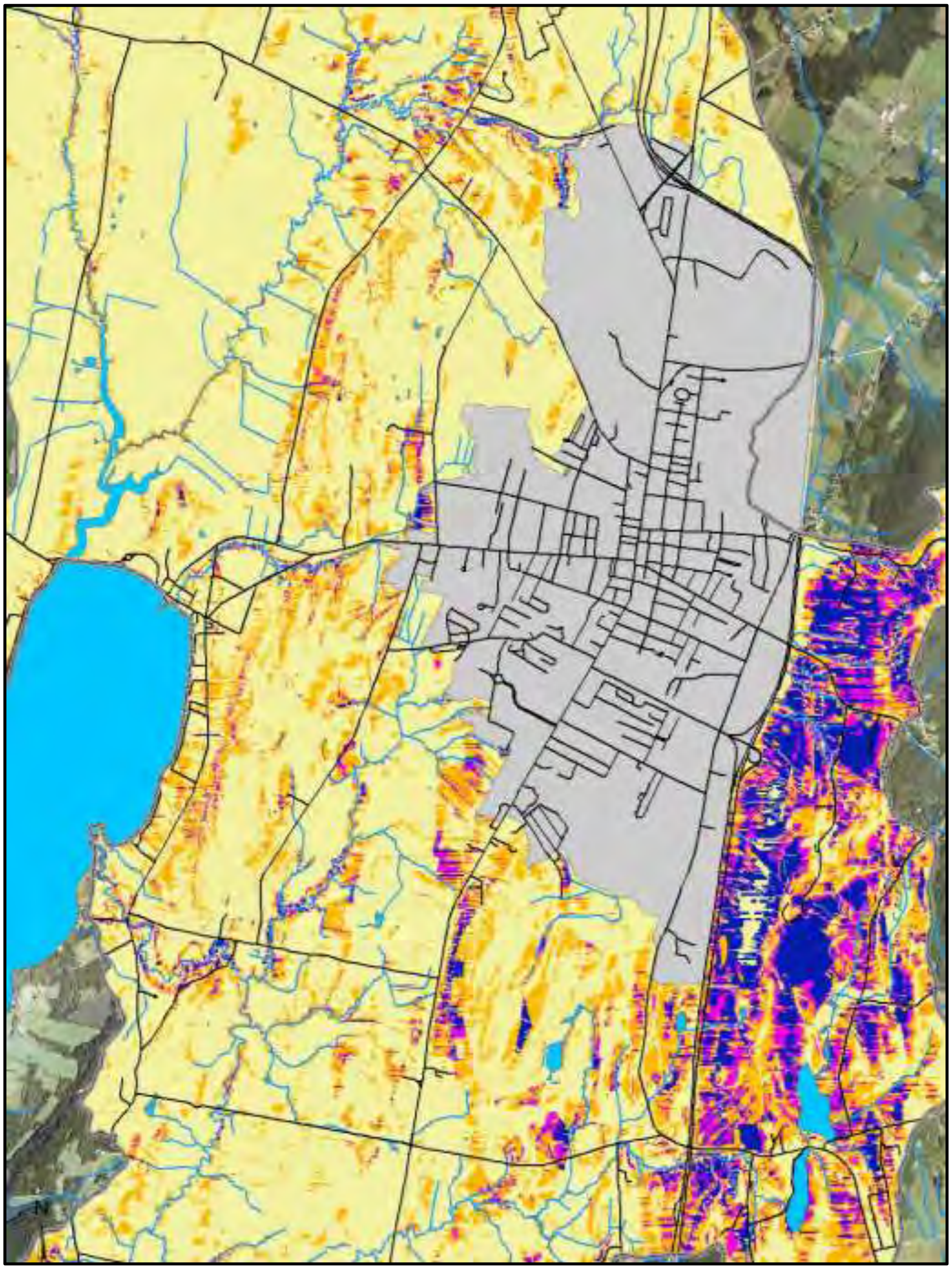
Identifying Capital Eligible Water Quality Projects and a Methodology for Mapping Potential Critical Source Areas: A St. Albans Bay Watershed Case Study

FINAL REPORT



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Funding for this project is provided by a grant from the VT Department of Environmental Conservation's Ecosystem Restoration Program.

Project Background:

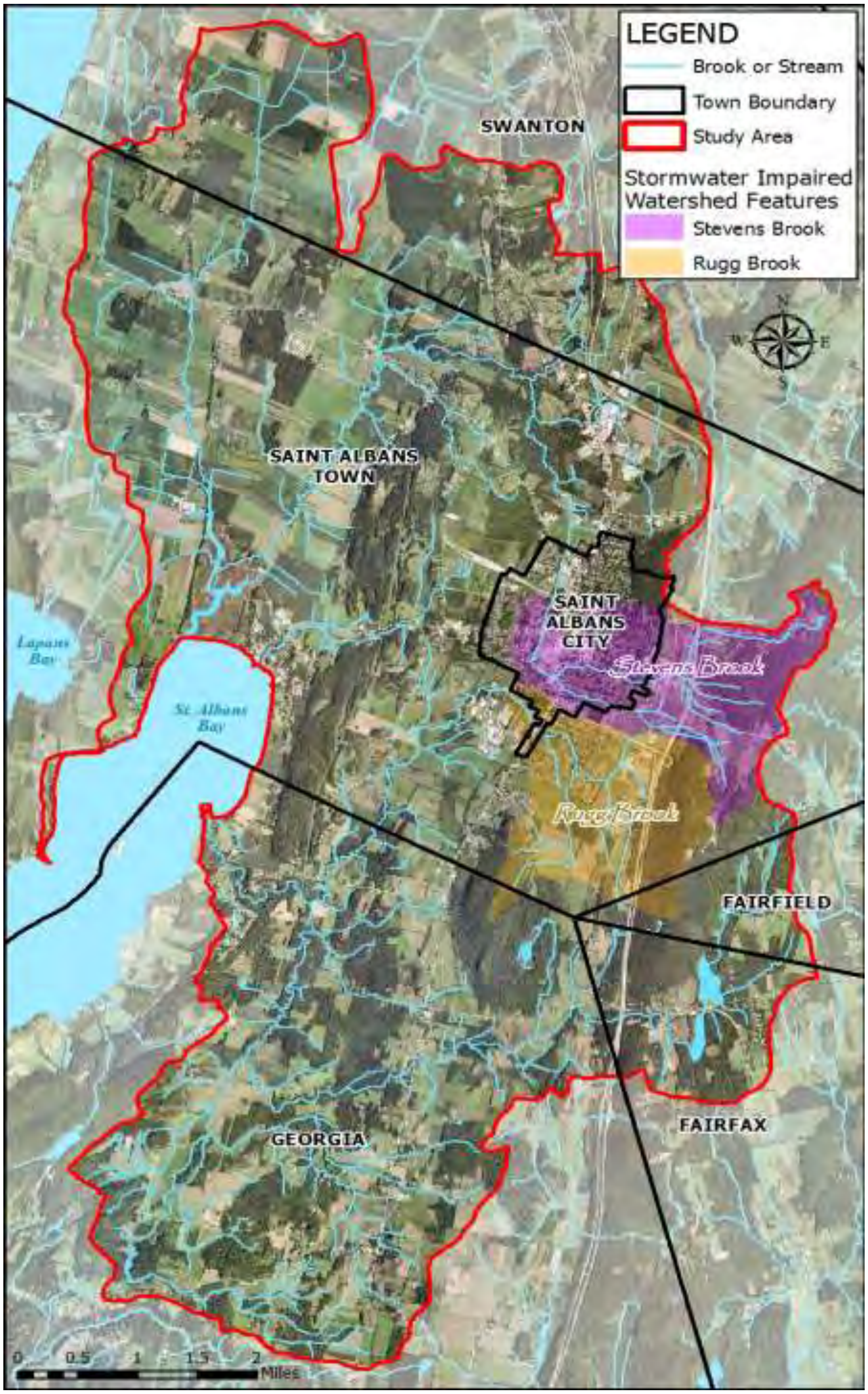


Figure 1. The project focused on the St. Albans Bay watershed.

NRPC conducted a multi-part project that focused on non-point source pollution in the St. Albans Bay watershed associated with erosion and runoff from transportation infrastructure (roads, bridges, and culverts) and stormwater from developed land. This project has three components; the first was to compile a list of recommended projects that address non-point source pollution based on previous studies, the second part was to inventory current road related stormwater projects outside the stormwater impaired watersheds, and the third was to conduct a GIS analysis of potential critical source areas at the watershed level.

PART I. List of Recommended Projects from Prior Studies:

NRPC reviewed 18 studies that have been conducted in the watershed since 2003 and interviewed several municipal and state agency staff to compile a list of projects that were recommended to address non-point source pollution. This effort focused on non-agricultural projects; additional projects and studies may exist that detail projects proposed and implemented in agricultural areas.

Summary of Identified Non-Agriculture Projects	
Total # of Projects Identified	60
# located outside the MS4 regulatory area	11 *(3 have been implemented)*
# of Projects that could be implemented basin-wide	8
# of Projects Completed	17 *(2 are partially complete)*

In total sixty projects were identified from past studies and only fifteen of these have been completely implemented. There are two sites where part of the project has been implemented but additional treatment or restoration can be constructed. These projects include: the St. Albans Industrial Park where a swale was installed but a stormwater pond has not been built as additional easements are needed and a 300ft of stream was daylighted at the Collins Perley Complex however, additional projects have been identified on site. A third effort that could also be considered incomplete is transitioning towns towards a lower phosphorus road sand and salt application; St. Albans Town uses a salt brine solution and this technology could be expanded to other communities.

A table is provided in the supplemental deliverables that summarizes all the projects that were referenced in past studies and still considered for implementation. Those projects that were given a specific location, versus being a basin-wide activity, were mapped (see Figure 2).

Below is a list of nine identified projects that are outside or partially outside of the MS4 regulated area. Completing these projects is likely to result in some level of improved water quality to area waters.

- Removal of unnecessary on-site drainage systems in residential areas.
- Install sediment removal devices in existing storm sewer systems.
- Address undersized bridge (B28) on Mill River Road (Georgia, VT).
- Address erosion around box culvert (B1) from unmanaged road runoff (Georgia, VT).
- Mill River restoration project to address runoff from Cline Road/Georgia Shore Road (Georgia, VT).
- Municipal use of salt brine for winter road maintenance in order to reduce sand usage given that phosphorus is found absorbed to sand particles.
- Shoreline stabilization projects.
- Institute town/city wide riparian corridor protection strategies on Reach M04 of Stevens Brook such as buffer zoning.
- Daylight section of stream and install stormwater best management practices on Hungerford Property (St. Albans Town, VT).

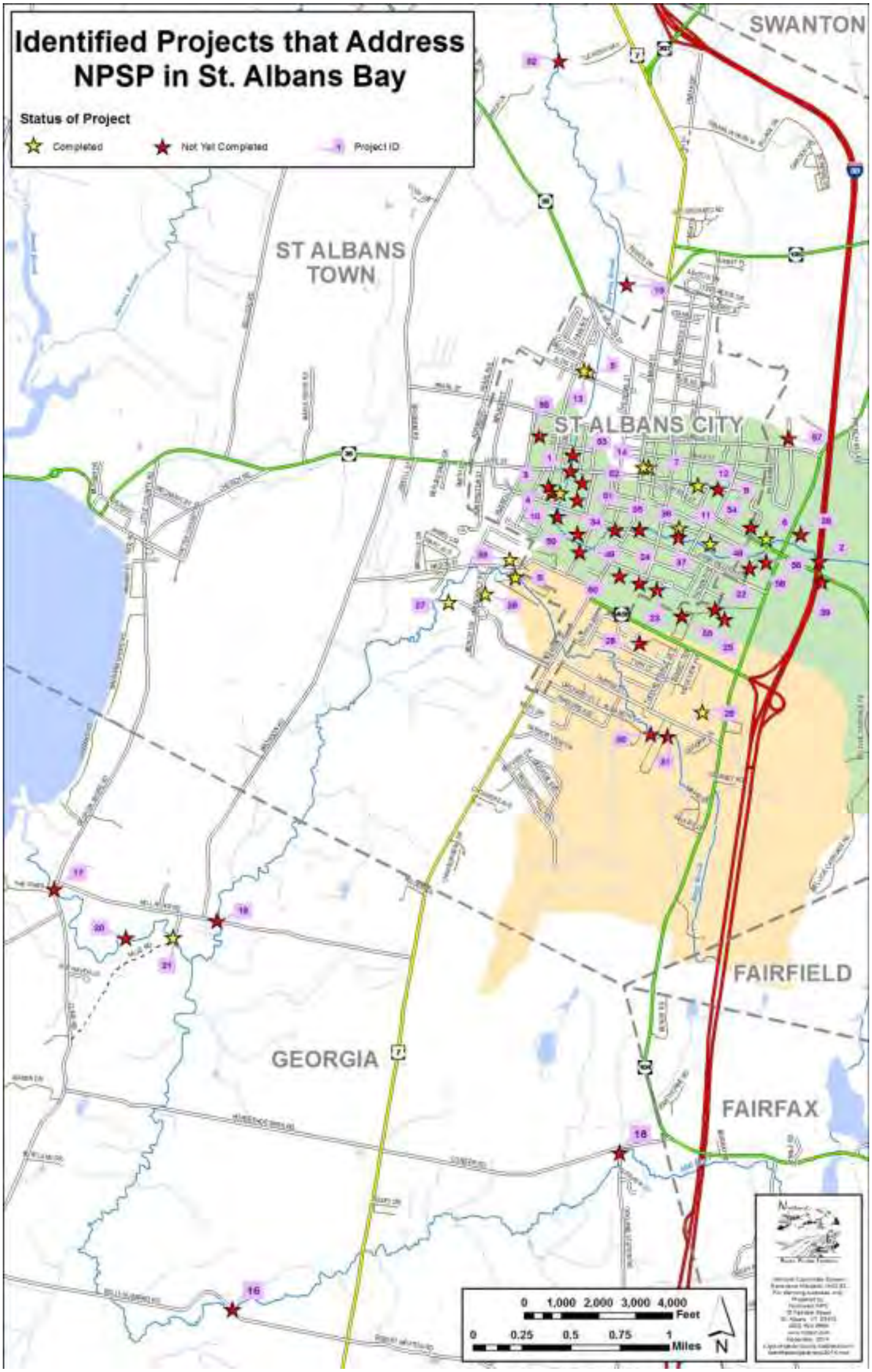


Figure 2. Map of projects identified in studies from 2003-2014.

Table 1. List of studies reviewed to identify projects that address non-point source pollution.

Reference #	Reference
1	Carmi Consulting (2007). *Mill River/Rugg Brook project development.* St. Albans, VT: Northwest Regional Planning Commission.
2	Carmi Consulting (2008). *Water quality improvement projects for Mill River and Rugg Brook.* St. Albans, VT: Northwest Regional Planning Commission.
3	Dubois, &, King, and Inc. (2003). *Watershed study report: Stevens Brook and Rugg Brook.* St. Albans, VT: Northwest Regional Planning Commission.
4	ENSR Corporation (2007). *Feasibility study for the control of internal phosphorus loading in St. Albans Bay, Lake Champlain.* Waterbury, VT: Vermont Agency of Natural Resources.
5	Lake Champlain Committee (2005). *Geomorphic assessment of Stevens, Rugg and Jewett Brooks in Franklin County, VT.* Burlington, VT: Vermont Agency of Natural Resources.
6	Northwest Regional Planning Commission and Ross Environmental Associates, Inc. (2008). *Fluvial erosion hazard mapping and phase 2 assessment report—For the municipalities of Georgia, Highgate and Saint Albans City.* St. Albans, VT: Northwest Regional Planning Commission.
7	Stone Environmental (2013). *Town of Georgia stormwater management plan—Final Report.* Swanton, VT: Friends of Northern Lake Champlain.
8	Vermont Department of Environmental Conservation (2009). *Water quality management plan for the northern Lake Champlain direct drainages—Draft report.* Waterbury, VT: Vermont Agency of Natural Resources.
9	Northwest Regional Planning Commission and Ross Environmental Associates, Inc. (2009). *Implementing Stormwater Management Practices and Water Quality Improvement Projects in the Stevens and Rugg Brook Watershed – Final Report.*
10	The Johnson Company, Inc. (2007). *Stevens Brook and Rugg Brook Project Development Status Report – Draft Report.*
11	Watershed Consulting Associates, LLC. (2011). *VTRANS Median Stormwater Upgrade Final Summary Report.*
12	Lake Champlain Sea Grant. (2011). *Rain Gardens in the City of St. Albans (Paired Watershed Study).*
13	VHB Pioneer. (2009). Mill River Stormwater Treatment and Bank Stabilization Project.
14	Watershed Consulting Associates, LLC. (2014). *Stevens Brook Flow Restoration Plan Study*
15	Stone Environmental Inc. (2014). *DRAFT Stormwater Management Planning Library. Town of St. Albans.*
16	Stone Environmental Inc. (2013). *Stormwater Management Plan for Swanton Town and Village*
17	Watershed Consulting Associates, LLC. (2014). *Stevens Brook Flow Restoration Plan*
18	Watershed Consulting Associates, LLC. (2012). *Hungerford Property Stormwater Feasibility Study*

PART II. Inventory of Road Related Stormwater Projects:

NRPC evaluated municipal culvert inventories, stream geomorphic assessment data and town bridge inspection reports to identify potential municipal bridge and culvert projects within the study. Based on available data, culverts and bridges in the watershed were highlighted as needing possible attention if it had been identified as having a known issue (poor condition, signs of erosion present, etc.) as well as the potential for erosion (undersized). The criteria for highlighting potentially troublesome culverts and bridges are included in Table 2.

