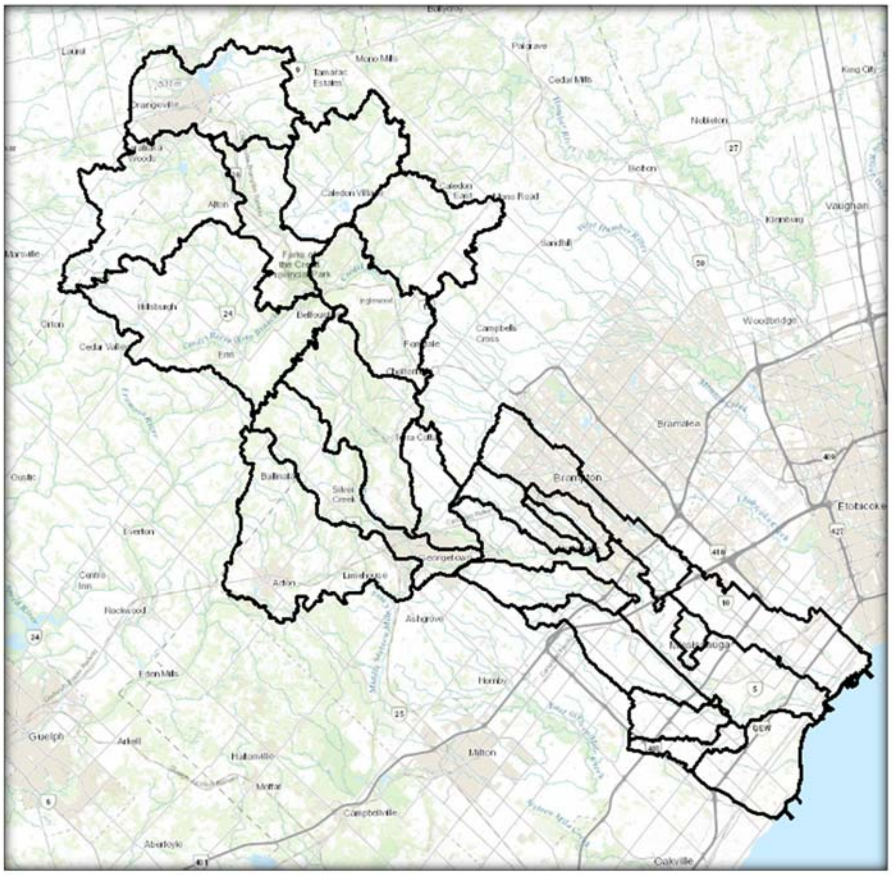
Conservation Success Index (CSI) Modelling, Scoring, Assumptions and Results in the Credit River Watershed

Trout Unlimited Canada



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May 2017

Trout Unlimited Canada Truite Illimitée Canada

Ontario Trillium Foundation Fondation Trillium de l'Ontario

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Acknowledgements

Trout Unlimited Canada (TUC) would like to acknowledge the support of the Ontario Trillium Foundation (OTF) whom provided Seed Funding to test and refine the Conservation Success Index (CSI) for Ontario using the Credit River as the test watershed. TUC would also like to thank the Credit Valley Conservation (CVC) for their help, enthusiasm and support of this initiative. The Fisheries Section and the Aquatic Research and Monitoring Section of the Ontario Ministry of Natural Resources and Forestry (OMNFR) also provided invaluable feedback and data on model development. Thank you to Trout Unlimited, USA for the many discussions and training that they provided to us to develop this model for a Canadian application. Seed funding to initiate this model development was provided initially, with gratitude, from the Salamander Foundation.

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Introduction and Background

The Conservation Success Index (CSI) model being developed by Trout Unlimited Canada (TUC) is a Geographic Information System (GIS) approach for assessing past, current, and future habitat, population, and risk conditions to Brook Trout (*Salvelinus fontinalis*) in Ontario, Canada. The CSI is used to help characterize the state and conditions of watersheds. When utilized in conjunction with advice from fishery specialists and conservation experts, the CSI can support the decision-making process towards making effective and efficient management strategies.

The study area for the CSI development in Canada is focused on the Credit River watershed in southern Ontario. This watershed was chosen because of the availability and diversity of spatial and non-spatial datasets that could be utilized for the development of the pilot CSI model to the highest possible standard. Where possible, spatial datasets received from the Credit Valley Conservation (CVC) were prioritized due to their accuracy and currency, followed by provincial datasets downloaded from Land Information Ontario (LIO), however supplemental datasets were derived from Environment Canada, Natural Resources Canada, and third parties if they were not available at the local, regional, or provincial scale.

The CSI model was built using the ModelBuilder application to create, edit, and manage the workflows which automates the processing and analytics of the model. ModelBuilder is an integrated application of ESRI's ArcGIS, which was utilized further for data management and mapping. Some processes and integrated sub-models were also programmed using Python, which is the current programming language standard utilized by ESRI. Due to software restriction and complexity of the modelling process, TUC understands that the intended users of the CSI are GIS professionals who understand concepts such as geodatabase file structures and management, ModelBuilder, scripting, and geospatial analysis with support from biologists and fishery management professionals.

Initial work for the CSI work for Ontario was undertaken in 2013/2014. The assumptions, constraints, scoring, and data modelling were based heavily on the original CSI model developed by Trout Unlimited in the USA (TU USA). Through an existing partnership, the CSI model was further modified to a limited degree to better suit Canadian geospatial data availability and structure and fishery management practices. However, the resulting analysis lacked accurate inputs and interpretation and did not produce expected results based on similar assumptions.

Starting in 2016, the CSI work was overhauled and remodelled from scratch. Processes and assumptions were driven and built primarily around the data available to the Credit River watershed and around Ontario and Canadian geospatial standards. However, where appropriate, TUC's CSI model for indicator assumptions and scorings were kept intact to mirror the work produced by the original CSI model.

Modelling Assumptions and Scoring

Mirroring the original CSI model created by TU USA, TUC's CSI model is an aggregation of four categories: Range-wide Condition, Population Integrity Condition, Habitat Integrity Condition, and Future Security Risks. These four categories are further subdivided into twenty indicators; five for each category. Scoring is additive, with a maximum possible score of 5 for each indicator and 25 for a category for a maximum total cumulative score of 100. All indicators have equal weights which also results in each category having equal weighing.

The framework and rationale for the development of each indicator and category also closely follows the design of the original CSI model. Where and when possible, the CSI utilizes the rules and inputs described by the original CSI model, however, when similar datasets were not immediately available, smaller scaled and coarse datasets were substituted in the analysis, but scoring rules were kept the same to emulate the indicator rationale. In some cases where the CSI rules were not appropriate to Canadian standards, TU USA assisted us in redeveloping the rules during the original redevelopment efforts in 2013/2014. For those affected indicators, the CSI continues to utilize and follow the inputs and scoring rules. However, during the current redevelopment phase of the CSI work, additional indicators were identified as being inappropriate for analysis, largely due to incompatible datasets and therefore unusable scoring rules. For these affected indicators, TUC attempted to keep the indicator the same, however the scoring rules were modified to work with available data in Ontario and Canada. The scoring rationales were discussed, modified, and agreed upon by TUC, CVC, and OMNRF for this iteration of the CSI, however, more generalized scoring rules and assumption may be developed as the CSI work evolves.

Unlike the original CSI modelling scores and assumptions, the current model being developed by TUC, incorporates the possibility of zeroes (0) and Nulls (no data) directly into the modelling and scoring process. An indicator can be scored 0 if conditions are non-existent or a population has been extirpated; it is therefore possible for a watershed study area to receive a total score of 0 if all test parameters are not met and/or the test population has been extirpated. An indicator can also be scored Null if no appropriate datasets are available for modelling or a test parameter is inappropriate for a specific study area. Nulls decrease the total score of a category by removing the affected indicator from consideration, which will in turn also decrease the cumulative scoring of the CSI model. Therefore, it is possible for a CSI to be modelled with a cumulative scoring of less than 100. Removing an indicator for considerations removes the effects of having improperly assigned zero scores skewing the overall CSI score.

To ensure increased modelling and analysis efficiency and to minimize inaccuracies, all geospatial datasets are housed in file geodatabases and not as shapefiles. Datasets are clipped, projected, and processed to a set spatial projection that is appropriate for the study area. For the development of the CSI model, the projection utilized was UTM Zone 17N, NAD 1983, with default linear units set to metres (m) and metres squared (m^2). The final scores for each indicator, category, and total CSI are presented both as a value and as a colour (Figure 1) in the various maps.

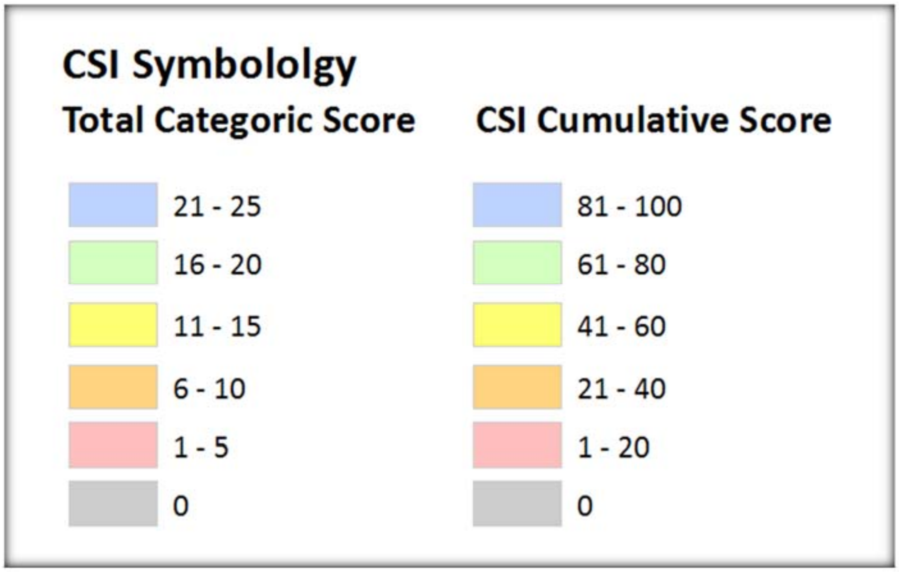

Figure 1: Symbology for CSI Scores for a category with full indicators for analysis and cumulative scores for a full analysis. Nulls resulting from unavailable datasets or assumptions inappropriate to a study area will rescale the score for a category and therefore the cumulative CSI score.

Habitat Range and Distribution Modelling

Table 1: Input features for the creation of the baseline current and historical Brook Trout habitat range datasets.

Initial Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Aquatic Resource Area (ARA) Line Segment	Land Information Ontario	August 11, 2016
Aquatic Resource Area (ARA) Polygon Segment	Land Information Ontario	August 11, 2016
Ontario Hydrological Network (OHN) Waterbody	Land Information Ontario	May 5, 2016
Ontario Integrated Hydrology Data	Land Information Ontario	November 7, 2016
Ontario Enhanced Watercourse Data	Land Information Ontario	November 7, 2016
Atlas of Brook Trout Streams and Rivers in Ontario, November 2003	Hardcopy	Digitized: August 16, 2016

Table 2: Input features for updating the modelled baseline datasets to reflect more accurate and observed watershed subwatershed conditions.

Quality Control Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
CVC Brook Trout Biomass 2013 - 2016	CVC	November 23, 2016
CVC Brook Trout Biomass 2012	CVC	N/A
CVC Pre-settlement Brook Trout Populations	CVC	January 2, 2017

Outputs: The final Brook Trout distribution outputs are derived models which reflects the as-known current and historical range/reaches and lakes/ponds. The baseline features created by the inputs from Table 1 were manually manipulated and updated to reflect more current and accurate distribution data using the quality control inputs provided by CVC in Table 2.

One of the biggest challenges to the CSI modelling work was the availability of a complete hydrological dataset coupled with the availability and currency of species distribution data in the study area. Since the CSI model also analyzes temporal changes as well as geographic changes, historical datasets were also important considerations. Unfortunately, after extensive research, analysis, and review, it was concluded that current distribution data for Brook Trout (and other recorded species) have not been captured extensively or updated in publicly available provincial data sources. It was also determined that there were issues with the validity and geometry of the various hydrological datasets when compared to one another and included such issues as: a) non-matching digitized segments, and b) missing segments or features. This data inaccuracy issue was further confounded when compared to the data provided by CVC. Since all the datasets were based off the Ontario Hydrological Network (OHN) and should theoretically match, it was decided that the ARA datasets would take priority as the baseline feature as they contained as-known species distribution data on a provincial level. This was then supplemented by the Enhanced Watercourse data as it contained Strahler Order information, which is a requirement for several indicators. Finally, missing segments were merged into the working file to create one complete watercourse and habitat range feature class. A similar process was utilized to create the pond and lake features for Brook Trout in the study area. After the initial Brook Trout distribution and range datasets were created, CVC was consulted to review and manipulate these baseline outputs to create more accurate and realistic habitat range and distribution datasets for the analysis portion of the CSI.

Retrieving historical data for Brook Trout proved to be a bigger challenge and after some research and work, the best-known resource for this data came out of the Atlas of Brook Trout Streams and Rivers in Ontario, which was published in November 2003 (Ontario Ministry of Natural Resources, 2003). This reference document contained known historical data points with Latitude and Longitude locations which was then digitized and used to model the temporal changes for Brook Trout distribution. Unfortunately, since reported sampling points were not extensive and the spatial coordinate information only reported to minute accuracy, this produced an error equivalent to ~800m in any given direction. Because of this, historical comparison was interpolated to a great level. The resulting datasets were massaged and error checked and the final resulting datasets represent our best attempt at modelling and mapping historical Brook Trout habitat ranges. Once again, CVC was consulted to review the historical habitat ranges, and a more accurate and realistic model was created for the analysis portion of the CSI.

A set of images demonstrating the differences in the various datasets and the proposed distribution of Brook Trout interpreted from the datasets have been included below. Figure 2 illustrates the proposed distribution using only current information available in the Provincial ARA database. Figure 3 is a map of historical data available from provincial sources and likely reflects the recorded distribution of Brook Trout interpolated from data collected in the 1950s. Figure 4 is the revised mapping with additional up-to-date data from CVC based on recent monitoring data and is the mapping and dataset that we used for current distribution. Figure 5 is the presumed historical distribution of Brook Trout in the Credit River watershed, perhaps as far back as the early 1800s and is based on information and discussion with CVC biological staff. This is the mapping and dataset used to determine historical range vs current range. Figure 6 shows a discrepancy in the mapping of what appears to be a tributary of Black Creek which is not connected to the Black Creek watercourse. It was excluded from further analysis but should be investigated to determine if this is a tributary of Black Creek or a tributary of another watershed.

Progression of Distribution Mapping

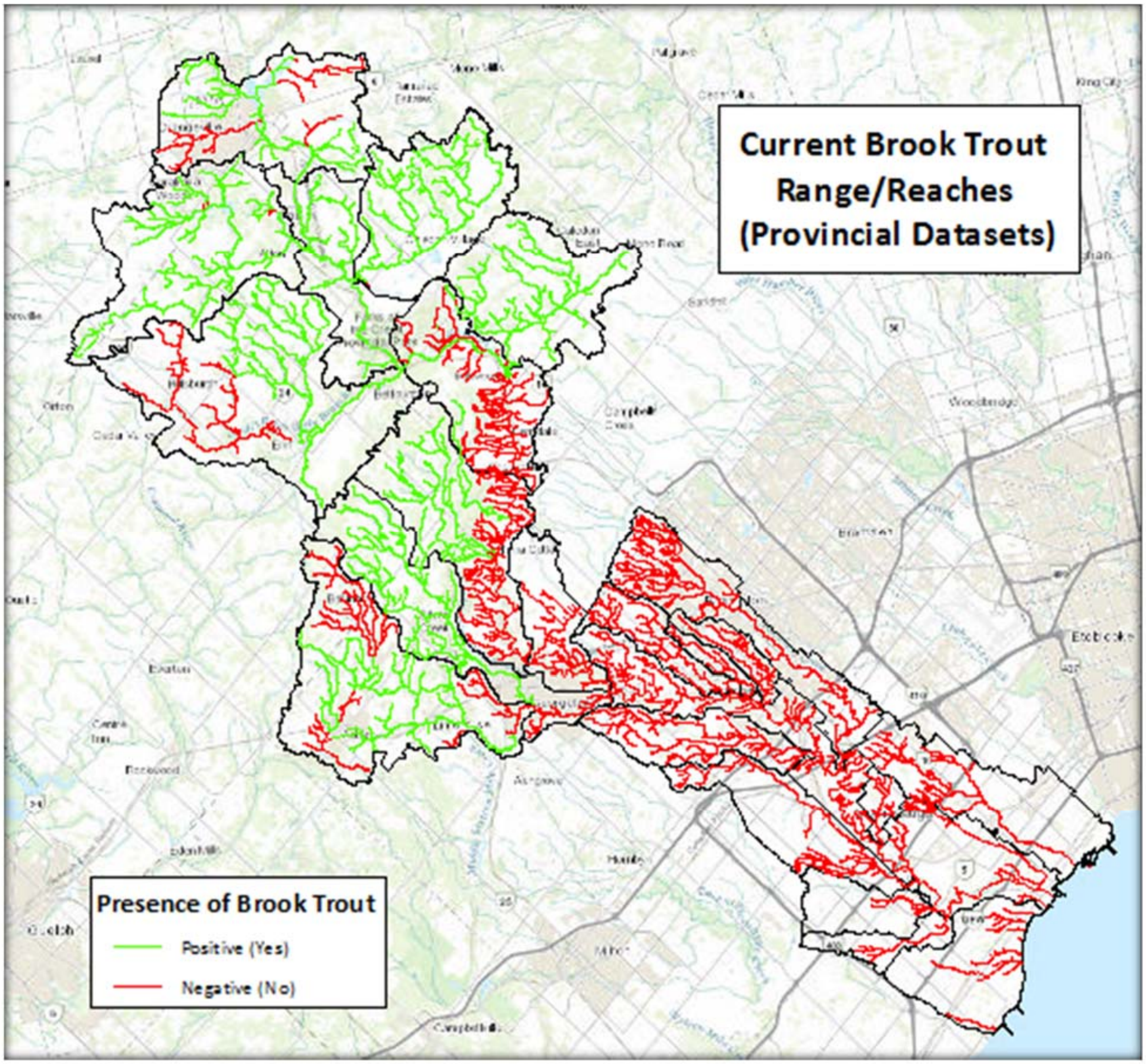

Figure 2: Modelled Brook Trout distribution data using available provincial datasets only (Green = Positive, Red = Negative).

