Sediment Loss Hot Spot Mapping

To Watershed Transformation

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Identify areas in a rural and an urban subwatershed which are the most vulnerable to sediment loss

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Identifying sediment source areas would help prioritize restoration activities within a subwatershed to help reduce sediment and sediment-bound contaminant (e.g. total phosphorous) loadings to the receiving water courses and Lake Ontario.

Study Areas

Rural and Urban

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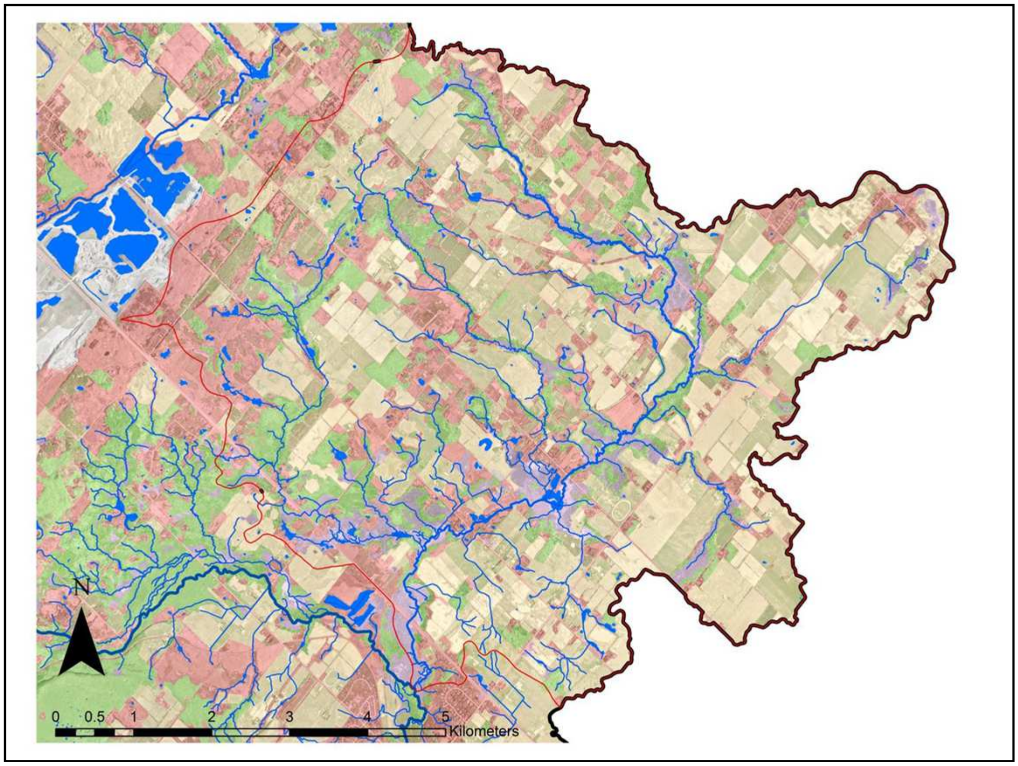
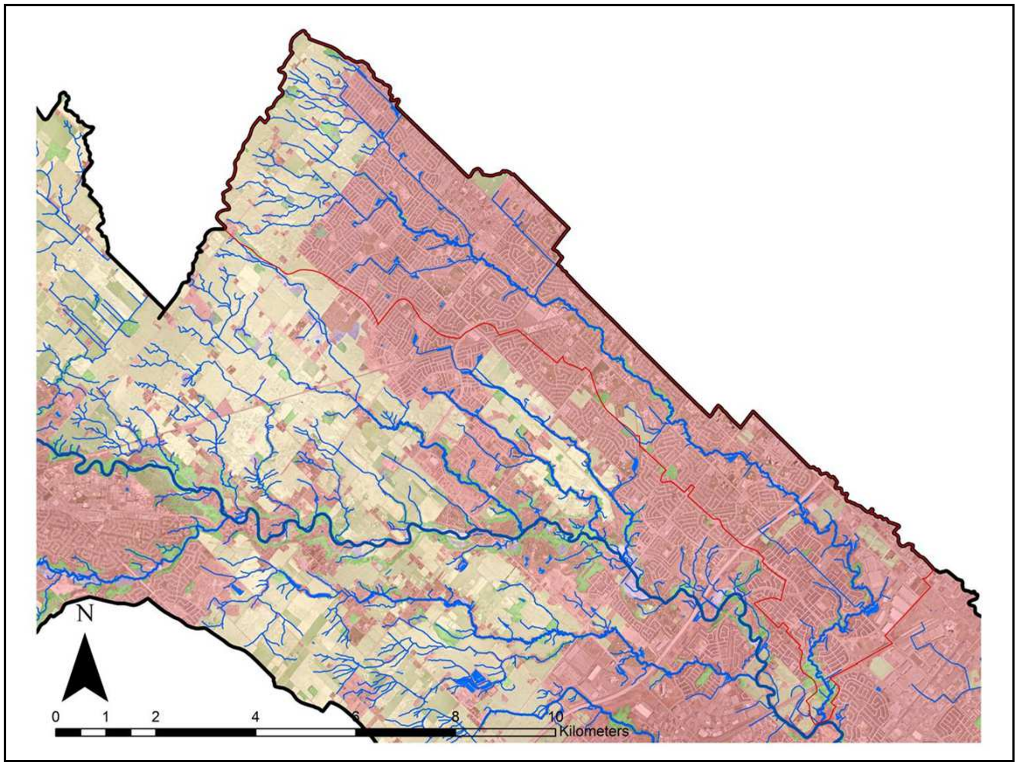
In this first iteration, two subwatersheds were used as study areas; one rural and one urban.



The East Credit River, roughly 50 km^2, was used as the rural subwatershed. It is mostly made up of agricultural land (shown in tan on this map), with some green space (shown in green on this map), and some developed land (shown in red on this map). No major urban centres exist in this subwatershed, and the primary water quality stressors are related to agricultural (nutrient) runoff.



Fletcher's Creek, roughly 50 km^2, was used as the urban subwatershed. It is mostly made up of developed land (shown in red on this map), with some agricultural areas (shown in tan on this map) in the upper reaches. The land-use is mostly residential, and the primary water quality stressors are related to stormwater runoff.