Table 2. Criteria for flagging potential bridge and culvert projects

Data Layer	Attributes (Infrastructure were highlighted if the following conditions are met)
Town Culvert Inventory	Overall Condition (Closed, Urgent, Critical, Poor) **The following fields are not available in the study area: Header condition, Year built, Poor culvert alignment, Culvert perched*
Town Bridge Inspection Reports (VTrans) for structures over 20ft	Bridge Span (identify if a channel constrictor), Waterway (identify if overtopping), Scour Critical (Y) → *Available for all Town structures over 20ft*
Geomorphic Assessment - River Corridor	Percent bankfull width (<75%), AOP Course Screen (Reduced or No AOP), AOP Geomorphic Compatibility (Structure is Mostly or Fully Incompatible)
Geomorphic Assessment - Bridge & Culvert Inventory	Skewed to Roadway (Y), Angle of stream flow approaching structure (Sharp Bend), Upstream/Downstream Bank Erosion (Y)

Identifying culvert and bridge projects was limited by available data (Table 3). The Town of Georgia had the most recent culvert inventory (completed in 2014) while Fairfax, Fairfield and St. Albans Town had inventories that were 6 to 11 years old. Stream geomorphic assessment field data was not available for the entire study area.

Table 3. Availability and age of data used in the St. Albans Bay watershed culvert and bridge evaluation.

Town	Availability of Data			
	Culvert Inventory	**Storm Drain Inventory**	**Geomorphic Assessment – River Corridor Measurements**	**Geomorphic Assessment – B&C Inventory**
Fairfax	2003, not entire town	NA	No	No
Fairfield	2003	NA	No	No
Georgia	2014	NA	2005	2005
St. Albans, City	Not applicable, storm drain system	2008	Yes	No
St. Albans, Town	2008	NA	Yes	No
Swanton	None	NA	No	No

Overall, 41 potential projects were identified in the study area—38 culverts and 3 bridges. The Town of Georgia had the most potential projects with 24 culverts that were highlighted and 3 bridges. St. Albans Town had 4 culverts identified, Swanton had 4, Fairfax had 3 and Fairfield had 3. Most culverts were highlighted under the Town Culvert Inventory Criteria rather than the Stream Geomorphic Assessment criteria. This is partly because the Stream Geomorphic Assessment data was available for relatively few structures in the study area. Figure 3 shows the locations of the potential culvert and bridge projects and Table 4 describes why they were highlighted being potentially troublesome structures. It should be noted that the table shows three columns of criteria used to identify structures, therefore if a structure has a positive response in more than one column, it shows there was more data available to evaluate the that structure by. It does not necessarily mean that it has a higher probability of being troublesome for erosion. For future analysis, it would be beneficial to collect additional characteristics of the culvert during condition surveys so supplement the stream geomorphic data.

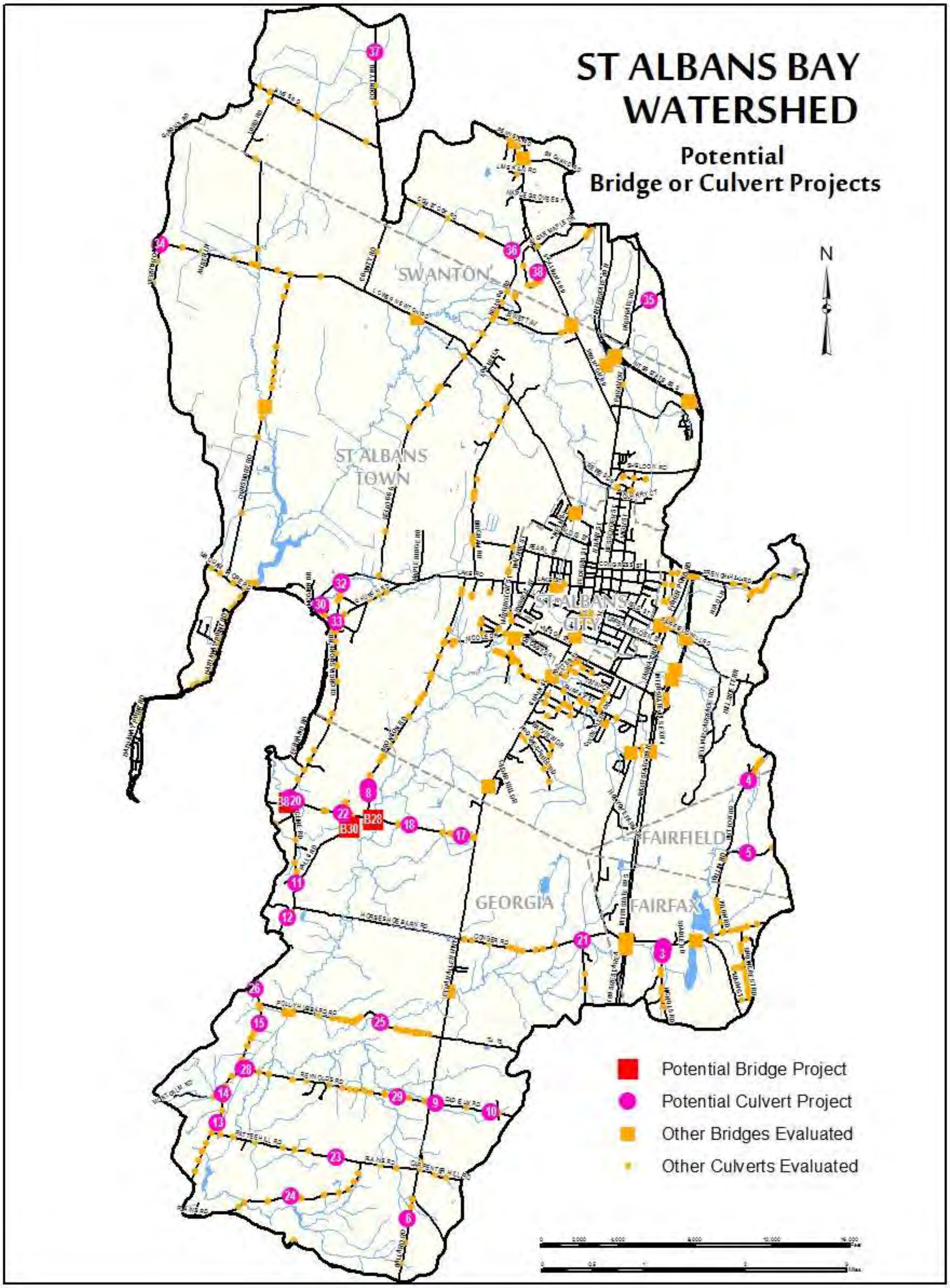


Figure 3. Map of potential municipal culvert and bridge projects

Table 4. List of potentially troublesome culvert and bridge projects

Map Label	Project Type	Town	Road	Sub-watershed	Identified Culvert Criteria	Identified Stream Geomorph Criteria	Identified Bridge Inspection Criteria
1	Culvert	Fairfax	Nichols Rd	Mill River	Yes	No	No
2	Culvert	Fairfax	Nichols Rd	Mill River	Yes	No	No
3	Culvert	Fairfax	Nichols RD	Mill River	Yes	No	No
4	Culvert	Fairfield	Button Rd	Mill River	Yes	No	No
5	Culvert	Fairfield	Gillin Rd	Mill River	Yes	No	No
6	Culvert	Georgia	Ballard Rd	Mill River	Yes	No	No
7	Culvert	Georgia	Bronson Rd	Mill River	Yes	No	No
8	Culvert	Georgia	Bronson Rd	Mill River	Yes	No	No
9	Culvert	Georgia	Cadieux Rd	Mill River	Yes	No	No
10	Culvert	Georgia	Cadieux Rd	Mill River	Yes	No	No
11	Culvert	Georgia	Cline Rd	Mill River	Yes	No	No
12	Culvert	Georgia	Cline Rd	Mill River	Yes	No	No
13	Culvert	Georgia	Georgia Middle Rd	Mill River	Yes	No	No
14	Culvert	Georgia	Georgia Middle Rd	Mill River	No	Yes	No
15	Culvert	Georgia	Georgia Middle Rd	Mill River	Yes	No	No
16	Culvert	Georgia	Georgia Shore Rd	Mill River	Yes	No	No
17	Culvert	Georgia	Mill River Rd	Mill River	Yes	No	No
18	Culvert	Georgia	Mill River Rd	Mill River	Yes	No	No
19	Culvert	Georgia	Mill River Rd	Mill River	Yes	No	No
20	Culvert	Georgia	Mill River Rd	Mill River	Yes	No	No
21	Culvert	Georgia	Oakland Station Rd	Mill River	No	Yes	No
22	Culvert	Georgia	Old Quarry Rd	Mill River	Yes	No	No
23	Culvert	Georgia	Pattee Hill Rd	Mill River	Yes	No	No
24	Culvert	Georgia	Plains Rd	Mill River	Yes	No	No
25	Culvert	Georgia	Polly Hubbard Rd	Mill River	No	Yes	No
26	Culvert	Georgia	Polly Hubbard Rd	Mill River	Yes	No	No
27	Culvert	Georgia	Reynolds Rd	Mill River	No	Yes	No
28	Culvert	Georgia	Reynolds Rd	Mill River	Yes	No	No
29	Culvert	Georgia	Reynolds Rd	Mill River	Yes	No	No
B28	Bridge	Georgia	Mill River Rd	Rugg Brook	No	No	Yes
B30	Bridge	Georgia	Falls Rd	Mill River	No	Yes	Yes
B8	Bridge	Georgia	Georgia Shore Rd	Mill River	No	Yes	No
30	Culvert	St Albans Town	Chubb St	Direct drainage	Yes	No	No
31	Culvert	St Albans Town	Little County Rd	Direct drainage	Yes	No	No
32	Culvert	St Albans Town	Little County Rd	Direct drainage	Yes	No	No
33	Culvert	St Albans Town	Patten Crosby Rd	Direct drainage	Yes	No	No
34	Culvert	St Albans Town	Perry Rd	Jewett Brook	Yes	No	No
35	Culvert	Swanton	Bushy Rd	Stevens Brook	Yes	No	No
36	Culvert	Swanton	Comstock Rd	Stevens Brook	Yes	No	No
37	Culvert	Swanton	County Rd	Jewett Brook	Yes	No	No
38	Culvert	Swanton	Mountain View Dr	Stevens Brook	Yes	No	No

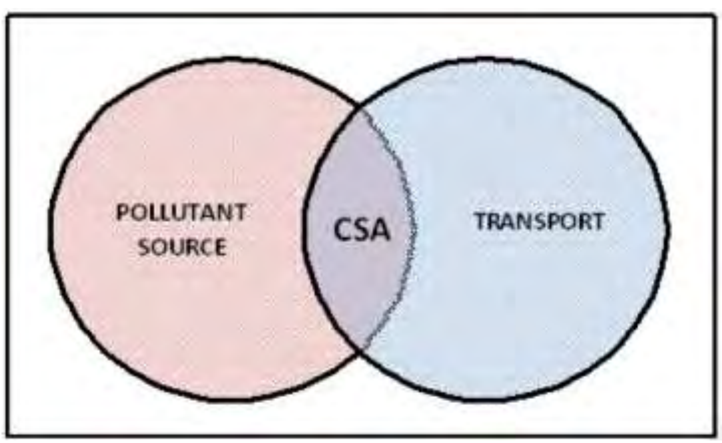
PART III. GIS Analysis of Potential Critical Source Areas:

NRPC is proposed a methodology to identify areas within the St. Albans Bay watershed that may be more likely to generate runoff and erosion as well as contribute sediment and phosphorus to the bay. The identification of these potential critical source areas (CSA) or areas where the potential contribution of pollutants (i.e. sediments, phosphorus) to the receiving water is significantly higher than the other areas, will aid in focusing non-point source related implementation efforts in the future. The aim of this exercise is to develop a methodology that is based on readily accessible data and GIS methods that could be implemented by watershed managers and planners.

NRPC used a two part methodology that will separately model potential CSAs in rural and developed areas. "Rural" areas would be primarily agricultural, forestland and low density residential. "Developed" areas will be defined as the City of St. Albans and development surrounding the City in Saint Albans Town, the extent of this area will primarily be defined based on the availability of the sub-watershed mapping outlined in the methodology. There will be a developed area in Swanton included in the rural methodology due to the lack of sub-watersheds data needed to include it in the developed methodology. This project did not focus on erosion and nutrient pollution from agricultural lands but agricultural land is included in the rural watershed analysis. For both of these analyses, the presence of existing best management practices (BMPs) was not accounted for and therefor it should be noted that the presence of these practices might further influence the manner in which erosion and phosphorus is generated.

PART III.A. RURAL METHODOLOGY

In the rural areas we utilized a **modified Universal Soil Loss Equation** (USLE) model as a base to map potential critical sources areas for phosphorus. This methodology uses a modified USLE equation (Wischmeier and Smith 1978) that utilizes a limited amount of data and can be readily processed in standard GIS software (ArcGIS and open source applications) to create a preliminary look at erosion risk. The methodology developed by Sivertun and Prange (2003) was the basis for NRPC's analysis. It is based on the association between erosion and the transport of nutrients to address non-point source phosphorus pollution. The use of this modified USLE



The concept of critical source areas (CSA). Source: NRCS

model to predict non-point source problem areas was also used by Winchell et. al (2011) and De la Hoz et al. (2008) and found to be an acceptable predictor.

This simplified methodology does not incorporate hydrologic processes or the actual nutrient levels in the soils. It is based more on the relationships between erosion factors and the type of land cover. Troy et al. (2007) estimated phosphorus export from the Lake Champlain basin utilizing a derived 2001 land cover layer for the basin and precipitation data; they found that there is a strong relationship between phosphorus export and land use/land cover conditions. The Soil and Water Assessment Tool (SWAT) conducted in the Missisquoi Basin found that the most influential factors in driving the magnitude of phosphorus was the soil hydrologic group and topography (Winchell et al. 2011). When Winchell et al. (2011) applied Sivertun and Prange's methodology they found that land use/land cover heavily influenced the analysis; specifically higher risk values were associated with agricultural, farmstead and developed areas and natural vegetated areas (forest and wetland) were lower risk.

The outcome of this methodology is to produce a map that identifies areas of possible risk and does not compute the amount of sediment nutrient load. The resulting map serves as a basic tool to identify areas of high risk of erosion or impact on surface water quality.

<u>Methodology (Layers, Sequence, Weights):</u>

The model is based on four main factors - soil, slope, watercourse distance and land use - using a 10-m raster grid as the unit of scale. This methodology closely follows the analysis developed by Silvertun and Prange (2003). This step will replicate that of prior studies and combine the four factors by raster value multiplication with the following equation:

$$\mathbf{P = K * S * W * U}$$

Where **P** is the map of risk of erosion and pollution elution, **K** is a soils factor, **S** is a topographic factor (slope and slope length), **W** is a watercourse factor, and **U** is a land use factor.

<u>Data Layers</u>

Soils (K): The NRCS Franklin County Soil Survey (SSURGO dataset) serves as the base layer. The K-factor from the survey, which is an erosion factor, shown in Table 16 *Physical and Chemical Properties of the Soil*, was used in the equation. As described by NRCS, the erosion factors are used to "predict the erodibility of a soil and its tolerance to erosion in relation to specific kinds of land use and treatment. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water." The KW table was used which indicates the erodibility of the whole soil.

The NRCS denotes values of 0.17 to be moderately erosive and 0.36 and above to be highly erosive. Figure 4 below shows the Model Builder workflow in ArcGIS that was used to process the soils data layer. Table 5 provides the weights that were applied to soil K values; they were weighted based on the higher the value the more susceptible to erosion the soil would be (with all other things being equal).

