff that typically carries the most pollutants and is targeted for treatment (i.e., the water quality volume that is taken as the runoff volume generated from 0.9 inches of rainfall in Vermont) increased 35% at the downstream Town Boundary, from 38 cubic feet per second (cfs) to 52 cfs. The 100-year peak flow increased 17% at the downstream Town Boundary, from 7,797 cfs to 9,151 cfs. Increased peak flows will increase chances of flooding and damage to infrastructure, reduce water quality, and present a future stormwater management need as development expands.

The modeled 2-year storm runoff volume increased between 0 and 65% under the full watershed buildout scenario indicating that increased development will increase the amount of water travelling in stormwater infrastructure and in need of treatment. The water will also be moving faster as the peak flow rate increased 0 to 142% under the buildout scenario and thus there is more potential for erosion. Flood flows move through the watershed faster and can cause increased flooding, impacts to habitat, and reduced water quality. Increased peak discharge values were on average 50% higher than existing conditions, with Village Growth Area subwatersheds increasing on average the same as non- Growth Area subwatersheds. Stormwater treatment for future development is a priority across the watershed, not just in high density development areas.

The existing conditions model illustrates that the small subwatershed in the Village Growth Area containing the intersection of Route 116 and Silver Street generates a large runoff volume in small area due to large amounts of impervious cover and limited storage and infiltration. The model has been used to create a conceptual design for a tiered rain garden to introduce stormwater storage and treatment lost as the area was developed and land was converted to impervious cover. The installation is proposed on the Town owned land where the Masonic Hall is located along Silver Street where a ditch and lawn currently exist. The rain garden captures and detains runoff from three pipes that now flow to a ditch and directly to the LaPlatte River without treatment. Installation of the rain garden would result in the removal of 87% of the total suspended solids from the water quality volume and removal of 34% of Total Phosphorus. Beyond improving local water quality, the rain garden design will enhance local aesthetics, be easy to maintain, and serve as a public demonstration of simple measures that can be used to treat stormwater in the built environment. A ballpark cost opinion for final design, permitting, and construction of the rain garden is $60,000 based on typical construction and material costs.

1.0 INTRODUCTION

In its entirety, the hydrologic cycle consists of water moving from ocean to atmosphere, precipitation on land, and runoff on land and rivers back to the ocean. Locally, the hydrologic cycle consists of precipitation and water leaving an area via evaporation, transpiration, infiltration, and runoff. As land cover changes with development, the movement of water into, out of, and across the land changes. Stormwater runoff increases as land is converted from natural conditions to a built condition (Figure 1). Increased impervious surfaces and increased channelization of flow paths increase the volume and flow rate of stormwater runoff. Alteration of watershed hydrology can lead to increased flooding, destabilization of river channel and more bank and bed erosion, reduction of water quality, and impacts to instream habitat.

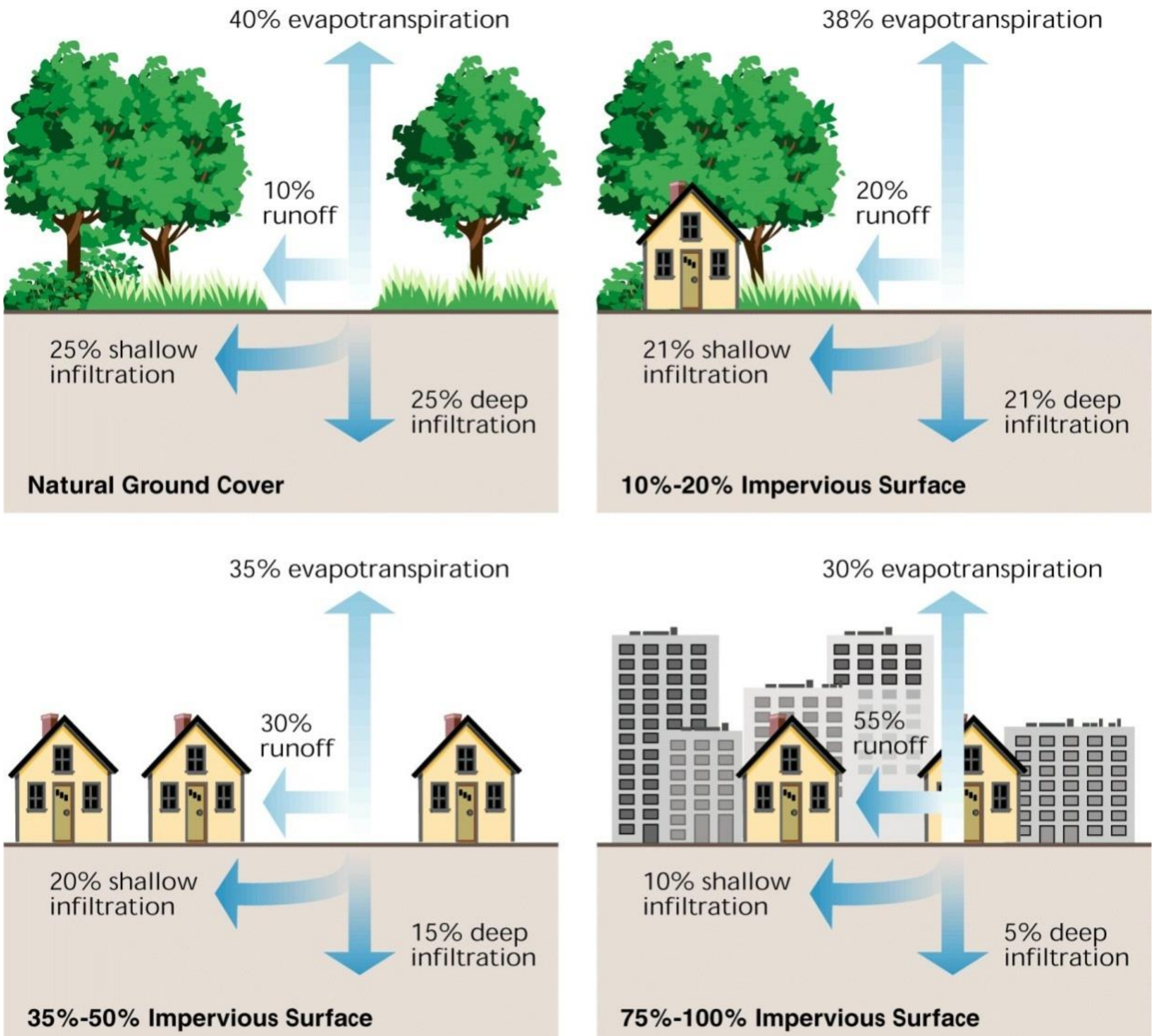


Figure 1: Alterations to the hydrologic cycle as impervious surface increases (FISRWG 1998).

The sources of non-permitted and unmitigated stormwater in the LaPlatte River watershed are abundant and widespread. In non-stormwater impaired subwatersheds like those found in Hinesburg, non-industrial projects creating less than 1 acre of impervious surfaces are not required to obtain a State of Vermont Stormwater Permit. The federal and state permitting environment does not regulate small to medium size developments where stormwater discharges are established incrementally. Discharge from these projects and from existing/historic development tends to go untreated, with the eventual responsibility for maintenance of stormwater infrastructure and level of treatment defaulting to the municipalities. For all of these reasons, it is in the Town's interest to do comprehensive stormwater planning, especially within the Village Growth Area where future development in anticipated.

The Town of Hinesburg has encouraged development in the Village Growth Area that requires a strategic look at the potential impediments to achieving the desired patterns laid out by the Town. The increase in impervious surfaces and related planning for stormwater treatment will help define the character and uses – both for infill on existing lots and buildout into expansion areas that are not yet developed. Planning needs to consider the pattern of development established by a 19th century village, and take full advantage of opportunities to utilize the still functioning green infrastructure of wetlands, buffers along streams and rivers, grass-lined swales, and pervious soils. This vision will be best achieved if it is planned on a comprehensive basis for the subwatersheds with the growth areas, and not limited to engineering and design on a lot-by-lot or development-by-development basis.

A previous study of stormwater patterns in the LaPlatte River watershed was completed (Schiff and Clark 2010) that included field investigation and GIS mapping of stormwater infrastructure in the LaPlatte River watershed. Watershed characteristics influencing stormwater runoff and general recommendations for stormwater management were discussed. The current study builds on the 2010 study for the Town of Hinesburg by refining previous mapping data with field investigation, developing a hydrology model, and exploring runoff patterns around the Town. The two reports in combination give a comprehensive view of stormwater patterns and condition and the potential for improvements.

Thresholds of impervious cover below which water quality and stream conditions deteriorate have been found to range between 5 and 10% (Brabec, Schulte et al. 2002; CWP 2003; Schiff and Benoit 2007). Subwatersheds in Hinesburg have already passed this threshold (T4.01 = 22%; M16.H1 = 14%; and M15S2.01.H1 = 10%). Impervious cover is an index to measure hydrologic changes including increased runoff peak discharge and volume. Specific thresholds of stream degradation due to increased runoff peak discharge or volume have not been quantified because there are too many variables. For hydrologic conditions there is not hard and fast rule of thumb for a community to base planning efforts. River responses to increased peak flows or volumes depend on site specific stream condition, including hydrology, hydraulics, and geomorphology. For example, increased peak flows may cause erosion in a sand bank channel, while a bedrock channel is unaffected or an increase in peak flows by 10% may cause a culvert in one location to overtop and flood a road every year, while another culvert may handle an increase of 20%. Any change in hydrology is unnatural and can begin to cause changes in stream stability, flooding, and habitat quality.

An existing conditions hydrology model was created for the Village Growth Area and upstream contributing areas using the HEC-HMS hydrology model (USACOE 2001). The SCS curve number runoff-volume method (SCS 1986; SCS 1992) was used that predicts the amount of runoff in designated subwatersheds based on land cover, soil type, vegetation, water travel time, rainfall, storage volumes, moisture condition of the ground, and hydraulic capacities of structures. The model predicts the amount of runoff as a function of time, including the attenuation affect due to dams, lakes, large wetlands, and floodplains.

Low-impact design and proper stormwater handling can be planned and designed starting with the existing conditions hydrology model. For example, the model can help identify priority treatment areas where existing development is causing excessive stormwater runoff relative to other areas in the watershed. Results of this analysis can guide where development takes place and how it can be best implemented to protect water resources. The modeling can also be used to formulate policy for future development that explicitly considers stormwater treatment. As an example, this study includes a comparison of existing conditions hydrology and an estimation of potential development based on current zoning regulations.