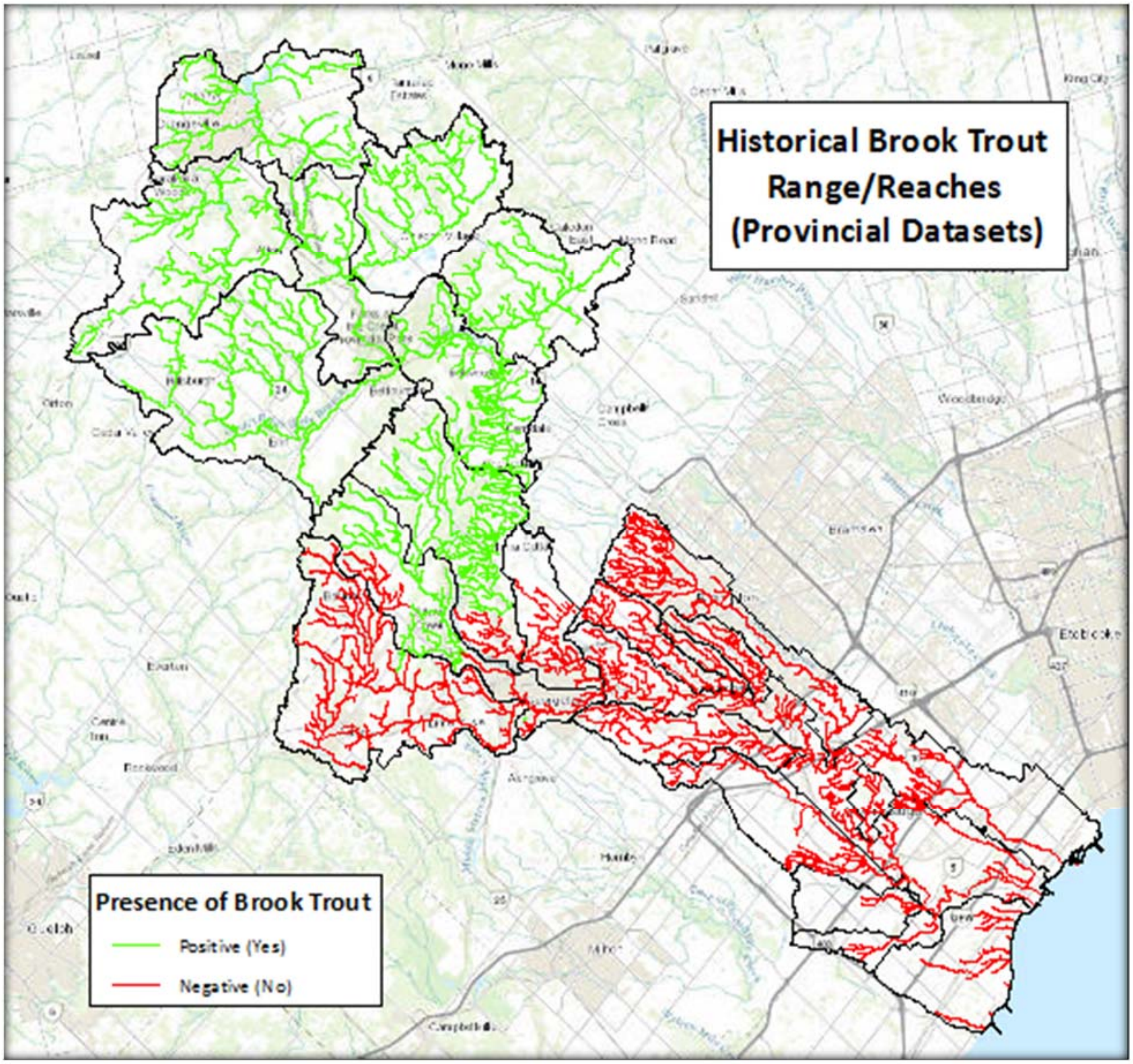

Figure 3: Modelled historical Brook Trout distribution data using available provincial datasets (Green = Positive, Red = Negative).

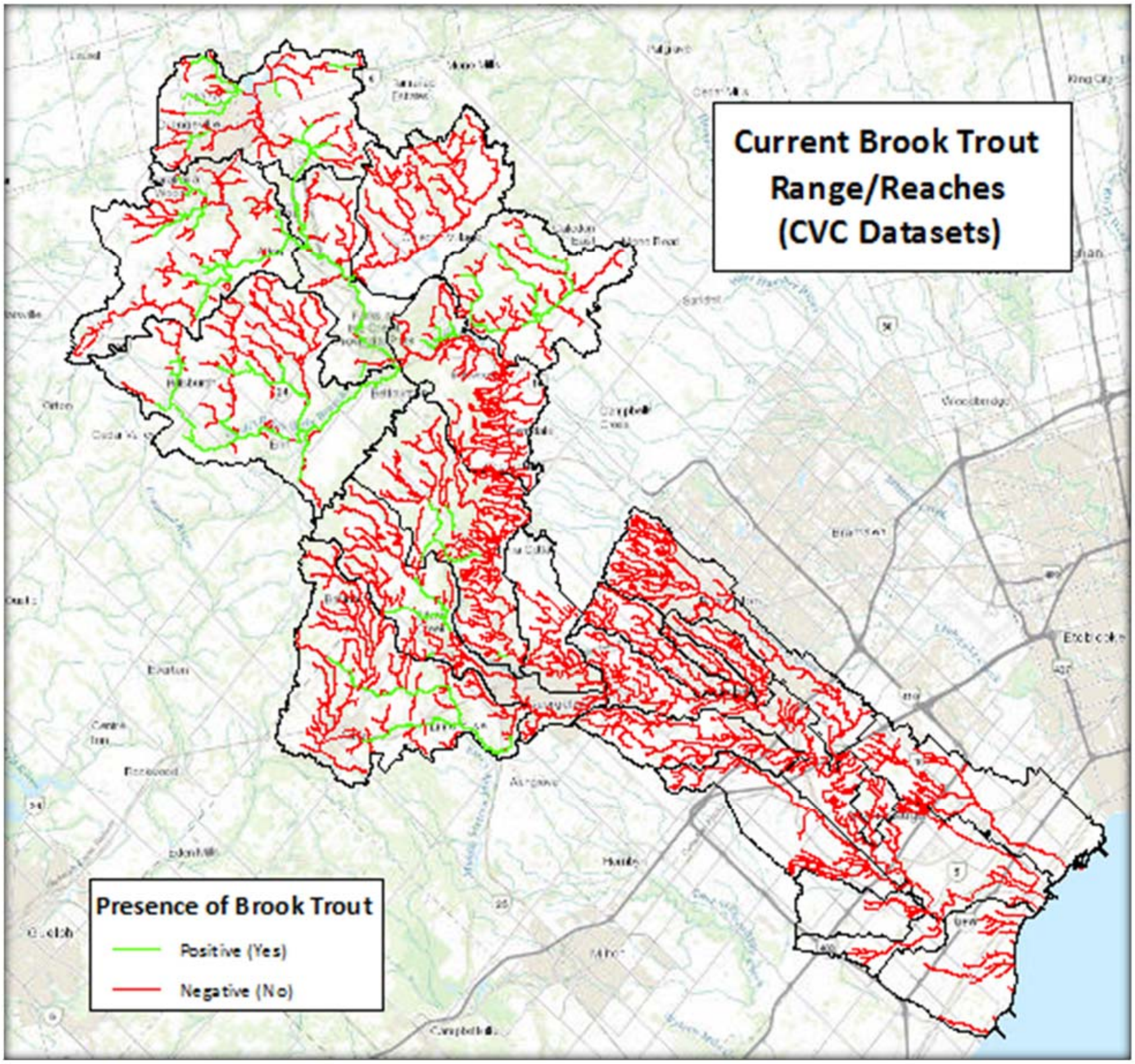

Figure 4: Re-Modelled Brook Trout distribution data using available datasets from the Credit Valley Conservation (Green = Positive, Red = Negative).

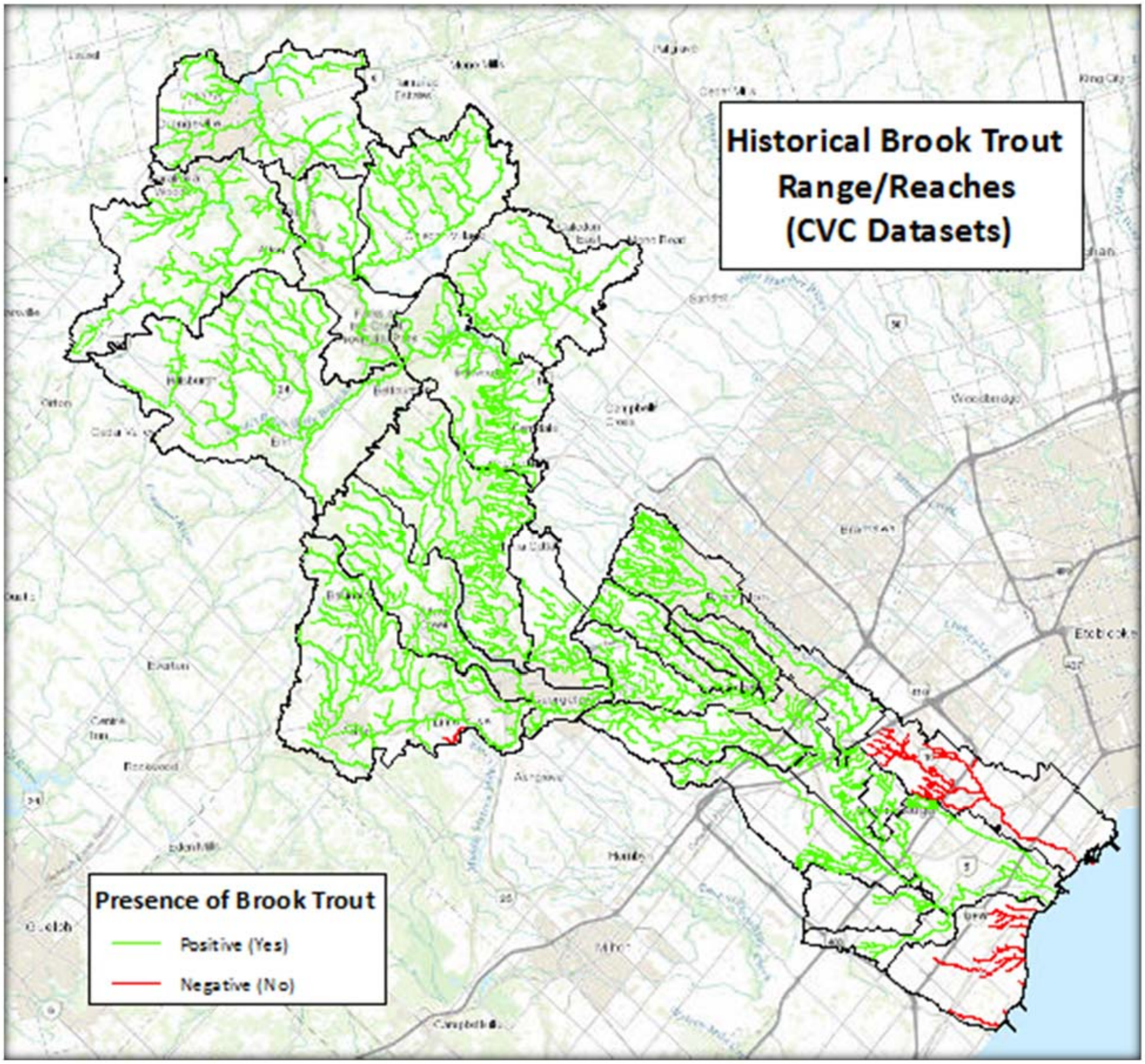

Figure 5: Re-modelled historical Brook Trout distribution data using available datasets from the Credit Valley Conservation (Green = Positive, Red = Negative).

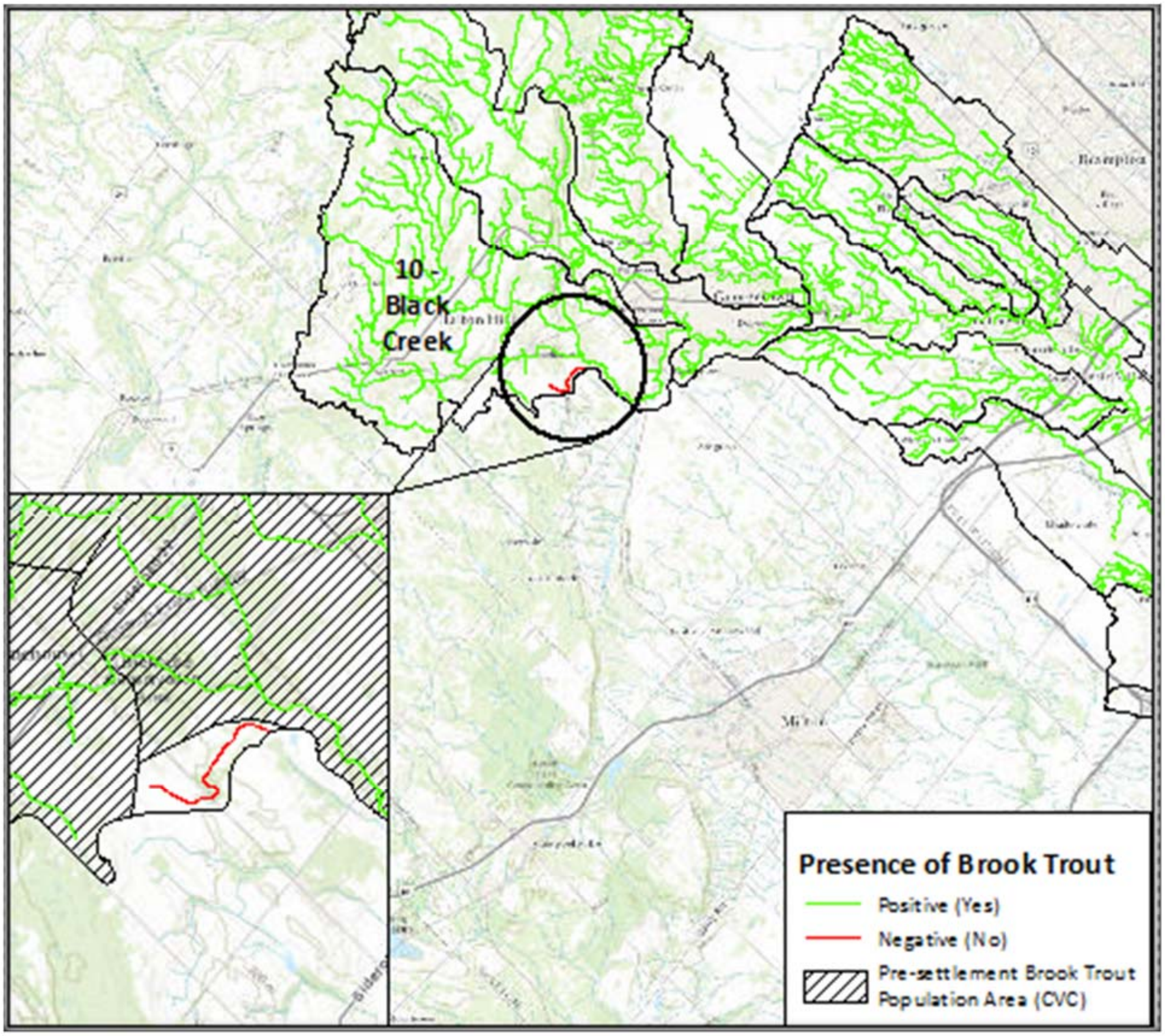

Figure 6: In subwatershed 10 – Black Creek, it was determined during review that there was a discrepancy in the historical modelled dataset due to the exclusion of this segment from the pre-settlement Brook Trout dataset obtained from CVC. Ground-truthing may be required to determine if the excluded segment is part of the Black Creek subwatershed or 16 Mile Watershed.

Range-wide Condition Category

Indicator 1: % Historical Stream Habitat Occupied

Table 3: Input features for category 1, indicator 1.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Brook Trout Range/Reach Historical	Trout Unlimited Canada	Derived: January 11, 2017

Table 4: Scoring Rules for category 1, indicator 1.

Scoring:

CSI Score	Rule (Historic Range Occupied) As Per TU USA
5	≥ 50%
4	35 - < 50%
3	20 - < 35%
2	10 - < 20%
1	< 10%
0	0 or Extirpated

Due to the extensive habitat and distribution modelling performed in Part 1.0, this analysis is simple as it is a comparison of current distribution extents versus historical reaches. Table 3 is a list of datasets used for this portion of the analysis, their source and acquisition/update date. Table 4 is the scoring used for this indicator and directly emulates the scoring rationale of the original CSI. Figure 7 is the output scoring map for the comparison of the historical range currently occupied by each subwatershed unit and includes the actual stream segments that either do have Brook Trout or where they are absent in each subwatershed.