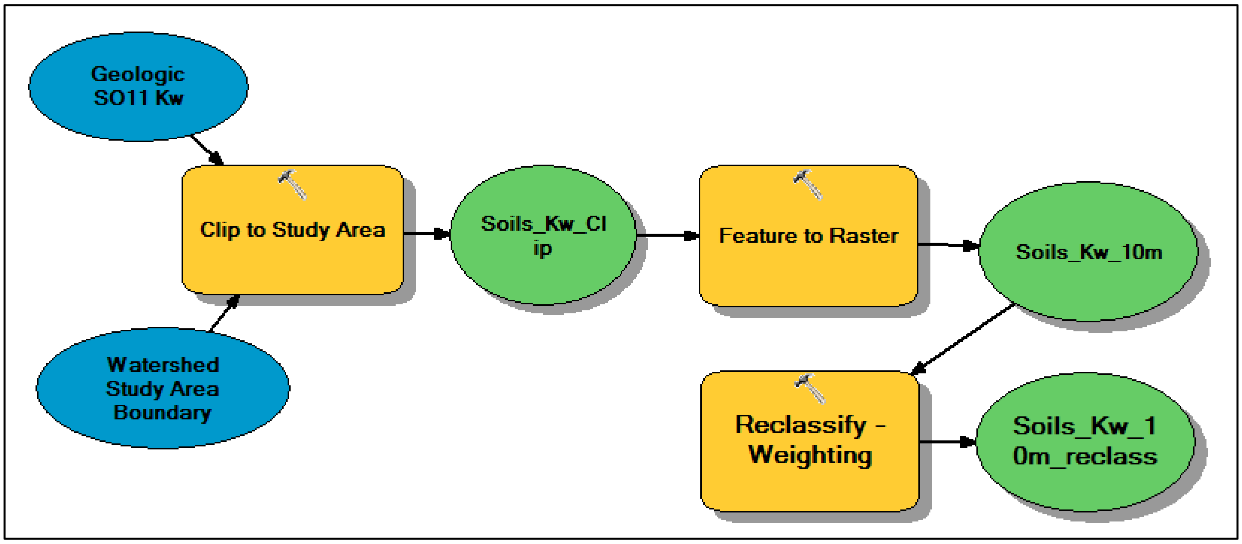


Figure 4. Workflow of soils data layer processing in ArcGIS.

Table 5. Values for the Soil factor map.

K Value	GIS Value (Weight)
No Data (Water)	0
0.10-0.15	1
0.17-0.24	3
0.28-0.32	6
0.37-0.49	10

Slope (S): The 2005 hydrologically corrected digital elevation model for the study area will be used to derive a digital elevation model and slope length; this data is provided at a 10-m resolution. Slope length is a factor that takes slope steepness and length into account. NRPC will follow methods described in Matthews and Norton (2013) and Sivertun and Prange (2003) to develop slope length; slope length is created from elevation data in meters to derive slope and a modified flow accumulation. Figure 5. Below shows the Model Builder workflow in ArcGIS that was used to process the soils data layer. The original slope length factor ranged from 0 to 1,162.5, given there were few high values; the layer was reclassified so that all values greater than or equal to 25 were given the value of 25. The streams were also removed from the layer using the flow accumulation layer to identify the streams.

It was originally proposed that 1-meter resolution LiDAR data wouldbe incorporated into the analysis. However the data that was readily available from VCGI was not hydrologically corrected, which meant that in its available format, it would not appropriately represent hydrological processes on a landscape. NRPC did spend some time working to correct the data but ran into unresolved processing issues and determined that given the amount of processing required to use the data, it was therefore outside the scope of creating a readily accessible processes for others to replicate.

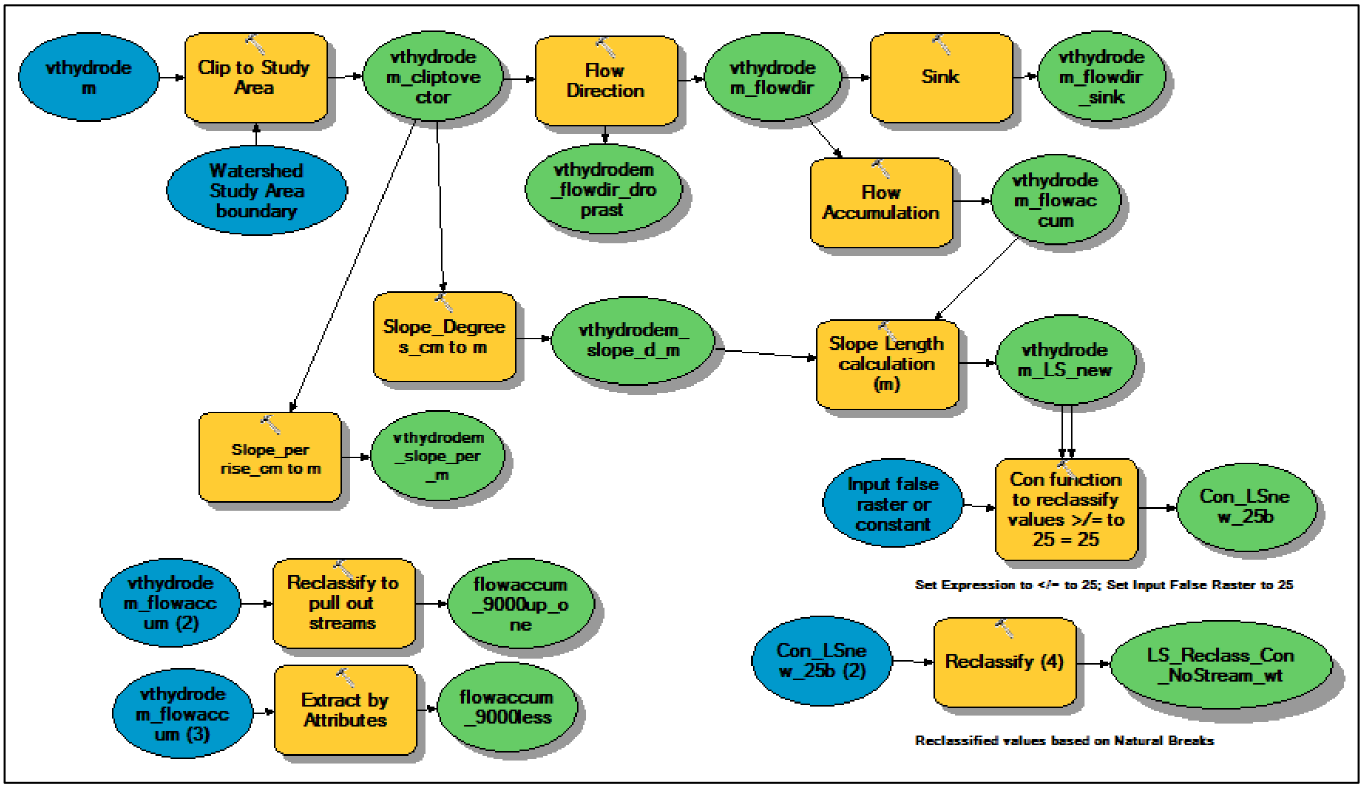


Figure 5. Workflow of slope length layer processing in ArcGIS.

Table 6 provides the weights that were applied to slope; they were weighted based on the higher the value the more susceptible to erosion the soil is (with all other things being equal).

Table 6. Values (classified by natural breaks) and weights for the slope length factor map.

LS Value	GIS Value (Weight)
0-1.274375	1
1.274375-3.921155	3
3.921155-8.136397	6
8.136397-14.606303	8
14.606303-24.997364	10

Distance to Watercourse in meters (W): The Vermont Hydrograph Dataset (VHD) was used to create a weighted distance to streams factor to estimate the potential likelihood of sediment reaching stream segments. As a starting point, Euclidian Distance was used to measure each cells distance to water and the equation above was applied to this layer (see Figure 6 for the ArcGIS Model Builder flow chart that outlines the processing. A weighted function, as developed by Sivertun and Prange (2003), was then used to compute cell values continuously depending on the actual distance of every specific cell using the following equation: F(x)= 0.6 / (e^0.002x – 0.4); this method was used as opposed to calculating a simple distance buffer. The weighted function equation was calculated in three steps in Raster Calculator.

1. (Exp((“Distance to Water” layer) * 0.002) - 0.4)
2. Power ((“Equation 1 output”), -1)
3. (“Equation 2 output”) * 0.6

The resulting watercourse variable map ranges in value from 0.07 to 1; with a value of 1 representing the stream.

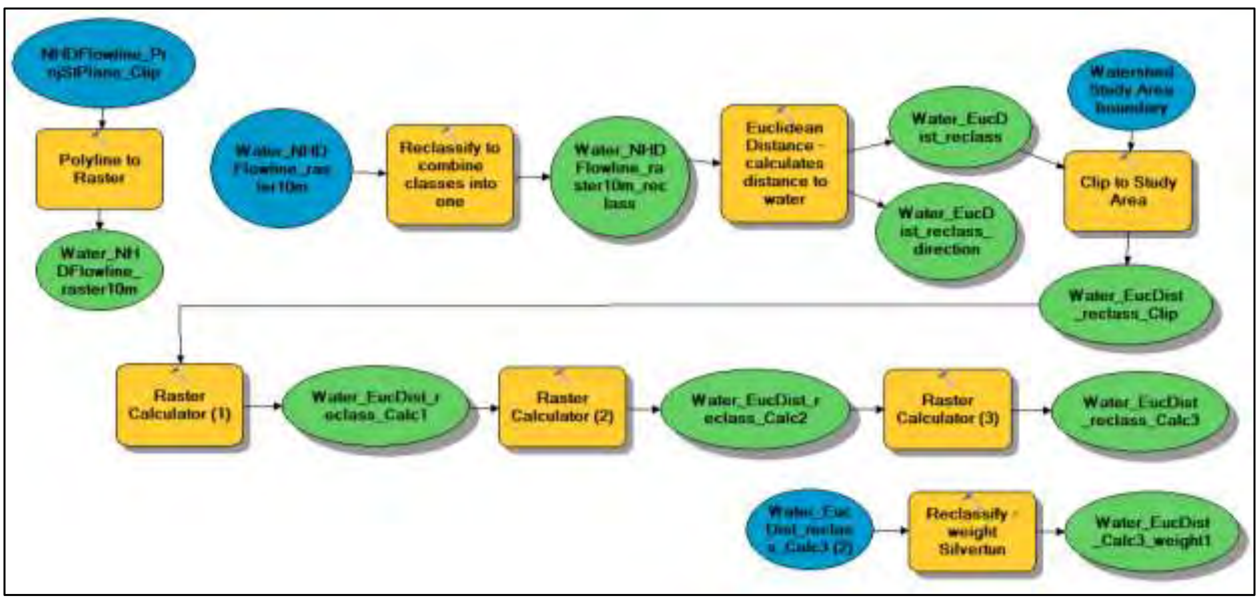


Figure 6. Workflow of the distance to water using Euclidean distance layer processing in ArcGIS.

Table 7. Identifies the weighted values assigned to the watercourse component map. The distance from water ranges represent the percent of sediment from each class that manages to reach the water (Silvertun and Prange, 2003).

Table 7. Values for the watercourse factor map based on Silvertun and Prange methodology.

Distance from Water	% of Sediment to reach the water	Watercourse Factor Values	GIS Value (Weight)
0-50m	100	0.6-1.0	10
50-200m	60	0.3-0.6	6
200-1000m	30	0.071634509-0.3	3
>1000m	0	0.071634509	1

As an alternate measure for the watercourse factor, NRPC created a distance factor that was based on flow length (Method 2). ArcGIS calculates flow length as the downstream distance along the flow path for each cell; since it uses flow accumulation as an input it is a measure that takes into account how the water would drain on the landscape versus using Euclidean distance as in Method 1.

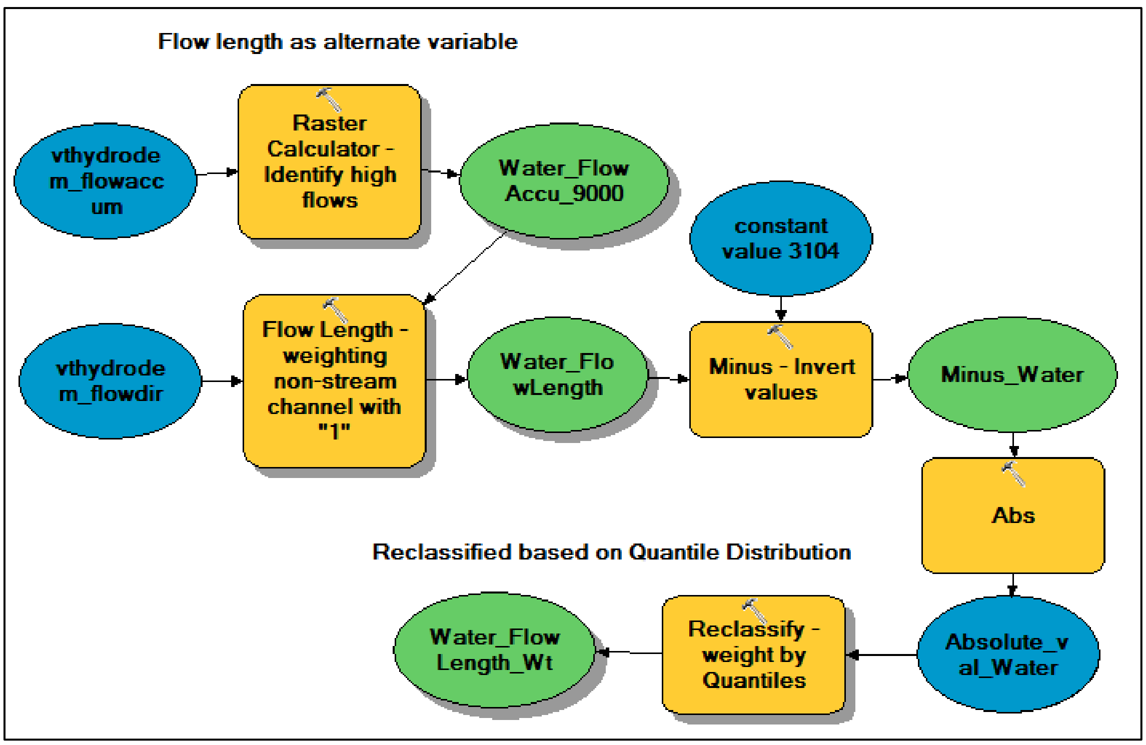


Figure 4. Workflow for the watercourse factor using flow length methodology.

Table 8. Values for the watercourse factor map based on flow length methodology.

Flow Length Value	GIS Value (Weight)
0.5056 - 1,655.7026	1
1,655.7026 - 2,215.5487	3
2,215.5487 - 2,690.2008	6
2,690.2008 - 3,104	10

Land Use/Land Cover (U): The base layer for the land use/land cover map will be the 2011 NLCD Land Use/Land Cover which has a 30-m resolution and 17 classes. NRPC reviewed additional data layers to use as input variables to further enhance the representation of the land cover following methods similar to Winchell et al. (2011, page 21). NRPC utilized a road data layer to further differentiate road categories that could have an impact on erosion.

- VTrans Road Centerline – Roads are currently represented in the NLCD layer as "urban" category or miss-classified. This layer will be integrated to distinguish between different classes of roads (paved and unpaved). The table below outlines the reclassification of roads in the VTransRoads2011 data layer.

New Layer Value	Road Surface Type	Original Value
1	Paved	1
2	Gravel	2
2	Soil or drained earth	3
2	Unimproved/primitive	5
2	Impassable/untraveled	6
2	Unknown	9

Figure 8 provides the Model Builder workflow in ArcGIS that was used to process the land use land cover data layer.

NRPC did review other data layers that could be used for enhancing classes, such as agricultural data and impervious surface layer. After initial review of the data we did not determine this to be necessary given the aims of the projects and the 2011 NLCD had a fair representation of on the ground classes based on visual inspection. The following is a description of the available data layers that were considered for enhancements:

- Enhancing the impervious surface cover utilizing the UVM Impervious Surface Layer (based on 2011 NAIP, 1m resolution) and the "Other Impervious" class of this dataset. This can aid in identifying additional developed land that is classified as non-developed in the NLCD data set.
- Agricultural land cover classes or cropland data could be further enhanced utilizing the annual outputs from the National Agricultural Statistics Service, Cropland Data Layer

that provides a crop-specific classification of land (30m resolution). For this study, annual data sets from 2010-2013 were reviewed to identify the typical crop type of a field during this timeframe. In this study area the majority of the sites did not show a lot of variation over this timeframe (i.e. crop rotation), therefore we did not do further enhancements to the agricultural classes. It should be noted that field based data, as was used in the Winchell et al. (2011) study was not publically available for use in this project.

The Land Use/Land Cover component, U, is based on a dimensionless ratio of soil loss from land under various cover and management conditions. The base values that each class was assigned, as shown in Table 9, was based on prior literature cited in Winchell et al. 2011.

Table 9. Land Use classes, the assigned coefficients and weights for the CSA analysis.