Methodology

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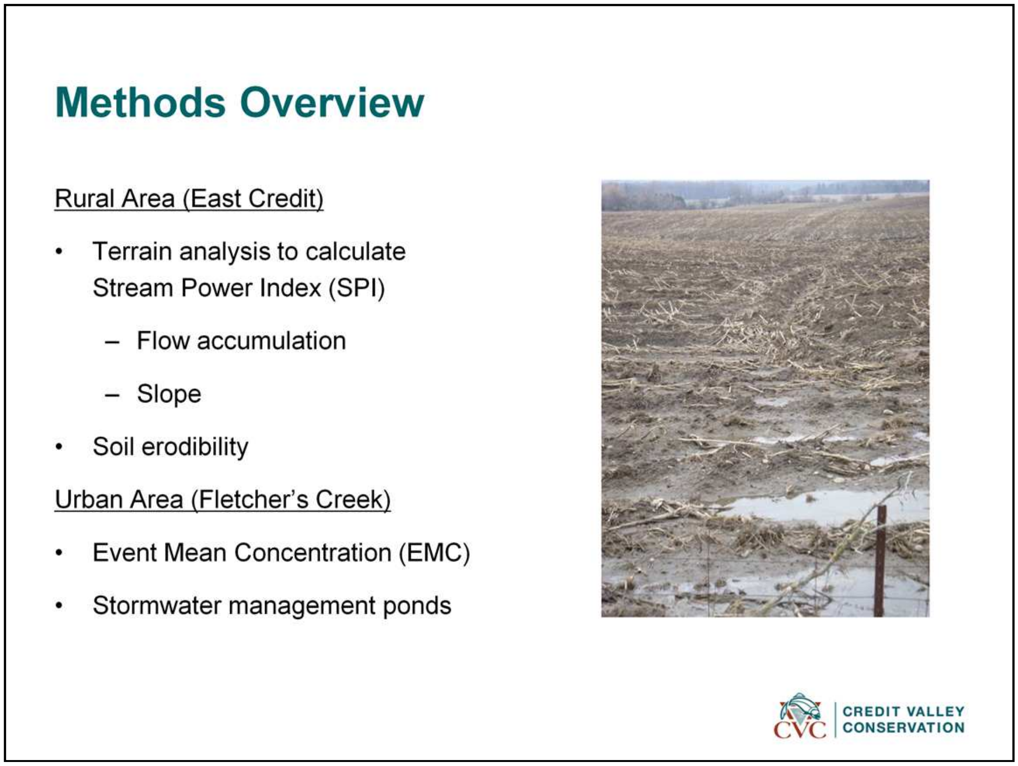

Given the differences between the two study areas different approaches were required to identify hotspots in each subwatershed.

In the East Credit River, runoff from agricultural areas is the primary source of sediment to receiving water bodies. As a result, we want to identify agricultural areas which are most vulnerable to erosion. Erosion comes in many forms including gully erosion, where small channels are formed which collect and runoff and mobilized sediment. The methodology applied in the East Credit River was designed to identify areas where gullies are most likely to form. A GIS terrain analysis was used to calculate stream power index (SPI) based on flow accumulation and slope. The restoration prioritization based on SPI was then augmented by the underlying soil type.

In Fletcher's Creek, stormwater runoff from urban land-uses is the primary source of sediment to receiving water bodies. In this subwatershed event mean concentrations (EMC) based on land-use were used to identify areas predicted to have the highest sediment contribution. This predicted contribution was reduced in areas serviced by stormwater ponds.

The details of both of these methods will be explained in the following slides.

East Credit River

Rural area – sediment loss from agricultural fields

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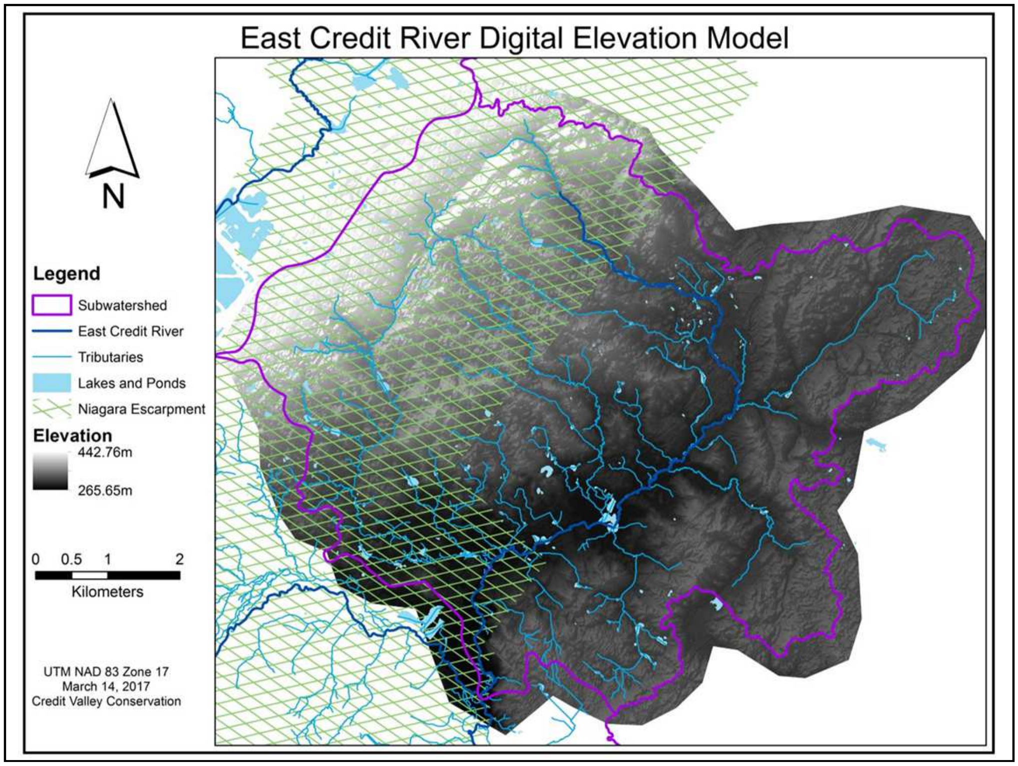
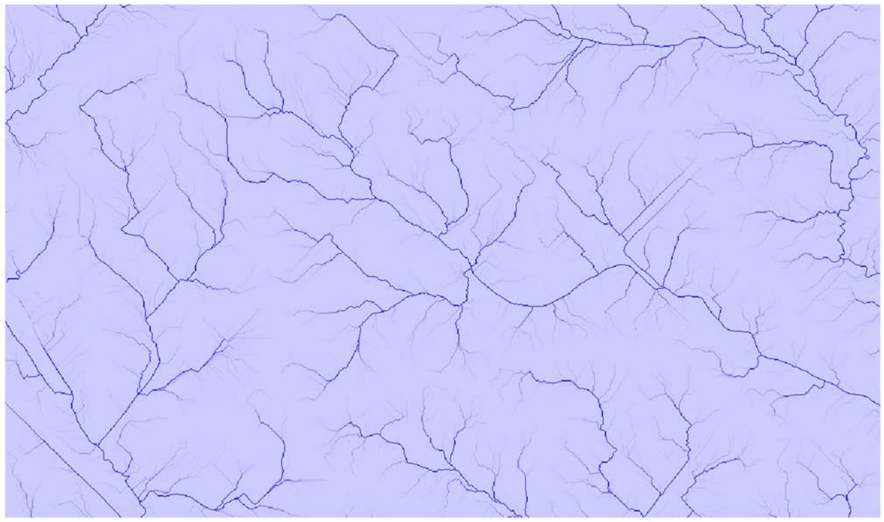


The analysis in the East Credit River subwatershed was based on a high resolution digital elevation model (DEM) generated from LiDAR (Light Detection and Ranging) data.