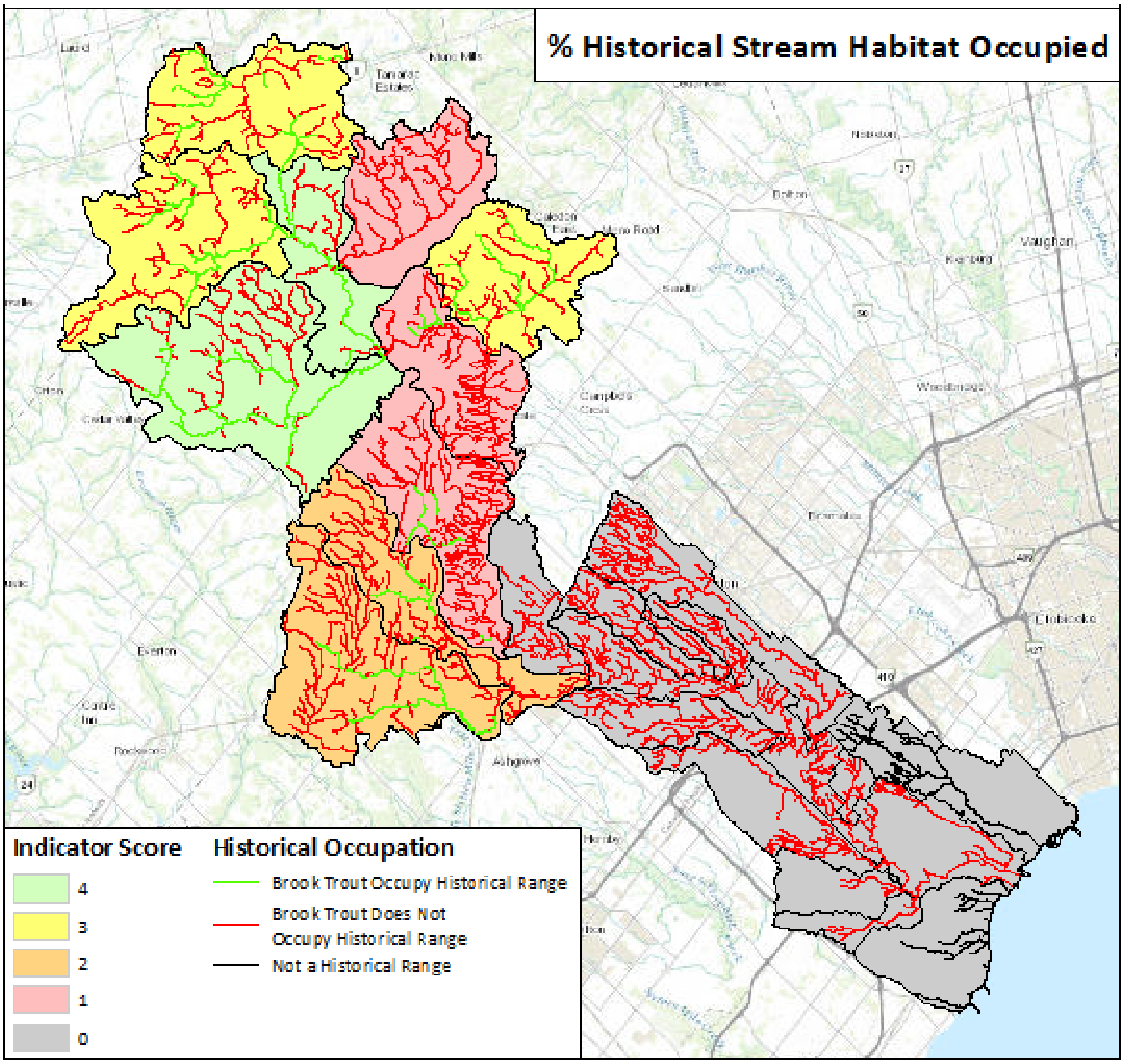

Figure 7: Range-wide Conditions Indicator 1: % Historical Stream Habitat Occupied.

Indicator 2: % Current Occupied Subwatershed

Table 5: Input features for category 1, indicator 2.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017

Table 6: Scoring Rules for category 1, indicator 2.

Scoring:

CSI Score	Rule (Current Occupation of Subwatershed) As Per TU USA
5	90 – 100%
4	80 – < 90%
3	70 – < 80%
2	50 – < 70%
1	> 0 – < 50%
0	0 or Extirpated

Ontario's watershed and hydrological features are not classified or created under the Hydrological Unit Code (HUC) hierarchical system that was created by the United States Geological Survey (USGS) which TU USA uses for their CSI work. In Ontario, watersheds are listed as primary, secondary, tertiary, quaternary. However, a problem arises when comparing the boundaries of the different watershed files; there are very little geographic differences between the secondary, tertiary, and quaternary watershed features for the Credit River watershed. The data are also too coarse for this level of analysis and would not provide meaningful analysis results. CVC has produced a subwatershed file using the Hydrologic Simulation Program – FORTRAN (HSPF) method which is similar in assessment size to a HUC 6 classification, and provides distinct boundaries within the study area that could be used to assess and prioritize conservation efforts. The subwatershed areas were used as the basis for the analysis of much of the CSI work. The model inherently contains the subwatershed identifying attributes, and a summary statistical analysis was performed for current occupation of the target species.

Table 5 lists the dataset used for this analysis. The dataset was synthesized by TUC from the information provided by CVC for current distribution. As mentioned above, the CVC subwatershed file was used as the constraining boundaries to calculate lengths of interpreted stream segment occupied by Brook Trout, then scoring the results. The scoring rules follows the original CSI model. The results are displayed in Figure 8.

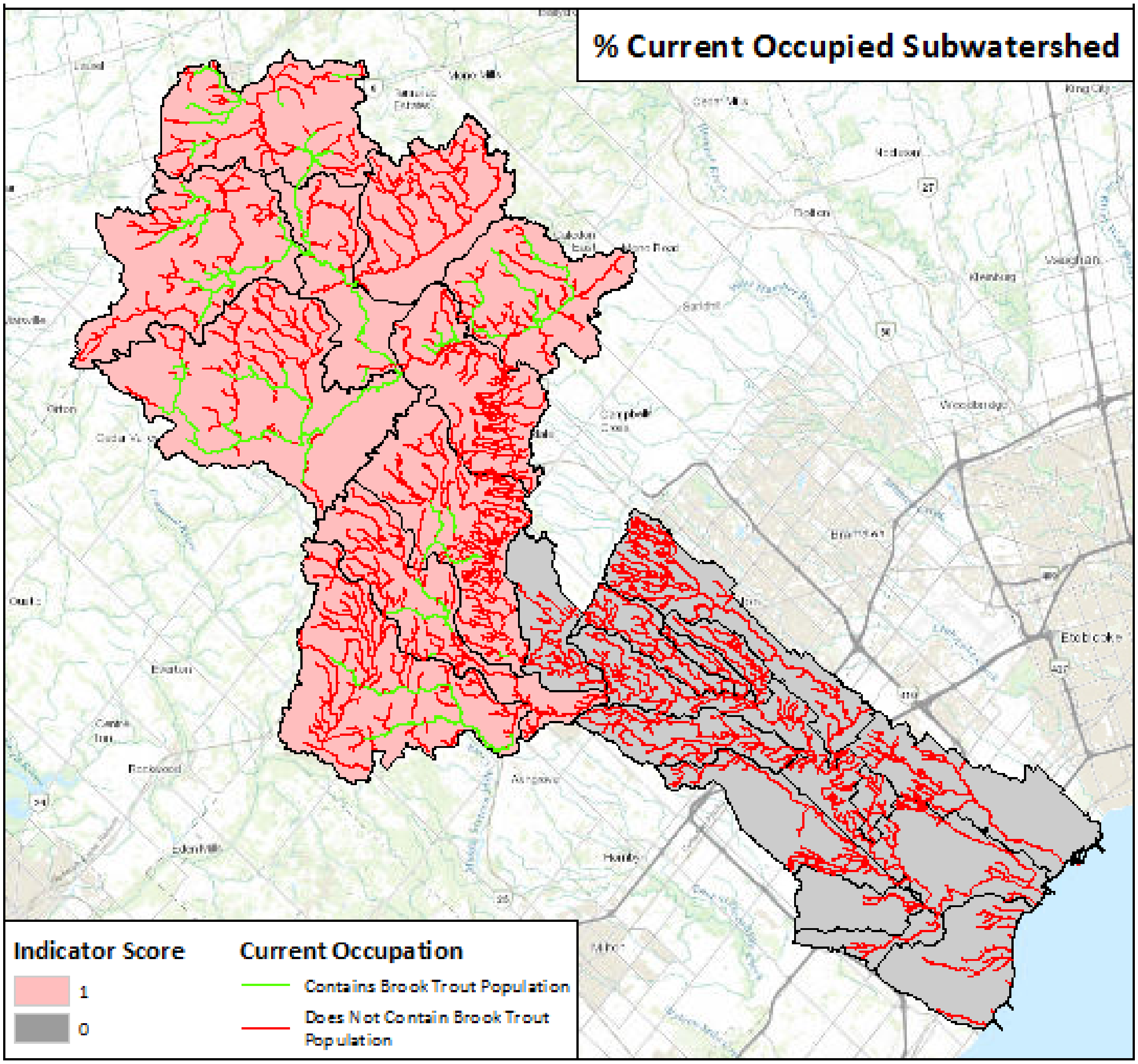

Figure 8: Range-wide Conditions Indicator 2: % Current Occupied Subwatershed.

Indicator 3: % Historical Subcatchment Occupied

Table 7: Input features for category 1, indicator 3.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Brook Trout Range/Reach Historical	Trout Unlimited Canada	Derived: January 11, 2017
Subcatchment Area/Boundary	CVC	N/A

Table 8: Scoring Rules for category 1, indicator 3.

Scoring:

CSI Score	Rule (Average Historical Occupation of Subcatchment)
5	80 – 100%
4	60 – < 80%
3	40 – < 60%
2	20 – < 40%
1	> 0 – < 20%
0	0 or Extirpated

Like the above analysis, there are no available HUC categorized features in Ontario. Instead, CVC has produced a subcatchment file which further divides the subwatershed features into smaller assessment areas. Similar to Indicator 1, this analysis is a straight comparison of current distribution extents versus historical reaches summarized up to the subcatchment level. Figure 9 demonstrates the final scoring for this indicator. Note that there are no high scores; the resulting scoring only goes up to a score of 3 or 40-60% of the historical reaches occupied.

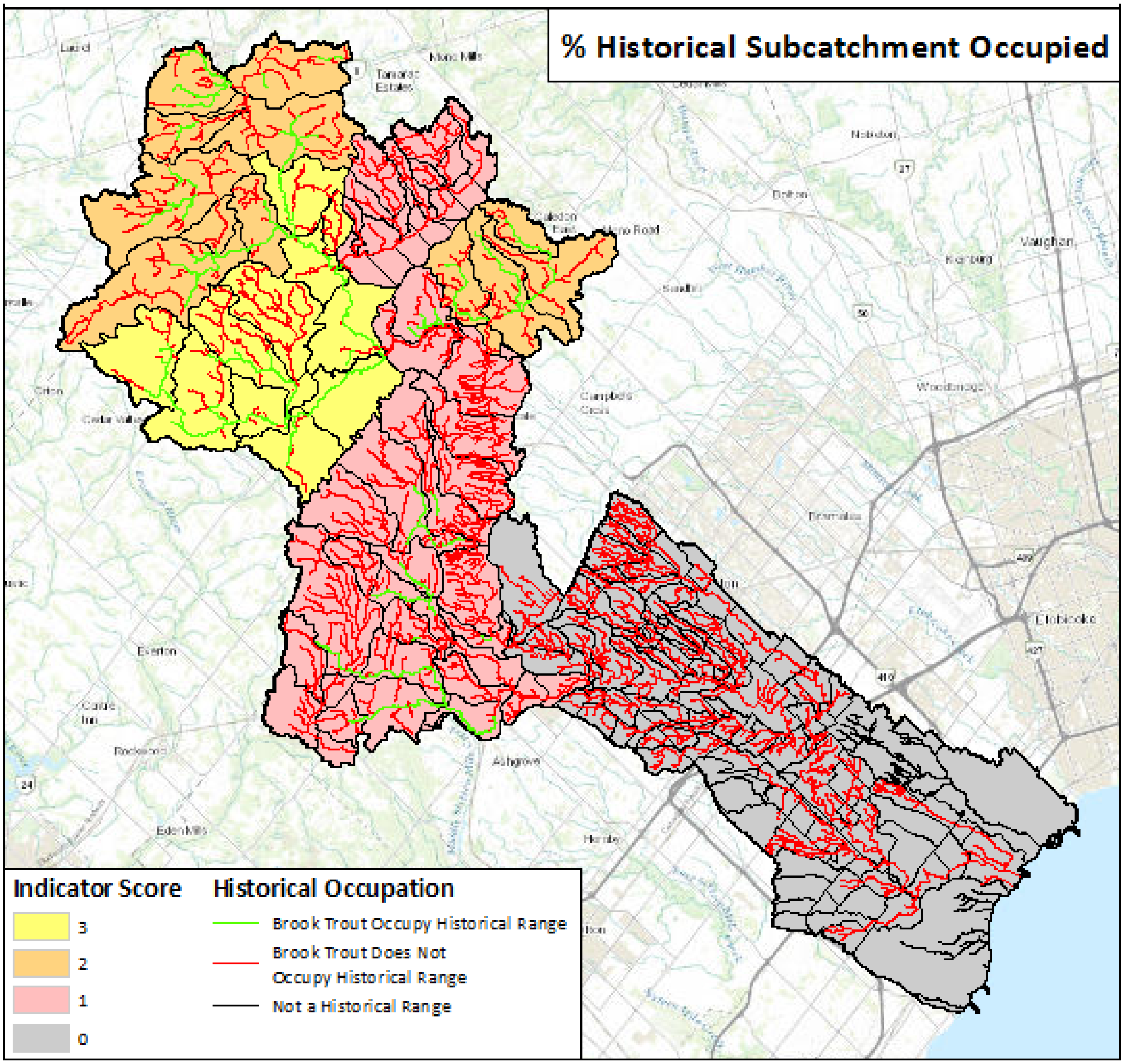

Figure 9: Range-wide Conditions Indicator 3: % Historical Subcatchment Occupied.

Indicator 4: % Habitat by Stream Order Occupied

Table 9: Input features for category 1, indicator 4.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017

Table 10: Scoring Rules for category 1, indicator 4.

Scoring:

CSI Score	Rule (% 2nd Order or Greater Stream Occupied) As Per TU USA
5	≥ 25%
4	20 - < 25%
3	15 - < 20%
2	10 - < 15%
1	< 10%
0	0 or Extirpated

Due to the habitat modelling performed in Part 1.0, this analysis is simple as the feature already contains the attributing Strahler Order information. The current distribution data can be queried out to include only features that are positively occupied and belong to a Strahler Stream Order that is not 1st order. Figure 10 demonstrates that there are still a number of 2nd order or larger streams in the headwaters that still support Brook Trout including portions of the West Credit River. However, although Brook Trout exist in the mainstem below Cataract River (3rd Order) they are not abundant there anymore. The Black Creek subwatershed scored a 3 suggesting that though it was historically a very healthy stream, it has deteriorated.

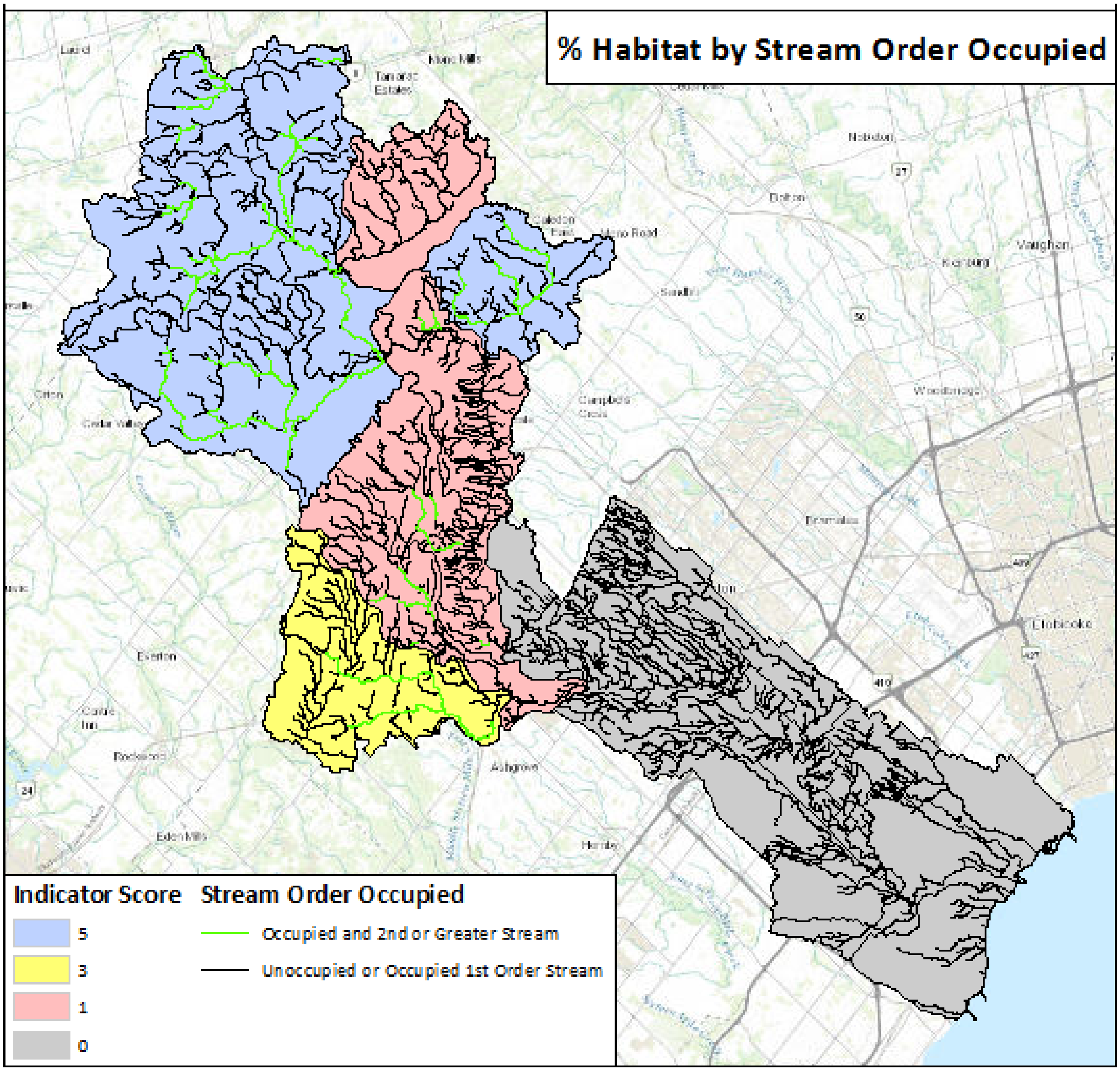

Figure 10: Range-wide Conditions Indicator 4: % Habitat by Stream Order Occupied.

Indicator 5: % Historic Lake Habitat Occupied

Table 11: Input features for category 1, indicator 5.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Pond/Lake	Trout Unlimited Canada	Derived: March 7, 2017*
Brook Trout Pond/Lake Historical	Trout Unlimited Canada	Derived: March 7, 2017*

*After the CSI workshop and review session, it was determined that only Caledon Lake and Dufferin Lake should be captured in the CSI Model. The current and historical lake/pond datasets were manually modified to reflect this assumption.