Class	Coefficient Value	Coefficient Source	GIS Value (Weight)
Developed, Med/High Intensity	0.11	Winchell et al. 2011	8
Developed, Low Intensity	0.07	Winchell et al. 2011	6
Developed, Open	0.05	Winchell et al. 2011	3
Roads, Paved	0.06	Winchell et al. 2011	3
Roads, Unpaved	0.06	Winchell et al. 2011	3
Agriculture, corn	0.15	Winchell et al. 2011	10
Agriculture, hay/pasture	0.08	Winchell et al. 2011	6
Forest	0.005	Sivertun & Prange 2003	1
Brush/Shrub	0.05	Winchell et al. 2011	3
Wetland	0.01	Winchell et al. 2011	1
Barren	0.06	Winchell et al. 2011	3
Water	0.00	Sivertun & Prange 2003	1

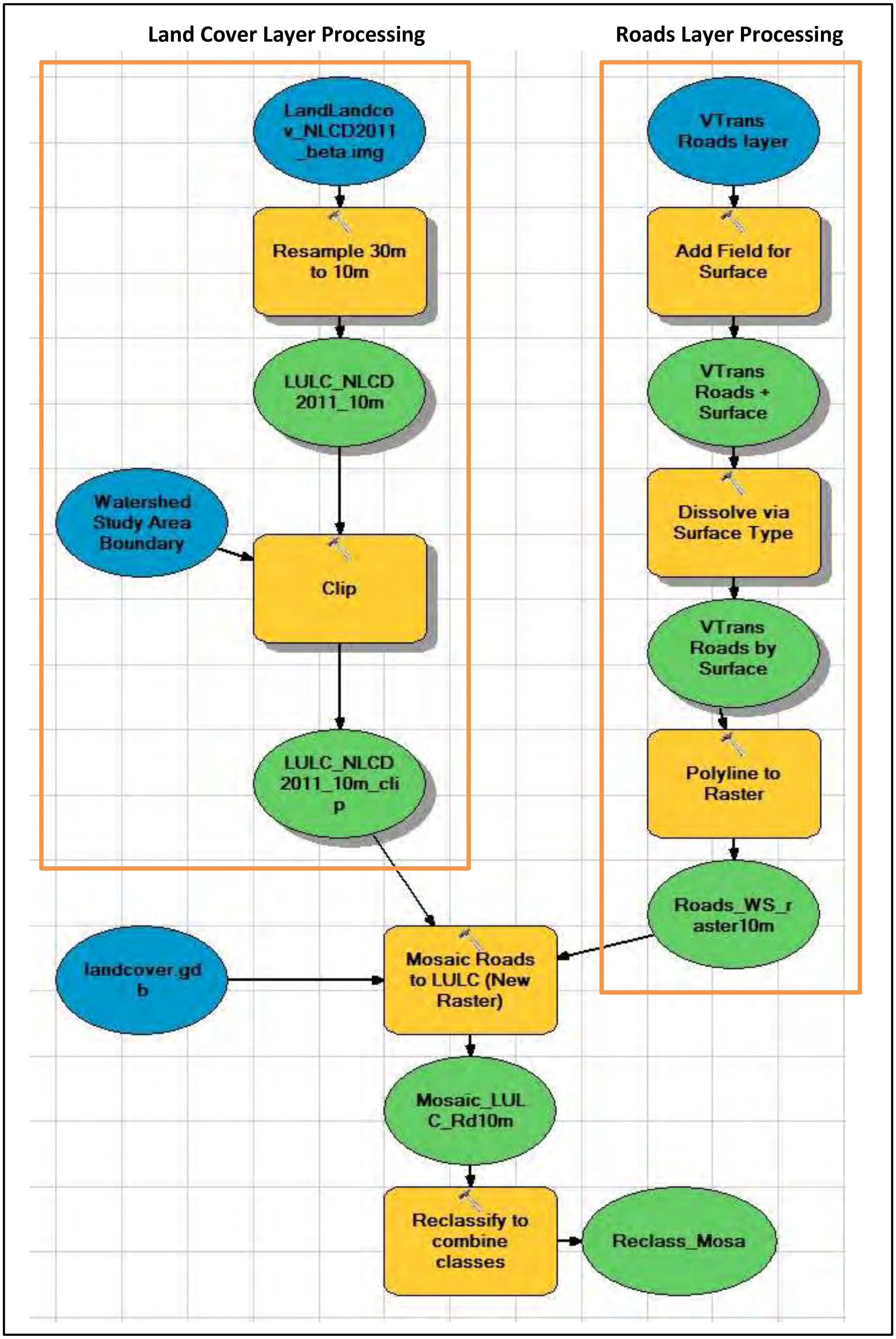


Figure 8. Workflow of land use land cover data layer processing in ArcGIS.

Component Weighting. Components were weighted to a common scale of 1 to 10; the higher the value the greater the influence the category could have on non-point source pollution.

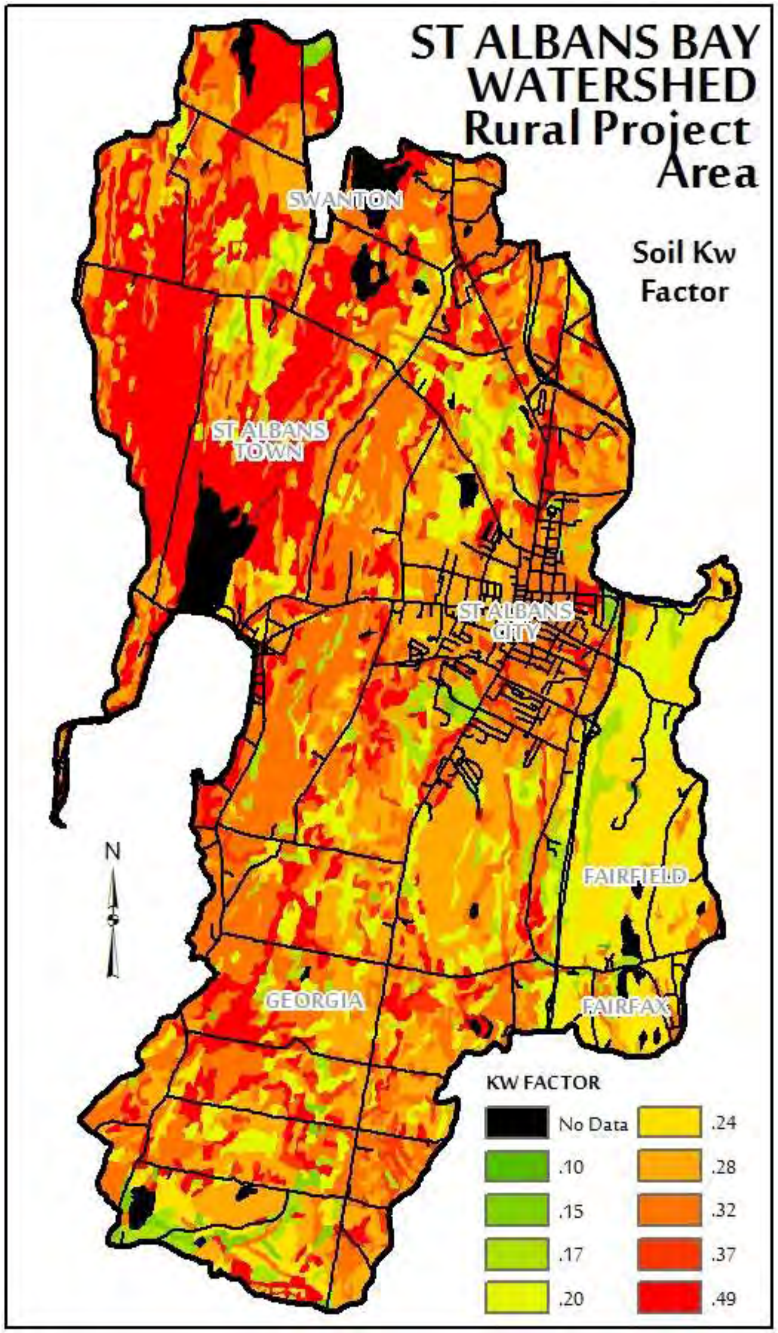
Results:

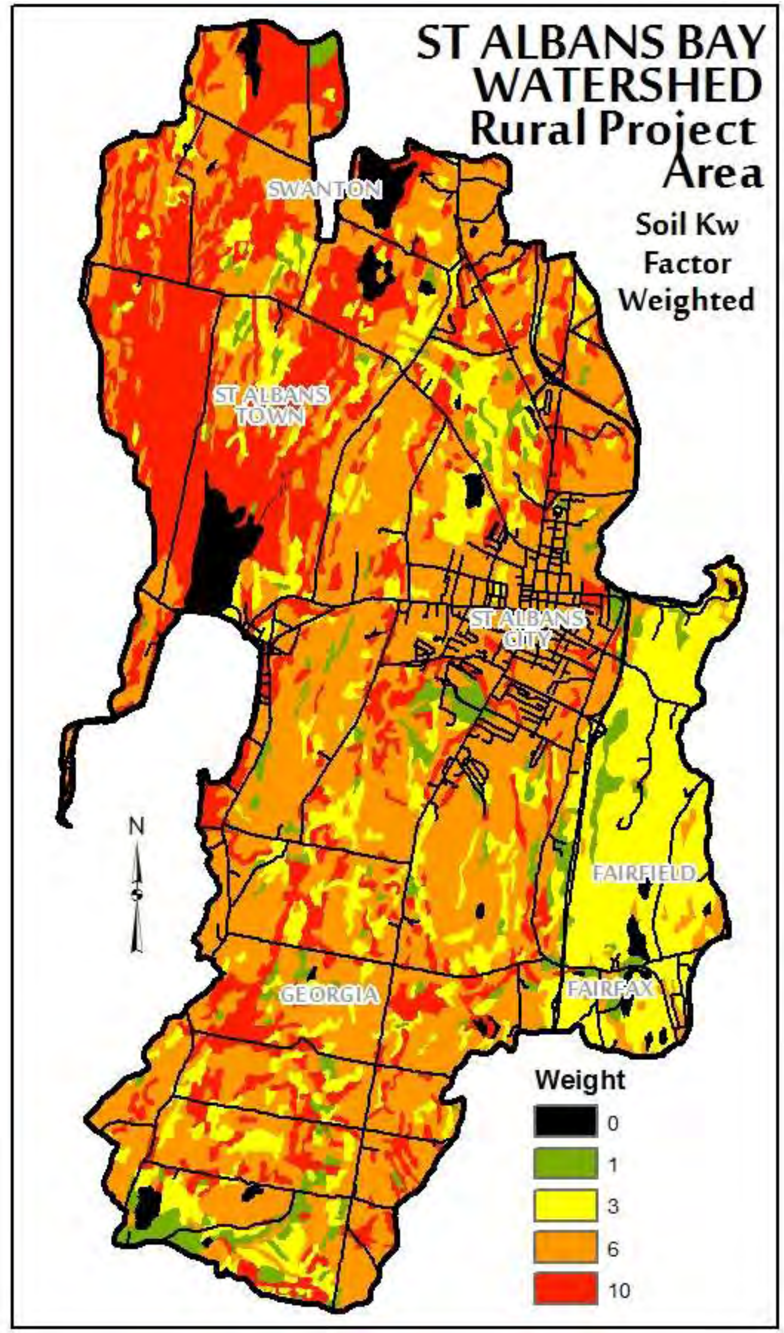
Individual factor maps have been generated and presented on the following pages; each factor is presented alongside the weighted map of the factor. From there the four factors put into a multiplicative equation. The final map class values were classified based on the standard deviation of the computed USLE values according to table below.

Type of Risk	Values
Low influence on water quality	Below Mean Value
Low Risk Area	0-1 S.D. above mean value
Moderate Risk Area	1-2 S. D. above mean value
High Risk Area	>2 S. D. above mean value

The USLE equation was run on non-weighted factors and two maps are presented to show the variation between the two methods for the Watercourse map. Overall the results between these two different features are very similar; differences mainly lie with the Low Risk Area. From visual analysis and comparisons of the non-weighted factors, High Risk Areas closely correspond to areas with steeper slopes and the watercourse factor for both methods. Given that the Watercourse factor map using Method 2 takes into account the direction the water would flow on the landscape given the topography versus the more buffered distance from the stream; the second method was preferred by NRPC as being a better representation of the on-the-ground conditions impacting erosion processes.

NRPC did run trials utilizing the weighted layers and found that the layers were fairly sensitive to the weights chosen. Given this part of the process is a subjective activity, sample results of the weighted analysis will be provided as a supplemental document.


ST ALBANS BAY WATERSHED
Rural Project Area
Soil Kw Factor
SWANTON
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
FAIRFAX
GEORGIA
N
KW FACTOR
No Data
.10
.15
.17
.20
.24
.28
.32
.37
.49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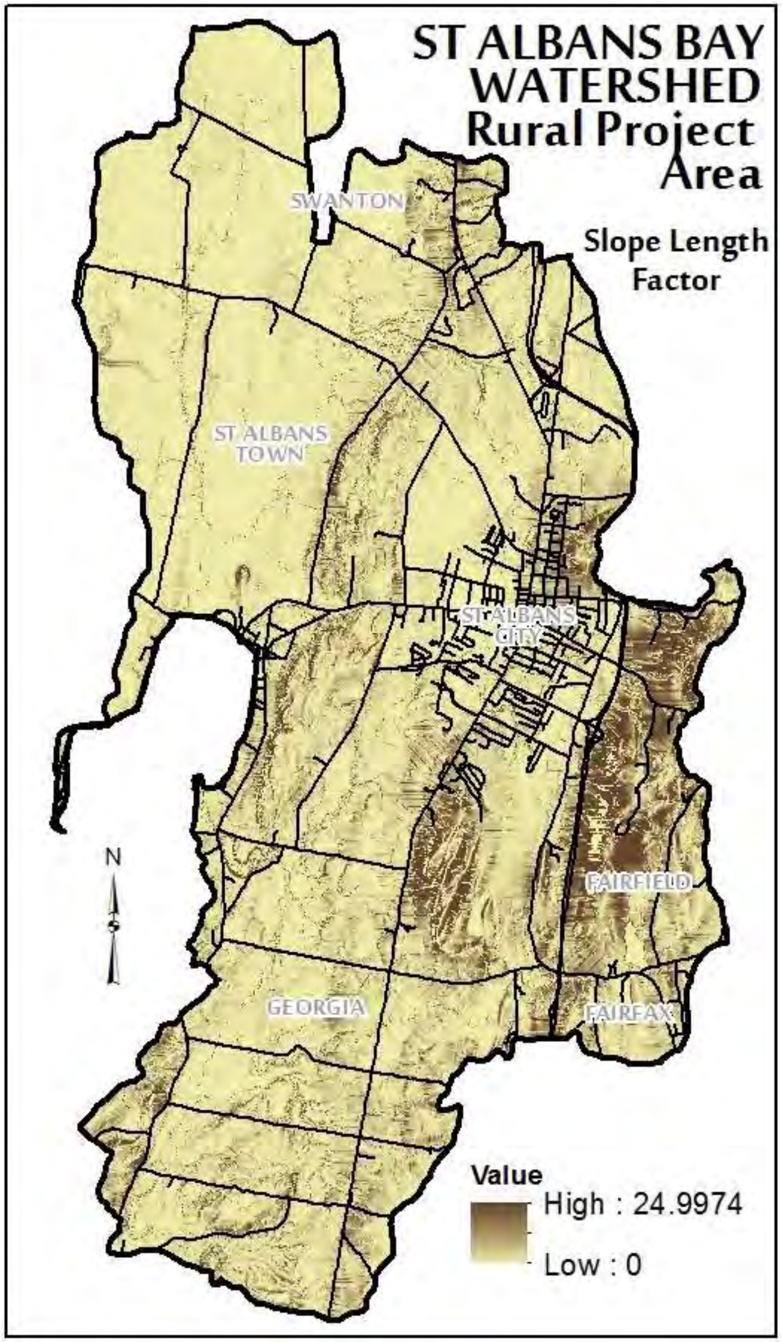
Rural Project Area
Soil Kw Factor Weighted
SWANTON
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
FAIRFAX
GEORGIA
N
Weight
0
1
3
6
10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Rural Project Area
Slope Length Factor
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ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
GEORGIA
FAIRFAX
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Value
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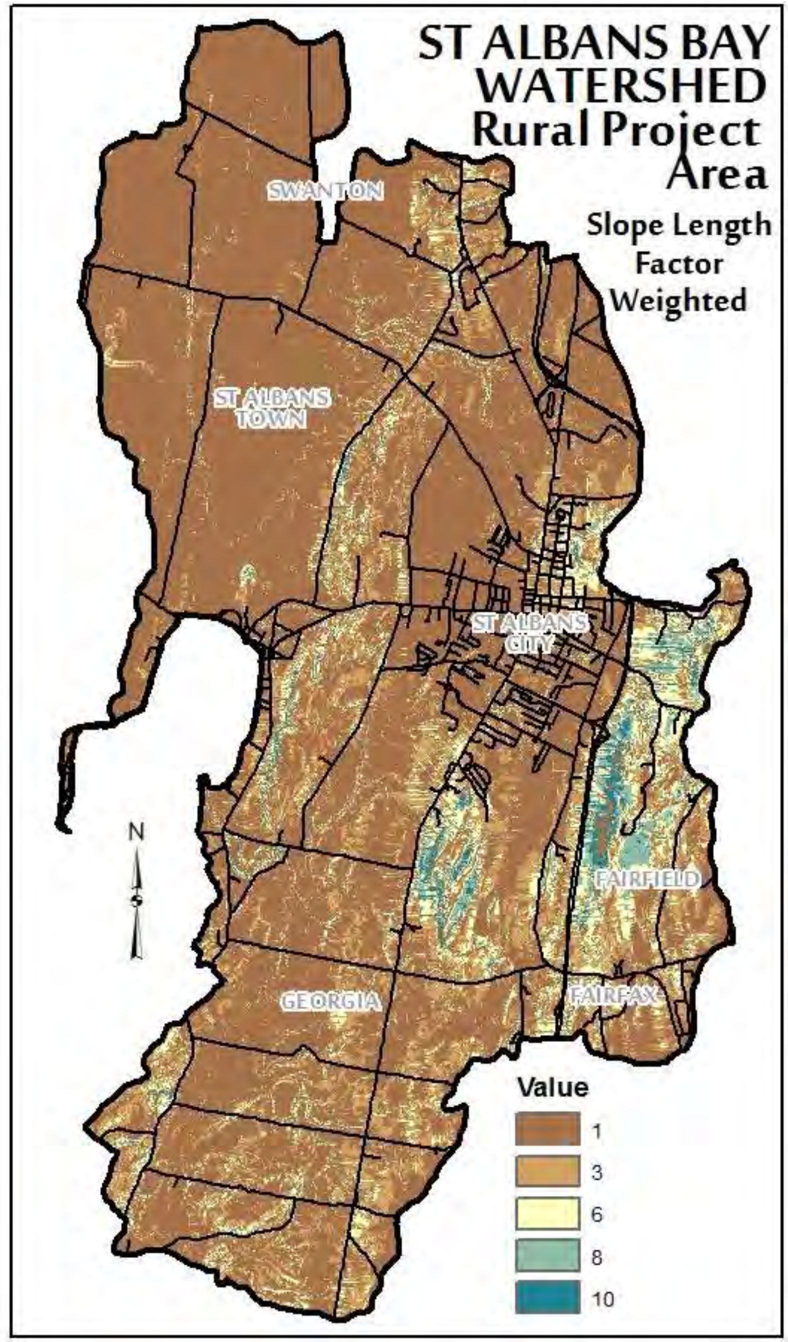
Low : 0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Rural Project Area
Slope Length Factor Weighted
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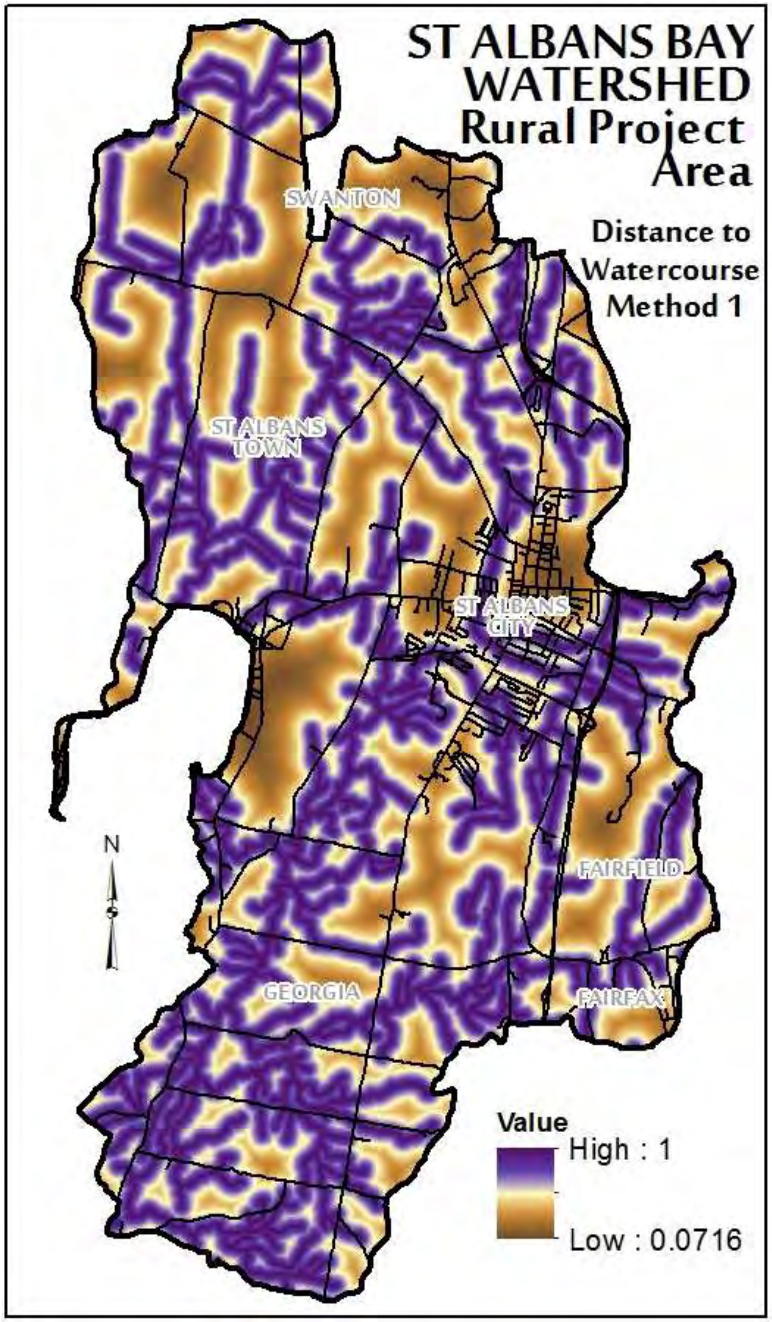
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
GEORGIA
FAIRFAX
N
Value
1
3
6
8
10