Flow Accumulation Grid

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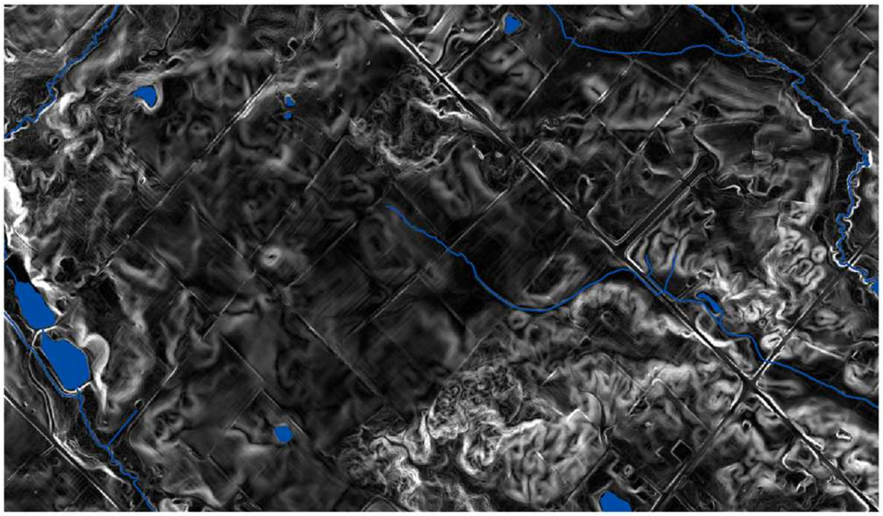
A flow accumulation grid was generated from the DEM. Each 2x2m grid cell is given a value that represents the number of upstream cells draining into it. This generates a high resolution flow network. A threshold can be applied to the flow accumulation grid to determine what amount of accumulation results in a stream forming.



Slope Grid

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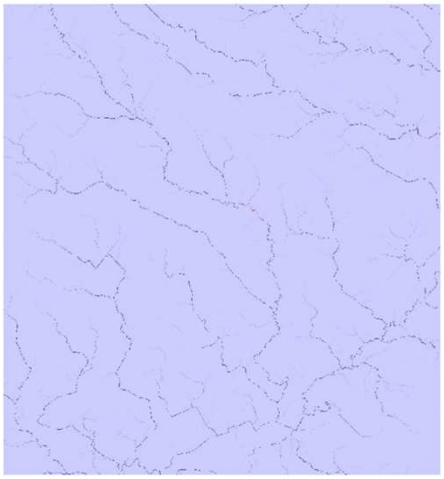
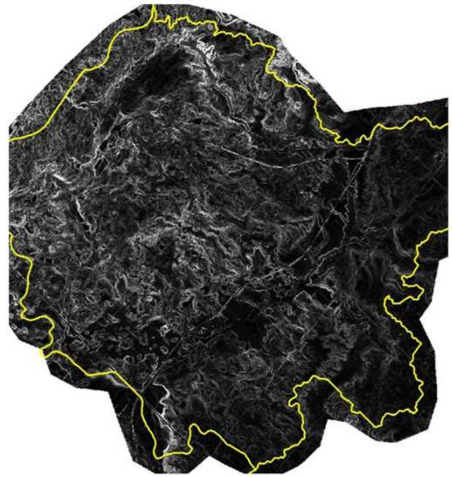
A slope grid was created from the DEM. Each 2x2m grid cell is given a value that represents the slope (in percent) between it and its downstream neighbour.





Stream Power Index =
ln(Flow accumulation x slope)

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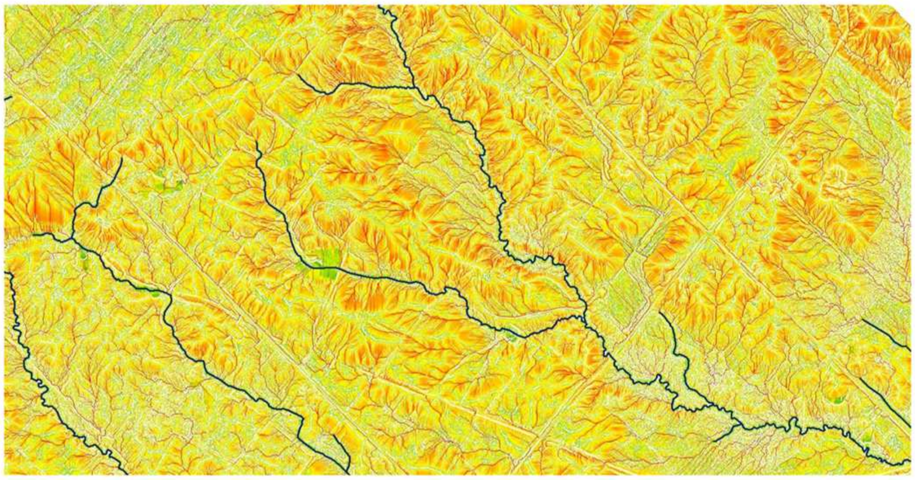
The SPI grid was then generated by simply calculating the log normal of the product of flow accumulation and slope for each grid cell.



Stream Power Index

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The SPI grid ranges from low values in green, to high values in red. The known stream network is shown in blue. If the blue lines were to be removed from this map, the underlying SPI values would show up in dark red. Permanent streams will naturally have a high stream power than surrounding lands.