Table 12: Scoring Rules for category 1, indicator 5.

Scoring:

CSI Score	Rule (Historic Lake Occupied) As Per TU USA
5	≥ 50%
4	35 - < 50%
3	20 - < 35%
2	10 - < 20%
1	< 10%
0	0 or Extirpated

Very similar to Indicator 1, this analysis is a comparison of current distribution extent versus historical. Tables 11 and 12 identify the data sources utilized in the assessment and the scoring parameters, which follows the original CSI. This Indicator is not a major indicator because there were few lakes historically occupied by Brook Trout in the Credit River watershed (other than Lake Ontario). Therefore, this is a somewhat simplified indicator as shown in Figure 11.

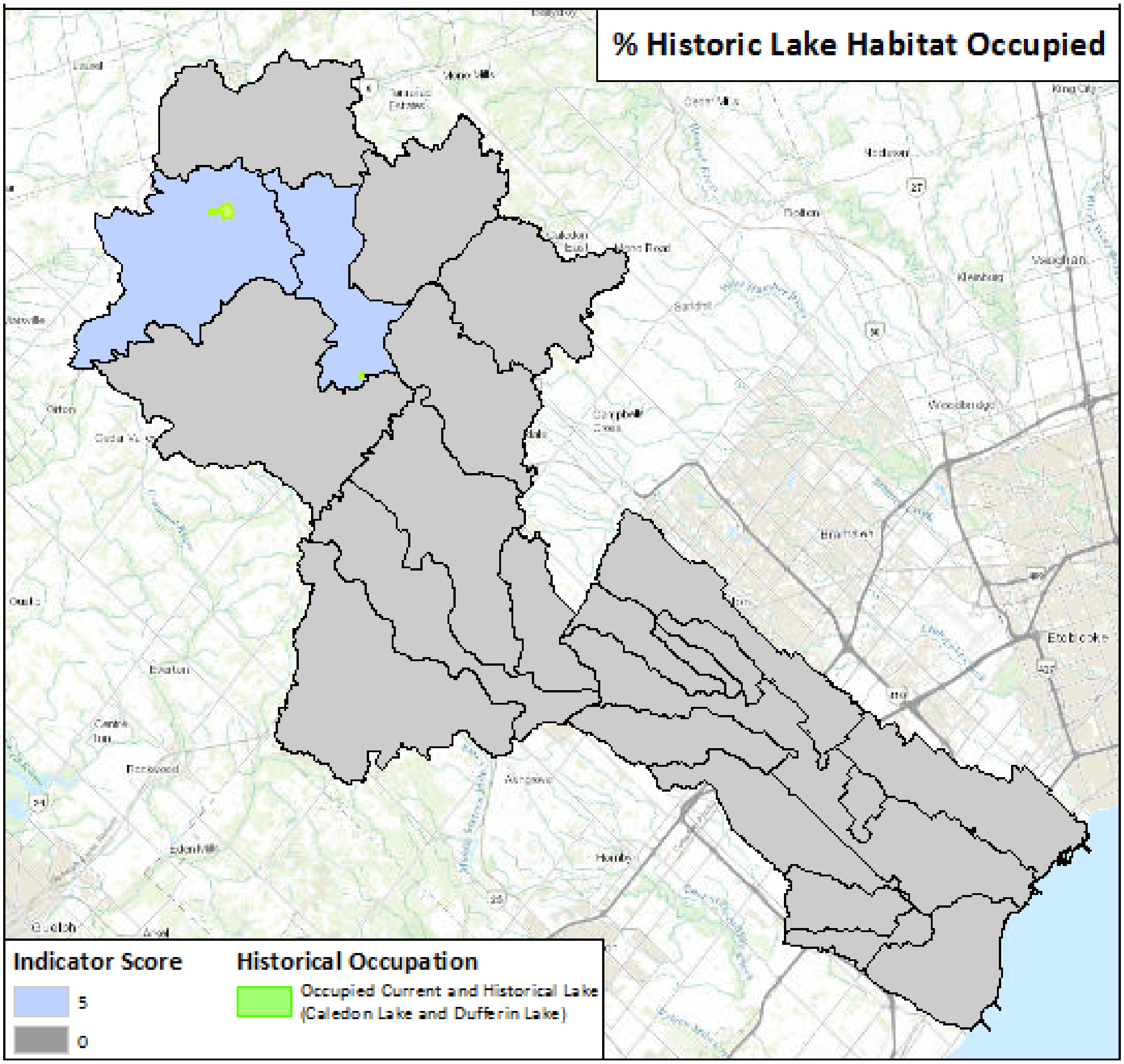

Figure 11: Range-wide Conditions Indicator 5: % Historic Lake Habitat Occupied.

Range-wide Conditions Summary

Since all five indicators were available for testing, there is a maximum score of **5** and a minimum score of **0** for each indicator. As there are no Nulls, the total maximum aggregate score for Category 1 is **25**.

Figure 12 below illustrates the total score for the Range-wide conditions both with the scoring value and the colour associated with that value. There was no excellent value within the watershed, but this is not a surprise given the low scoring for some of the indicators.

Table 13 provides a summary of all the subwatersheds assessed and their scores for each of the indicators.

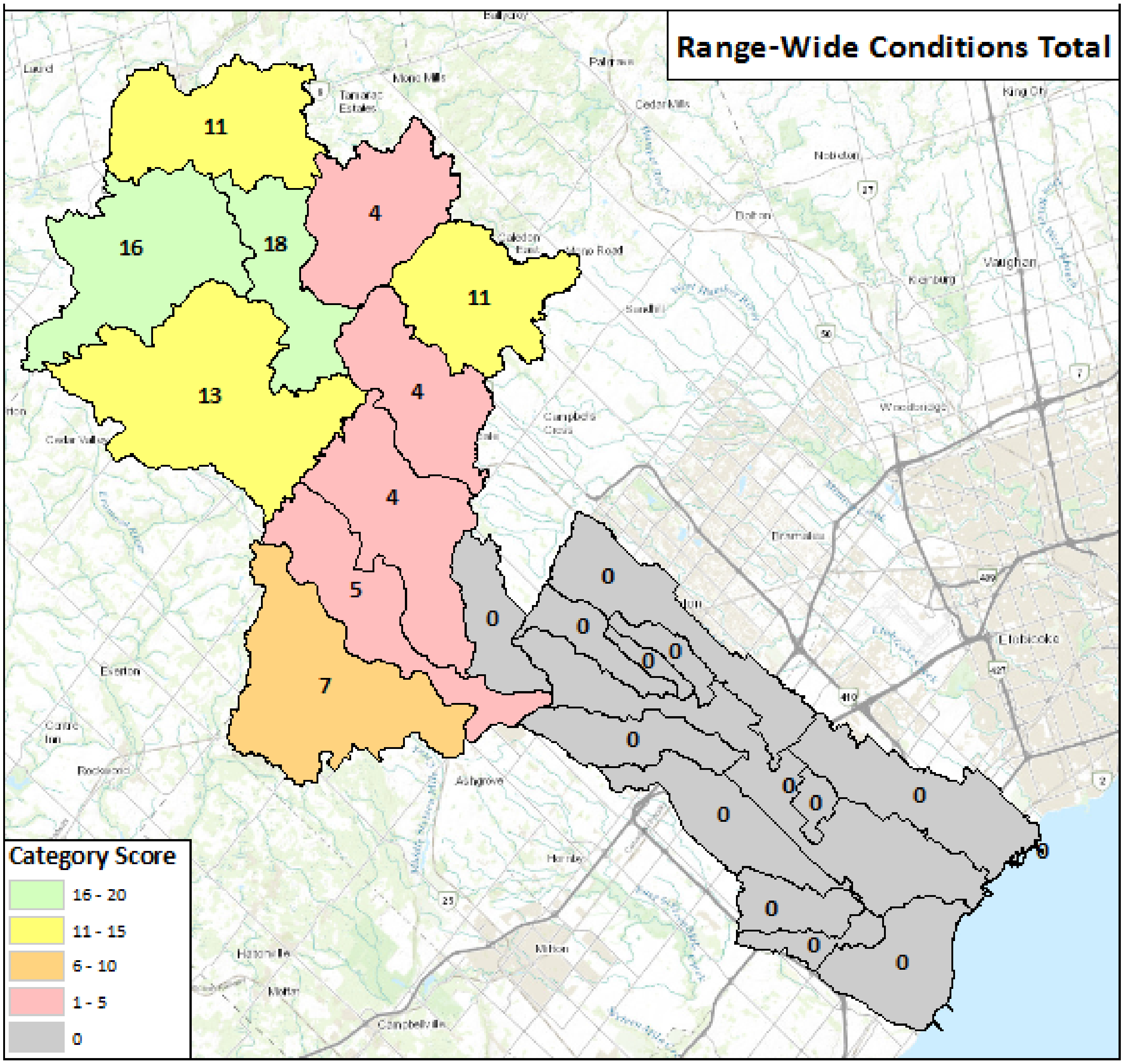

Figure 12: Aggregate Score for Category 1: Range-wide Conditions.

Table 13: Cumulative Scoring for Category 1: Range-wide Conditions.

Subwatershed Number	Name	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	CSI 1 Total
1	Loyalist Creek	0	0	0	0	0	**0**
2	Carolyn Creek	0	0	0	0	0	**0**
3	Sawmill Creek	0	0	0	0	0	**0**
4	Mullett Creek	0	0	0	0	0	**0**
5	Fletcher's Creek	0	0	0	0	0	**0**
6	Levi Creek	0	0	0	0	0	**0**
7	Huttonville Creek	0	0	0	0	0	**0**
8a	Springbrook Tributary	0	0	0	0	0	**0**
8b	Churchville Tributary	0	0	0	0	0	**0**
9	Norval to Port Credit	0	0	0	0	0	**0**
10	Black Creek	2	1	1	3	0	**7**
11	Silver Creek	2	1	1	1	0	**5**
12	Cheltenham to Glen Williams	1	1	1	1	0	**4**
13	East Credit River	3	1	2	5	0	**11**
14	Glen Williams to Norval	0	0	0	0	0	**0**
15	West Credit River	4	1	3	5	0	**13**
16	Caledon Creek	1	1	1	1	0	**4**
17	Shaw's Creek	3	1	2	5	5	**16**
18	Melville to Forks of the Credit	4	1	3	5	5	**18**
19	Orangeville	3	1	2	5	0	**11**
20	Forks of the Credit to Churchville	1	1	1	1	0	**4**
21	Lake Ontario Shoreline West	0	0	0	0	0	**0**
22	Lake Ontario Shoreline East	0	0	0	0	0	**0**

Population Integrity Condition Category

Indicator 1: Population Density

Table 14: Input features for category 2, indicator 1.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Brook Trout Electrofishing and Biomass Data	CVC	November 22, 2016

Table 15: Scoring Rules for category 2, indicator 1.

Scoring:

CSI Score	Rule (Count/Habitat Unit Area) As per TU USA
5	> 400/Mile
4	151 - 400/Mile
3	50 - 150/Mile
2	< 50/Mile, Overall ≥500
1	< 50/Mile, Overall <500
0	0 or Extirpated

Table 14 lists the datasets used for this indicator. Population distribution and density data are not available at the provincial level. Density data was received from CVC and was calculated as an average from their electrofishing survey data from 2012-2016 and should be considered an approximation. The electrofishing data were reported count numbers per unit in metres and was recalculated and converted to miles to match the units defined in the scoring table (Table 15), which are the rules created for the original CSI model. Survey/electrofishing data were not extensive and the data were interpolated through the modelled habitat range dataset where there was a positive presence for Brook Trout. Negative or extirpated segments were assigned a value of zero to ensure population breaks. The resulting scoring table contains average reach density per subwatershed unit. This information is summarized in Figure 13.

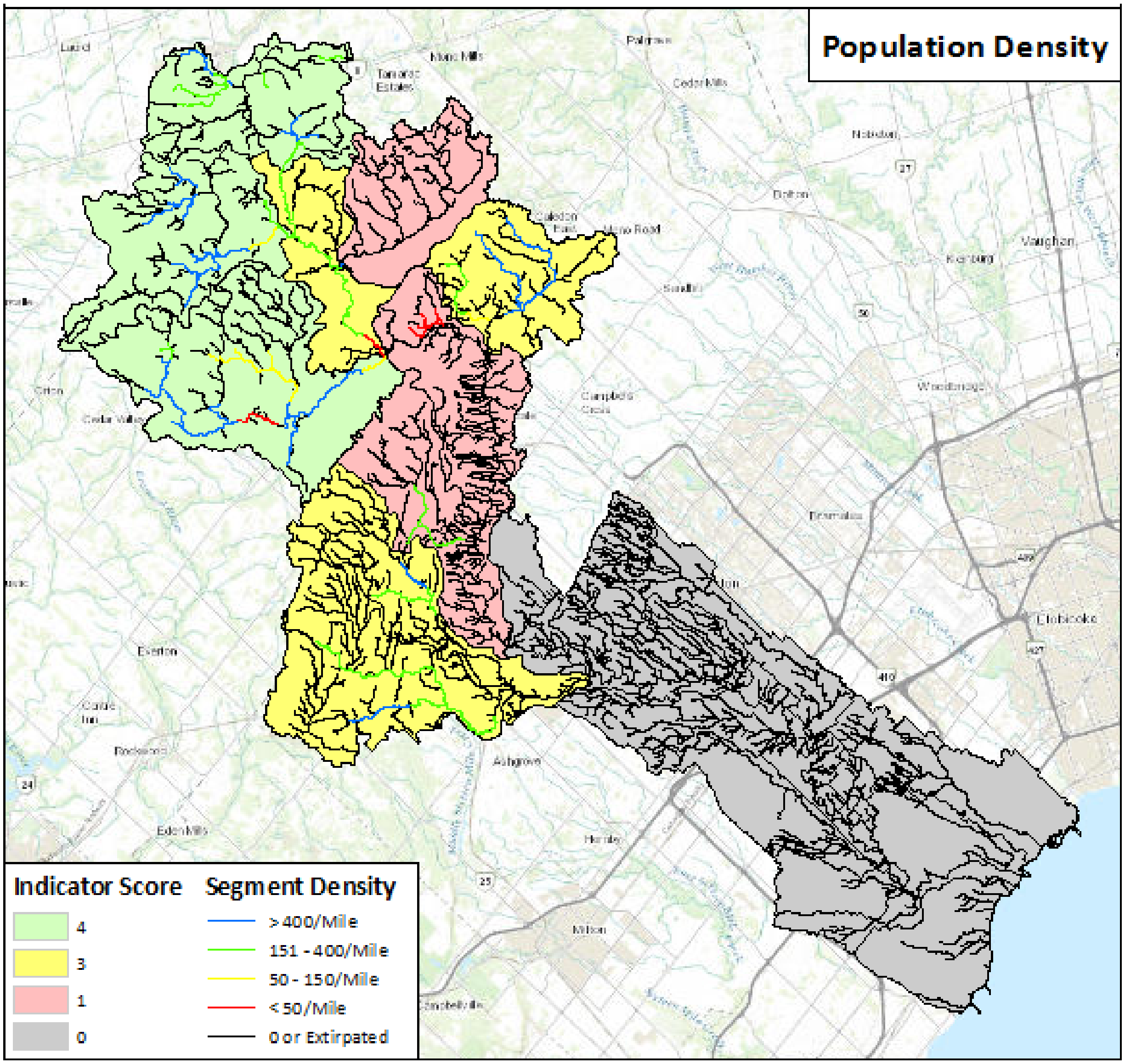

Figure 13: Population Integrity Indicator 1: Population Density.

Indicator 2: Population Extent

Table 16: Input features for category 2, indicator 2.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Perched Culverts 2014-2015	CVC	October 18, 2016
Dams Final External (Confirmed Only)	CVC	October 17, 2016
Natural Barriers	CVC	January 2, 2017

Table 17: Scoring Rules for category 2, indicator 2.

Scoring:

CSI Score	Rule (Km of Available Habitat to Population)
5	≥ 5km of Interconnected Populations
4	3 - < 5km
3	2 - < 3km
2	1 - < 2km
1	< 1km
0	0 or Extirpated

Note that Table 17 represents a modification of the original CSI Scoring Rule below (Table 18), which are the values created by TU USA. After discussion and review with biological staff at the CVC, it was recommended that the scoring parameters be divided by a favor of 10 to reflect current observations and the relative size of subwatersheds and subcatchments in southern Ontario.

Table 18: TU USA CSI Scoring Rules from literature for category 2, indicator 2.

CSI Score	Rule (Km of Available Habitat to Population)
5	Large Interconnected Populations (≥ 50km)
4	30 – 50km
3	20 – 30km
2	10 – 20km
1	< 10km
0	0 or Extirpated

Figure 14 represents the indicator score based on the scoring criteria in Table 17. Included in the map are the reaches of stream identified where they do and do not have Brook Trout present.