ST ALBANS BAY
WATERSHED
Rural Project
Area
Distance to
Watercourse
Method 1
SWANTON
ST ALBANS
TOWN
ST ALBANS
CITY
FAIRFIELD
GEORGIA
FAIRFAX
N
Value
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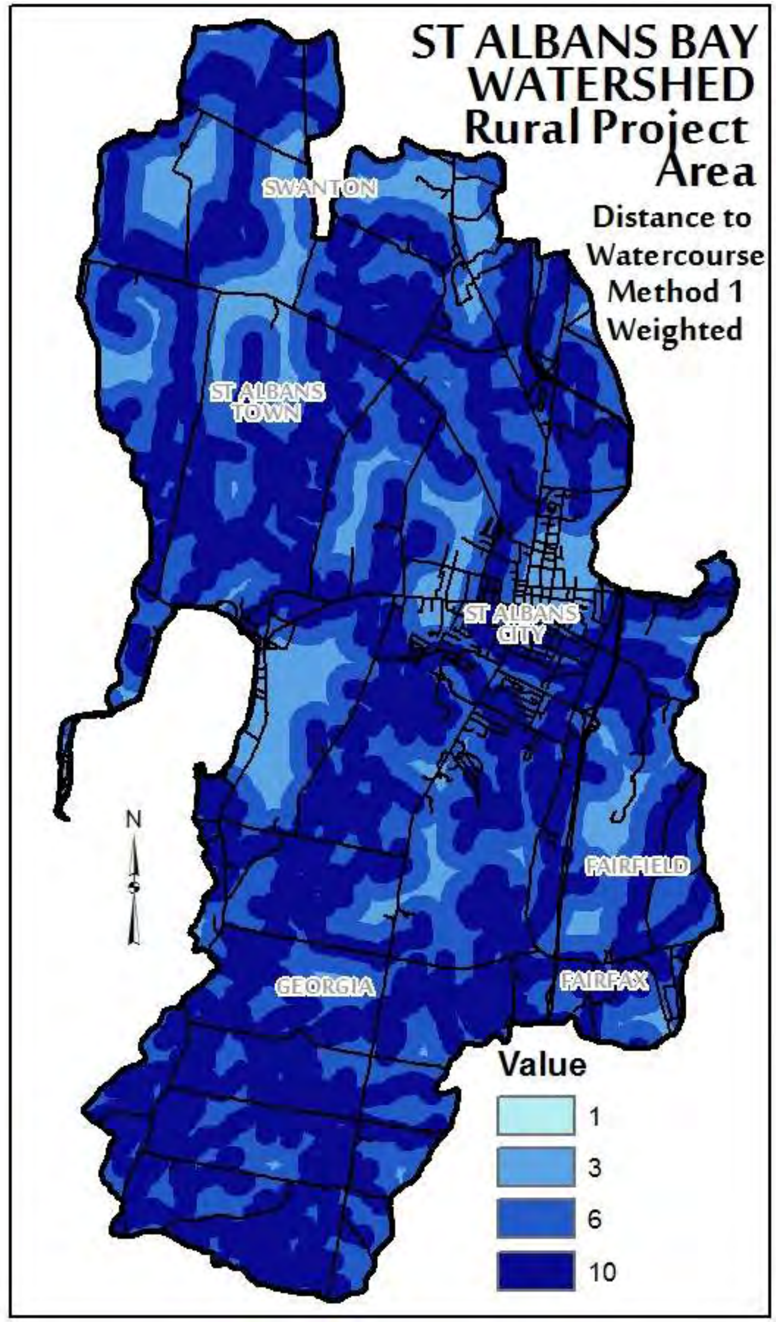
Low : 0.0716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WATERSHED
Rural Project
Area
Distance to
Watercourse
Method 1
Weighted
SWANTON
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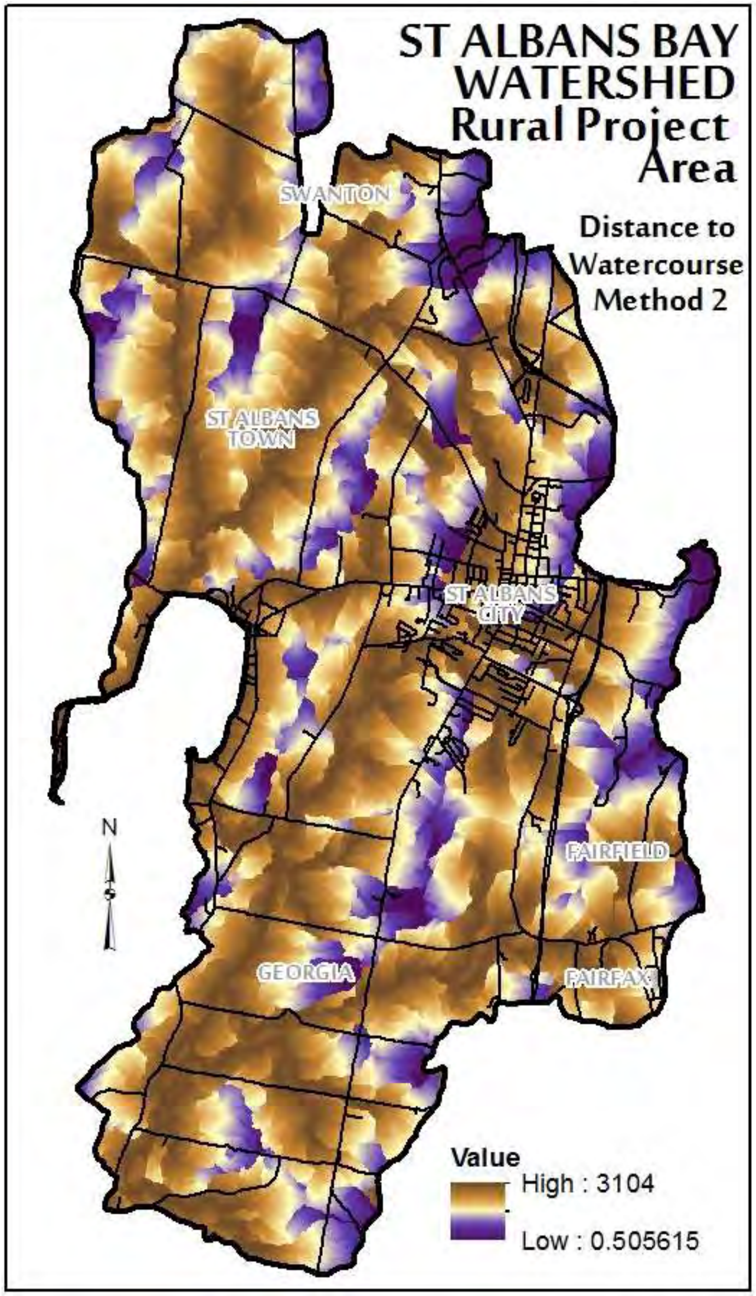
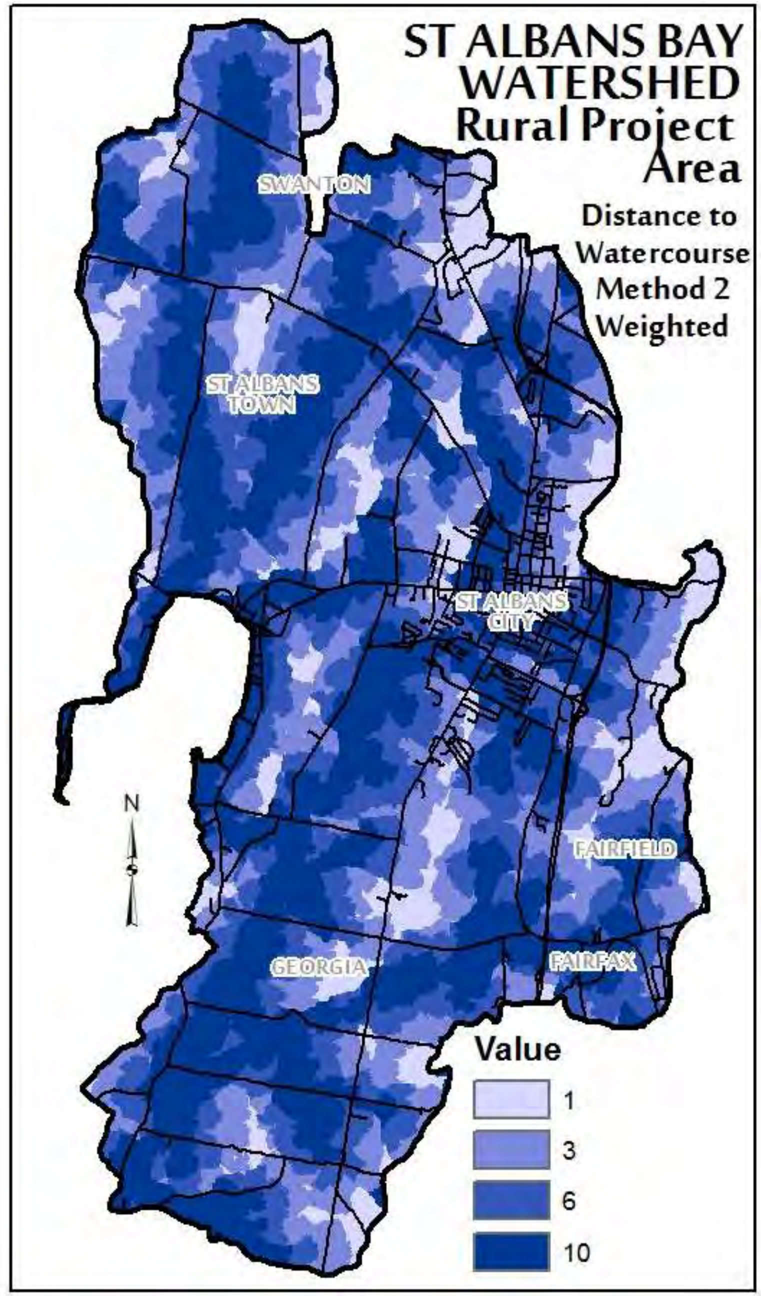
TOWN
ST ALBANS
CITY
FAIRFIELD
GEORGIA
FAIRFAX
N
Value
1
3
6
10


ST ALBANS BAY
WATERSHED
Rural Project
Area
Distance to
Watercourse
Method 2
SWANTON
ST ALBANS
TOWN
ST ALBANS
CITY
FAIRFIELD
GEORGIA
FAIRFAX
N
Value
High : 3104
Low : 0.505615