Delineating SPI Catchments

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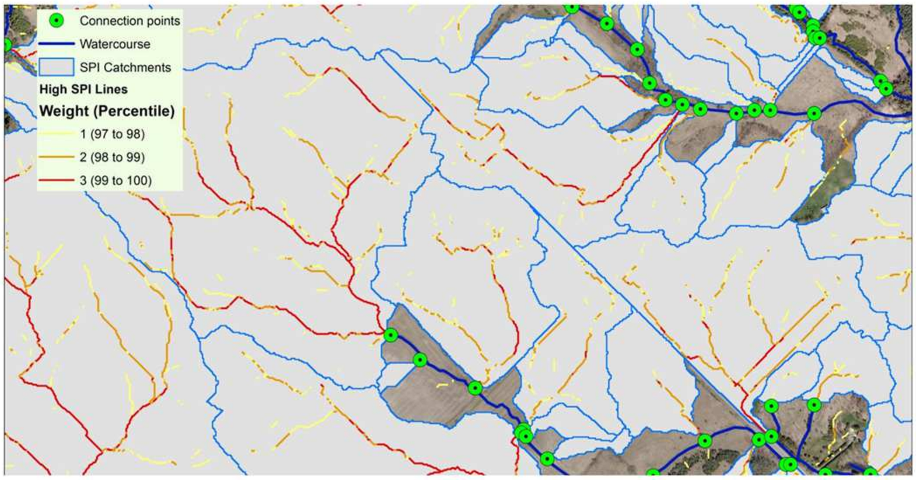
Only the grid cells with the highest SPI values were extracted. We chose to use the highest 3 percentiles of SPI values. These were then converted to the lines shown on this map. Anywhere a high SPI line intersects with the known stream network, a point was created. This is to ensure that the hotspots identified are areas where sediment lost will be transported to the stream network, and not deposited on a neighbouring field.



Delineating High SPI Catchments

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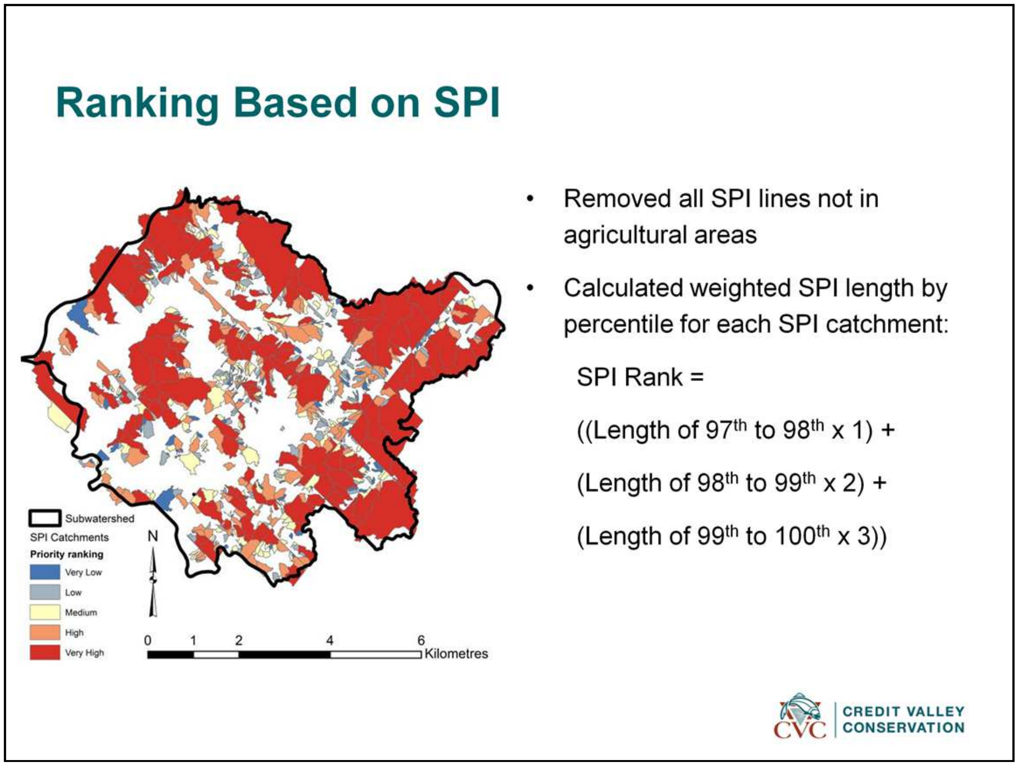
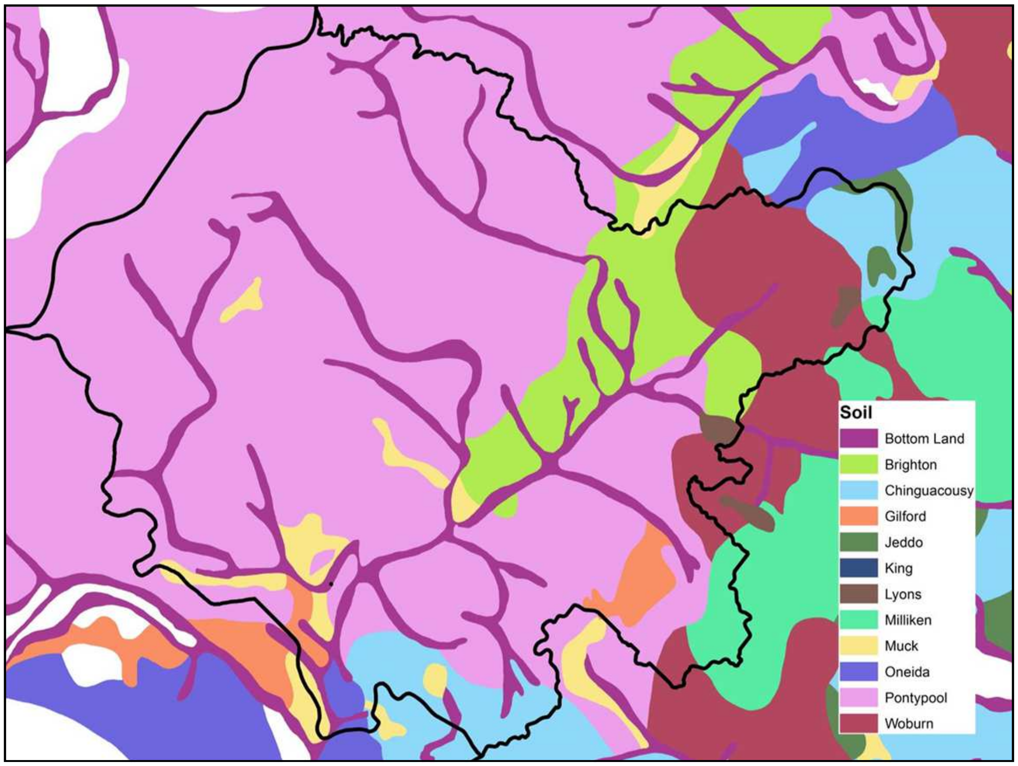
The drainage area was delineated to each of the high SPI/known stream network intersection points. The drainage areas became the base unit of the ranking system.



All high SPI lines that did not fall in an agricultural area (such as a forest or urban area) were removed. In this study we are interested in identifying areas where sediment is at risk of being lost from agricultural fields only. Other land-uses are not likely to be affected by stream power.