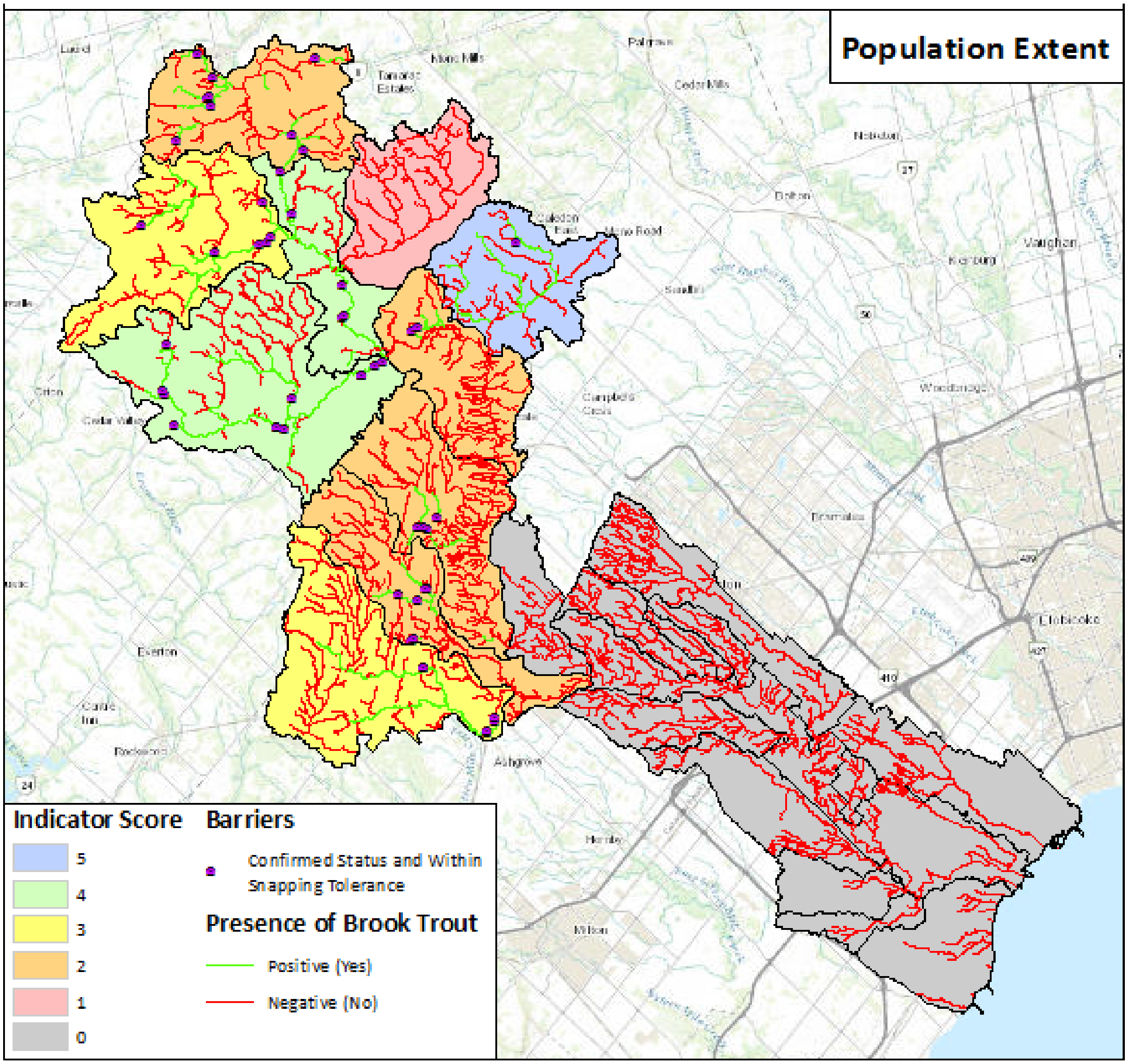

Figure 14: Population Integrity Indicator 2: Population Extent.

Indicator 3: Genetic Purity

Inputs:
No spatial datasets are available currently, however, after review from OMNRF and CVC, it was concluded that current population groups contained no hybrids or hatchery stock. Based on the literature rules (see Table 19 below), any subwatershed units containing pure Brook Trout populations were given a score of **5**, any subwatershed with no Brook Trout populations were given a zero. The only exception to this assumption is Caledon Lake which stocks Brook Trout; this will result in subwatershed 17 (Shaw's Creek) having a score of 4.

Table 19: Scoring Rules for category 2, indicator 3.

Scoring: (From Literature only)

CSI Score	Rule (% of known/suspected hybridization) As per TU USA
5	No Hybridization
4	No Hybridization Known, but Proximity to Hatchery Derived Trout Causes Concern
3	Hybridization < 10%
2	Hybridization 10 - 20%
1	Hybridization > 20%
0	Extirpated

At this time, the most current assessment of purity was undertaken in the early 1990s by Dr. Moira Ferguson, University of Guelph. At that time, the Brook Trout samples which were collected from several locations in the watershed were deemed wild (J. Imhof, pers. comm.). The CVC is undertaking a new set of genetic assessments of Brook Trout populations in the Credit River watershed with the support of Dr. Chris Wilson, OMNRF Research, but the results of this more recent initiative will not be known for several years.

Figure 15 illustrates the scoring for this indicator using the methodology described above.

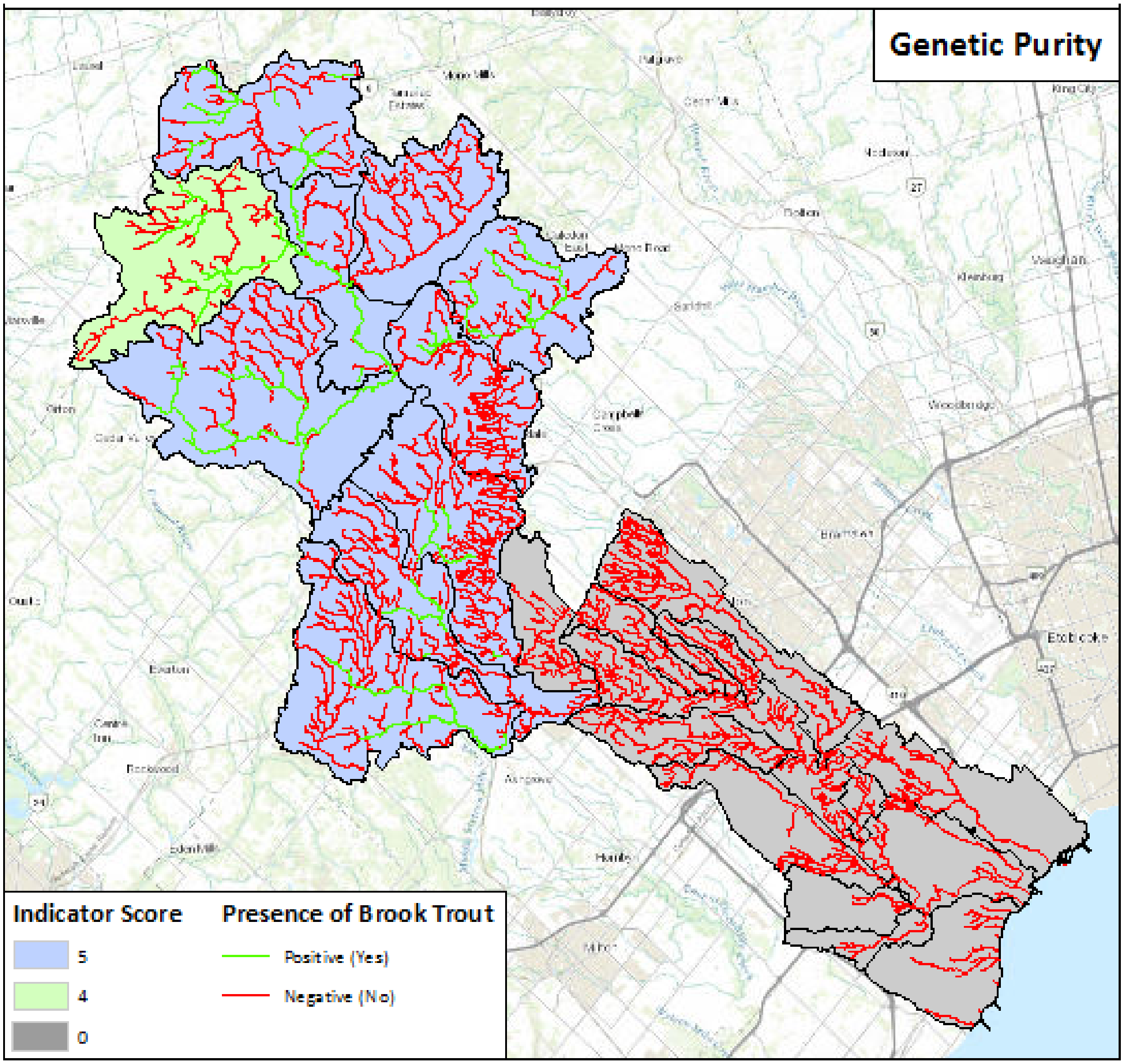

Figure 15: Population Integrity Indicator 3: Genetic Purity.

Indicator 4: Disease Vulnerability

Table 20: Input features for category 2, indicator 4.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Fish Pathogen Management Zone	Land Information Ontario	August 9, 2016

Table 21: Scoring Rules for category 2, indicator 4.

Scoring:

CSI Score	Rule (Non-Native Diseases or Parasites)
5	No Disease/Pathogen
4	None Present but Proximity > 10km
3	Disease/Pathogen Present but not in Target Fish
2	Disease/Pathogen Present in Habitat but not in Target Fish
1	Disease/Pathogen Suspected in Target Fish
0	Disease/Pathogen Confirmed in Target Fish

The only currently available dataset for testing disease vulnerability is the Fish Pathogen Management Zone polygon features which represents broad geographic zones of pathogen management in the province (see Table 20). For the CSI development work, only the Viral Hemorrhagic Septicemia (VHS) Pathogen Management Zone intersected the subwatershed boundary and was treated as the target disease. However, this dataset does not provide observed disease distribution amongst fish populations, therefore the output cannot be 0 currently, as there are no confirmations in the dataset. The scoring rules above contain slight modifications to the literature rules created for the original CSI (see Table 21).

Figure 16 illustrates the scoring based on the criteria in Table 21 with specific reference to the potential VHS Pathogen Management Zone.

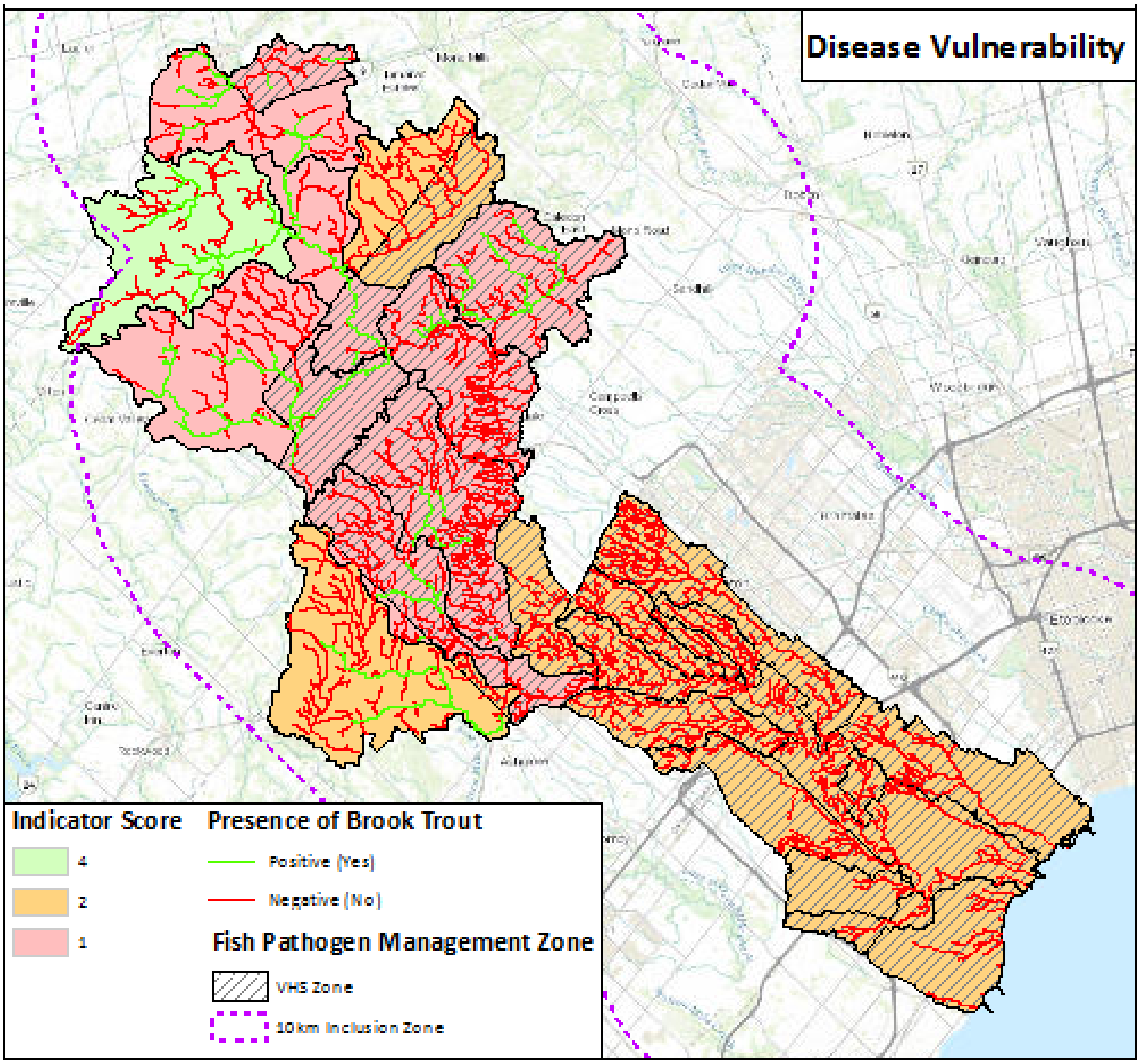

Figure 16: Population Integrity Indicator 4: Disease Vulnerability.

Indicator 5: Life History Diversity

Inputs:

The data sets are not available currently, however viable alternatives could include migration data of native trout populations. After the CSI workshop and review sessions, it was suggested that because of the methodologies utilized for fishery management practices in Ontario, that for the CSI, life history diversity should be represented by one life history form only and is reflective of the presence or absence of a target fish species (see Table 22 compared to TU USA scoring in Table 23).

Table 22: Scoring Rules for category 2, indicator 5.

Scoring:

CSI Score	Rule (Life History Form by Presence of Target Species)
5	Target Species Present Within Subwatershed
0	Target Species Absent or Extirpated

Table 23: TU USA CSI Scoring Rules from literature for category 2, indicator 5.

CSI Score	Rule (# of Life History Forms) As per TU USA
5	All Life History Forms Present
3	Two or More Life Histories Present but at Least One Absent
1	One Life History Present, Others Absent

Originally this was a non-testable indicator due to the lack of appropriate data and all subwatershed boundary units were given a score of Null, which would have push the Population Integrity category down to **20** and the final CSI Aggregate score to **95**. However, upon revising the CSI analysis based on the suggestion from the CSI workshop and review sessions, this indictor was reset, and the category score was increased back to **25** to include life history diversity.

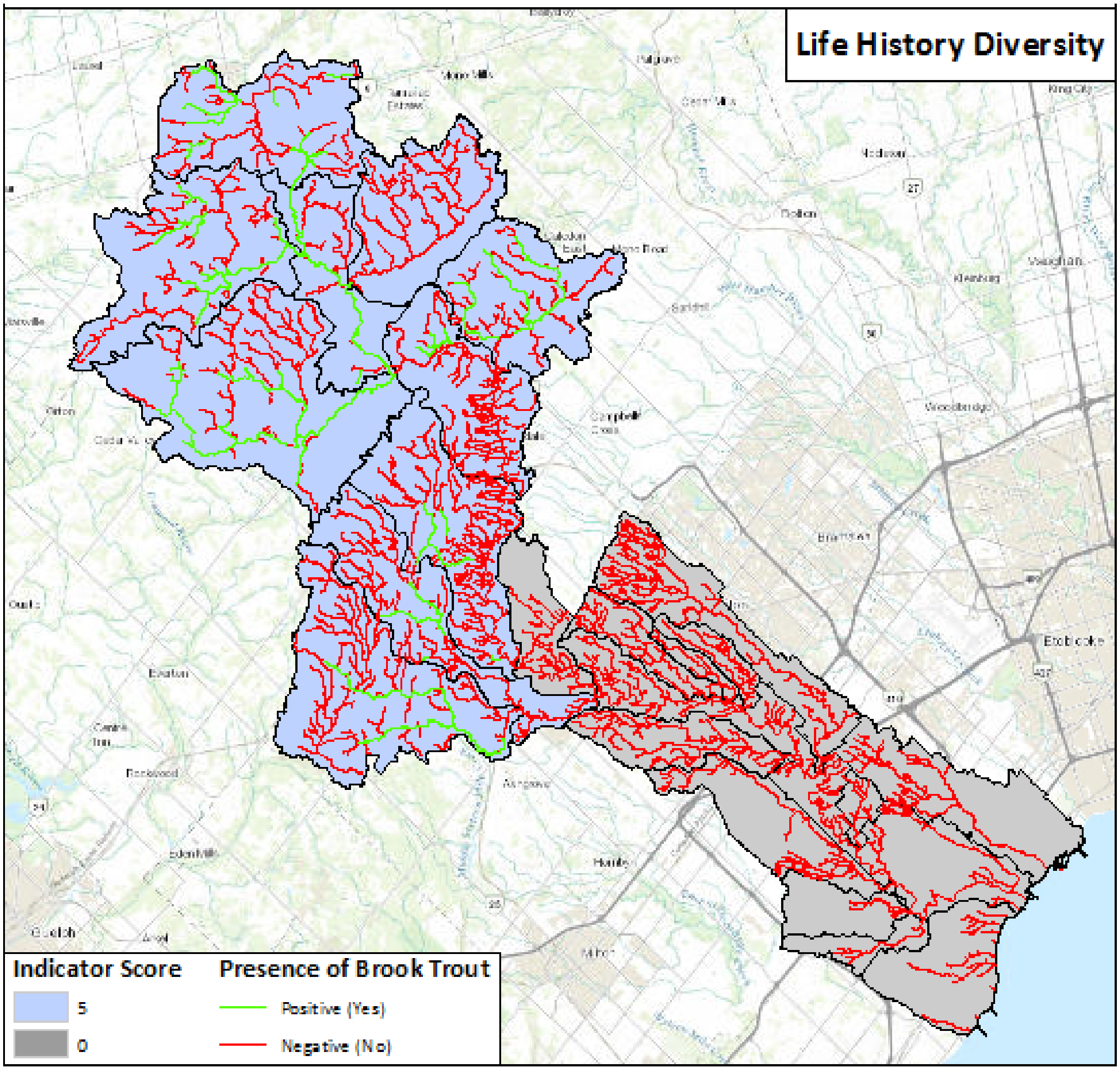

Figure 17: Population Integrity Indicator 5: Life History Diversity.

Population Integrity Conditions Summary

The data available for the Population Integrity Conditions are particularly weak. Available spatial datasets are largely unavailable at the provincial level; however, CVC was able to provide a substantial amount of this valuable data at the regional level. Assumptions and suggestions provided by fishery experts provided valuable insights for indicators that lacked spatial datasets completely: genetic purity and life history diversity. Since all five indicators were available for testing, there is a maximum score of **5** and a minimum score of **0** for each indicator. As there are no Nulls, the total maximum aggregate score for Category 2 is **25**. Figure 18 illustrates the scoring distribution within each subwatersheds. No subwatershed exhibited an excellent score. The summary of the scoring for each subwatershed is presented in Table 24.