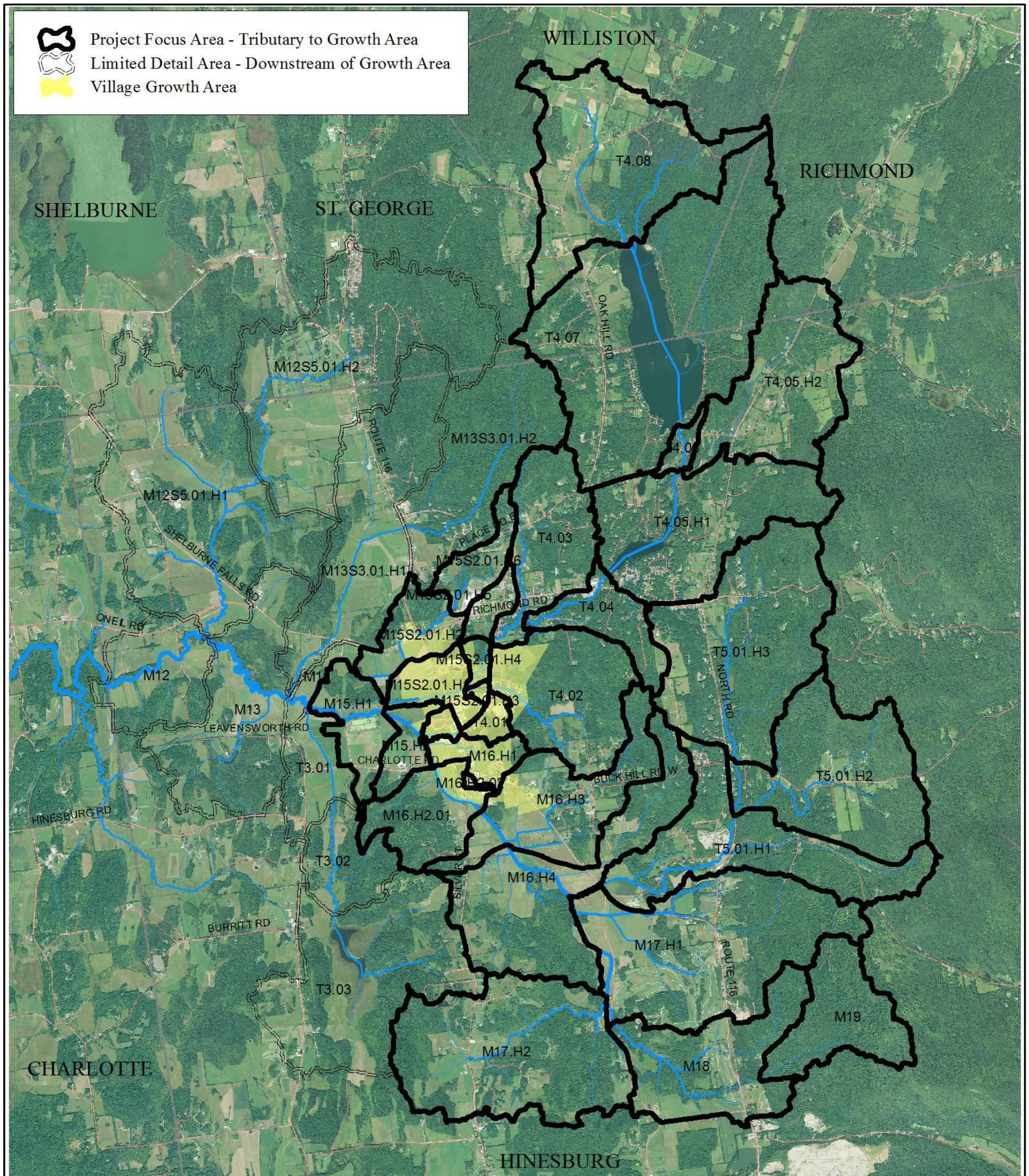
2.0 EXISTING CONDITIONS HYDROLOGY MODEL

2.1 Subwatersheds

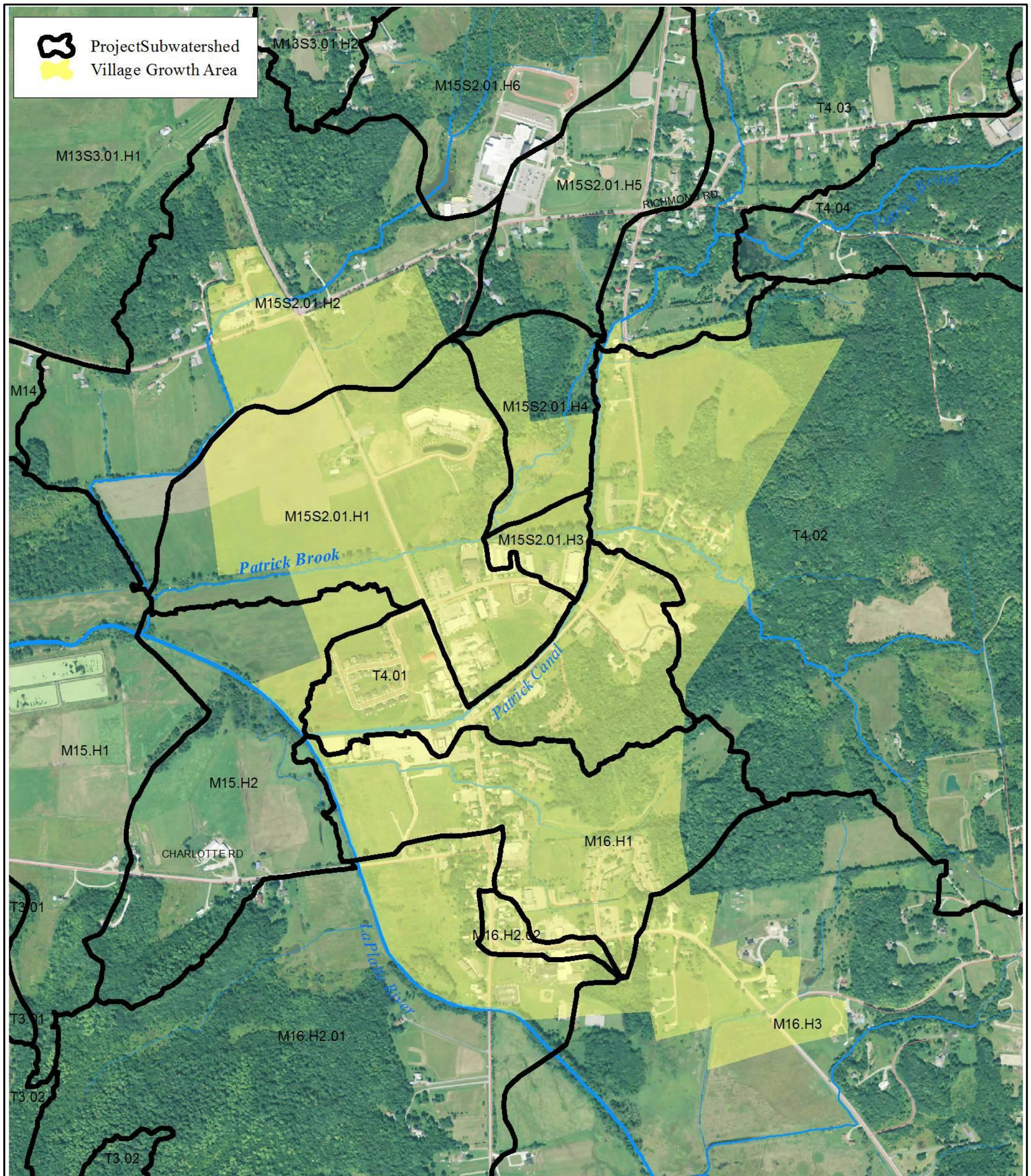
The LaPlatte River watershed runs approximately southeast to northwest and drains into Shelburne Bay of Lake Champlain. The LaPlatte River watershed has an area of approximately 53 square miles, with 46% of the contributing area falling in Hinesburg. The study focuses in the Hinesburg Village Growth Area and upstream contributing areas, and also includes almost the entire LaPlatte River watershed in Hinesburg.

Subwatersheds were delineated based on LIDAR-based topography data collected in 2004. Initial subwatershed divides were located at stream reach break locations identified in the Stream Geomorphic Assessment Phase 1 and Phase 2 assessments (LWP 2006; VTANR 2007). The subwatershed delineations were corrected in 2010 based on known stormwater patterns and infrastructure in the watershed (Schiff and Clark 2010).

Subwatersheds were refined for this hydrology study to generate subwatersheds of similar sizes and to increase the level of detail in the Village Growth Area. The study resulted in 39 subwatersheds ranging in size from 6.7 acres to 361.7 acres (Figures 2 and 3).



Engineering, Landscape Architecture and Environmental Science **MILONE & MACBROOM®**	**Project Subwatersheds**	0.5 0.25 0 0.5 Miles
1233 Shelburne Road, Suite 150 **South Burlington, VT 05403** **(802) 864-1600 Fax: (802) 864-1601** **www.miloneandmacbroom.com**	**Growth Center Existing Conditions Hydrology Study**	**DATE:** November 2011 **SCALE:** see scale bar **SHEET:** Figure 2



Engineering, Landscape Architecture and Environmental Science MILONE & MACBROOM® 1233 Shelburne Road, Suite 150 South Burlington, VT 05403 (802) 864-1600 Fax: (802) 864-1601 www.miloneandmacbroom.com	**Project Subwatersheds in Village Growth Area** **Growth Center Existing Conditions Hydrology Study**	N W E S 500 250 0 500 Feet **DATE:** November 2011 **SCALE:** see scale bar	**SHEET:** **Figure 3**

2.2 Runoff Curve Number

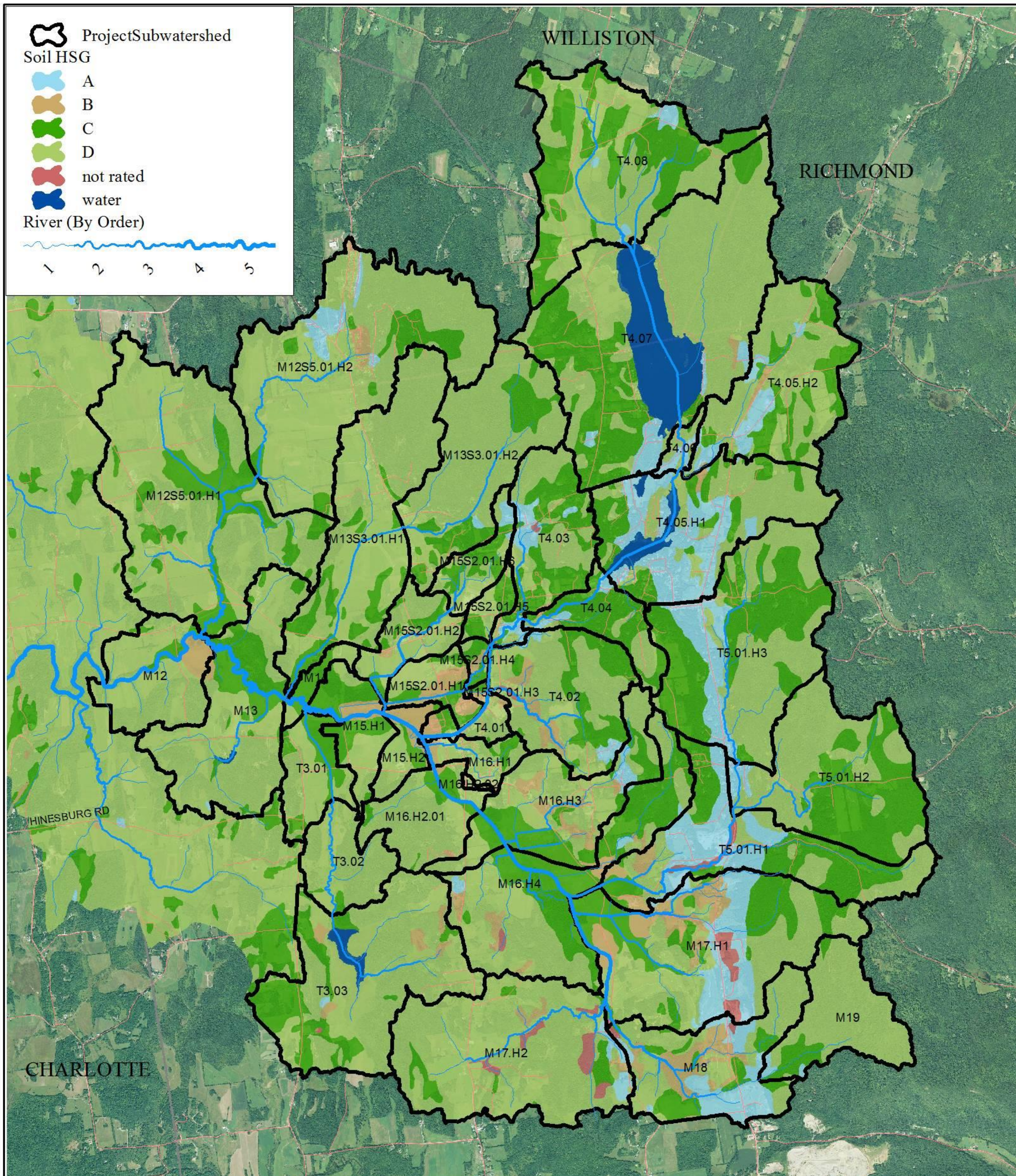
The runoff curve number is an empirical parameter used to estimate runoff from an area based on hydrologic soil group land cover, and antecedent moisture condition (SCS 1986).

Soil types and hydrologic soil group in the watershed were determined from the NRCS soil survey for Chittenden County, Vermont (Figure 4). Four hydrologic soil groups exist (i.e., A, B, C, or D) that are a function of infiltration capacity – the maximum rate water can enter the soil. A soils are well-drained and have high infiltration capacity, while D soils have the lowest infiltration capacity and generate the highest runoff rates. The LaPlatte River watershed is dominated by clay soils with hydrologic soil groups C and D that are poorly drained and tend to produce a lot of runoff. There is a band of well drained A soils parallel to North Road, south of Lake Iroquois and sections of B soils scattered in a loose band running parallel to Route 116 and the LaPlatte River. Many of these scattered sections of A and B soils are located in the Village Growth Area and near other areas of clustered rural development, where they could be used to infiltrate collected stormwater.Within the Villiage Growth Area, a band of soils with good infiltration capacity runs along the LaPlatte River from Charlotte Road North incluing the Saputo property, Farmall Drive, across Route 116 in front of NRG and east towards Mechanicsville Road. Other patches of soils with good infiltration exist at Commerce Street, Mulberry Lane, north of Hawk Lane, and along Route 116 near Buck Hill Road.

Land cover information was obtained from the 2006 National Land Cover Dataset. Land cover information was refined based on field observations and 2008 National Agriculture Imagery Program aerial photography (Figure 5). Landcover is primarily forested east of the Village Growth Area and the LaPlatte River corridor. The western portion of the watershed is a mixture of agriculture, development, with some forested sections. The divide in landcover tracks a change in underlying landform with compacted glacial till and bedrock in the eastern portion and glaciolacustrine clay deposits with interspersed bedrock outcrops in the western 2/3 of the watershed.

Development is currently centered within the Village Growth Area with sprawling development along roadways most prevalently Richmond Road, North Road, and Route 116. There is also a cluster of development in the watershed outside of Hinesburg at the intersection of Routes 116 and 2A . The remaining watershed has some rural residential areas mixed within a primarily agricultural area to the west and forested area to the east.

Curve number values were assigned for an average antecedent moisture condition based on cover type, soils, and hydrologic condition listed in Table 2-2a of the TR-55 user's manual (SCS 1986). Curve numbers were weighted by area for each subwatershed (Table 1), with values ranging between 63 and 94. Calculation sheets for each subwatershed are included in Appendix A.