Each high SPI line was given a weight depending on its value and was multiplied by that segment's length. This weighted length was then summarized for each of the drainage areas, resulting in the rank shown on this map. Naturally, larger drainage areas will have the highest ranking because they will have a higher flow accumulation value.



The ranking system was augmented based on the underlying soil type.

The subwatershed is made up mostly of the less vulnerable sandy, Pontypool soil in the north west. Soil types in the south east tend to be more clayey and more vulnerable to erosion.

Ranking Based on Erodibility Factor

Name	% sand	% silt	% clay	% very fine sand	% organic	Structure code	Permeability code	K Factor
Bottom Land	15	60	25	10	3.9	3	3	0.043
Brighton	87	9	4	2	1.3	1	1	0.018
Chinguacousy	21	50	29	11	1.9	4	4	0.051
Gilford	47	44	9	21	4	2	3	0.044
Jeddo	17	49	34	7	2.6	4	4	0.042
Lyons	69	20	11	9	2.3	2	2	0.018
Milliken	28	46	26	9	1.9	2	3	0.036
Muck	-9	-9	-9	-9	20			0
Oneida	39	34	27	0	2.7	4	4	0.031
Pontypool	82	13	5	48	1.4	1	1	0.046
Woburn	38	50	12	17	2.2	2	3	0.054

- Calculate erodibility factor from RUSLE for each soil type.

$(((2.1*M^{1.14})*(10^{-4})*(12-O)+(3.25*(S-2))+(2.5*(P-3)))/100)/7.59$

M = (100-%clay)*(%silt+VF Sand), S = structure code, P = permeability code, O = % organic

- Use only soils within agricultural areas
- Calculate area-weighted K-factor for each SPI catchment

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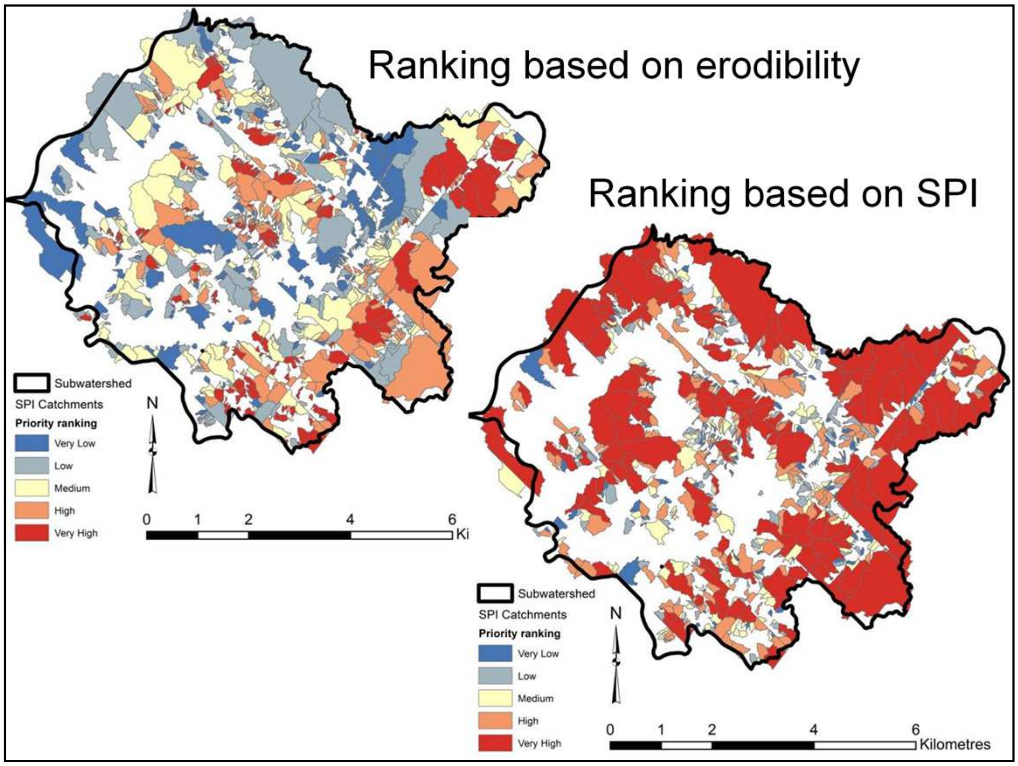
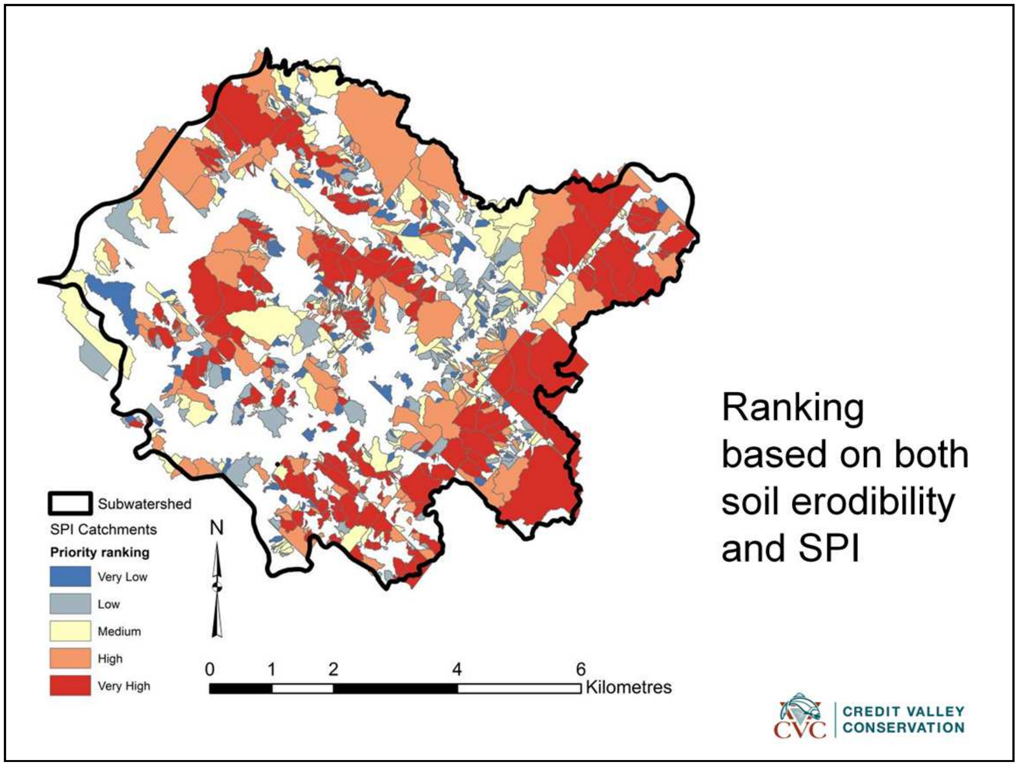
We wanted to include the revised universal soil loss equation (RUSLE) factors into the ranking system, however, most of the factors were not appropriate for our purposes, or for this scale. The rainfall (R) factor would be universal across the watershed, the length of slope (LS) factor is taken into account with the SPI, the crop (C) factor is less important because we are interested in spring runoff when crops are not growing, the management practice (P) factor cannot be used because we don't have that level of data across the watershed, and we want to see what the risk of sediment loss is before any best management practices (BMP) are implemented. We used the soil erodibility (K) factor.