ST ALBANS BAY
WATERSHED
Rural Project
Area
Distance to
Watercourse
Method 2
Weighted
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CITY
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FAIRFAX
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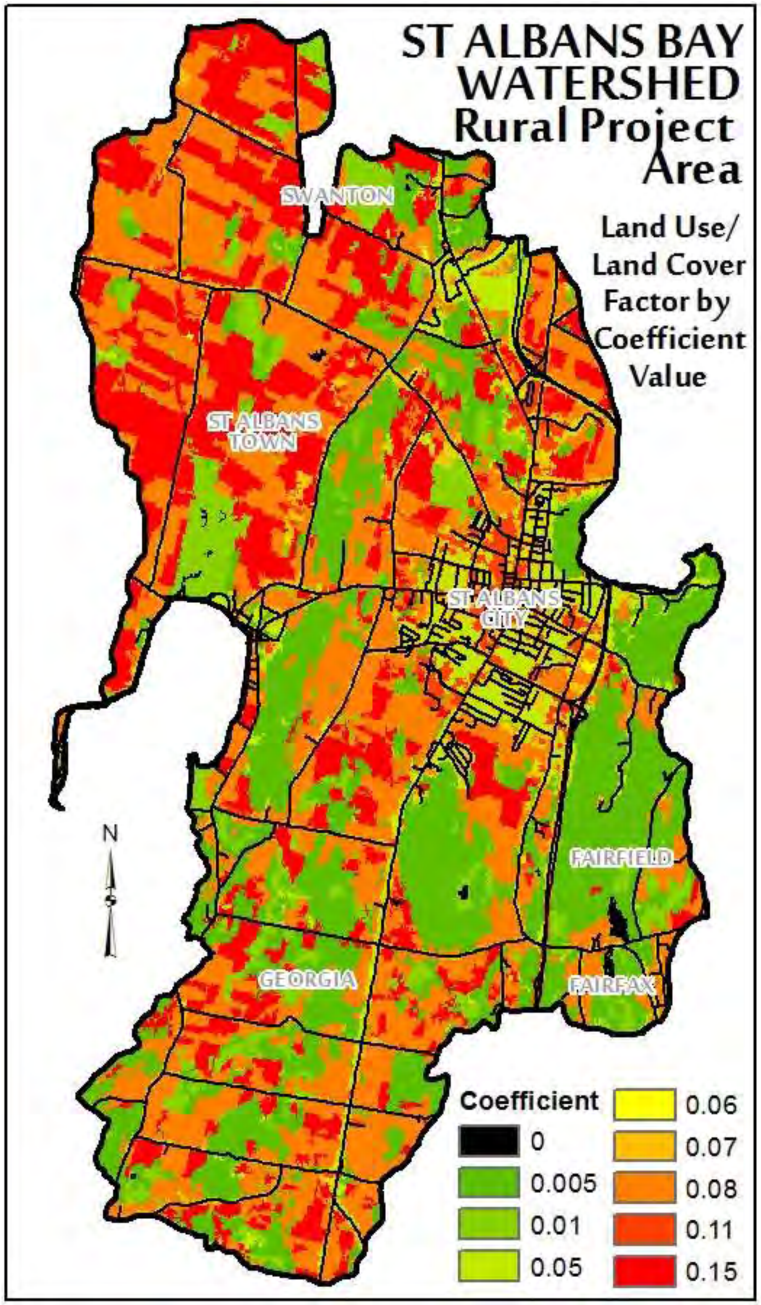
ST ALBANS BAY
WATERSHED
Rural Project
Area
Land Use/
Land Cover
Factor by
Coefficient
Value
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ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
GEORGIA
FAIRFAX
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Coefficient
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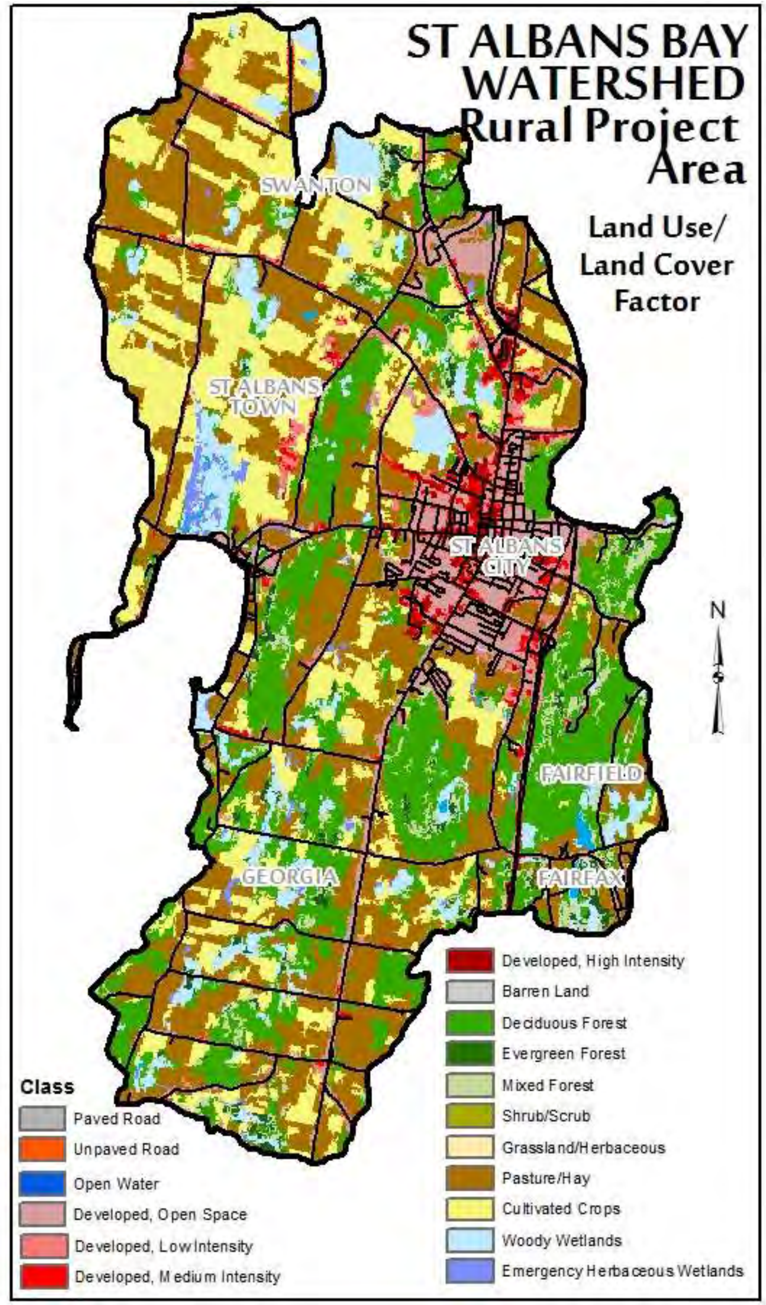
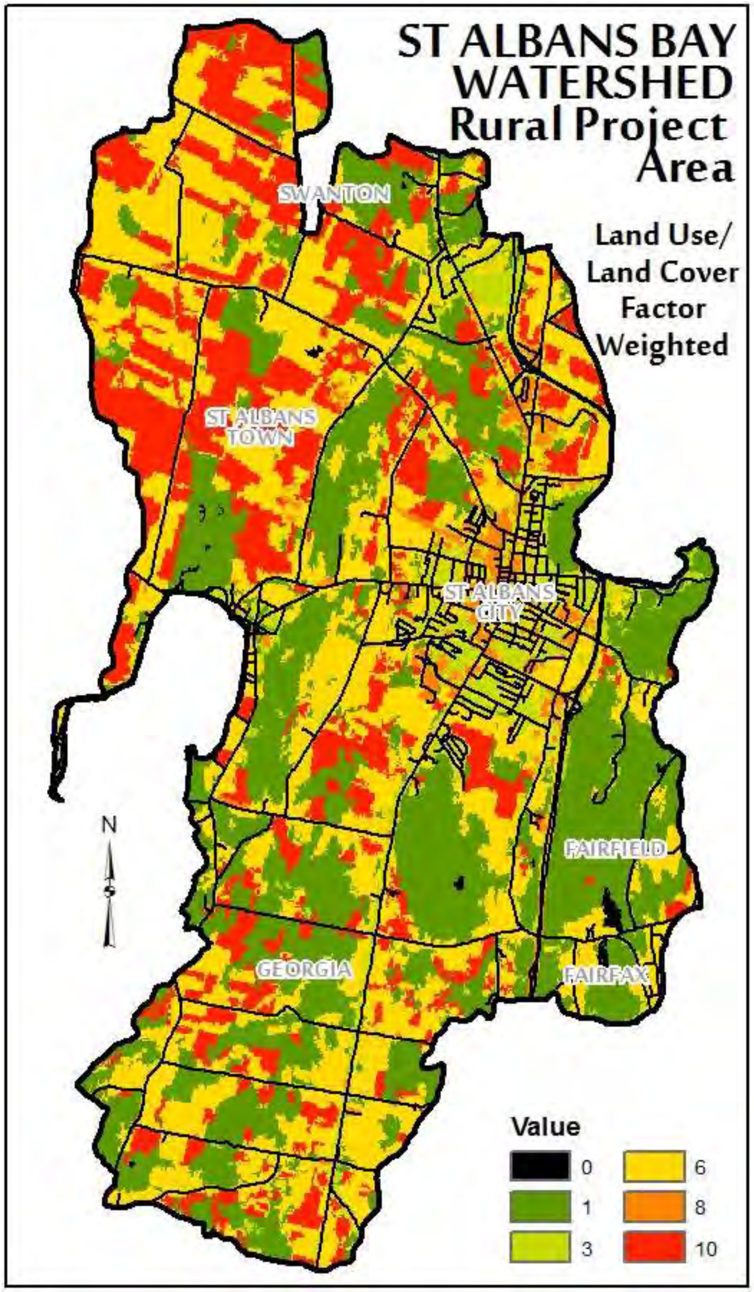
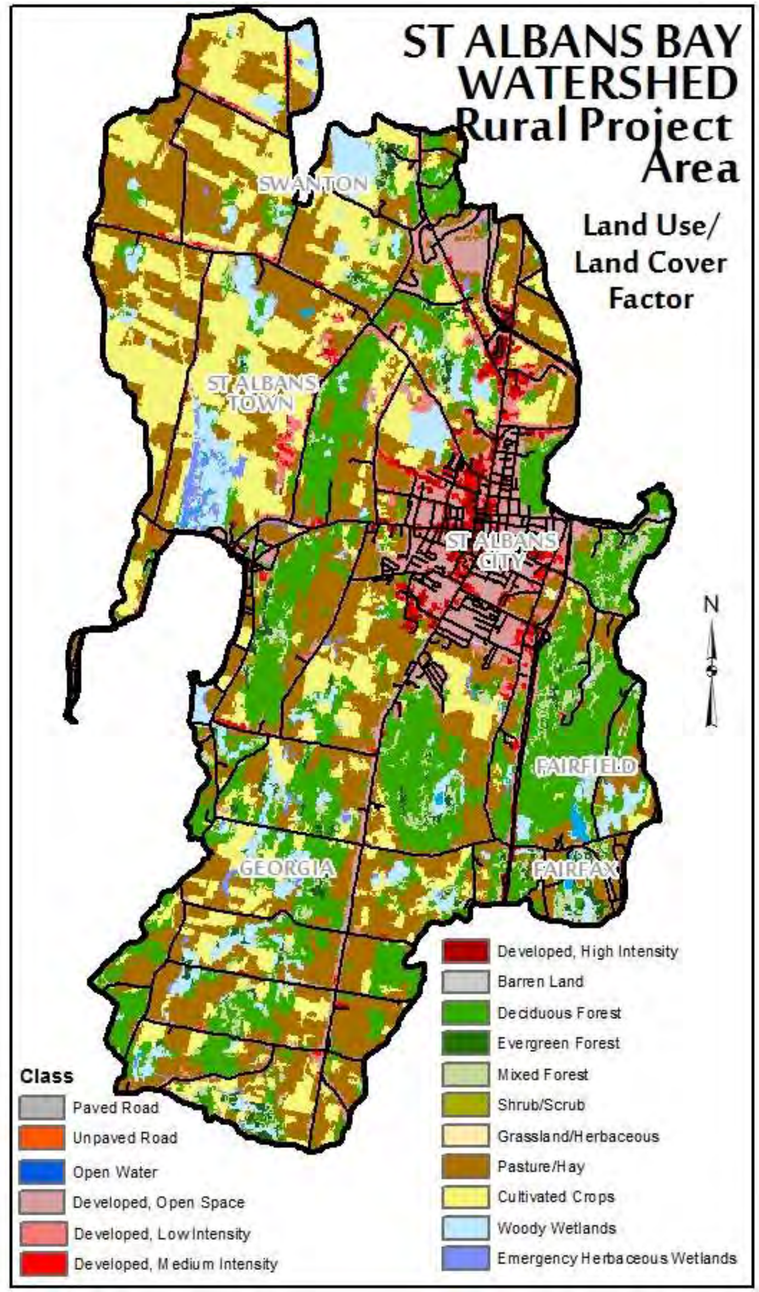

ST ALBANS BAY
WATERSHED
Rural Project
Area
Land Use/
Land Cover
Factor
SWANTON
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
GEORGIA
FAIRFAX
N
Class
Paved Road
Unpaved Road
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergency Herbaceous Wetlands


ST ALBANS BAY WATERSHED
Rural Project Area
Land Use/ Land Cover Factor Weighted
SWANTON
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
FAIRFAX
GEORGIA
N
Value
0
1
3
6
8
10


ST ALBANS BAY WATERSHED
Rural Project Area
Land Use/ Land Cover Factor
SWANTON
ST ALBANS TOWN
ST ALBANS CITY
FAIRFIELD
FAIRFAX
GEORGIA
N
Class
Paved Road
Unpaved Road
Open Water
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergency Herbaceous Wetlands

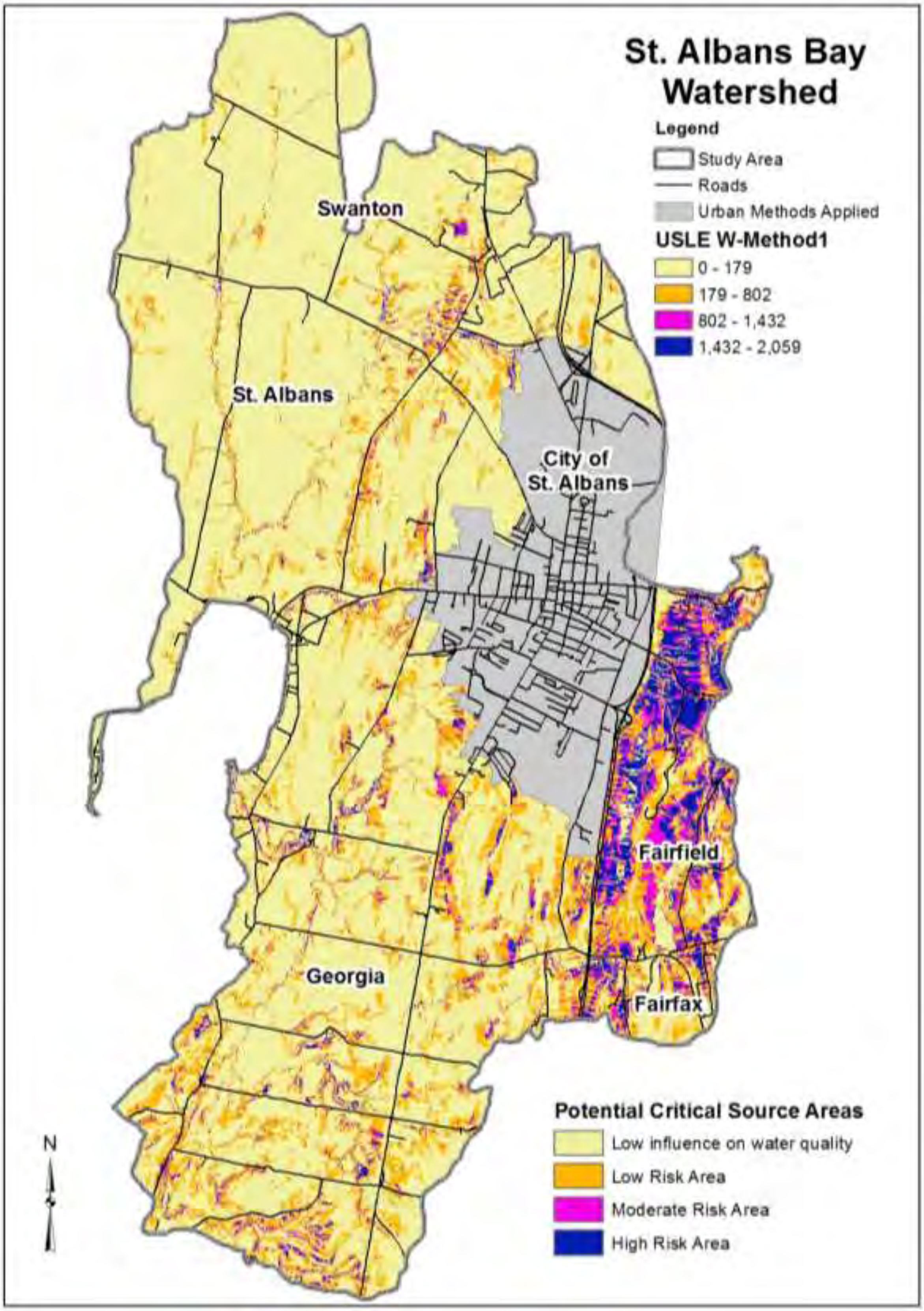


Figure 9. Results of USLE analysis with Watercourse Factor Method 1.