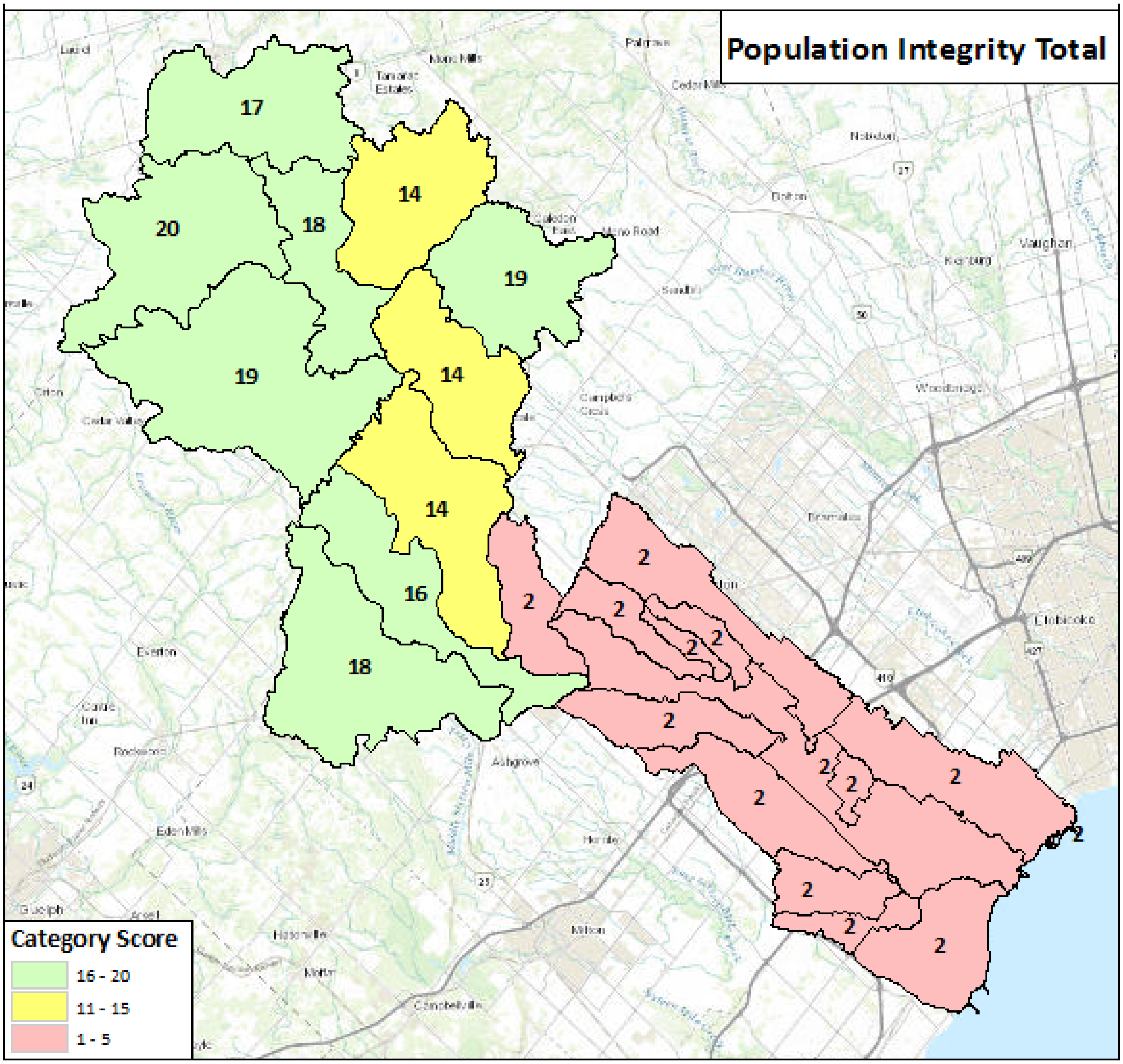

Figure 18: Aggregate Score for Category 2: Population Integrity Conditions

Table 24: Cumulative Scoring for Category 2: Population Integrity.

Subwatershed Number	Name	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	CSI 2 Total
1	Loyalist Creek	0	0	0	2	0	**2**
2	Carolyn Creek	0	0	0	2	0	**2**
3	Sawmill Creek	0	0	0	2	0	**2**
4	Mullett Creek	0	0	0	2	0	**2**
5	Fletcher's Creek	0	0	0	2	0	**2**
6	Levi Creek	0	0	0	2	0	**2**
7	Huttonville Creek	0	0	0	2	0	**2**
8a	Springbrook Tributary	0	0	0	2	0	**2**
8b	Churchville Tributary	0	0	0	2	0	**2**
9	Norval to Port Credit	0	0	0	2	0	**2**
10	Black Creek	3	3	5	2	5	**18**
11	Silver Creek	3	2	5	1	5	**16**
12	Cheltenham to Glen Williams	1	2	5	1	5	**14**
13	East Credit River	3	5	5	1	5	**19**
14	Glen Williams to Norval	0	0	0	2	0	**2**
15	West Credit River	4	4	5	1	5	**19**
16	Caledon Creek	1	1	5	2	5	**14**
17	Shaw's Creek	4	3	4	4	5	**20**
18	Melville to Forks of the Credit	3	4	5	1	5	**18**
19	Orangeville	4	2	5	1	5	**17**
20	Forks of the Credit to Churchville	1	2	5	1	5	**14**
21	Lake Ontario Shoreline West	0	0	0	2	0	**2**
22	Lake Ontario Shoreline East	0	0	0	2	0	**2**

Habitat Integrity Condition Category

Indicator 1: Land Stewardship

Table 25: Input features for category 3, indicator 1.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Areas of Natural and Scientific Interest (ANSI)	Land Information Ontario	October 14, 2016
Greenbelt Designation (Niagara Escarpment Plan and Oak Ridges Moraine Conservation Plan Only)	Land Information Ontario	October 14, 2016
Provincial Park Regulated	Land Information Ontario	October 14, 2016
Canadian Heritage River System	Land Information Ontario	October 14, 2016
Natural Heritage System Area	Land Information Ontario	October 14, 2016
CVC Property	CVC	N/A
CVC Landform Conservation	CVC	N/A

Table 26: Scoring Rules for category 3, indicator 1.

Scoring:

CSI Score	Rule (% Protected/Land Stewardship Area)
5	≥ 40%
4	30 – < 40%
3	20 – < 30%
2	10 – < 20%
1	< 10%
0	Not Protected

Table 27 list the original scoring rule for the indicator as created by TU USA. The original CSI scoring rule did not include a rule for scores of 0 for non-protected areas. These areas are highly susceptible to changes and it is disadvantageous to give a study area a positive score which may influence it's categoric and total CSI score. For our CSI work, these rules were rescored to include a score of 0 for non-protected areas, with inputs from the project partners during the review sessions and the assessment workshop (Table 26). Figure 19 is the resulting map of the revised scoring and includes the areas identified provincially as protected through various acts and legislation.

Table 27: TU USA CSI Scoring Rules from literature for category 3, indicator 1.

CSI Score	Rule (% Protected/Land Stewardship Area) As per TU USA
5	30% or more of Subwatershed in protected status
4	20 – 29% protected
3	10 – 19% protected
2	1 – 10% protected
1	No protected habitat

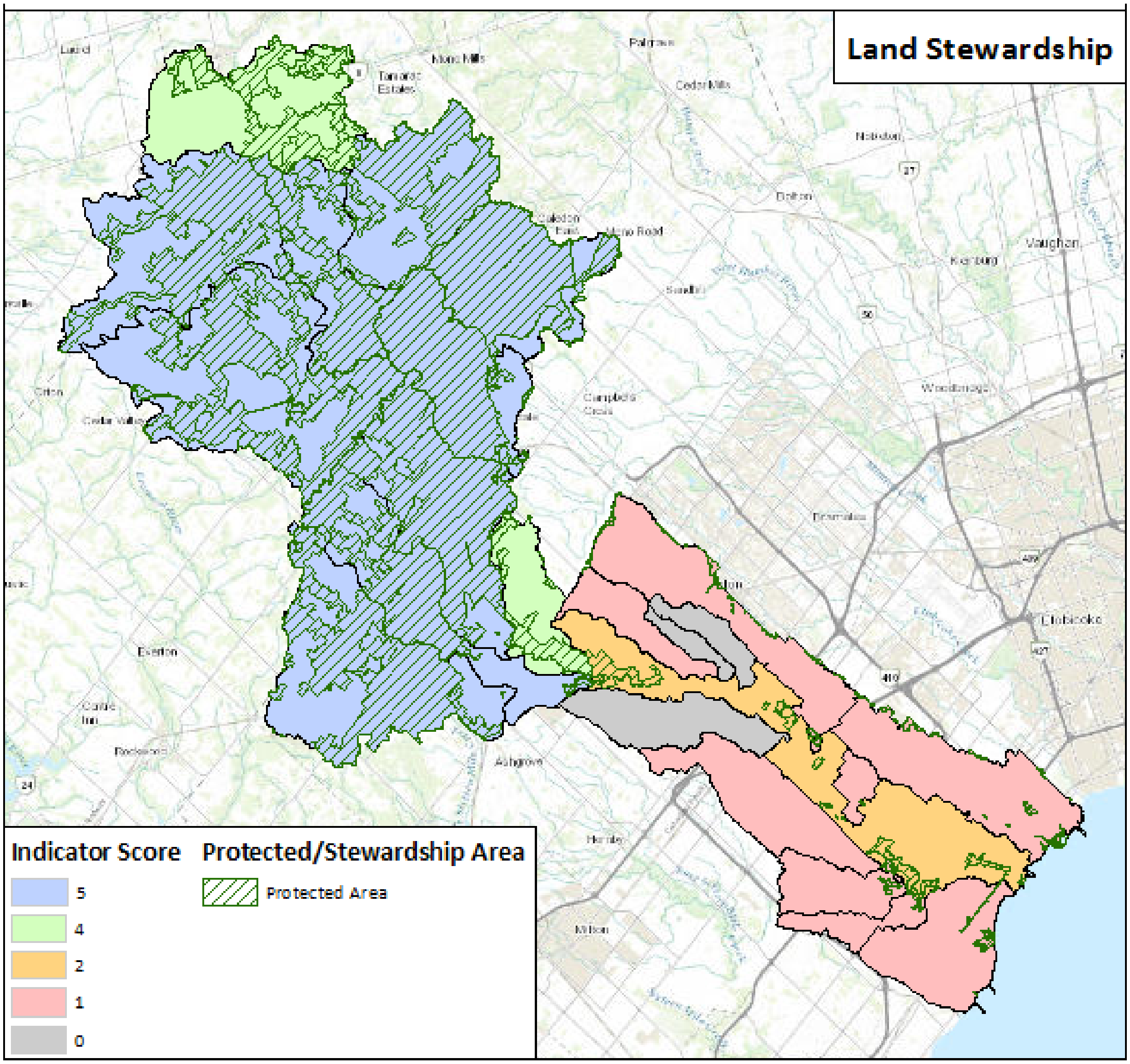

Figure 19: Habitat Integrity Indicator 1: % Protected/Land Stewardship Area.

Indicator 2: Watershed Connectivity/Degree of Fragmentation

Table 28: Input features for category 3, indicator 2.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current (Baseline habitat feature)	Trout Unlimited Canada	Derived: January 11, 2017
Perched Culverts 2014-2015	CVC	October 18, 2016
Dams Final External (Confirmed Only)	CVC	October 17, 2016
Natural Barriers	CVC	January 2, 2017

Table 29: Scoring Rules for category 3, indicator 2.

Scoring:

CSI Score	Rule (% Watershed Connectivity)
5	100%
4	80 – < 100%
3	60 – < 80%
2	40 – < 60%
1	20 - < 40%
0	< 20%

Table 30: TU USA CSI Scoring Rules from literature for category 3, indicator 2.

CSI Score	Rule (Watershed Connectivity) As per TU USA
5	All Streams Connected
4	Streams Connected but Fragmented at Watershed Scale
3	Minor Fragmentation Within Subwatershed
2	Moderate Fragmentation
1	High Fragmentation

Table 28 list the input datasets for the analysis performed for this indicator. Table 30 is the original CSI scoring rule created by TU USA; however, it does not contain quantitative ranking which can be assessed and ranked easily in the CSI work without manual interpretation. For the CSI redevelopment work, the ranking rules identified in Table 29 were derived using equal statistical breaks.

subwatershed units can contain many connected or unconnected streams; the analysis first determines the total connectivity count of stream "branches" in the entire watershed and then breaks this determination down into their subwatershed boundary units. "Branches" in this study are the interconnected streams which have a common sink or end-point. Barriers are not included in the development of the baseline file, because the hydrological inputs do not contain these breaks. Dams, culverts, and barriers are then factored in, creating fragmentation groups within these baseline branches. The analysis then assesses the average maximum remaining lengths of each fragmented stream branches within the subwatershed boundary. The modelling methodology is demonstrated below in a series of sequential figures (Figures 20 – 23). The final resulting map is shown as Figure 24.

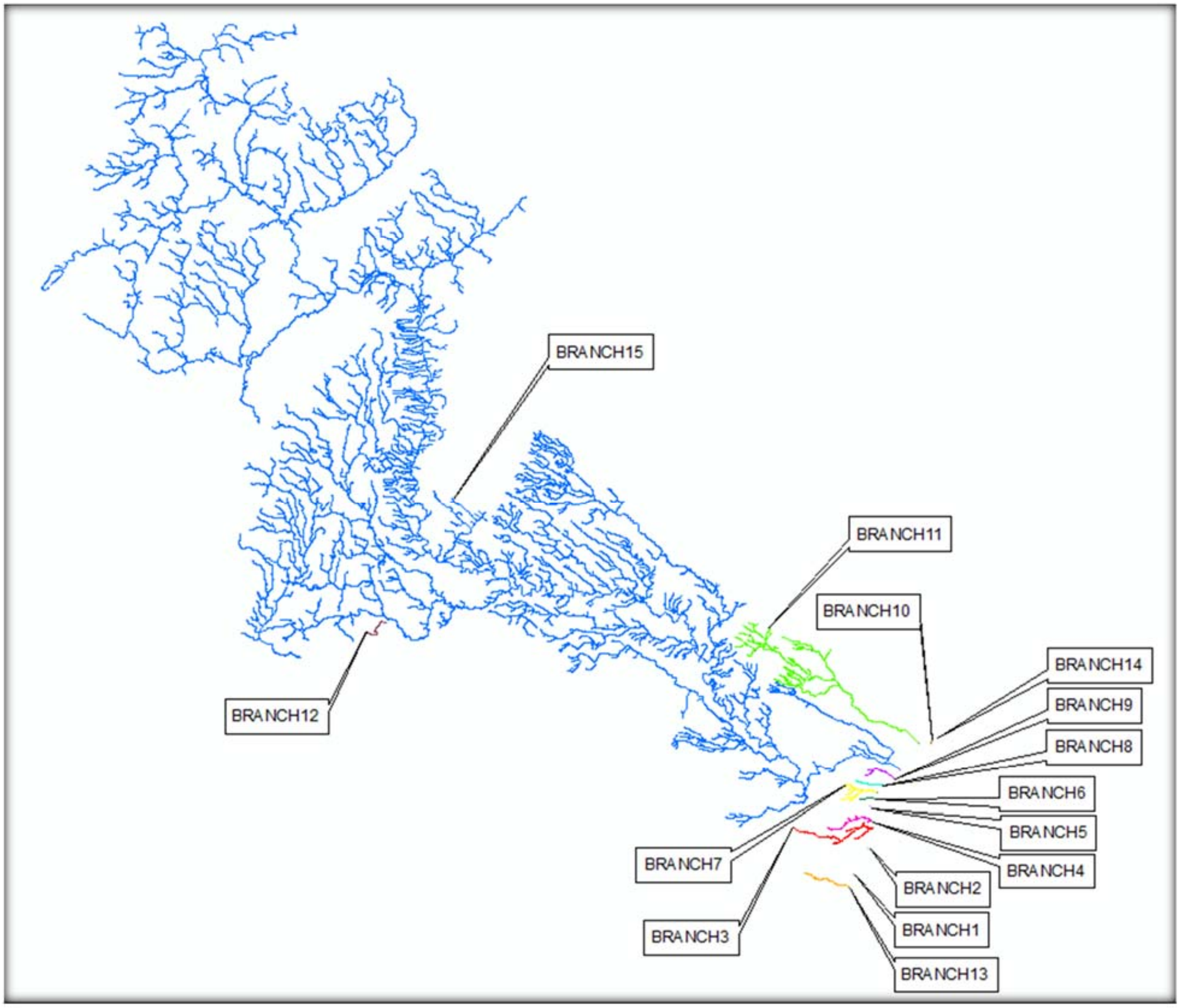

Figure 20: Modelling total connectivity and auto-determining “Branch” groups due to natural breaks in the hydrological datasets. Model automatically assigns a numerical value to each unique branch.