The K factor was calculated for each soil type and once again, only agricultural areas were used. An area-weighted K-factor was calculated for each of the SPI drainage areas.

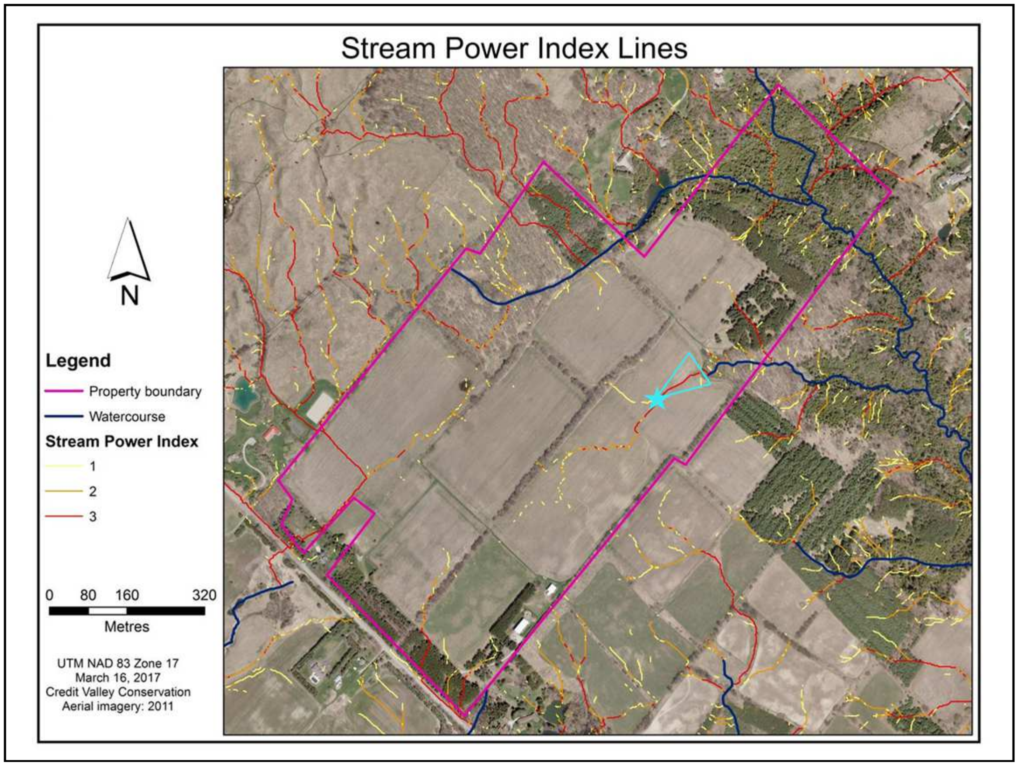


The map on the top left shows the ranking of SPI catchments according to soil erodibility alone. The highest vulnerabilities occur in the south east, where clayey soils exist.

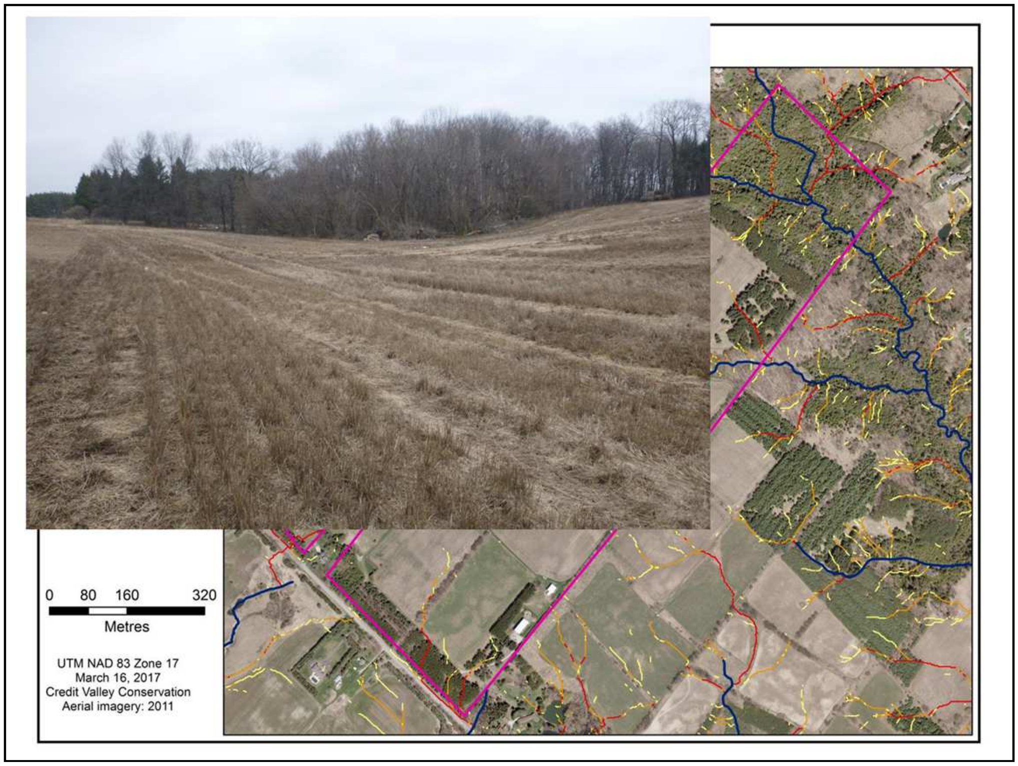
The map on the bottom right is the same map from a previous slide, showing ranking according to weighted SPI length alone.