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Hydrologic Soil Group

Growth Center Existing Conditions Hydrology Study

N W E S

0 0.25 0.5 1 Miles

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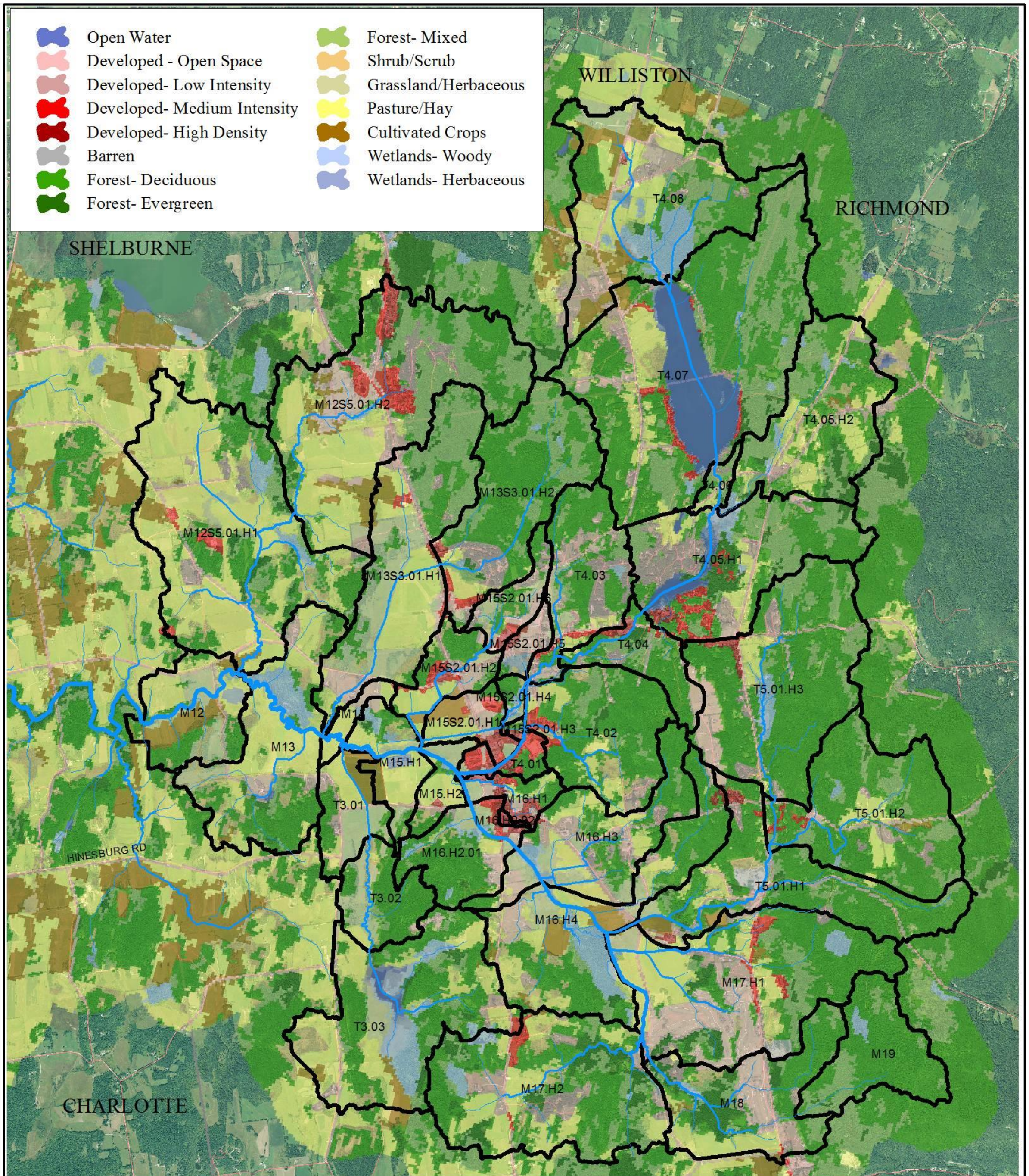

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Landcover

Growth Center Existing Conditions Hydrology Study

0 0.25 0.5 1 Miles

DATE: November 2011

SCALE: see scale bar

SHEET: **Figure 5**

Table 1: Curve Number values based on landcover type and HSG.

NLCD #	NLCD Category	TR-55 Category	Hydrologic Soil Group			
			A	B	C	D
11	Open Water	Water	98	98	98	98
21	Developed - Open Space	Open Space - Good	49	69	79	84
22	Developed - Low Intensity	Residential - 2 acre	46	65	77	82
23	Developed - Medium Intensity	Residential - 1/2 acre	54	70	80	85
24	Developed - High Intensity	Commercial and Business (include Res. 1/8 acre or less)	89	92	94	95
31	Barren	Newly Graded Areas	77	86	91	94
41	Forest - Deciduous	Woods - Good	30	55	70	77
42	Forest - Evergreen	Woods - Good	30	55	70	77
43	Forest - Mixed	Woods - Good	30	55	70	77
53	Shrub/Scrub	Brush - Good	30	48	65	73
71	Grassland/Herbaceous	Meadow	30	58	71	78
81	Pasture/Hay	Pasture - Good	39	61	74	80
82	Cultivated Crops	Row Crops - Contoured - Good	64	75	82	85
92	Wetlands - Woody	Wood - Fair	36	60	73	79
95	Wetlands - Herbaceous	Meadow	30	58	71	78

2.3 Time of Concentration

Time of concentration is defined as the time it takes a drop of water to travel from the most hydrologically distant point in the subwatershed to the subwatershed outlet. This value generally defines the rate that runoff moves through a subwatershed. Time of concentration is a function of flow sheeting across surfaces as it initially hits the ground (i.e., sheet flow), overland runoff as flow builds depth and makes its way towards defined channels (i.e., shallow concentrated flow), and flow in a defined channel such as a ditch, stream, or river. Sheet flow and shallow concentrated flow values were determined based on topography and landcover. Channel dimensions and characteristics for 22 previously assessed reaches were taken from geomorphic data, and field observations were conducted at 49 channel locations to determine bankfull width, depth, bank side slopes, and hydraulic roughness. Calculations of the time of concentration for each subwatershed are presented in Appendix B.

The HEC-HMS model requires input as lag time rather than time of concentration. Although there are varying definitions of lag time, it is typically taken as the length of time from the start of runoff to the peak of the runoff at a given observation point in the watershed. The standard relationship between lag time and time of concentration (Lag time = 0.6 x Time of concentration) was used for this hydrology model.

2.4 Surface Water Storage and Reservoir Routing

Surface water bodies provide watershed storage decreasing flow volumes and rates and slowing the time it takes for flood waters to travel downstream. Lakes and ponds were initially reviewed on maps and in past studies to identify the water bodies that may provide enough storage to attenuate flood flows and should thus be included in the model. The initial guideline for inclusion was 1 acre of ponded area in or upstream of the

Village Growth Area and 2 acres of ponded area downstream of the Village. Field investigations were then conducted to confirm initial findings and collect the necessary data for inclusion in the hydrology model (i.e., stage-storage relationship of the water body as derived from LIDAR and stage-discharge relationships as determined from field measurements). Five water storage areas were ultimately included in the model (Table 2). Additional potential storage areas were visited in the field and determined to have limited hydrologic influence in their current condition due to either a small contributing drainage area or a small amount of existing available storage.

Table 2: Summary of Storage Areas.

Storage Area	Subwatershed	Approximate Location	Base Ponded Area (acres)	Base Elevation (feet)
Lake Iriquois	T4.07	Upstream of Pond Brook Road on Patrick Brook	251.0	688
Beaver Pond	T3.03	Large Beaver Pond off of Baldwin Road	95.8	378
Sunset Lake	T4.05.H1	Between Pond Brook Road and Richmond Road on Patrick Brook	65.7	664
CVU Pond	M15S2.01.H6	Fire Detention Pond at CVU	1.4	406
Cemetery Pond	T4.04	Upstream of the Hinesburg Cemetery off of Mechanicsville Road on Patrick Brook	1.0	470

2.5 Channel Routing

Once water reaches a stream channel or pipe and begins travelling downstream its movement is determined based on uniform open-channel or pipe flow. As runoff is generated in a given subwatershed, previously accumulated flow from upstream subwatersheds works its way through the channel and two flood waves join at the subwatershed outlet. The peak, volume and timing at the subwatershed outlet is a function of the addition (i.e., superposition) of the two flood waves. The amount of time it takes for water to travel to the subwatershed outlet in the open channel or pipe is a function of the size, shape, slope, and roughness of the open channel or pipe. Channel routing was applied to 25 reaches in the hydrology model using the Muskingum-Cunge method. Channel dimensions and characteristics were observed while collecting data for time of concentration calculations.

2.6 Diversion Structures

A diversion structure made of large concrete blocks exists at the downstream end the junction of Patrick Canal and a tributary entering the canal from the east behind the NESTEC building (T4.02, Photo 1, Figure 6). During a field visit October 18, 2010 while flow was at normal levels more than half of the water in Patrick Canal was spilling into the channel that leads to the original Patrick Brook channel north of the buildings on Commerce Street. Water is ponded (i.e., backwatered) in the Patrick Canal to this location from the sluice gate structure at Route 116 that acts like a dam. A large amount of the water flows into the original Patrick Brook channel due to the configuration of the diversion structure and backwatering under the observed flow condition. The amount of water will vary with flow and if the deteriorated structure changes. The diversion structure was included in the model to allow water to split at the downstream end of Patrick Canal (T4.02 into T4.01) and leading to Historic Patrick Brook (M15S2.01.H3). The diversion flow is estimated based on hydraulics of the diversion structure and channel capacity at the location.

Photo 1: Diversion structure along Patrick Canal at T4.02, looking upstream along Canal.

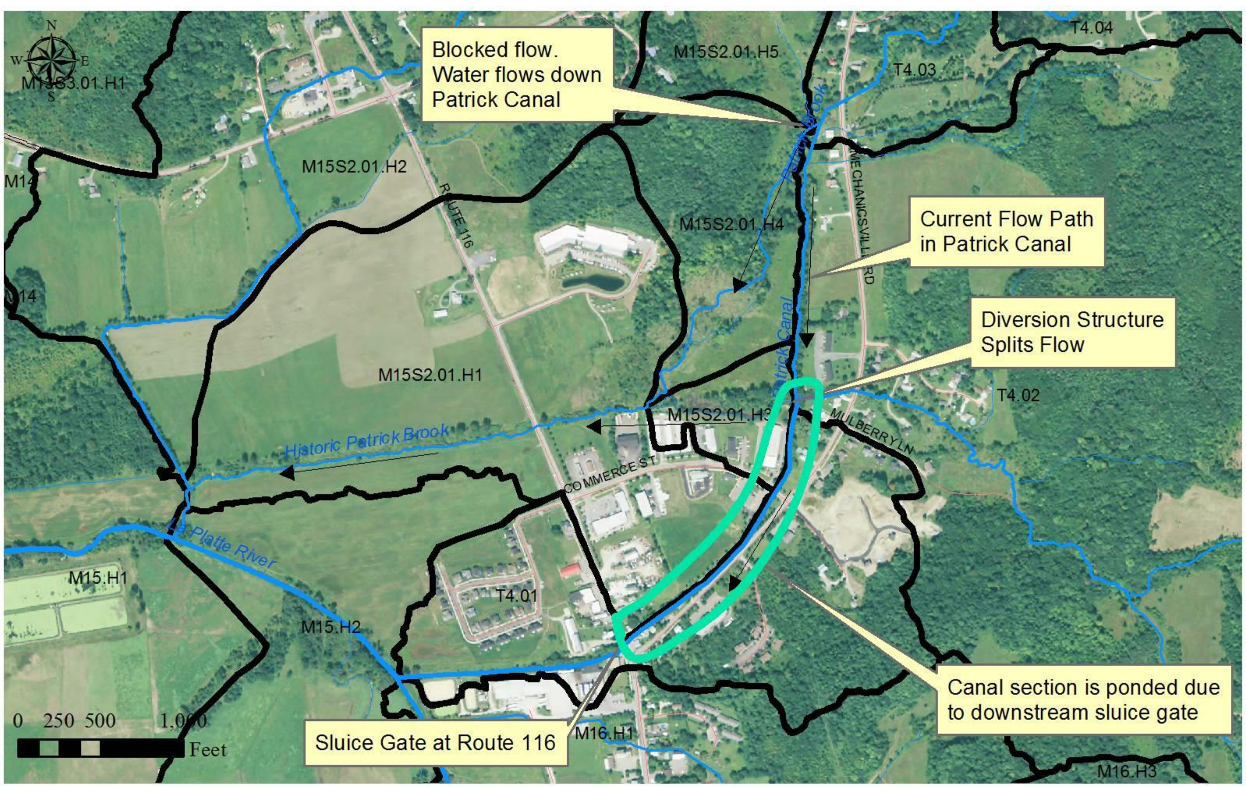


Figure 6: Patrick Brook and Patrick Canal flow paths near Village Growth Area.

2.7 Precipitation

A hydrology model is driven by a real or synthetic rainfall distribution. Due to a lack of suitable local data over the long term, the standard procedure of using rainfall depth and intensity to generate a synthetic rainfall was used. Technical Paper 40 (Hershfield 1961) is the default source of rainfall information and is recommended for design in the Vermont Stormwater Manual (VTDEC 2002) (Table 3). A Type II rainfall with intense short duration storms was selected based on standard practice (SCS 1986).

Storm events modeled were chosen based events used to set regulatory treatment levels for permits (VTDEC 2002). The Water Quality Storm is often used for design of stormwater treatment and represents the “first flush” of runoff after a rain event and is considered to capture 90 percent of the annual storm events. Larger flood events are sometimes required in stormwater treatment design depending on the site conditions to meet regulations for Channel Protection, Overbank Flood Protection, and Extreme Flood Protection.

***Table 3: Rainfall depths for modeled recurrence intervals*.**

Storm	24-hour rainfall depth (inches)	Vermont Stormwater Treatment Standard Criteria
Water Quality	0.9	Water Quality
1-year	2.1	Channel Protection
2-year	2.3	not used in regulation
10-year	3.2	Overbank Flood Protection
100-year	5.2	Extreme Flood Protection

2.8 Validation

A validation of the model results was completed by comparing modeled and measured flow rates on the LaPlatte River during two recent storms. Stream gauge data were recorded on the LaPlatte River downstream of the project (USGS 04282795 LaPlatte River @ Shelburne Falls, DA=44.6 square miles) and obtained from the USGS website. Flow data were scaled by drainage area to transfer to the model outlet location near the Hinesburg/Charlotte town boundary (DA=26.8 square miles). Rainfall data were measured in Burlington, Vermont (KBTV, Burlington, Vermont and obtained from the Wunderground website.).

A storm event on December 12-13, 2010 yielded a 1-2-year recurrence interval flood at the USGS gauge. This event came after a smaller storm earlier in the week and continued light rain and snow and occurred with partially frozen ground. The model peak flow value of 450 cubic feet per second agrees with the measured value of 493 cubic feet per second (Figure 7). The volume of runoff, defined by the area under the hydrograph curve, is not well–represented in the model. The departure in the curve shape is likely a function of the actual storm distribution deviating from the synthetic rainfall distribution.