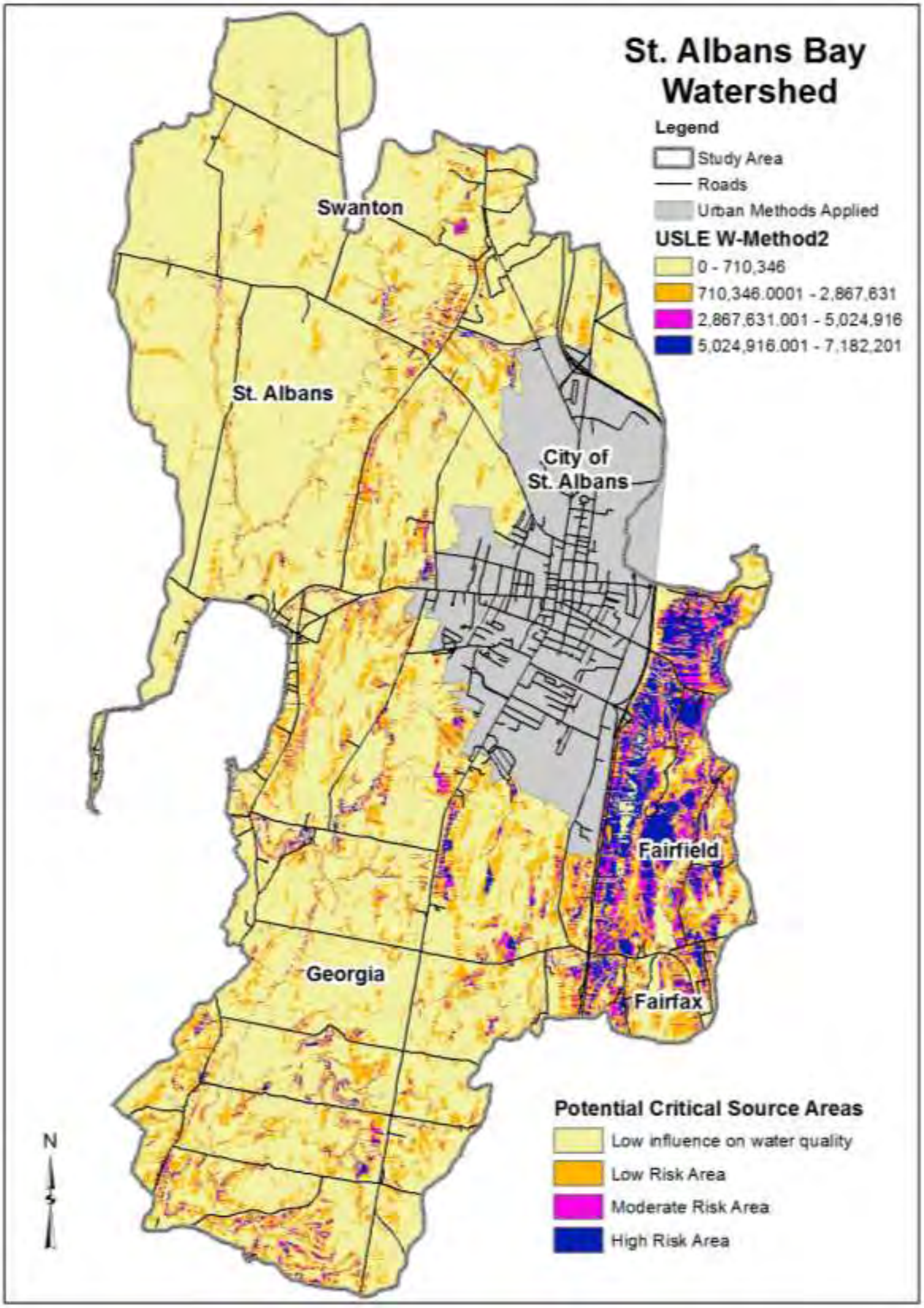


Figure 10. Results of USLE analysis with Watercourse Factor Method 2.

PART III.B. DEVELOPED METHODOLOGY

In the areas identified as “developed”, a different methodology based on pollutant loading with stormwater runoff will be applied to account for the differences in the how the urban landscape functions. For the majority of the watershed we were able to use sediment as the predictor of potential critical source areas (see “rural” methodology); however mapping of soils in urban areas is not as reliable due to fill and land disturbance during development. In addition, the hydrology is different in an urban environment with the addition of areas of impervious surfaces and the integration of storm drains and other infrastructure that captures and directs runoff on the site.

In the developed areas NRPC will utilize the **Simple Method** to map potential critical sources areas for phosphorus. This technique can similarly be processed using minimal inputs in an ArcGIS or a similar spatial environment along with some external data processing in Excel. The Simple Method produces an estimation of annual stormwater pollutant export that may be delivered from small urban developed sites; it is intended for sites less than one square mile in area (Schueler 1987, 2007).

As stated previously “developed” areas will be defined as the City of St. Albans and development surrounding the City in Saint Albans Town, the extent of this area will primarily be defined based on the availability of the sub-watershed mapping outlined in the methodology. There will be some residential development that will fall outside the developed area in Swanton along Route 7 that does not have delineated sub-watersheds and will therefore fall under the “rural” methodology.

The outcome of this proposed methodology does produce an estimated pollutant loading (TSS or P) in pounds per year. The resulting map of loadings per sub-watershed will serve as a tool to identify areas of higher potential pollutant loadings.

<u>Methodology (Inputs, Equation):</u>

The model is based on four main inputs – rainfall, percent impervious surface, phosphorus concentration and sub-watershed area. Sub-watersheds will be the unit of scale for this analysis and are discussed further below. This methodology is utilized by VT DEC’s stormwater division. These factors will go into the following equation:

$$\mathbf{L = [(P * Pj * Rv)/12) * C * A *2.72}$$

Where **L** is an annual pollutant load (lbs/yr) for a sub-watershed, **P** is average annual rainfall depth (in), **Pj** is the fraction of rainfall events that produce runoff, **Rv** is a runoff coefficient, **C** is the mean concentration of phosphorus (mg/l), and **A** is the area of the sub-watershed (Schueler 1987, 2007).

Inputs

- **Average Annual Rainfall (P)**: P is the average annual rainfall for the St. Albans area and was defined as **32.4 inches**. This is the constant used by DEC in their 2009 Stormwater Mapping Project in St. Albans.
- **Fraction of rainfall events that produce runoff (Pj):** This is a correction factor to account for the fraction of rain events that do not generate stormwater runoff. Precipitation from smaller storms may evaporate or infiltrate. Prior studies identified that 90% of the rainfall produce runoff. Therefore, Pj should be set at **0.9**
- **Runoff Coefficient (Rv):** Rv is a value derived from the amount of impervious cover (I) on the sites (expressed as a percent of total area). Rv is calculated with the following equation: **Rv = 0.05 + 0.009*I** where I would be 60 if the site is 60% impervious. This equation is based on the linear relationship that the ratio of rainfall to runoff has with impervious cover.
- **Pollutant Concentration (C):** This is the event mean concentration of the stormwater pollutant of concern. This value is set at **0.5 mg/l** for the study (per conversation with J. Pease, VT DEC).
- **Area of the sub-watershed (A):** This is a data layer that combines previously mapped spatial layers into one dataset. Area is calculated in acres. The sources of the data layers included: sub-watersheds delineated by Andres Torizzo (Stevens Brook FRP 2013, Town of St Albans Stormdrain Mapping 2011), the 2009 DEC mapping in the City and Town of St Albans, and a 2005 state Sub-watershed layer of impaired waters. The base layer was developed in ArcGIS from the most recent data layer (2013) and the remaining layers will be used to expand the coverage of this layer with the priority given to the more recent layers.

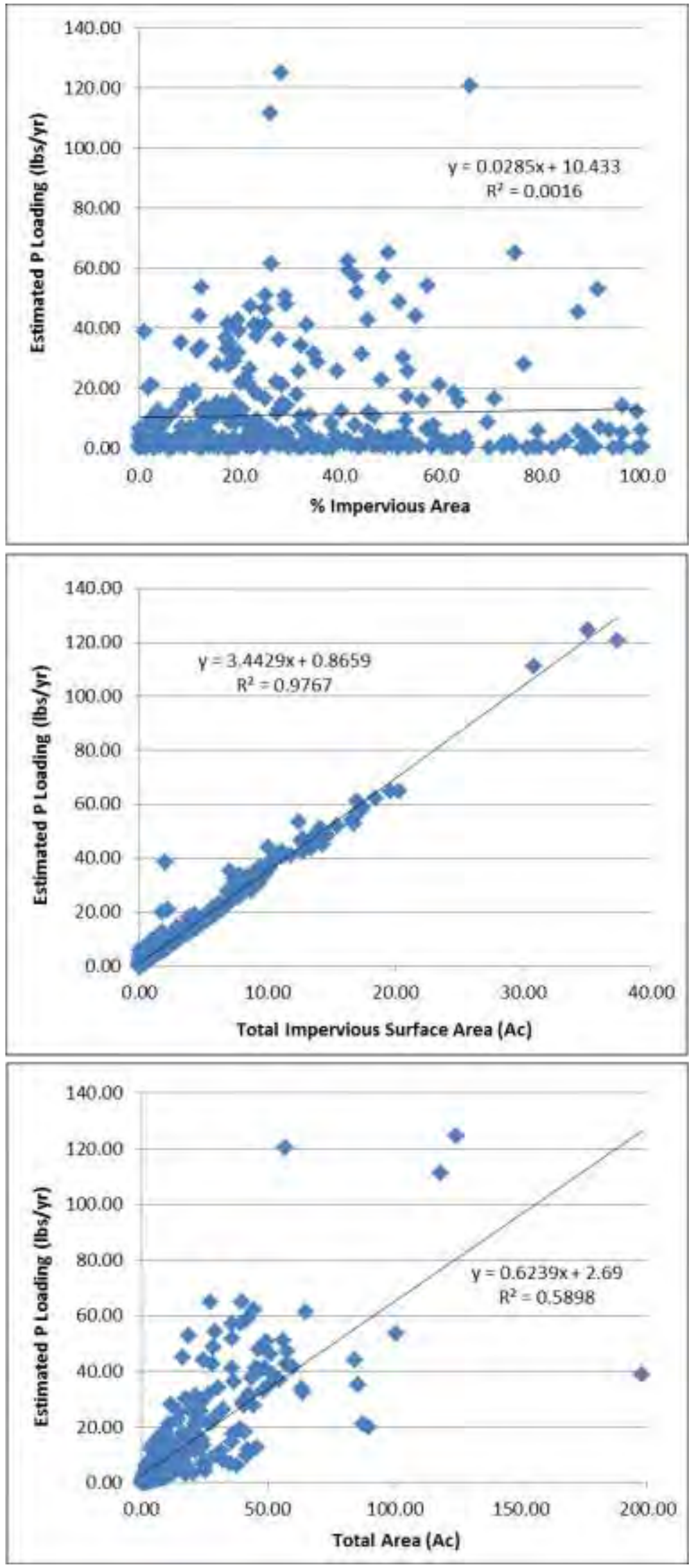
Results:

The first step was to create a single sub-watershed data layer for the concentrated area of development in the watershed which is St Albans City and the immediate surrounding area. This resulting layer of the City and surrounding area involve a total land area of 4,660.63 acres and have 336 sub-watersheds delineated. Using a mapped impervious cover layer (2011), the percent impervious cover for each sub-watershed was calculated. This data was brought into Excel to run the Simple Model analysis (see separate Excel table with supplemental deliverables). The Simple model provided an estimate of the potential phosphorus loading for each sub-watershed. The results show that areas of higher annual phosphorus loading do closely correspond to areas with higher amounts of impervious surfaces. Maps of the analysis are provided below.

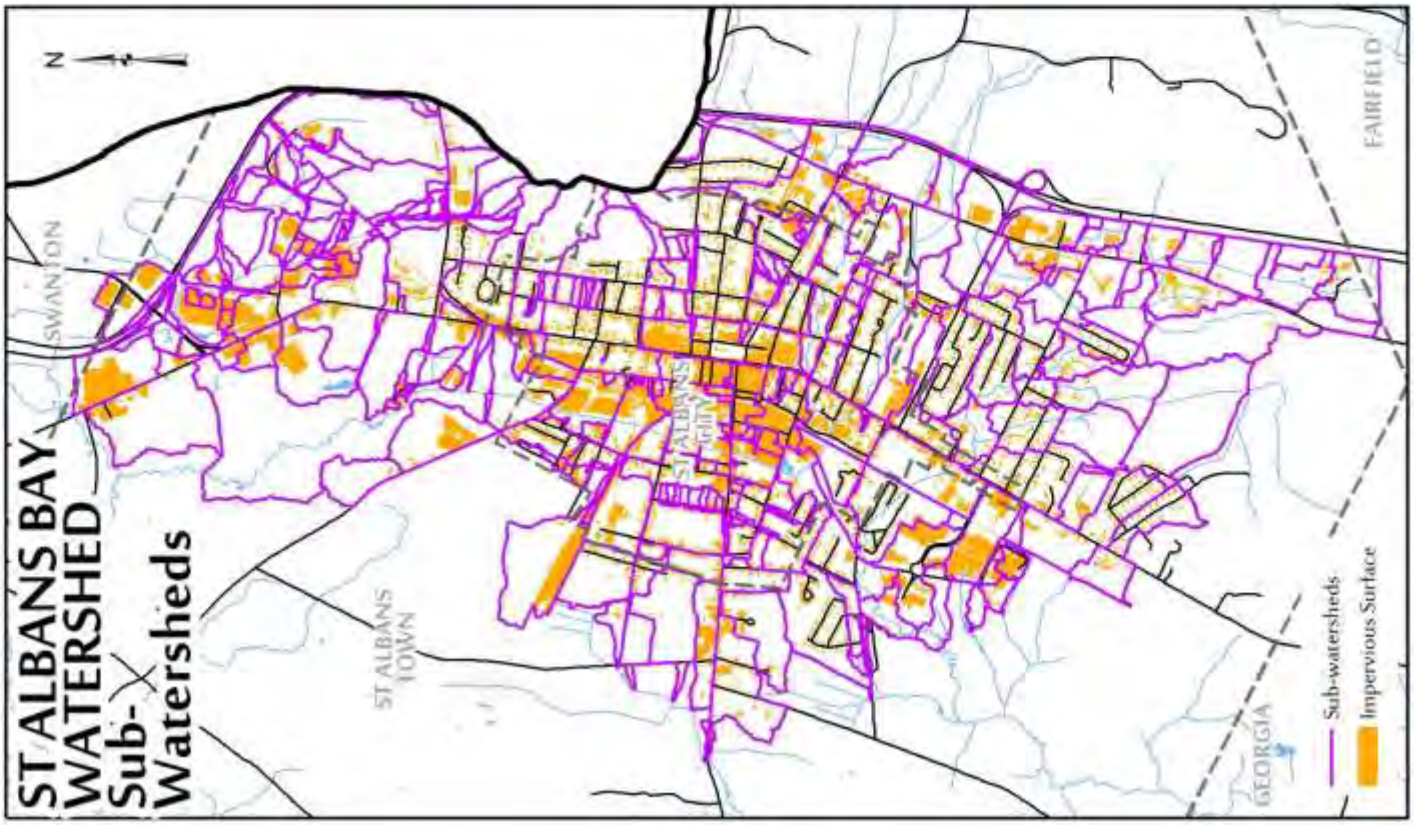
Of the inputs to this calculation, all but two variables are constants; the variables that change are percent impervious cover and total area per sub-watershed.

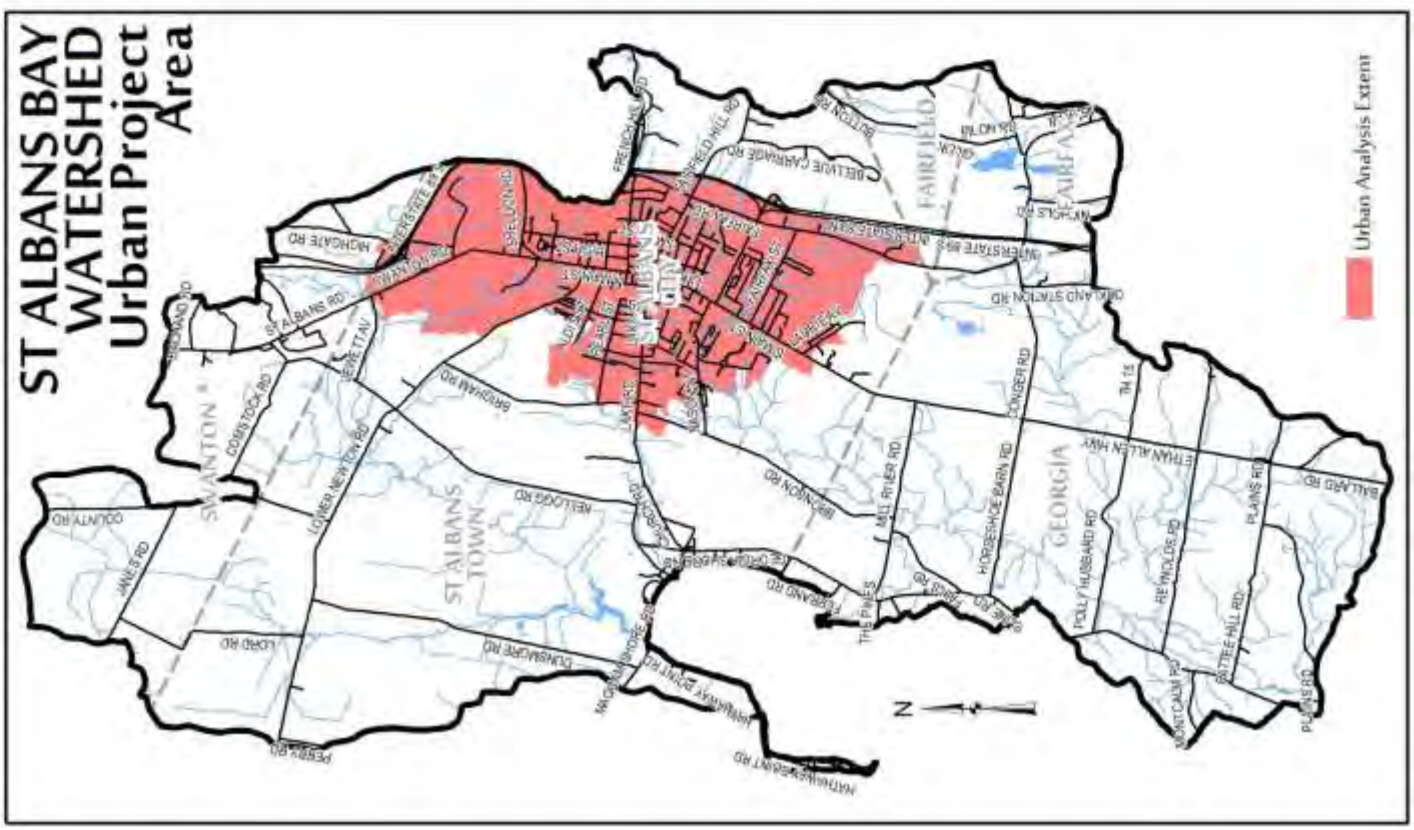
The graphs on the right show the sub-watershed relationship of the estimated phosphorus loading to the percent impervious area (top graph), total impervious area (middle graph), and total sub-watershed area (bottom graph). The factor that has the largest influence on the estimated P loading is the total area of impervious surface per sub-watershed as shown in the middle chart to the right.