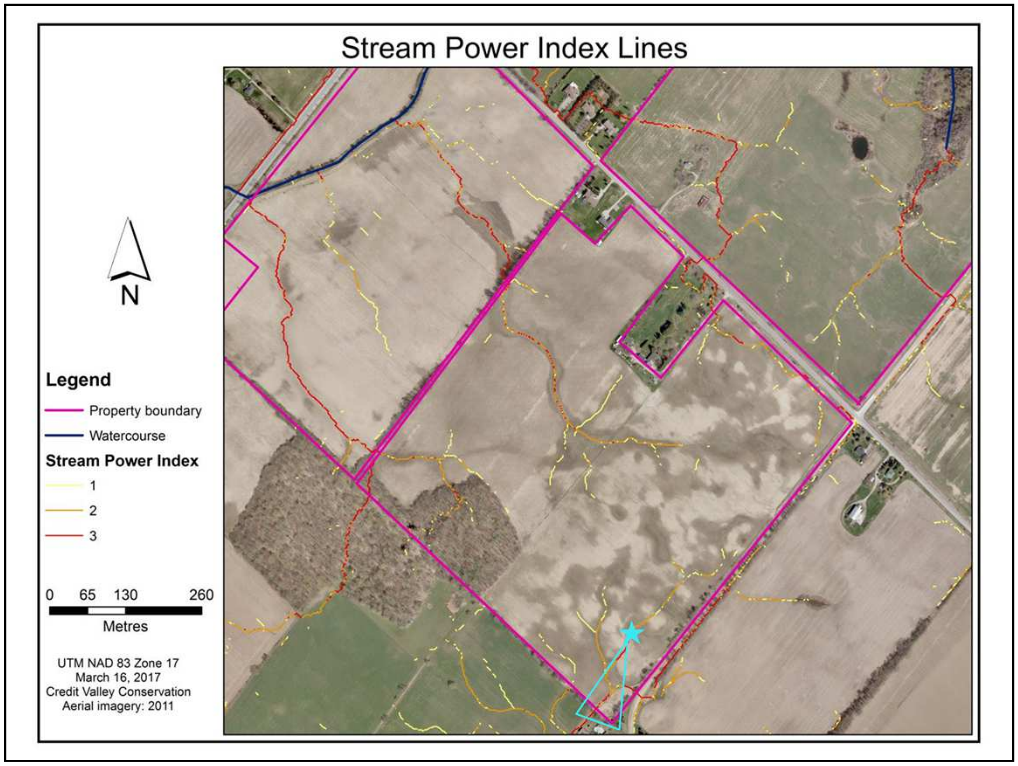
When the rankings using both weighted SPI length and soil erodibility are combined, this is the result. Areas in red are likely the highest contributors of sediment and should be prioritized for restoration activities or BMP implementation.

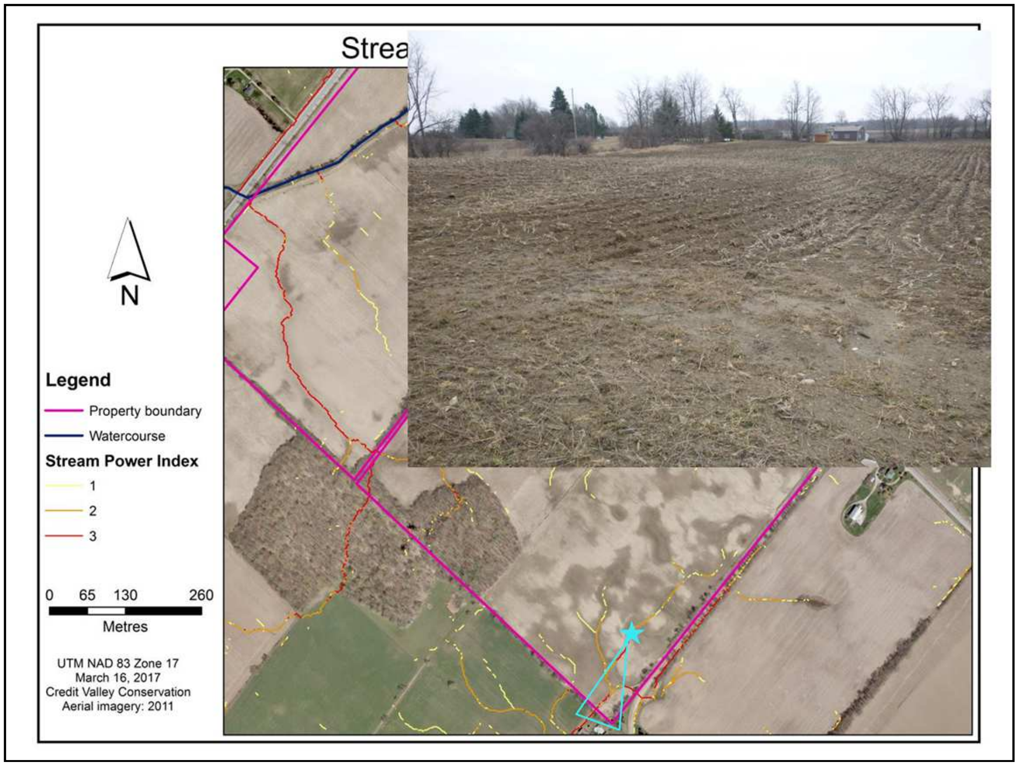


Several farms were visited in order to verify the prediction of SPI lines.



In this case, no gully erosion was visible. This is attributed to the very high level of ground cover remaining, and the low erodibility of the soil in this area.


Stream Power Index Lines
N
Legend
Property boundary
Watercourse
Stream Power Index
1
2
3
0 65 130 260
Metres
UTM NAD 83 Zone 17
March 16, 2017
Credit Valley Conservation
Aerial imagery: 2011



The land owner at this location reported that a large, persistent gully had been present, however, restoration practices were already in place to correct the issue.

How Does this Information Help Farmers and the Environment?

Targeting of Conservation Actions

- Conservation Tillage
- Cover Crops
- Erosion Control Structures
- Water Retention Systems

Outcomes

- Reduced runoff and increased infiltration
- Reduce sediment and nutrient loading
- Improved soil health/productivity
- Improved farm operation efficiencies

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This tool allows conservation practitioners to assist farmers in planning for the effects of extreme precipitation events. Conservation actions promoted to reduce the likelihood of gully erosion include:

- Conservation tillage
- Cover crops
- Erosion control structures such as grassed waterways and rock chute spillways
- Water retention systems such as water and sediment control basins

When these conservation actions are successfully implemented erosion of topsoil from farmland is minimal, which improves soil health and the long-term productivity of the farm.