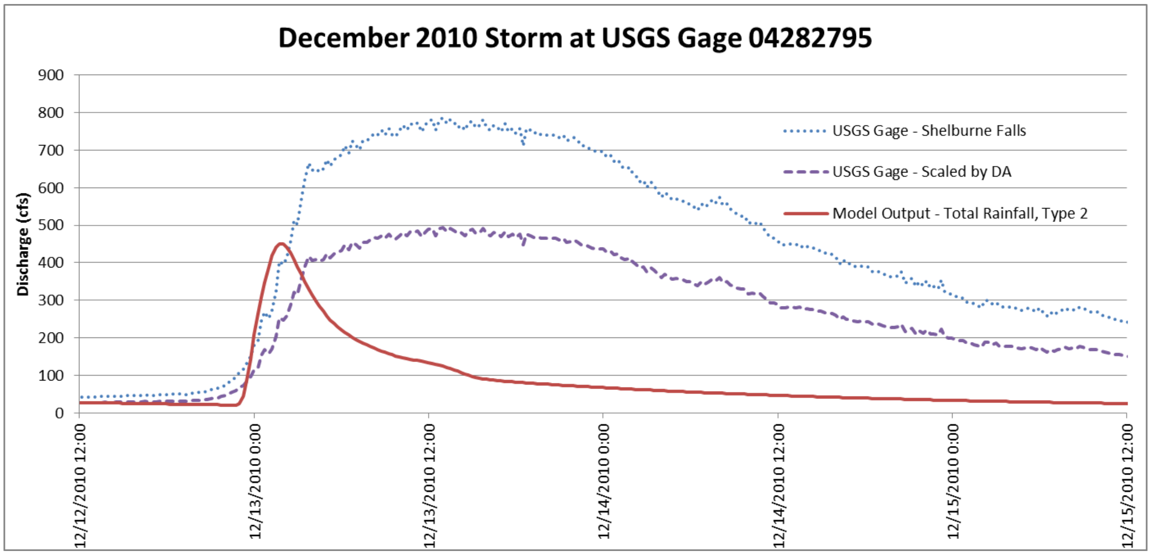


Figure 7: December 2010 USGS gage flow data and model output.

Tropical Storm Irene occurred on August 28, 2011 resulting in a measured flood having a 5 to10-year recurrence interval at the USGS gauge. The model peak flow of 3,202 cubic feet per second is nearly four times larger than the scaled observation of 892 cubic feet per second (Figure 8). The large difference is likely due to the fact that the storm occurred during a dry period and thus more infiltration may have taken place than predicted by the model that assumes a normal ground saturation condition. A storm of this type may have higher than normal infiltration and could lead to some level of overestimation. A larger peak flow rate in the model is also likely due to the fact that the model does not explicitly consider floodplain storage and structural hydraulic controls such as bridges and culverts that can reduce flood peaks and alter timing.

These modeled storms show that the model may not exactly model real storm events due to the variability in the intensity and conditions associated with individual storm events. The model was able to closely represent the peak flow for the smaller storm measured, although the shape of the hydrograph and therefore predicted volume did not match. For the larger storm event, the modeled peak value was much higher than measured, although the shape of the hydrograph and therefore volume estimation matched well. In the case of the larger storm, the model is conservative. This shows that the results are within an acceptable range of measured storm data, although the resulting hydrographs may not represent all conditions of a specific event. The model is suitable for comparisons between existing and proposed conditions.

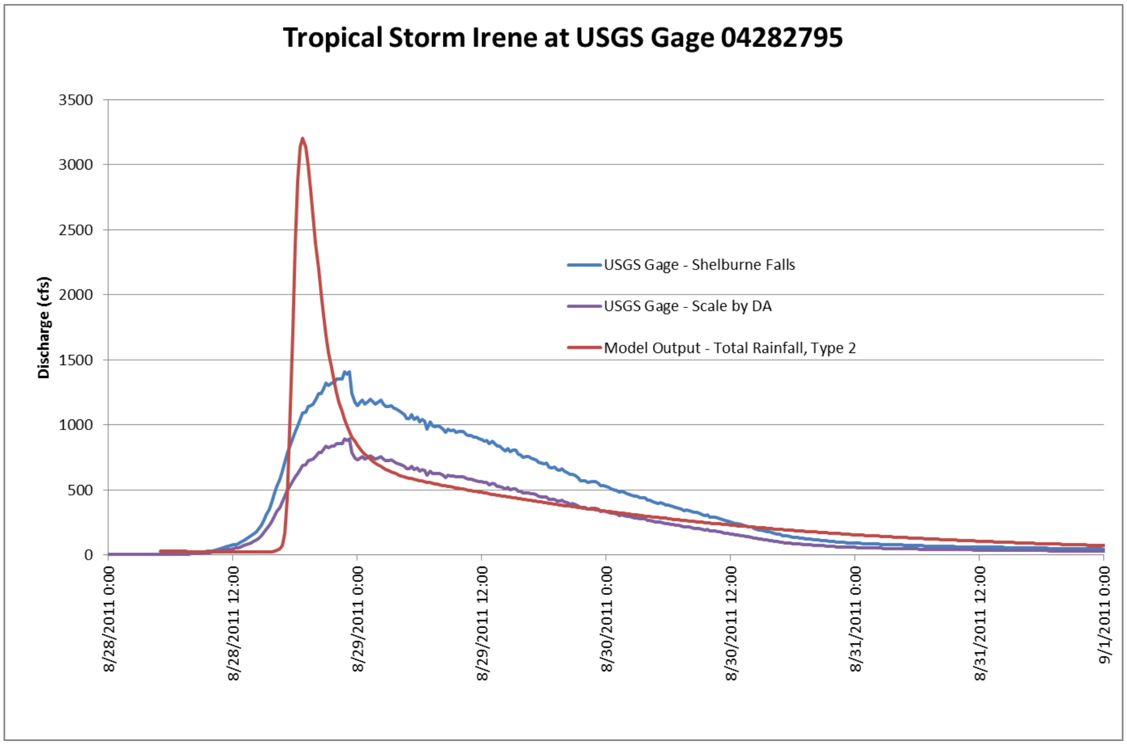


Figure 8: August 2011 USGS gage flow data and model output.

2.9 Existing Conditions Results

Runoff volume and peak flows have been predicted for the Water Quality Storm (P=0.9 in)(VTDEC 2002), 1-year, 2-year, 10-year, and 100-year recurrence interval storm events. Peak runoff volume and flow rates for each of the modeled storm events are presented in Appendix C. The 2-year storm has been selected for reporting results because it is the channel-forming flood that is important for water quality, flooding, erosion risks, and habitat maintenance. Runoff peak flow is normalized by watershed area to identify subwatersheds contributing large amounts of runoff per unit area. Runoff volume is also normalized by area to represent runoff depth or precipitation excess (inches).

The existing conditions model results show higher runoff (Figure 9) and peak flows (Figure 10) in more developed areas such as the Village Growth Area than in more rural areas during all storm events. Runoff depth ranges between 0.3 and 3.6 inches (Table 4). The maximum runoff volume per watershed area of 3.6 inches was predicted near the intersection of Silver Street and Route 116 where existing homes, businesses, and the elementary school create a large amount of impervious surface. This subwatershed is small and therefore contributes only 1.9 acre-feet to the total runoff volume. Conversely, the subwatershed with the minimum runoff depth of 0.3 inches is a large watershed near the confluence of the LaPlatte River and Beecher Hill Brook at North Road. Due to the larger size of the subwatershed it contributes a runoff volume of 15.2 acre-feet to the river system.

Peak discharge values from individual watersheds ranged between 26 and 770 cubic feet per second per square mile (cfsm) (Figure 10). The smaller, Village Growth Area subwatersheds produced the highest peak flow values. These subwatersheds have a higher percentage of developed land with impervious and compacted surfaces that lead to increased runoff rates and depths. The Village Growth Area subwatersheds do not contain large undeveloped areas to dampen runoff peaks by storage or infiltration. Runoff travels to the subwatershed outlet quickly in the Village Growth Area due to the small watershed size and limited hydraulic roughness over the flow paths. Water flows over roads, buildings, sidewalks, gutters, lawns and makes its way to pipes, swales and ditches.

The amount of runoff tracks watershed landuse trends that can generally be described as developed in the Village Growth Area, forested to the east, and agricultural to the west. High runoff depths and volumes were estimated in the northern portions of the Village Growth Area near the corner of CVU Road and Route 116, and near CVU school property. Precipitation in these areas has limited opportunity to infiltrate or enter storage areas and thus rapidly becomes runoff. The lowest amount of runoff occurs in the east and south sections of the Town where forest cover dominates the landscape and where some soils have high infiltration capacity. Moderate runoff depths were predicted in the western and northern sections of Town where agriculture, rural development, and some clustered development exist on clay soils with poor drainage.

Some subwatersheds such as the Lake Iroquois drainage have a large runoff depth and volume. Lake Iroquois generates a lot of runoff because all of the rain hitting the large lake surface immediately turns to runoff and enters the stream channel with no infiltration. However, the peak flow is lower than in other subwatersheds due to the storage and a longer travel time through forest land that attenuates and delays the peak flow.

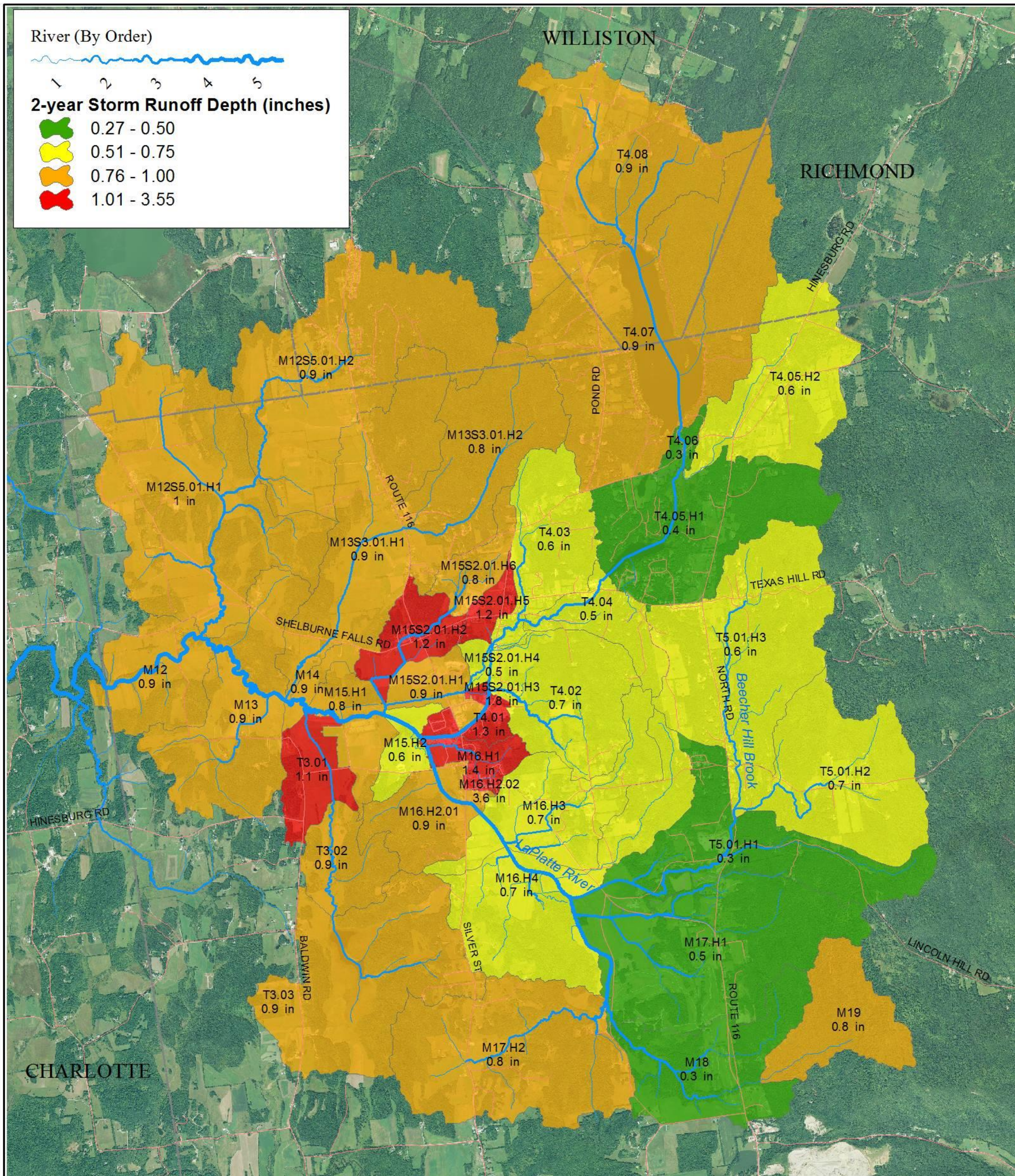
The six subwatersheds contributing the highest peak runoff and the highest runoff depth are located in and immediately upstream of the Village Growth Area (Figure 11). These subwatersheds are generally located along Route 116 between Commerce Street and Silver Street, extending along Mechanicsville Road (M16.H2.02, M16.H1, T4.01, M15S2.01.H3), and along CVU road to the north (M15S2.01.H2 and M15S2.01.H5). Comparison of runoff hydrographs shows that the subwatersheds with higher peak values also have a shorter duration runoff period, contributing flood waters to the receiving water body quickly.

Other subwatersheds within the Village Growth Area have more naturally shaped runoff hydrographs with smaller and wider peaks indicative of lower runoff flows and depths.. Low runoff areas that have less development and more natural land cover are located along the northern portion of Mechanicsville Road (T4.02, M15S2.01.H4) and along Route 116 south of the intersection with CVU Road (M15.S2.01.H1). Due to their location in the Village Growth Area, these subwatersheds may see additional development in the future and stormwater controls could be put in place to maintain the existing natural hydrographs.

A watershed map poster has been created displaying runoff hydrographs and runoff depth for each subwatershed to facilitate comparisons at the scale of the Town (Appendix D). The map illustrates the influence of land use on stormwater runoff. Rural watersheds outside of the Village Growth Area generally have hydrographs that show a longer runoff duration and smaller peak flow. Many of subwatersheds in the Village Growth Area have a shorter, faster, runoff time and a larger peak flow compared to subwatersheds outside the Village Growth Area. The hydrographs also show a trend of higher peak discharge values occurring earlier during a storm in the agricultural lands with clay soils in the western section of town compared to the forested subwatersheds in the eastern part of town.