Based on the relationship identified above, as a future step for this analysis the delineation of sub-watersheds and impervious cover should be reviewed for updates. The sub-watersheds used should be evaluated to identify if any can be combined; this layer was created from different data sources and the sub-watersheds vary in the level of detail used for delineation. Impervious cover is another layer that should be updated; the data that mapped impervious cover was from 2011 and does not capture newer development such as the Walmart parcel. Using the Simple Method, a change in the amount of impervious area in a watershed will



impact the total loading therefore having accurate delineations of sub-watersheds will provide better estimations of pollutant loading. Once more recent data is available, this analysis could be rerun.


ST ALBANS BAY
WATERSHED
Sub-
Watersheds
Sub-watersheds
Impervious Surface
ST ALBANS CITY
ST ALBANS TOWN
SWANTON
GEORGIA
FAIRFIELD


ST ALBANS BAY
WATERSHED
Urban Project
Area
Urban Analysis Extent
ST ALBANS CITY
ST ALBANS TOWN
SWANTON
GEORGIA
FAIRFIELD

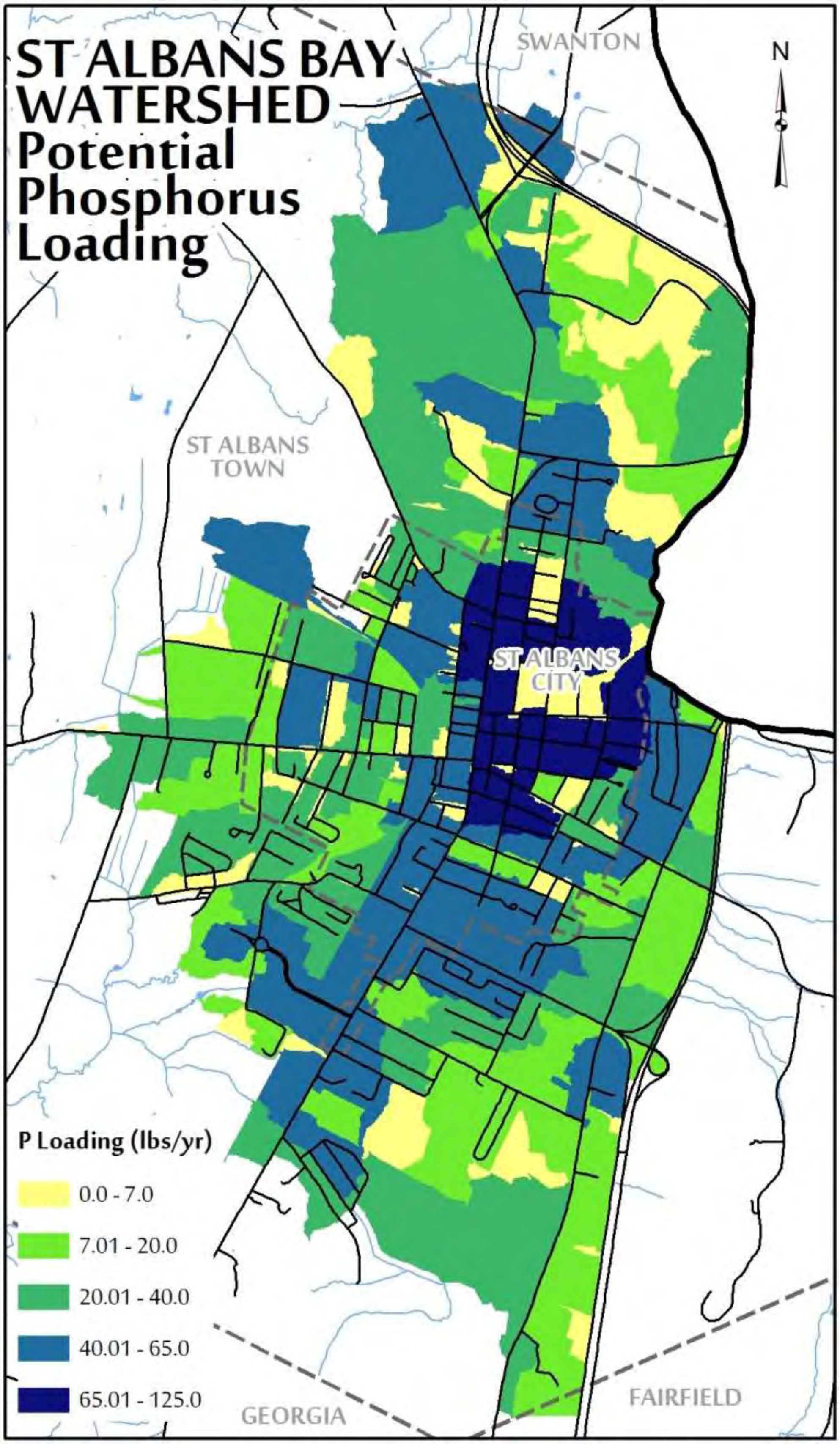


Figure 11. Results of developed methods analysis.

Assumptions, Strengths and Weaknesses of CSA Methodologies:

Overall

Neither of these methods account for preexisting and properly functioning non-point source controls (best management practices) that may be in the watershed. To run the analysis it is assumed that no controls are in place and so this factor should be noted when using this analysis to visit the sites of high potential risk.

Rural Methodology

Based on the studies that have used GIS to employ a modified USLE analysis, several strengths and weakness have been identified. Some of the strengths include the relative ease of conducting the factors in the analysis can be modified to account for available data layers and modifications to incorporate updated data can be easily made (Siverun and Prange 2003). This methodology provides a low cost option for doing a broad analysis and the results can be used to determine where more detailed study can be done.

Winchell et al. (2011) found the results of the GIS analysis compared to a SWAT model were heavily influenced by land use classes. They did find that the results of the GIS analysis compared well for the land use classes of denser urban and forested areas; they also noted agricultural classes as well but utilized a more data intensive method to refine classes than proposed here. Winchell et al. (2011) noted the stronger influence by the land use factor given that their soil factor was based on soil texture only and incorporating other soil factors such as percent organic matter may further inform P loading. Mattheus and Norton (2013) also noted that with a modified USLE the land-cover factor exerted a strongest control on soil-erosion model variance, their coefficient values ranged from 0 to 1. This analysis did not find land use to be a dominant factor influencing the analysis outcome; this could be accounted for in differences in how the hydrology was utilized in the model. Winchell et al. (2011) used a different input source to method 1 by deriving an 'enhanced hydrologic network' to feed into the distance equation. In addition they were able to process and utilize the finer resolution lidar data for use in deriving a water factor and the slope factor as well.

It should be noted that soil survey information for developed areas may not accurately represent the "on the ground" conditions due to the potential for fill to be brought in when the site was developed. Given that this methodology is not being applied to the dense urban areas, this should have a minor impact on the accuracy of the results.

Developed

Similar to the rural methodology being employed, the Simple Method also has the strength of being able to compute general planning estimates from relatively simple inputs. The main limitation that should be noted for this application is that the Simple Method pollutant load estimates refer only to loads derived after a storm event and do not consider pollutants associated with baseflow volume. Therefore it is not a measure of total pollutant load from an area. It should be noted that there is a strong relationship between total pollutant loading and the total amount of impervious surface in a sub-watershed.

Predicting Erosion from Rural Roads:

The Central Vermont Regional Planning Commission has developed a spatial desktop analysis to identify road segments that are more susceptible to erosion and sedimentation. This analysis is based on identifying the presence or absence of five individual constraints along 100ft segments of Class 3 and Class 4 roadways. NRPC ran this analysis in the study area to compare road segments that are identified as having a high number of constraints to the rural development risk map; this analysis was proposed to provide a general indication of the sensitivity of the modified USLE analysis for non-point source pollution from roads. It should be noted that none of the constraints used in this analysis were used in Part 2 of the analysis so a future actin could be to overlay this road analysis with the earlier results as a way to further prioritize road related water quality projects.

Methodology (Inputs, Analysis):

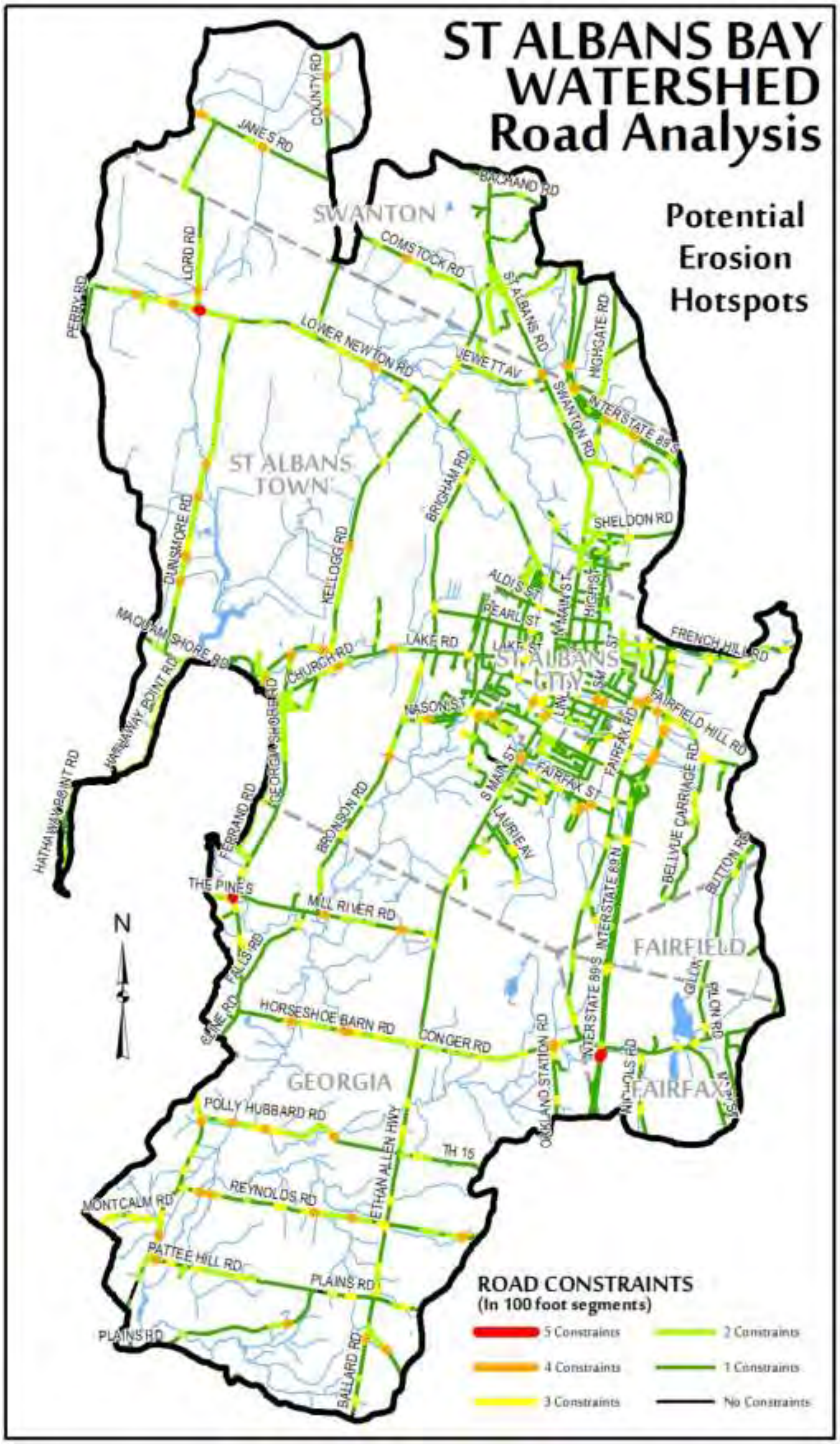
A layer of class 3 and 4 roads for the study area was derived from E911 Roads Centerline layer; roads were segmented into 100-ft sections for the analysis. Road segments were evaluated for the presence or absence of five factors along the segment – direct intersection with a stream, proximity to stream (within 50 feet), proximity to wetland (within 50 feet), steep slopes and erodible soils. If a constraint is present along the segment than it is assigned a value of 1; the potential for erosion likely to impact water quality increases based on the total number of constraints encountered (maximum of 5 constraints per road segment).

Table 2: GIS constraints analysis parameters

Constraint	Criteria or Threshold	Data Source
Stream Crossing	Road/Stream Intersection	Vermont Hydrography Dataset (VHDCARTO, 2010)
Stream Buffer Width	Within 50 feet	Vermont Hydrography Dataset (VHDCARTO, 2010)
Class 2 Wetland Buffer	Within 50 feet	Vermont Significant Wetlands Inventory (VSWI, 2010)
Slope	Road Rise/Run > 15%	LiDAR Dataset (University of Vermont Spatial Analysis Lab, 2009); will utilize DEM derived for Rural Methodology
Soil Erodibility	"Highly Erodible Soils" or Kw factor > 0.36	Natural Resource Conservation Service (NRCS) Soil Survey (Geologic_SO, 2011)

Results:

The Rural Roads analysis was conducted on all road types and can be utilized to compare results of areas with high erosion risk in the rural area analysis. For results of this analysis, see map to the right. When comparing the road segments identified by the analysis, there are some similar areas highlighted from the rural analysis such as the intersection of Lower Newtown Road and Lord Road in St Albans and a few other areas. The areas that are similar may be explained by the inputs of the analyses. Many of the potential road erosion hotspots are calculated from water based factors (stream crossing, buffers, etc) and in the Rural methodology the Watercourse factor had a higher influence on the results.



Conclusion:

This report summarizes three related project efforts starting with a compiled list of previously recommended non-agricultural projects that address non-point source pollution. The project then completed an inventory of current road related stormwater projects outside the stormwater impaired watersheds using a GIS-based analysis on known conditions of the infrastructure. And the final piece of the project was to conduct a GIS-based analysis of potential critical source areas at the watershed level. This report has outlined the methodology taken to develop all variables used in the different sections of the project to allow for replication and additional manipulation of the information to further refine the analysis.

The results of the review of prior studies in part one of this project, identified a list of projects that should be revisited by the municipalities and partners as potential implementation projects or actions. The database created can also be used to track the stage that the project may be in and reasons it may be determined to be unfeasible in the future so that this information is captured in a single document.

The inventory analysis completed for the second part of the project identified a need for obtaining more current data on infrastructure; both the culvert inventories and stream geomorphic assessments were dated and either did not have condition data or it was likely no longer current. NRPC assisted the Town of Georgia in updating their culvert inventory in 2014 and plans to aid the Town of Swanton in the near future to develop an inventory. Given this analysis is based on a quick assessment of the data, as more current data becomes available this analysis can easily be re-run to assist in prioritizing infrastructure for replacement and upgrades that will also improve water quality in the watershed.

For the rural methodology critical source areas analysis, NRPC would advise running this analysis again when higher resolution, hydrologically corrected, elevation data is available. As noted earlier, it was anticipated that this project would utilize a lidar dataset with a 1.6m resolution. However, this data was not hydrologically corrected and therefore was not appropriate for calculating the slope length factor. This analysis was run with 10-m resolution elevation data however this is not sensitive enough to capture ditches and other finer scale features that have impacts on sedimentation from erosion activities. Additionally the land cover data is based on a 30-meter resolution; information such as field boundaries on farmland could be incorporated into this layer to improve the land cover differentiation between cropland and hay/pasture classification.

As stated in the outset of this report, these methods in Part 2 and 3 of this report are being proposed to aim for a methodology that is applicable to a wide range of users such as watershed planners and coordinators with readily accessible data. This methodology can be used to point to areas of possible risk or the high potential for phosphorus non-point source pollution. This methodology is also built to allow for future modifications as newer data becomes available or portions of the methods need to be changed to fit conditions present in a different region of the state.

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