Example Best Management Practices

No-till

Cover Crop

Grassed Waterway

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Picture 1) no till soybeans into a previous corn crop

Picture 2) Pea and oat cover crop protecting the soil from snowmelt

Picture 3) grassed waterway protecting the “low draw” in a field from gully erosion

Fletcher’s Creek

Urban

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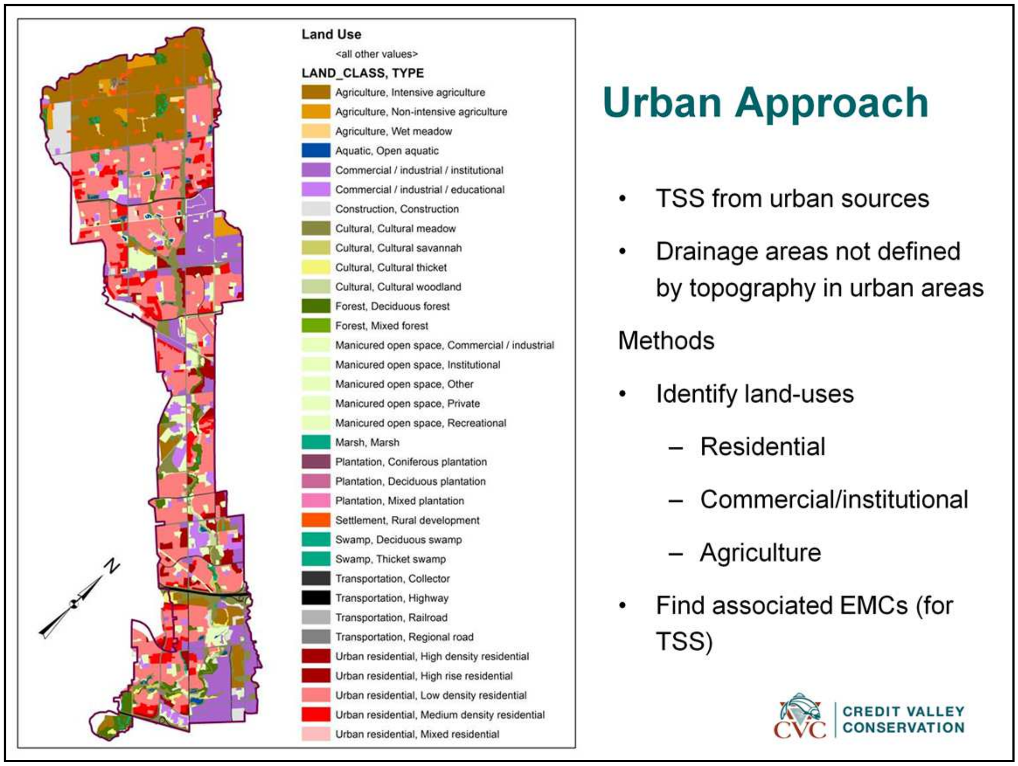
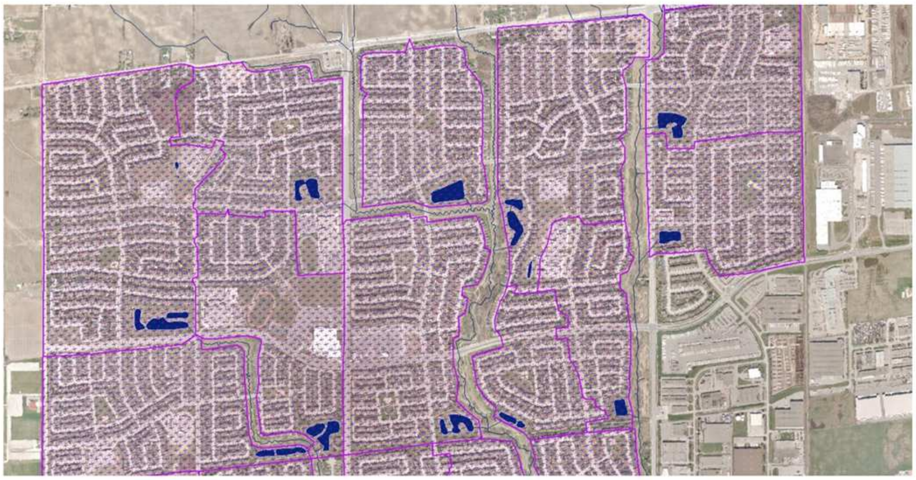


In the Fletcher's Creek subwatershed a different approach was required. In urban areas, erosion (and thus stream power) is not a major contributor to sediment loading from the land to receiving water bodies. Rather, sediment comes from urban land-uses and is mobilized by stormwater. Additionally, drainage areas are not defined by the topography as they are in rural areas, they are instead defined by man-made drainage networks (storm sewers).

To begin with, the event mean concentration (EMC) for total suspended solids (TSS) for each land-use type was identified.



Stormwater Pond Drainage Areas

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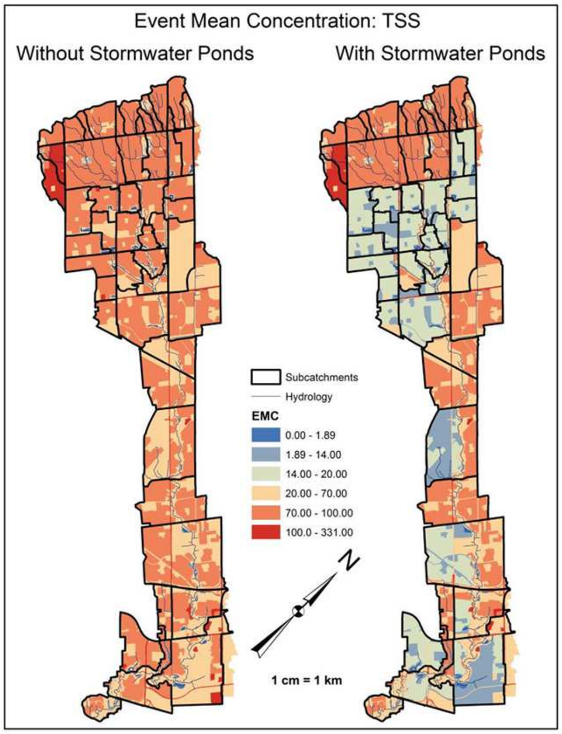
Based on the sewer network, the areas draining into stormwater ponds in the subwatershed were identified. These ponds are designed to reduce sediment load by 80%, so we reduced the underlying EMC value by 80% in areas serviced by stormwater ponds.



EMC Reduction by SWM ponds

- SWM pond drainage areas delineated by sewer network
- Reduce the EMC concentration by 80% in areas serviced by SWM ponds
- Calculate area-weighted EMC for each subcatchment
- Highest contributors: industrial/commercial, construction

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The resulting map shows the areas contributing the most sediment to Fletcher's Creek with and without stormwater ponds.

From this map, we are able to see areas (in red) where restoration activities should be prioritized.

Questions

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Support From

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Environment and Climate Change Canada   Environnement et Changement climatique Canada

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Together, it's our nature to conserve and our future to shape.