Table 4: Summary of Subwatershed Parameters and Model Results for the 2-year Storm Event.

Element	CN	TC (hour)	Drainage Area (square mile)	Peak Discharge (cfs)	Peak Discharge (cfsm)	Volume (acre-ft)	Runoff Depth (inches)
M12	77	1.4	0.5	68.6	140.0	24.3	0.9
M12S5.01.H1	78	1.8	1.8	230.1	128.5	90.7	1.0
M12S5.01.H2	78	3.1	1.6	143.8	87.7	77.0	0.9
M13	77	1.3	0.9	138.1	146.9	47.1	0.9
M13S3.01.H1	78	2.2	1.1	127	111.4	56.5	0.9
M13S3.01.H2	76	1.6	0.9	106.4	115.7	41.2	0.8
M14	77	1.4	0.1	12.4	137.8	4.4	0.9
M15.H1	75	2.0	0.3	26.3	90.7	11.9	0.8
M15.H2	71	1.3	0.2	12.3	76.9	5.1	0.6
M15S2.01.H1	77	1.6	0.2	25.9	129.5	9.7	0.9
M15S2.01.H2	79	0.7	0.3	63.8	236.3	17.6	1.2
M15S2.01.H3	79	0.2	0.0	4.6	460.0	1.0	1.8
M15S2.01.H4	69	0.7	0.0	4.1	83.7	1.4	0.5
M15S2.01.H5	79	0.7	0.1	24.3	245.5	6.5	1.2
M15S2.01.H6	74	0.7	0.2	29.9	149.5	8.9	0.8
M16.H1	82	0.9	0.2	40.8	272.0	11.5	1.4
M16.H2.01	78	2.0	0.4	46.1	118.2	19.3	0.9
M16.H2.02	94	0.4	0.0	7.7	770.0	1.9	3.6
M16.H3	74	2.4	0.7	52.5	72.9	26.5	0.7
M16.H4	75	2.4	1.0	81.3	80.5	39.9	0.7
M17.H1	69	1.6	1.4	74.6	54.5	35.1	0.5
M17.H2	77	2.8	1.3	113.7	88.1	57.8	0.8
M18	65	1.3	0.8	25.1	33.0	13.4	0.3
M19	75	1.3	0.5	61.3	120.2	22.0	0.8
T3.01	78	0.8	0.3	60.2	207.6	17.2	1.1
T3.02	77	1.4	0.3	46.7	141.5	16.4	0.9
T3.03	77	2.3	1.3	125.1	99.3	57.8	0.9
T4.01	80	0.9	0.1	26.7	242.7	7.5	1.3
T4.02	73	1.0	0.7	80.6	111.9	27.6	0.7
T4.03	71	1.6	0.6	38.8	68.1	17.6	0.6
T4.04	74	2.7	0.3	15	50.0	8.5	0.5
T4.05.H1	66	1.0	1.1	47.2	45.0	21.3	0.4
T4.05.H2	71	1.7	0.8	55.1	65.6	25.5	0.6
T4.06	63	1.0	0.1	1.8	25.7	1.0	0.3
T4.07	78	1.9	2.2	273.6	122.1	112.3	0.9
T4.08	76	1.3	1.3	169.1	135.3	58.7	0.9
T5.01.H1	64	0.8	0.9	31.9	34.7	15.2	0.3
T5.01.H2	73	1.0	1.0	112.2	110.0	39.2	0.7
T5.01.H3	70	1.3	1.3	90	69.2	38.1	0.6



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Existing Conditions Runoff Depth
2-year Storm Estimate

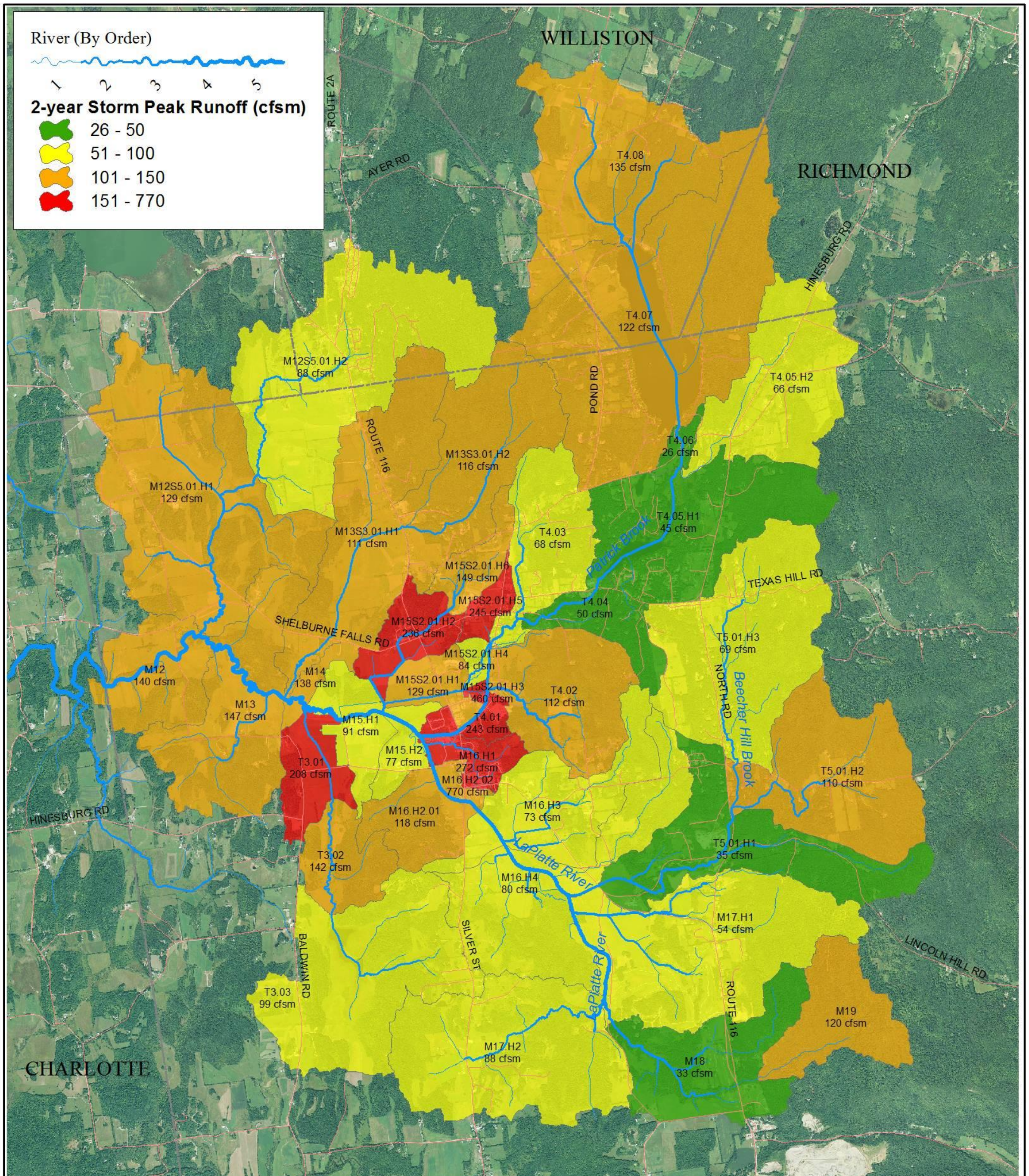
N W E S — 0 0.25 0.5 1 Miles

Growth Center Existing Conditions
Hydrology Study

DATE: December 2011

SCALE: see scale bar

SHEET: **Figure 9**



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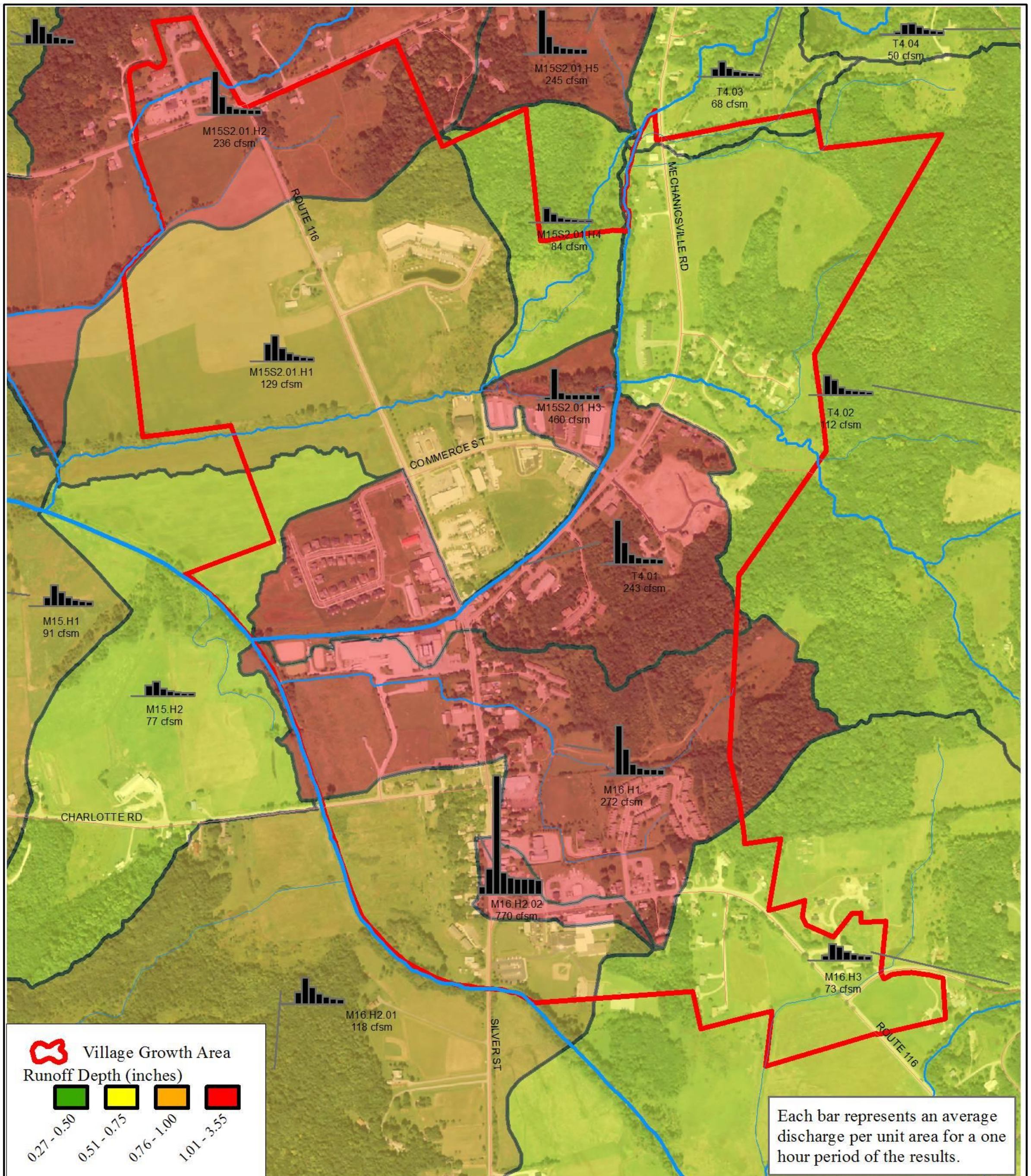

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Existing Conditions Village Center
Subwatershed Discharge
2-year, 24-hour Storm Estimate

N W E S — 0 250 500 1,000 Feet

Growth Center Existing Conditions
Hydrology Study

DATE: December 2011	SHEET:
SCALE: see scale bar	Figure 11

Modeled peak flows show the expected increase moving downstream as drainage area increased (Table 5). Peak discharge values for all modeled storms more than double between upstream of the Village Growth Area and the Hinesburg-Charlotte Town boundary at the model outlet.

The confluence of Patrick Brook and the LaPlatte River occurs within the Village Growth Area where the drainage area of the river doubles. However, peak flow only increases a small amount in this location (Table 5) due to the large amount of flood storage along upper Patrick Brook. These storage areas are important for reducing flood risks in the Village Growth Area.

Table 5a: Summary of Model Results along the LaPlatte River Mainstem.

Location	Model Node	Drainage Area (sq. miles)	Peak Discharge (cfs)				
			Water Quality	1-year	2-year	10-year	100-year
LaPlatte River Upstream of Village Growth Area	J-M16.H3	8.9	9.2	406.5	551.2	1389.2	3932.3
LaPlatte River at Confluence with Patrick Brook	J-M16.H1	16.69	15.3	487.5	650.4	1621.2	4527.4
LaPlatte River Downstream of Village Growth Area	J-M15.H2	17.58	19.1	554.6	739.6	1835.7	5189.5
LaPlatte River at Town Boundary	J-12	26.77	38	913.6	1194.9	2824.9	7796.9

Table 5b: Summary of Model Results along the LaPlatte River Mainstem, normalized by drainage area.

Location	Model Node	Drainage Area (sq. miles)	Unit Peak Discharge (cfsm)				
			Water Quality	1-year	2-year	10-year	100-year
LaPlatte River Upstream of Village Growth Area	J-M16.H3	8.9	1.0	45.7	61.9	156.1	441.8
LaPlatte River at Confluence with Patrick Brook	J-M16.H1	16.69	0.9	29.2	39.0	97.1	271.3
LaPlatte River Downstream of Village Growth Area	J-M15.H2	17.58	1.1	31.5	42.1	104.4	295.2
LaPlatte River at Town Boundary	J-12	26.77	1.4	34.1	44.6	105.5	291.3

3.0 FULL BUILDOUT SCENARIO

Working from the existing conditions hydrology model, many different scenarios can be modeled to investigate how changes on the landscape influence stormwater runoff. The current analysis includes one example modeling exercise to explore changes in runoff associated with a full buildout scenario in Hinesburg.