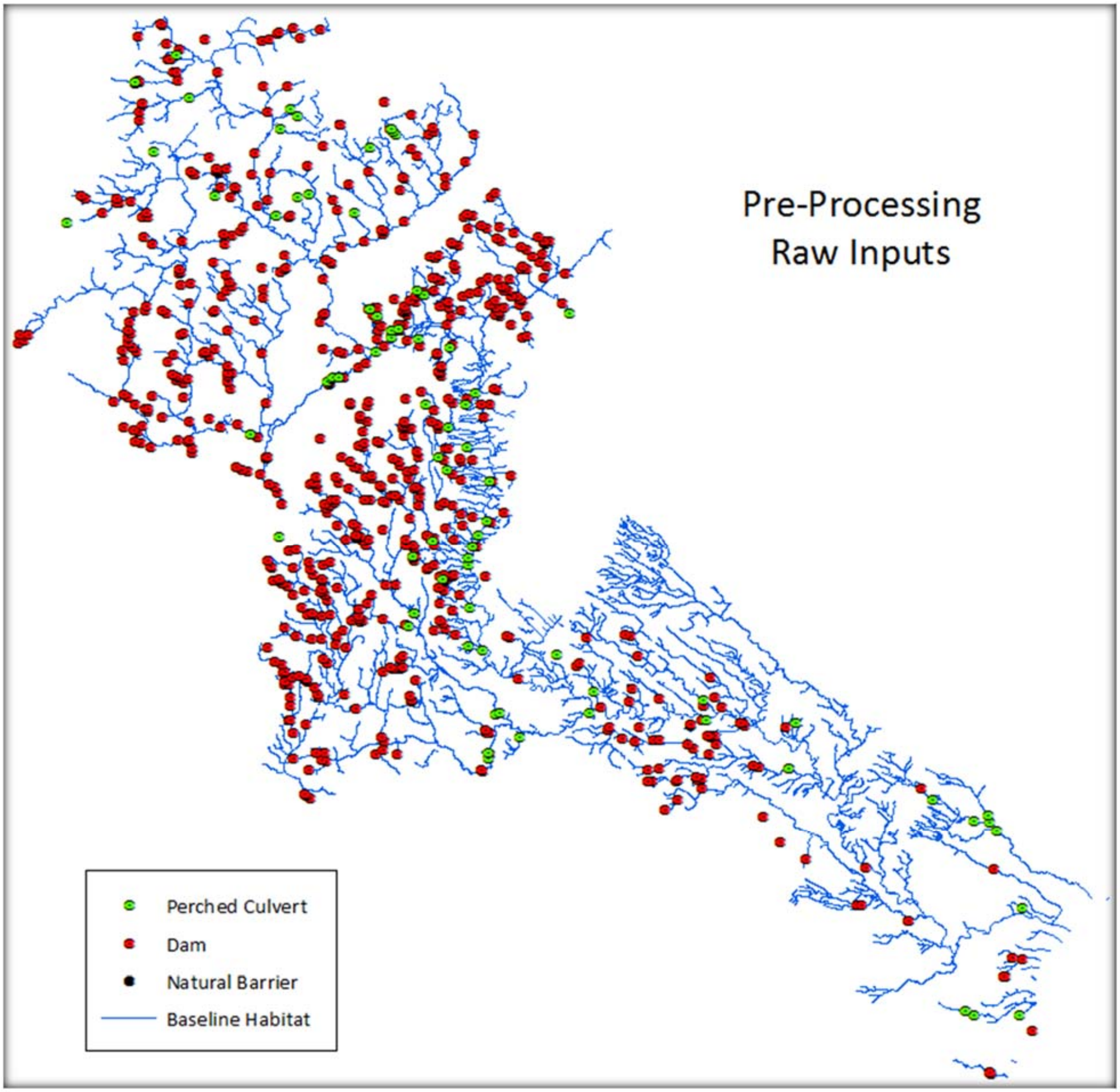

Figure 21: Pre-processed barriers inputs supplied by CVC.

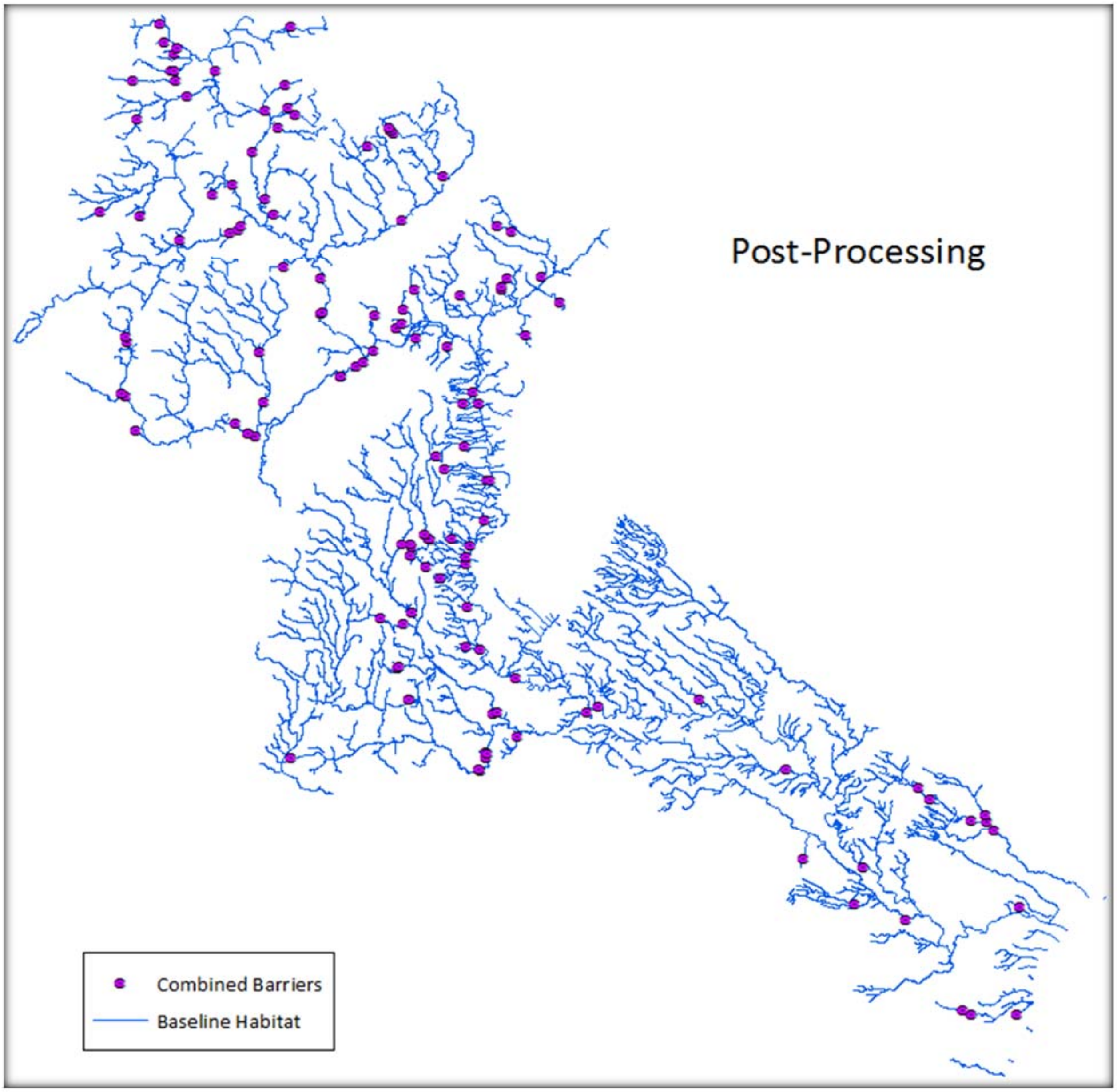

Figure 22: Post-processed barriers output created by Trout Unlimited Canada after a series of modelled automated quality assurance processes were run. Dams with a status of “Unconfirmed” were removed to decrease error due to uncertainty, the remaining features were analyzed against the Natural Barriers dataset to remove overlapping or duplicate features, the remaining dams were then merged with the Perched Culvert dataset to create a single barrier dataset. The compiled barrier dataset was analyzed against the baseline habitat feature to autocorrect their geospatial location to match the baseline habitat dataset. The analysis also eliminated barriers that exceeded the snapping tolerance set by the correcting process. The final resulting feature dataset contains the corrected combined dams, natural barriers, and perched culverts that are confirmed and within snapping tolerance of the baseline habitat feature.

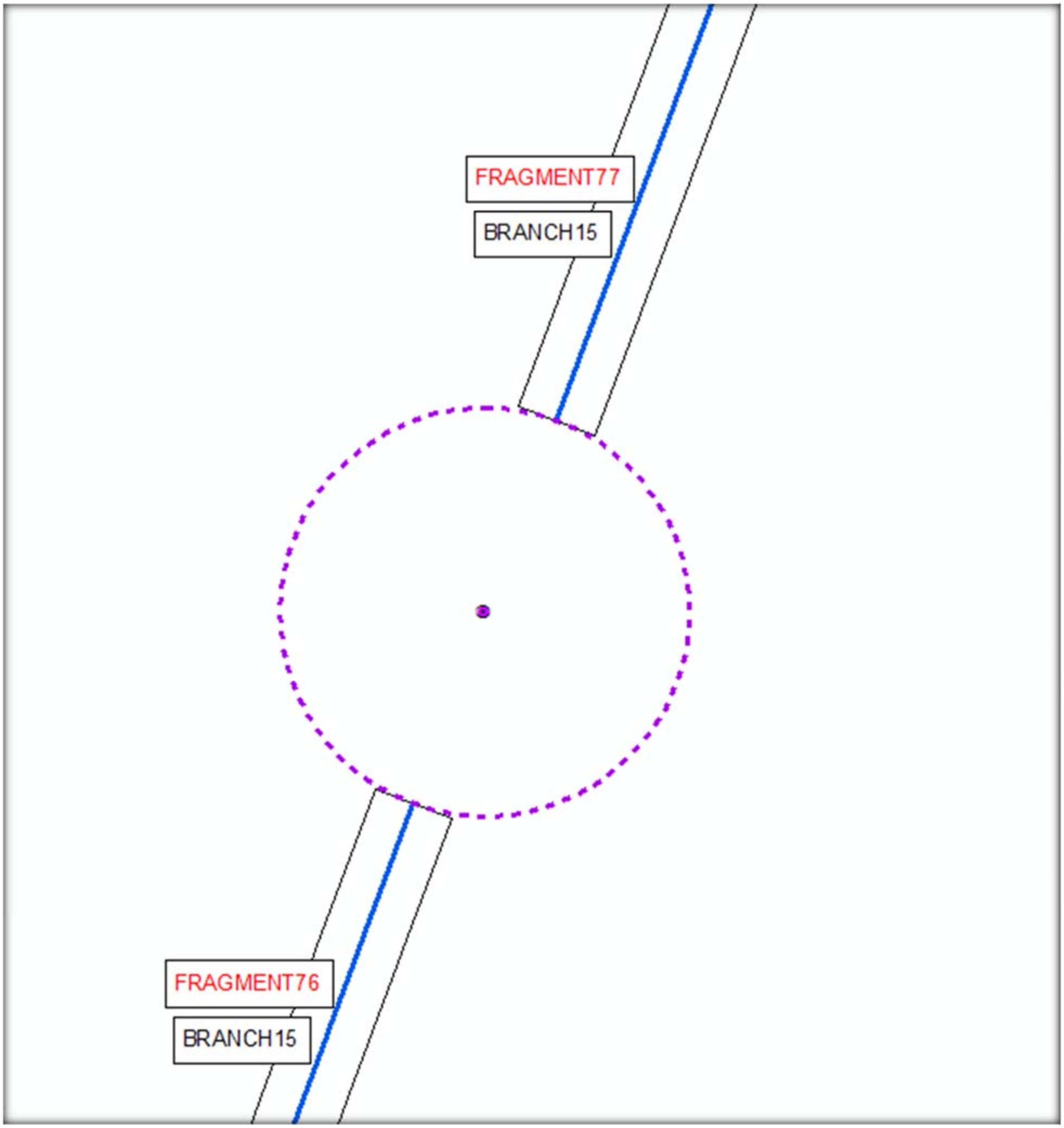

Figure 23: The corrected barrier features create small breaks in the baseline habitat which creates new fragmented groupings while still maintaining the originally identified branch grouping. This makes the resulting analysis and scoring easy as users can identify the original stream branch, average fragmented lengths, and maximum fragmented lengths within each subwatershed area.

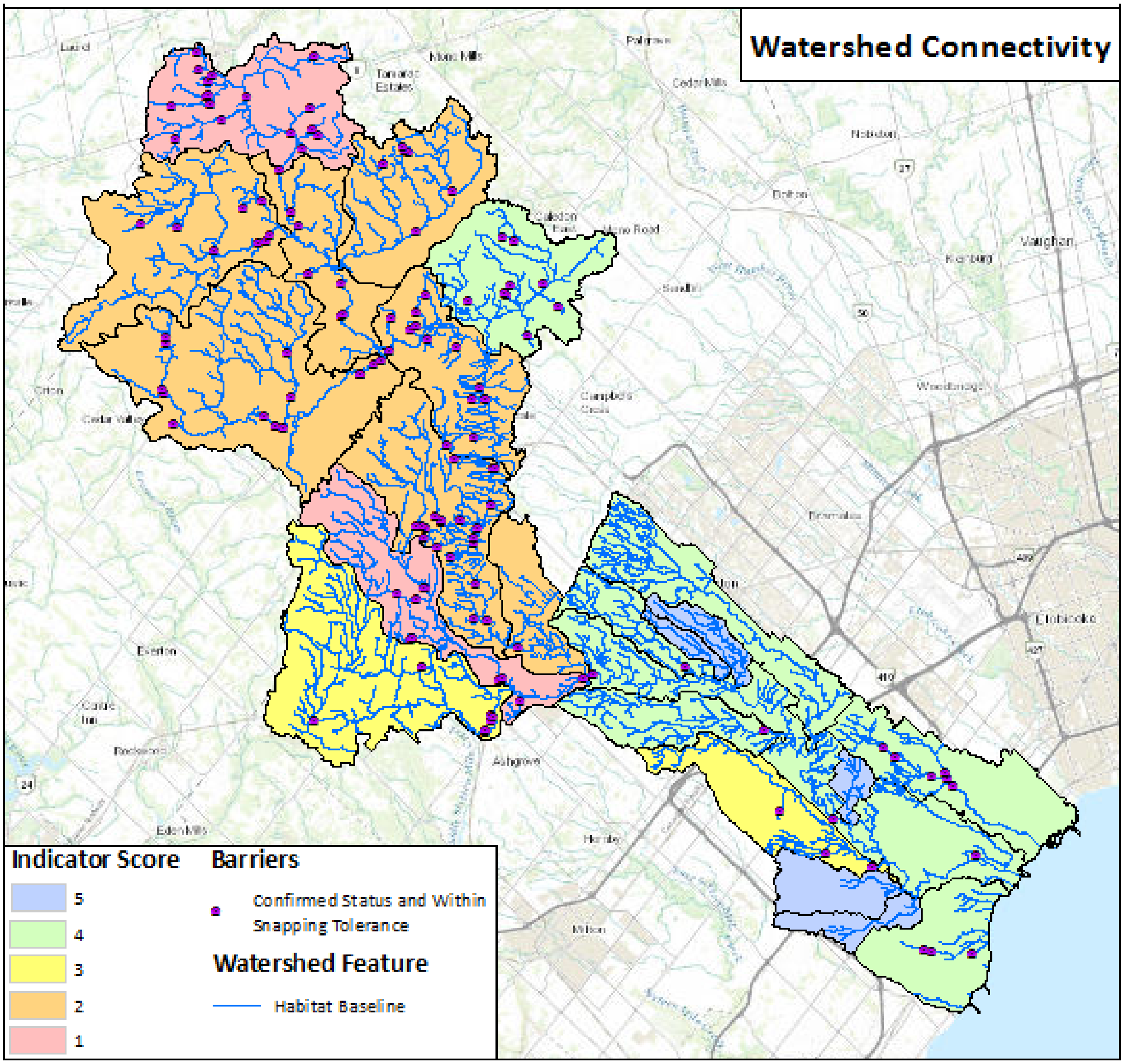

Figure 24: Habitat Integrity Indicator 2: Watershed Connectivity.

Indicator 3: Watershed Conditions

Table 31: Input features for category 3, indicator 3. *On recommendation from the specialist from the Ontario Ministry of Natural Resources and Forestry (OMNRF), only evaluated wetlands are included as accepted input into the model.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Ontario National Road Network (NRN) Segments	Government of Canada	August 8, 2016
Wooded Area	Land Information Ontario	October 14, 2016
Wetland*	Land Information Ontario	October 14, 2016

Table 32: Scoring Rules for category 3, indicator 3.

Scoring: As Tested, Based on Previous TU USA Assisted Analysis.

CSI Score	Rule (% Riparian Area)
5	≥ 85%
4	65 – < 85%
3	45 – < 65%
2	15 – < 45%
1	< 15%
0	0
Penalty	**Rule (Road Density in mi/mi^2)**
-1	1.7 – < 4.7
-2	≥ 4.7

Table 33 is the original CSI Scoring Rule as noted below. Although the literature defines this indicator as being measured by road density, riparian function, stream habitat complexity, and/or deep pools as determinates on population persistence, the scoring rules only considered road density. During the original CSI redevelopment work, TUC collaborated with TU USA to modify the original scoring and created the rules listed above in Table 32. These new rules were tested with the support of TU USA, and the current CSI analysis for this report follows these scoring rules. Figure 27 is the product of the analysis using this scoring rule.

Table 33: TU USA CSI Scoring Rules from literature for category 3, indicator 3.

CSI Score	Rule (Road Density in mi/mi^2) As per TU USA
5	0 – 0.1
4	0.1 – 0.7
3	0.7 – 1.7
2	1.7 – 4.7
1	> 4.7

The riparian area/buffer was built on guidelines for riparian corridors by the Office of Water of the New South Wales (NSW) Government (Office of Water, NSW Government, 2012). These do represent some aspects of the function and values of riparian zones both from a width and contiguous extent. The recommended buffer widths are per side and are generated by Strahler Order Classification:

1^{st} + 2^{nd} order = 10m
3 = 30m
4+ = 40m

The riparian buffer was then used as the basis for the riparian area calculation as well as extracting the road density information (see Table 32). The minimum score that a subwatershed can receive for this indicator is 0, even if the penalty applied is larger than the riparian health score as the CSI does not include negative scoring. The modelling methodology for creating the riparian areas is described below in Figure 25 and 26, the result is illustrated in Figure 27.