3.1 Methods

The existing conditions hydrology model was used as a base and modified to reflect a theoretical full buildout condition. The current zoning regulations were consulted to determine the maximum allowable development in the project area. The following assumptions were used to adjust the existing land use within the Town of Hinesburg to represent the full buildout scenario. Landuse in the areas determined to be eligible for development were reassigned in GIS based on development patterns allowed under the appropriate zoning category (Table 6).

1) Land already developed will continue to be developed at the current level. The High Intensity, Medium Intensity, Low Intensity, and Open Space Developed landuse categories were maintained.

2) Open water is not developable and will continue to be Open Water.

3) Wetlands are not suitable building locations and will continue to be wetlands, including both Herbaceous and Woody Wetland land use categories.

4) The following land use categories could be developed: Barren, Cultivated Crops, Pasture/Hay, Forest- including Deciduous, Mixed, and Evergreen, Grassland/Herbaceous, Shrub/Scrub.

5) Areas identified by the Town of Hinesburg as likely “undevelopable” retained the original landuse category. These areas include:

- Fluvial Erosion Hazard Zone (defined by VT Agency of Natural Resources);
- FEMA Special Flood Hazard Area (100-year floodplain, defined by FEMA);
- Prime Agricultural soils within the Agriculture Zoning Area - Important agricultural soils (prime and statewide, no conditional classes) only within Hinesburg's Agricultural zoning district (west side of town). Note, this does not represent all of Hinesburg's agricultural soils (conditional statewide classes were excluded and geographic extent limited to just AG district), but it represents the best of the best in the area of town most likely to see continued agricultural operations;
- Public or Private Conserved Lands (Town, State or Privately Conserved);

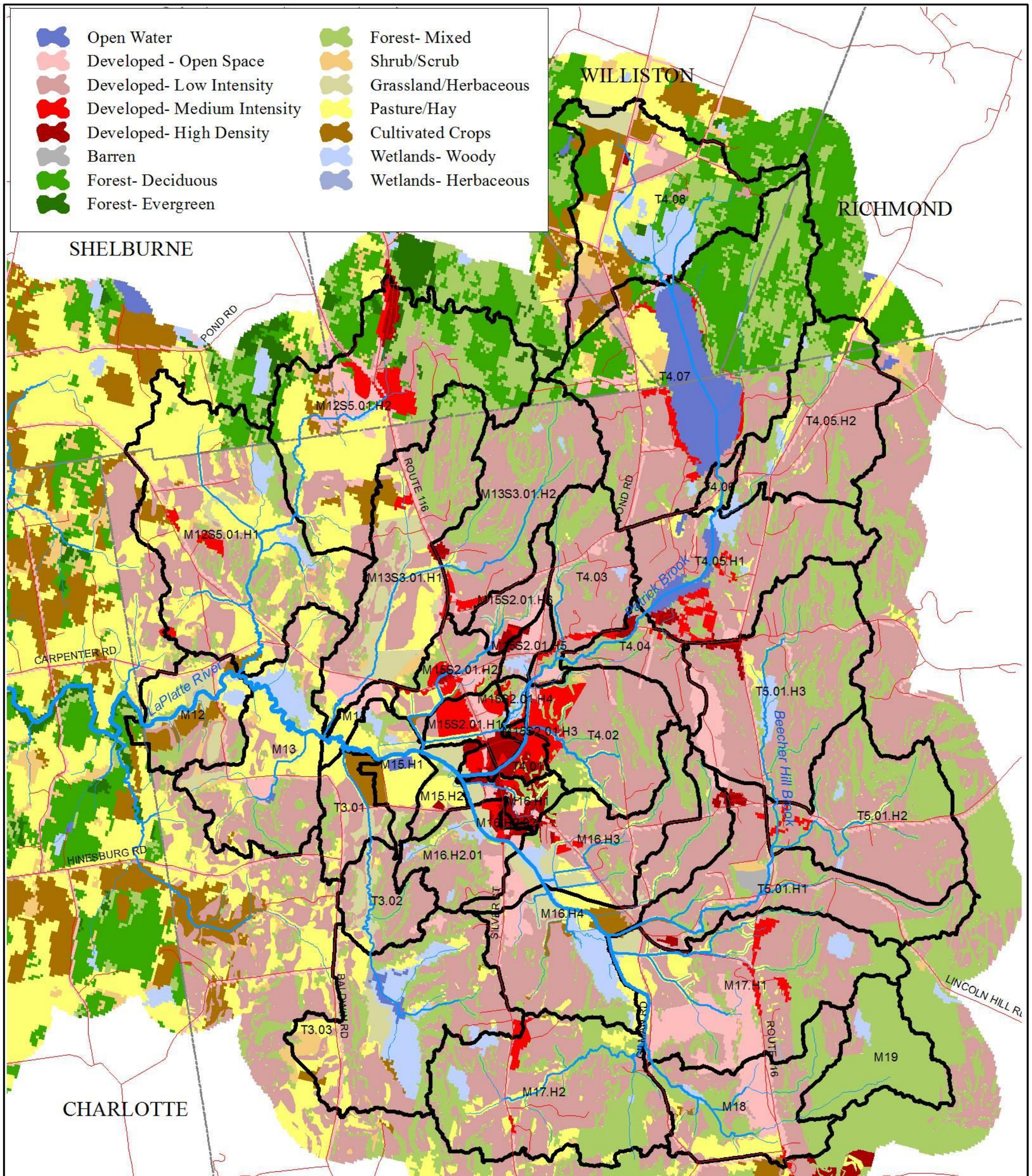
- Steep slopes of 25% or greater (identified from high resolution digital elevation data from 2004 LIDAR acquisition, processed by Chittenden County Regional Planning Commission GIS staff);
- Stream and Lake 75 foot Buffer - 75' setback on each side of water bodies (streams, lakes, ponds) per the Hinesburg Zoning Regulations (water bodies identified from VHD-Carto dataset from VCGI - buffered by Town staff in ArcView) - NOTE, does not include Village Growth Area - see dataset below for stream buffers in the Village Growth Area;
- Village Stream Buffers - Special/variable stream buffer area only within the Village Growth Area (see Hinesburg Zoning Regulations for details);
- Wetland Buffers - VT Significant Wetland Inventory (available from VCGI) clipped to Hinesburg and buffered by 50 feet to include buffer area protected by VT Wetland Rules. NOTE, this dataset partially overlaps with the UMASS wetland dataset mentioned below; and
- Other Wetland Buffers- wetland areas identified via a special project in Hinesburg in 1990s done by the University of Massachusetts;

Table 6: Hinesburg Zoning Districts and Buildout Landuse Category.

District	Minimum Lot Size	Maximum Lot Coverage	Landuse Category Assigned
AG	2 acres	20%	Developed - Low Intensity
RR 1	3 acres, 1 if town sewer	20%	Developed - Low Intensity
RR 1	3 acres, 1 if town sewer	20%	Developed - Low Intensity
VG	6,000 sf	75%	Developed - High Intensity
VG-NW	6,000 sf	60%	Developed - Medium Intensity
VG-NE	6,000 sf	60%	Developed - Medium Intensity
R-1	6,000 sf	60%	Developed - Medium Intensity
R-2	6,000 sf	60%	Developed - Medium Intensity
C	none	60%	Developed - High Intensity
I-1	40,000 sf	75%	Developed - High Intensity
I-2	40,000 sf	60%	Developed - High Intensity
I-3	40,000 sf	80%	Developed - High Intensity
I-4	40,000 sf	80%	Developed - High Intensity
S	3 acres, 1 if >=100 ft lake frontage	10%	Developed - Low Intensity

The theoretical full buildout land use distribution shows significantly more high density development in the Village Growth Area and lower density development spread around the watershed (Figure 12) compared to existing conditions (Figure 5). Small pockets of agriculture in the west and forest in the east were maintained. These new land use GIS map was used to re-calculate subwatershed Runoff Curve Number values that dictate the amount of runoff in each subwatershed. Curve Number values increased between 0 and 4 (Appendix E). For example, one subwatershed in the Village Growth Area is already at full buildout and the existing conditions Curve Number value of 94 did not change (M16.H2.02). Another Village Growth Area subwatershed near the corner of Mechanicsville Road and Route 116 had increased development and the Curve Number increased from 80 to 84 (T4.01). Some rural subwatersheds also showed increases in Curve Number. An upper Patrick Brook subwatershed Curve Number increased from 66 to 70 under the buildout scenario (T4.05.H1).

The full buildout scenario landuse was also used to determine changes in time of concentration calculations. As development occurs, flow paths are often smoothed and shortened (i.e. water flows quicker over smooth lawn or pavement than a forest floor or meadow). Flow paths can also be shortened by short-circuiting (i.e. a driveway or road cuts across a forest, collecting flow in a ditch earlier in the flowpath). For a sub-set of subwatersheds, time of concentration calculations were re-calculated to reflect land use changes and assumed changes to the runoff flow path. For example, a rural watershed buildout analysis time of concentration was 97% of the existing time (a small increase in travel time) because of a small change in roughness associated with land use change (M17.H1). A subwatershed in the Village Growth Area showed the largest change in time of concentration because runoff in wooded areas is slower than the runoff over the assumed lawn surface after development (T4.02). The re-calculated time of concentration values averaged 70% of the existing conditions time of concentration, and thus this change was applied across the entire watershed where land use changed. Some subwatersheds did not have a change in time of concentration because their land uses were unchanged(Appendix F).



Buildout Scenario Landcover

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N W E S — 0 0.25 0.5 1 Miles

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SCALE: see scale bar

SHEET: **Figure 12**

3.2 Results

The results of the full buildout scenario model predict increases in runoff throughout the watershed. Runoff depth increased between 1 and 0.7 inches, the largest increase occurring in a Village Growth Area subwatershed that is currently not highly developed (T4.01, Table 7, Figure 13). The maximum runoff depth of 3.55 inches was unchanged from existing conditions because that subwatershed is already fully developed (M16.H2.02). Subwatersheds located outside Hinesburg in the headwaters (T4.08) and one subwatershed with many conservation easements (M19) also did not show changes during this example. Existing conditions only shows 7 subwatersheds with a runoff depth greater than one inch, while the buildout scenario shows 21 subwatersheds. The subwatersheds with the largest runoff depths are located in the Village Growth Area and the agricultural areas to the west.

Peak discharge increased an average of 53 cfsm, ranging between 60 and 770 cfsm. The subwatershed with the maximum increase in discharge of 193 cfsm is located in the Village Growth Area also had the largest runoff depth (T4.01). Increased peak discharge values were on average 50% higher than existing conditions, with Village Growth Area subwatersheds increasing on average the same as non- Growth Area subwatersheds. Of the subwatersheds with the 10 largest increases in discharge per watershed area, half were in the Village Growth Area and the other five were in the agricultural areas with clay soils to the west (T3.02, T3.01) and located to the north of the Village Growth Area (M13S3.01.H2, M15S3.01.H5, M15S2.01.H6).

The timing of the peak discharge is also affected by the development represented in this example. The peak discharge reached subwatershed outlets between 0 and 45 minutes sooner than in existing conditions. Peak timing of subwatershed runoff combines so that the buildout scenario peak discharge occurs 30 minutes earlier than existing conditions in the mainstem LaPlatte River.

In many subwatersheds the hydrograph shape was changed to show a much higher peak discharge value, without proportional increases in flow at the beginning and end of the storm. The most pronounced differences in peak discharge are located in Village Growth Center subwatersheds that do not have a high percentage of existing development (T4.01 and T4.02). The small subwatershed near the intersection of Silver Street and Route 116 does not show changes in the hydrograph because it is fully developed under existing conditions.

Increased runoff in individual subwatersheds compounded to show large increases in instream flows for all modeled storm events (Tables 8 & 9). The largest increases are seen for the smaller storm events. The Water Quality Storm peak discharge increased 35% at the model outlet, at the Town Boundary, from 38 cfs to 52 cfs. The 100-year peak discharge increased 17% at the Town Boundary, from 7797 cfs to 9151 cfs. Increased peak flows of this magnitude will require more floodplain storage and increase chances of flooding and damage to infrastructure.

Table 7: Comparison of Existing Conditions and Buildout Scenario Hydrology Model Results for 2-year Storm.

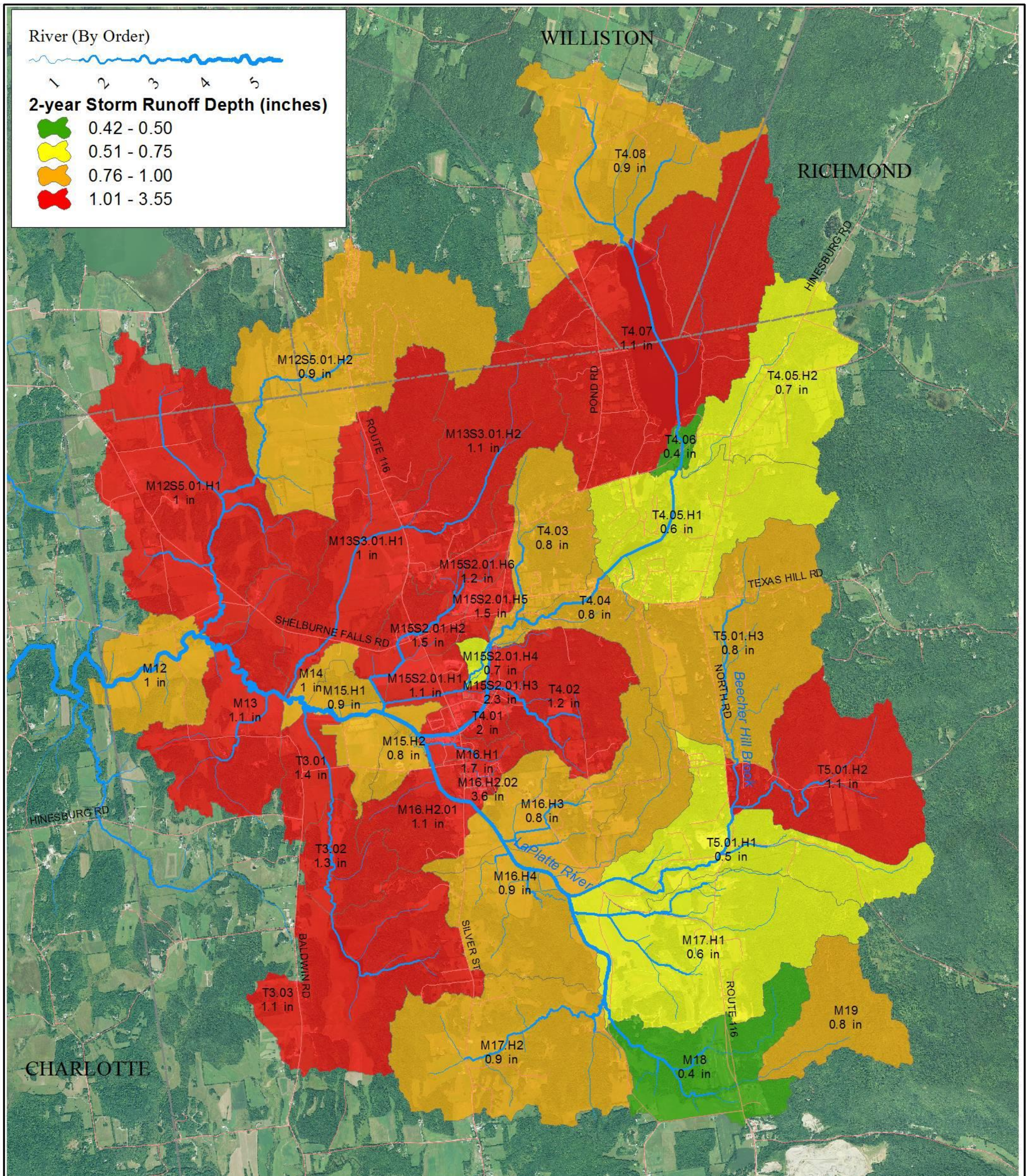
Element	Existing Peak Discharge (cfs)	Buildout Peak Discharge (cfs)	Increase in Discharge (%)	Existing Runoff Depth (inches)	Buildout Runoff Depth (inches)	Increase in Runoff Depth (inches)	Reduction in Peak Time (min)
M12	68.6	75.1	9%	0.93	1	8%	0
M12S5.01.H1	230.1	250.8	9%	0.95	1.01	6%	0
M12S5.01.H2	143.8	143.8	0%	0.88	0.88	0%	0
M13	138.1	188.2	36%	0.94	1.09	16%	-15
M13S3.01.H1	127	176.1	39%	0.93	1.04	12%	-30
M13S3.01.H2	106.4	169.9	60%	0.84	1.11	32%	-15
M14	12.4	15.6	26%	0.92	1	9%	-15
M15.H1	26.3	36.1	37%	0.77	0.86	12%	-30
M15.H2	12.3	21.1	72%	0.6	0.76	27%	-10
M15S2.01.H1	25.9	31.3	21%	0.91	1.05	15%	0
M15S2.01.H2	63.8	87.4	37%	1.22	1.48	21%	0
M15S2.01.H3	4.6	5.8	26%	1.82	2.27	25%	0
M15S2.01.H4	4.1	6.6	61%	0.54	0.7	30%	-15
M15S2.01.H5	24.3	32.3	33%	1.24	1.49	20%	0
M15S2.01.H6	29.9	51	71%	0.83	1.19	43%	0
M16.H1	40.8	47	15%	1.44	1.65	15%	0
M16.H2.01	46.1	68.4	48%	0.93	1.13	22%	-30
M16.H2.02	7.7	7.7	0%	3.55	3.55	0%	0
M16.H3	52.5	81	54%	0.69	0.83	20%	-30
M16.H4	81.3	124.7	53%	0.74	0.89	20%	-30
M17.H1	74.6	98	31%	0.48	0.58	21%	0
M17.H2	113.7	138.3	22%	0.84	0.92	10%	-15
M18	25.1	45.4	81%	0.33	0.44	33%	-30
M19	61.3	61.3	0%	0.81	0.81	0%	0
T3.01	60.2	88.7	47%	1.11	1.43	29%	-15
T3.02	46.7	76	63%	0.93	1.25	34%	-15
T3.03	125.1	200.5	60%	0.86	1.05	22%	-45
T4.01	26.7	47.9	79%	1.28	1.96	53%	-15
T4.02	80.6	184.9	129%	0.72	1.19	65%	-15
T4.03	38.8	66.9	72%	0.58	0.77	33%	-15
T4.04	15	28.5	90%	0.53	0.78	47%	-45
T4.05.H1	47.2	100.1	112%	0.38	0.59	55%	-15
T4.05.H2	55.1	75.8	38%	0.57	0.73	28%	-15
T4.06	1.8	4.3	139%	0.27	0.42	56%	-30
T4.07	273.6	321.9	18%	0.94	1.07	14%	0
T4.08	169.1	169.1	0%	0.88	0.88	0%	0
T5.01.H1	31.9	77.2	142%	0.31	0.51	65%	-15
T5.01.H2	112.2	203.9	82%	0.72	1.05	46%	-15
T5.01.H3	90	177.9	98%	0.55	0.81	47%	-15

Table 8: Comparison of Existing and Buildout discharge (cfs) values at select locations.

Location	Water Quality			1-year			2-year			10-year			100-year		
	Existing (cfs)	Buildout (cfs)	Increase (%)	Existing (cfs)	Buildout (cfs)	Increase (%)	Existing (cfs)	Buildout (cfs)	Increase (%)	Existing (cfs)	Buildout (cfs)	Increase (%)	Existing (cfs)	Buildout (cfs)	Increase (%)
LaPlatte River Upstream of the Village Growth Area	9.2	13.6	**48%**	406.5	588.8	**45%**	551.2	779.6	**41%**	1389	1851.8	**33%**	3932	4954.2	**26%**
LaPlatte River at Confluence with Patrick Canal	15.3	21.6	**41%**	487.5	700.4	**44%**	650.4	918.7	**41%**	1621	2162.2	**33%**	4527	5585.9	**23%**
LaPlatte River Downstream of the Village Growth Area	19.1	26.9	**41%**	554.6	793.2	**43%**	739.6	1042.4	**41%**	1836	2438.6	**33%**	5190	6363.5	**23%**
LaPlatte River at Town Boundary	38	51.2	**35%**	913.6	1166.4	**28%**	1195	1509.2	**26%**	2825	3455.1	**22%**	7797	9151.0	**17%**

Table 9: Comparison of Existing and Buildout unit discharge (cfsm) at select locations.

Location	Water Quality			1-year			2-year			10-year			100-year		
	Existing (cfsm)	Buildout (cfsm)	Increase (%)	Existing (cfsm)	Buildout (cfsm)	Increase (%)	Existing (cfsm)	Buildout (cfsm)	Increase (%)	Existing (cfsm)	Buildout (cfsm)	Increase (%)	Existing (cfsm)	Buildout (cfsm)	Increase (%)
LaPlatte River Upstream of the Village Growth Area	1.0	1.5	**48%**	45.7	66.2	**45%**	61.9	87.6	**41%**	156.1	208.1	**33%**	441.8	556.7	**26%**
LaPlatte River at Confluence with Patrick Canal	0.9	1.3	**41%**	29.2	42.0	**44%**	39.0	55.0	**41%**	97.1	129.6	**33%**	271.3	334.7	**23%**
LaPlatte River Downstream of the Village Growth Area	1.1	1.5	**41%**	31.5	45.1	**43%**	42.1	59.3	**41%**	104.4	138.7	**33%**	295.2	362.0	**23%**
LaPlatte River at Town Boundary	1.4	1.9	**35%**	34.1	43.6	**28%**	44.6	56.4	**26%**	105.5	129.1	**22%**	291.3	341.8	**17%**



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Buildout Scenario Runoff Depth
2-year Storm Estimate

Growth Center Existing Conditions
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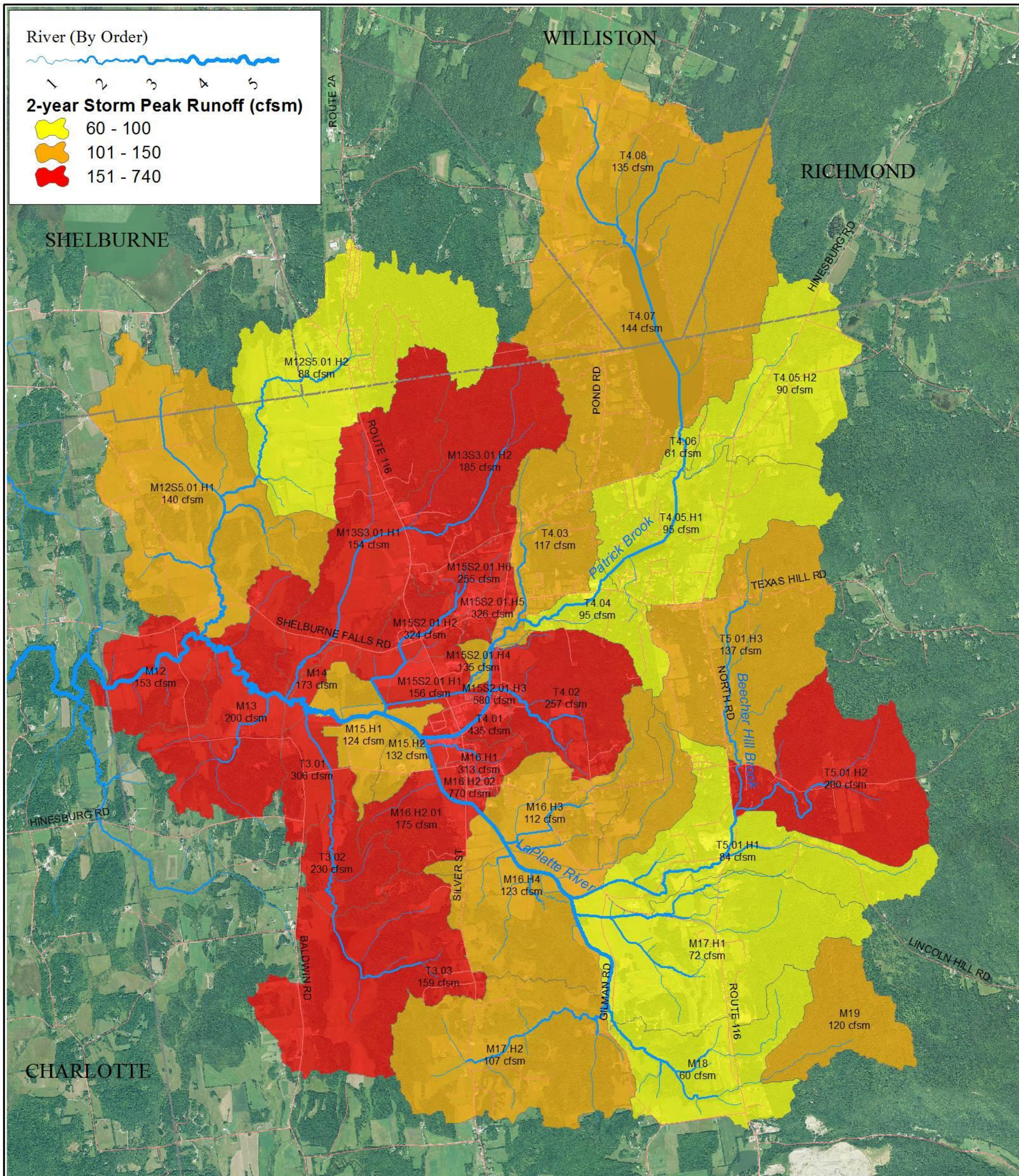
SCALE: see scale bar
SHEET: **Figure 13**



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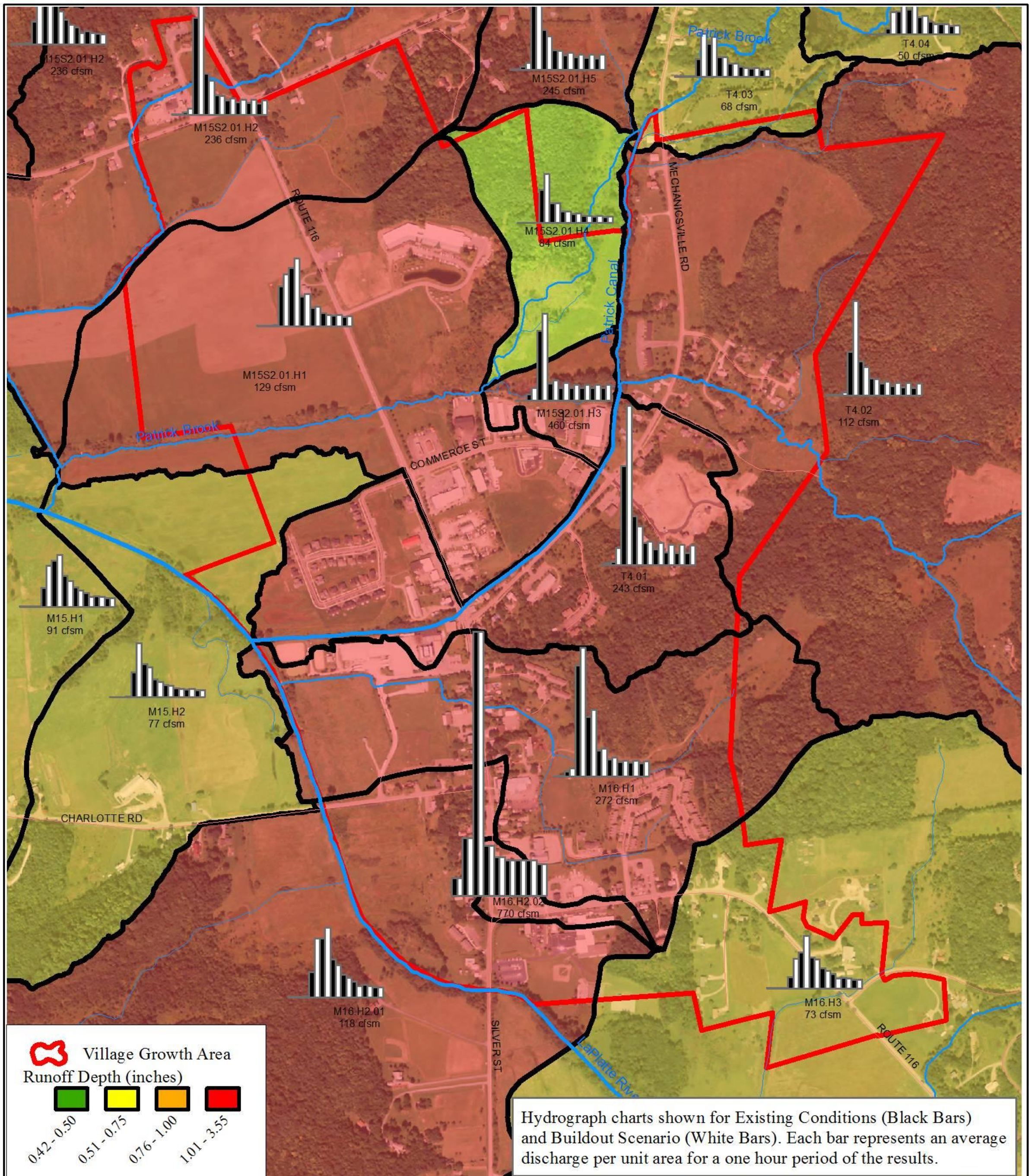
Buildout Scenario Peak Runoff Discharge
2-year Storm Estimate

Growth Center Existing Conditions
Hydrology Study

DATE: December 2011

SCALE: see scale bar

SHEET: **Figure 14**



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Buildout Scenario Village Center Subwatershed Discharge 2-year Storm Estimate

Growth Center Existing Conditions Hydrology Study

N W E S — 0 250 500 1,000 Feet

DATE: December 2011

SCALE: see scale bar

SHEET: **Figure 15**

4.0 DISCUSSION AND FUTURE CONSIDERATIONS

4.1 Discussion

The existing conditions hydrology model predicts current runoff characteristics in the portion of the LaPlatte River watershed that lies within the Town of Hinesburg. Modeled runoff patterns indicate that some subwatersheds in developed areas over clay soils are generating a large amount of runoff relative to the small amount of runoff generated from rural forested subwatersheds. Developed areas need retrofitting to install stormwater treatment and controls, undeveloped areas in the Village Growth Area need stormwater management guidelines to protect water quality and reduce flood risks, and existing flood storage and natural water filtration in undeveloped rural areas needs to be preserved.

Stormwater treatment for future development can be addressed at the project, parcel, neighborhood, and Town scales. In areas zoned for more dense development the Town could provide or guide placement of a centralized stormwater treatment system that would maximize development potential in desired locations. Treatment areas could be chosen based on locations of soils with high infiltration potential or proximity to dense existing development. Treatment areas could also be sited in areas that would not otherwise provide a beneficial use to the Village Growth Area's overall master plan.

Village Growth Area subwatersheds were found to have the most existing runoff. Zoning has been put in place to direct additional development into this area. Each additional impervious surface will increase runoff in these subwatersheds that are already producing large amounts of runoff. One approach to mitigation of existing stormwater runoff in these areas could be shared by the developers of new projects. Infill development in these subwatersheds could be required to treat stormwater from new impervious surfaces as well as a percentage of existing stormwater runoff. If additional stormwater treatment is not possible on the site, the new development could pay into a stormwater treatment fund that would be used to pay for stormwater retrofit projects.

The subwatersheds with the highest peak discharge values have a larger portion of the existing development. These subwatersheds are prime candidates for implementation of stormwater treatment projects. Many of these subwatersheds have stormwater collection systems in place that could be retrofit to direct stormwater to a treatment area before releasing to the river. Numerous treatment options exist that can reduce runoff and promote storage and infiltration. Options include detention in ponds, smaller scale detention in rain gardens, or separation of solids in a swirl separator and removal during regular maintenance. Where soils allow for infiltration, many practices can be implemented that direct surface water into the ground such as an infiltration basin, a set of underground galleys, tree wells, raingardens, disconnecting roof leaders, and reducing impervious surfaces. Water collected in existing storm drainage systems could be directed to a new treatment system before discharge.

Stormwater infrastructure planning is an important aspect of planned Town growth that often is overlooked. Creation of a Town Stormwater Utility would allow for active management and authority to address existing and future stormwater concerns comprehensively. If a utility is not feasible, a first step is to identify and set aside land specifically for stormwater collection and treatment.

The widespread presence of clay soils with poor drainage in the LaPlatte River watershed limits the potential for treatment practices using infiltration in many areas. The few areas where permeable soils exist are important green infrastructure where runoff reduction can take place due to high infiltration capacity. Areas of permeable soils, wetlands, vegetated stream buffers, and floodplains form the green infrastructure network that naturally collects, stores, and treats stormwater. Conservation of these permeable and storage areas should be considered as they are an important component of stormwater treatment in future development enabling smart growth.

Existing conditions stormwater runoff is produced at a higher level in Village Growth Area subwatersheds and expected future development will increase runoff from these areas. Although these developed areas are a priority for retrofits to initiate treatment, stormwater treatment is a priority across all parts of the watershed. The buildout scenario showed that rural subwatersheds generate more runoff volume and higher peak flows due to increased development. Modeled peak discharges were increased by an equal amount in Village Growth Area subwatersheds and rural subwatersheds. Although zoning specifies that future development densities may be lower outside of the designated Village Growth Area, the cumulative impact of stormwater is equivalent and needs to be addressed equally throughout the watershed.

Under current regulations, only a small amount of development projects are required to obtain stormwater permitting and subsequently many projects are not required to install stormwater treatment practices. Specifically, smaller scale development with less than one acre of impervious surface often does not include treatment. Smaller projects have an incremental and cumulative effect on runoff patterns and will compound to produce a large amount of runoff. The Town may want to guide treatment requirements for smaller projects that are not covered by the State. Furthermore, an innovative approach to stormwater treatment regulation would be to implement treatment requirements of no net increase in volume or peak flows based on the existing runoff characteristics of the subwatershed rather than the individual parcel or project. The model created during this project could be used to implement such a policy.

New development that is required to install stormwater treatment bases the design for the treatment practice on a particular level of treatment that varies by project size. Stormwater treatment can be designed to maintain or reduce existing flows and volumes various storms. Current design practice typically requires matching peak flows before and after development for the 100-year storm or a smaller storm. Only large projects (more than 10 acres of impervious surface) are required to treat up to the 100-year storm. Local regulations could require a higher level of treatment for all projects, specifying that matching peak flows before and after development of the 100-year storm is required for even smaller projects. Stormwater mitigation using Low Impact Development (LID) techniques should be used. The ultimate goal is mimicking pre-development hydrology by reducing runoff volume for future development (Smith 2010). LID techniques reduce stormwater runoff (Bedan and Clausen 2009), improves the quality of receiving waters, is often aesthetically pleasing in village centers, and is cost-effective design approach (USEPA 2007).

Runoff volume is also an important factor to consider when treating stormwater. Additional local level regulations could be put in place to require treatment standards to match pre-development runoff volumes. Low-impact design approaches attempt to maintain existing runoff volumes so there is no change of runoff characteristics with development. This approach protects water quality, reduces flood risks, and maintains aquatic habitat.

The buildout scenario showed that runoff combines in the mainstem LaPlatte River channel to produce a larger peak flood that occurs more quickly than under existing conditions. Both increases in peak discharge and volume could destabilize river channels that have naturally attained a particular shape and size to carry the existing flows. A channel will find an equilibrium size, shape, sinuosity that matches the hydrology and sediment load (Lane 1955). As flows in the rivers are increased, such as under future development, the rivers will work towards a new equilibrium. While changing form, a river will generally experience increased bank and bed erosion. The path of a river can change leading to increased flood and erosion risks.

Flooding is naturally stored in floodplains, allowing the volume of water in the channel to spread out and slow down. Stormwater treatment planning should include increased floodplain protection of all non-developed floodplain storage areas and require that no additional development occur within 100-year floodplains. Filling the floodplain transfers flooding to downstream areas.

The predicted stormwater runoff increase in the buildout scenario model illustrates that larger floodplain areas should be targeted for conservation under future development scenarios to limit flood and erosion risks. Increased flows from land cover conversion, and from the on-going increase in the size of storms and floods (Collins 2009), suggest more land adjacent to rivers will be required for flood storage. It is important to use the most up to date information in determining the extent of the floodplain. Keeping development outside of floodplains will reduce flood and erosion hazards to public infrastructure, protect private property, and support natural stormwater treatment.

Storage areas in the upper watershed reduce flood risks downstream and should be maintained. Specifically, storage areas in the Patrick Brook subwatershed reduce peak flows that travel through the Village Growth Area. Upstream floodplain, wetlands, and other storage areas should be conserved to protect their vital function of reducing flooding locally and in the Village Growth Area.

The information provided in this report builds on a previous study of stormwater patterns in the LaPlatte River watershed (Schiff and Clark 2010) that included field investigation and GIS mapping of stormwater infrastructure in the LaPlatte River watershed. Watershed characteristics influencing stormwater runoff and general recommendations for stormwater management were discussed. The current study builds on the 2010 study for the Town of Hinesburg by refining previous mapping data with field investigation, developing a hydrology model, and exploring runoff patterns around the Town. The two reports in combination give a comprehensive view of stormwater patterns and condition and the potential for improvements.

4.2 Future Considerations

The hydrology model has created a starting point for exploring stormwater runoff in the Town. Additional information can be acquired from the hydrology model that can guide future planning efforts.

Which soils with high infiltration characteristics should be conserved as green infrastructure to maintain natural treatment via runoff reduction?

How do peak flow rates and volumes change by construction of stormwater detention areas or other practices?

How do specific stormwater detention areas influence downstream hydrology?

How do proposed changes in zoning regulations influence hydrology and treatment potential?

Are existing floodplain setbacks along river channels such as the FEMA floodway, the 75-foot stream buffer, and the fluvial erosion hazard zone providing adequate storage area to contain the predicted existing and buildout flood levels?

5.0 CONCEPTUAL DESIGN

Most of the runoff in Hinesburg enters the river channels untreated. Many opportunities for improved treatment exist. As an example, the existing conditions hydrology model was used to create a conceptual stormwater treatment design at the intersection of Silver Street and Route 116. This area was found to generate the most runoff in the Town. Runoff from this subwatershed originates from a portion of the village including homes, businesses, and part of the Town owned property on Route 116 and drains to the corner of Route 116 and Silver Street Stormwater is currently collected using catch basins and transferred to the Silver Street- Route 116 intersection area in pipes. The pipes discharge to a grass-lined swale along Silver Street that leads to the LaPlatte River.

A rain garden is proposed in the area where the pipes discharge along Silver Street and the edge of the Town owned land near the Masonic Hall. There is currently a small depression and some unmaintained vegetation existing at the outlet of the drainage systems at the corner. A tiered, three-chamber system is proposed. Water would enter a sediment forebay, and either sit, infiltrate or flow to the next bay. Water would flow down to the third bay under large storms and re-enter the swale for discharge to the LaPlatte River as before.

The Vermont Stormwater Manual recommends treatment of the Water Quality Volume (VTDEC 2002). For the study subwatershed of, The Water Quality Volume was calculated as 0.2 acre-feet for the subject subwatershed (6.7 acres, 39% impervious cover). The existing conditions hydrology model predicted a larger water quality volume of 0.5 acre-feet.

A rain garden was designed to fit within the vegetated and sloping sections of undeveloped ground at the southeast corner of Route 116 and Silver Street (Appendix H). The treatment system minimizes the footprint in the lawn near the buildings owned by the Town A preliminary planting list and views of the cross section and profile of the system are included to facilitate future design.

The rain garden stores 0.3 acre-feet in three chambers covering an approximately 100 foot wide by 170 foot long area. This design would store enough volume to treat the Water Quality Volume as calculated by the VT Stormwater Manual equation, but only 60% of the Water Quality Volume calculated by the hydrology model. Installation of the rain garden would result in the removal of 87% of the total suspended solids (TSS) from the water quality volume (UNH 2010). Assuming a stormwater concentration of 180 milligram TSS per liter of water, 127 pounds of solids would be removed from the water quality volume.

The rain garden would result in removal of 34% of total phosphorus (TP) that is equivalent to 0.14 pounds assuming a stormwater concentration of 0.5 milligrams TP per liter of water. The removal efficiencies represent the removal during any storm that generates runoff that is equal to or larger than the water quality volume. Beyond improving local water quality, the rain garden design will enhance local aesthetics, be easy to maintain, and serve as a public demonstration of simple measures that can be used to treat stormwater in the built environment.

A ballpark cost opinion has been completed based on knowledge of local construction projects and information provided in the Vermont Rain Garden Manual (WNRCD 2009). The rain garden is estimated to cost $60,000 (Table 10). Costs assume hiring a contractor to complete the installation. These costs could be lower if labor or plantings were donated to the Town. Based on typical rates listed in the Vermont Rain Garden Manual the costs could be up to $90,000.

Table 10: Ballpark cost estimate for conceptual rain garden design.

	Unit Cost	Unit	Number	Cost
Site Prep / Erosion Control	$ 3,000.00	lump sum	1	$ 3,000.00
Plantings and Material	$ 5.00	square foot	9132	$ 45,660.00
Excavation	$ 6.24	cubic yards	490	$ 3,057.60
Restoration	$ 3,000.00	lump sum	1	$ 3,000.00
Engineering Design	$ 5,000.00	lump sum	1	$ 5,000.00
Estimated Cost (rounded)=				$ 60,000.00

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