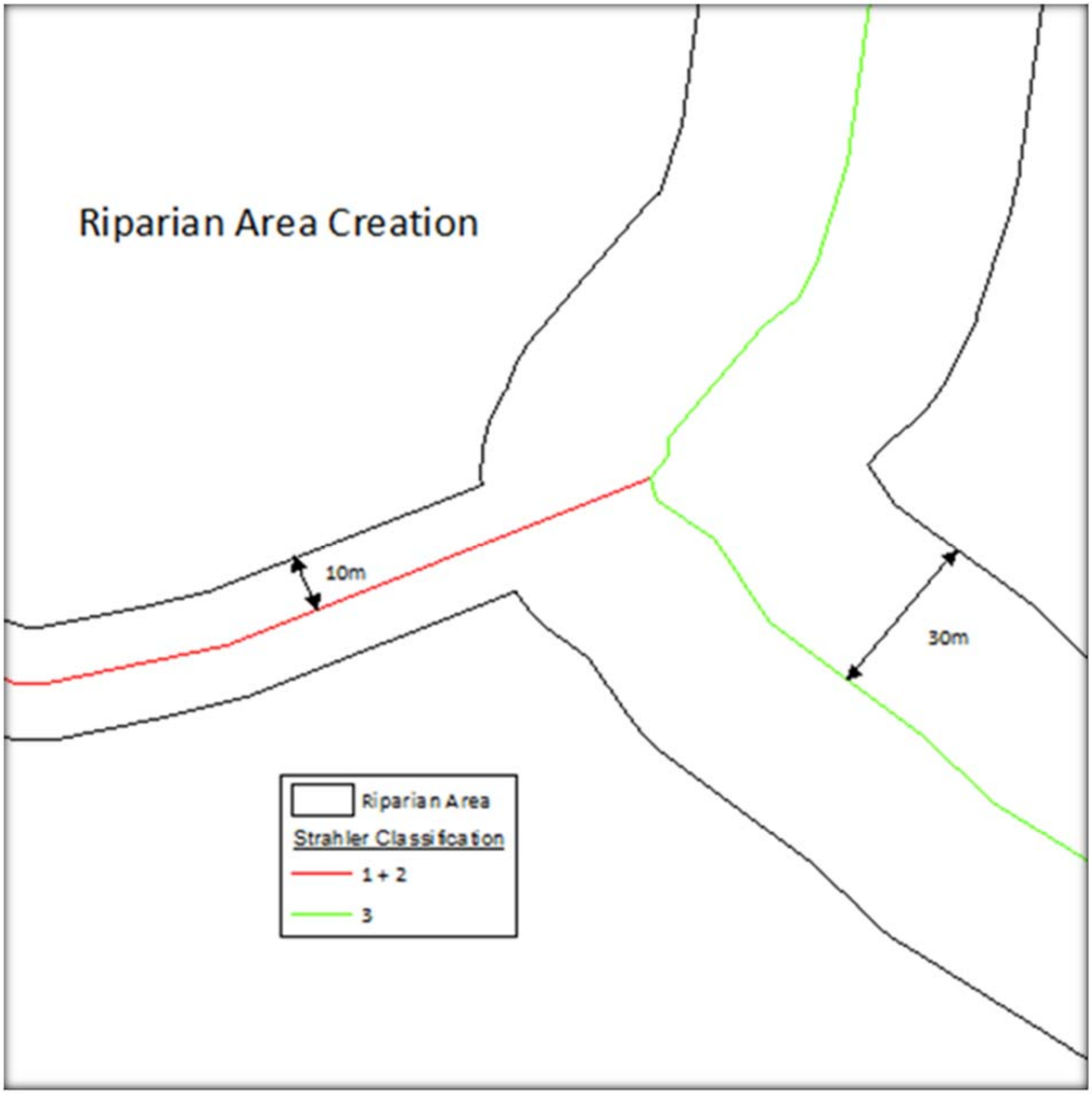

Figure 25: Creation of the riparian buffer area by the Strahler Order Classification value that was preassigned to each stream segment.

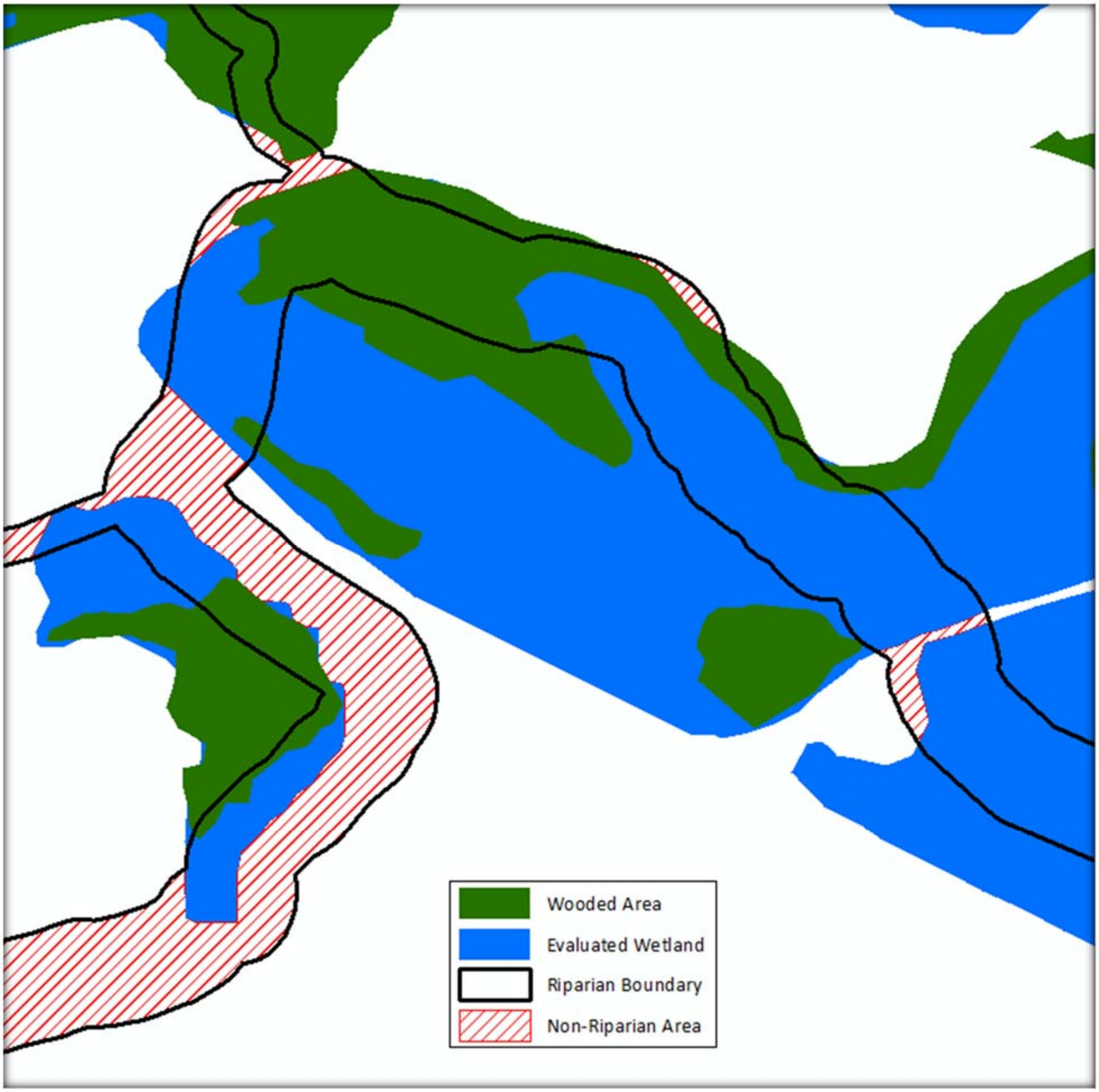

Figure 26: Identifying riparian areas within the buffer.

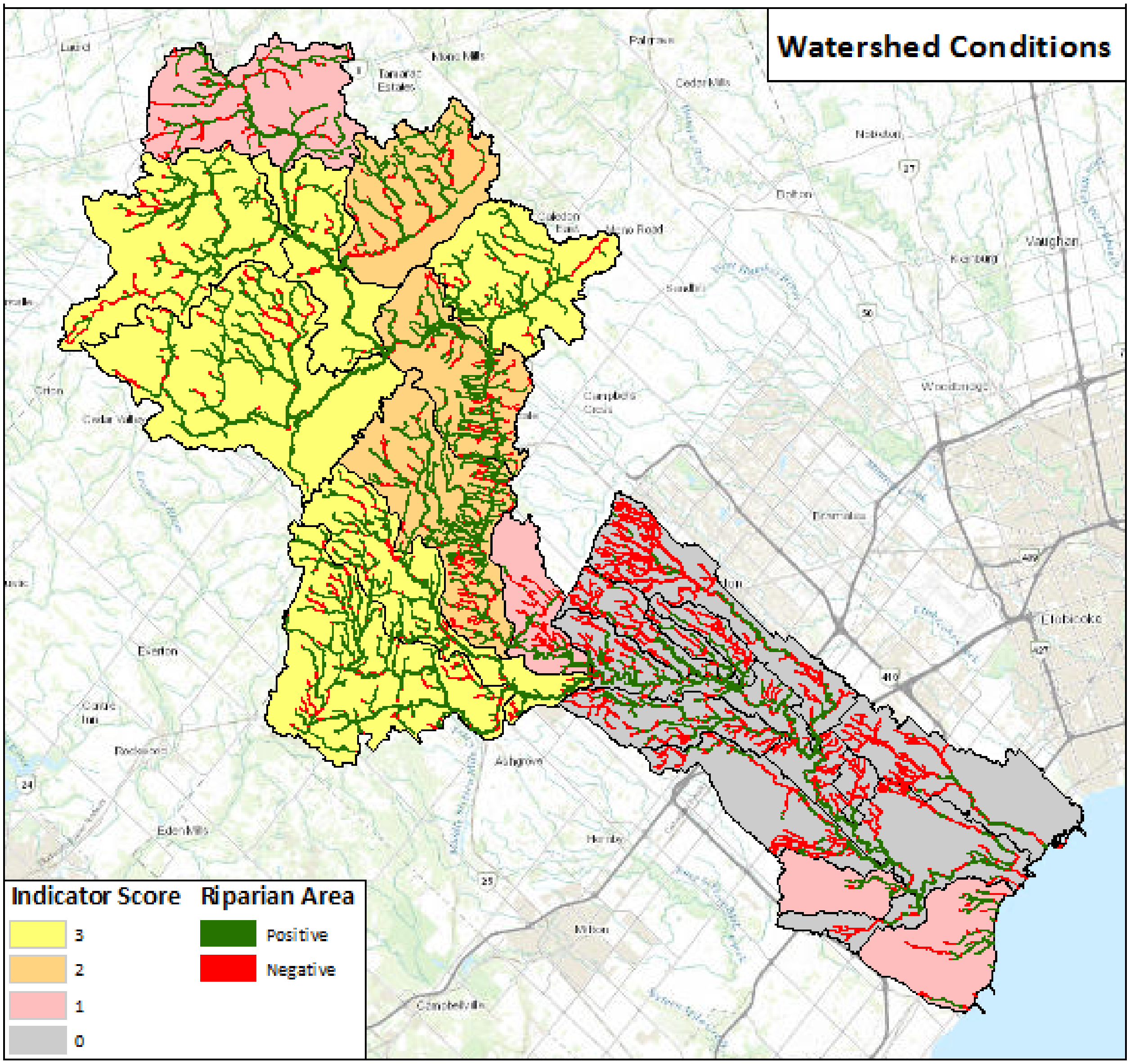

Figure 27: Habitat Integrity Indicator 3: Watershed Conditions.

Indicator 4: Water Quality/Converted Land

Table 34: Input features for category 3, indicator 4.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Aggregate Site Authorized Active	Land Information Ontario	October 14, 2016
Aggregate Site Authorized Inactive	Land Information Ontario	October 14, 2016
Tile Drainage Area	Land Information Ontario	October 14, 2016
Built Up Area (Impervious)	Land Information Ontario	October 14, 2016
Ecological Land Classification (ELC) Polygons	CVC	N/A

Table 35: Scoring Rules for category 3, indicator 4.

Scoring:
As Tested, Based on Previous TU USA Assisted Analysis:

CSI Score	Rule (% Converted Land)
5	0 - < 5%
4	5% - < 15%
3	15% - < 27%
2	27% - < 57%
1	57% - < 100%
0	100% Converted or Non-Native Land Only

Table 36 describes the original CSI Scoring Rule used by TU USA. TUC did not use these scoring rules for our analysis; the original CSI scoring rules used Section 303(d) information from the USA Clean Water Act. The water quality measurements derived from this regulatory requirement are used to assess the decrease of water quality due to reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants. However, the analysis does not include methodology and quantitative assessment for scoring nor do we have this type of legislation and information in Canada. The study area also lacks the matching spatial data for analysis of this type. During the original CSI redevelopment work, TUC worked with TU USA and the rules above in Table 35 were developed and tested with the support from TU USA. The current CSI analysis for the Credit follows these scoring rules. Figure 28 summarizes the results of the scoring using the datasets listed above in Table 34.

Table 36: TU USA CSI Scoring Rules from literature for category 3, indicator 4.

CSI Score	Water Quality As per TU USA
5	High Quality, no 303(d) Segments
4	High Quality, Minor Pollution Sources
3	Moderate to High Quality
2	Moderate Quality with Significant Sources of Pollution
1	Poor Quality

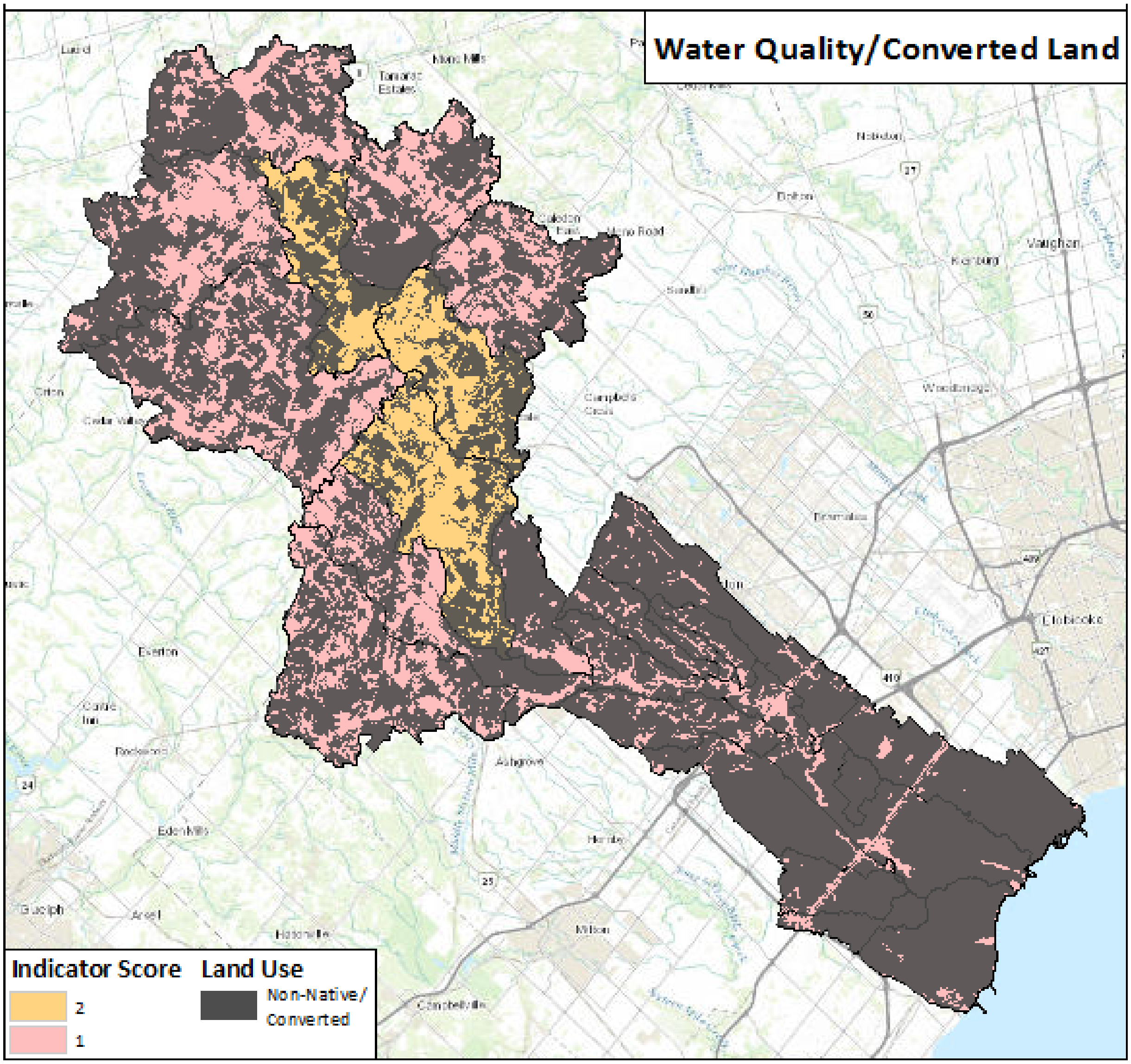

Figure 28: Habitat Integrity Indicator 4: Water Quality/Converted Land.

Indicator 5: Flow Regime

Table 37: Input feature for category 3, indicator 5.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Hydrometric Data (HYDAT)	Environment Canada	September 9, 2016

Table 38: Scoring Rules for category 3, indicator 5.

Scoring:

CSI Score	Rule (Average Annual Change in Flow Rate Since Monitoring by EC)
5	100% of Historical, Flow Regime Unaltered
4	90 - < 100% of Historical
3	75 - < 90% of Historical
2	50 - < 75% of Historical
1	25 - < 50% of Historical, Highly Modified
0	0 - < 25%, Extremely Modified

Table 39 is the original CSI Scoring Rule developed by TU USA. TUC does not have a matching dataset to assess for seasonal fluctuations and total flows. However, to emulate the work of the original CSI, the scoring rules redeveloped by TUC follows original scoring rules closely.

Table 39: TU USA CSI Scoring Rules from literature for category 3, indicator 5.

CSI Score	Flow Regime As per TU USA
5	Flow Regime Unaltered
4	Flows Approx. 90% of Historical
3	Flows Approx. 75% of Historical
2	Flows Approx. 50% of Historical
1	Flows Highly Modified, < 50% of Historical

Currently, the flow regime model is based on the HYDAT database, which monitors and collects data through hydrometric gauging stations which are operated by Water Survey of Canada's eight regional offices. However, this dataset is very coarse, the number of sampling/monitoring points is low, and the recording time per station varies. To create the baseline to measure the change in flow regime, the earliest recorded full year measurement for each station were set as the historical value. The change in the annual flow rate values were calculated and then averaged per station. Due to the limitation of the dataset, an Inverse Distance Weighting (IDW) statistical approach was chosen to interpolate the values across the study area, rather to the reach data. Gauging stations around the study area were also captured so that the data did not have to be extrapolated, further increasing the inaccuracy of the analysis. In future analyses, TUC hopes to assess this indicator on a more refined scale with more accurate flow regime measurements down to the reach level. Table 38 reflects the scoring criteria created using this approach. Figure 29 is the final product and reflects the coarseness of this indicator.

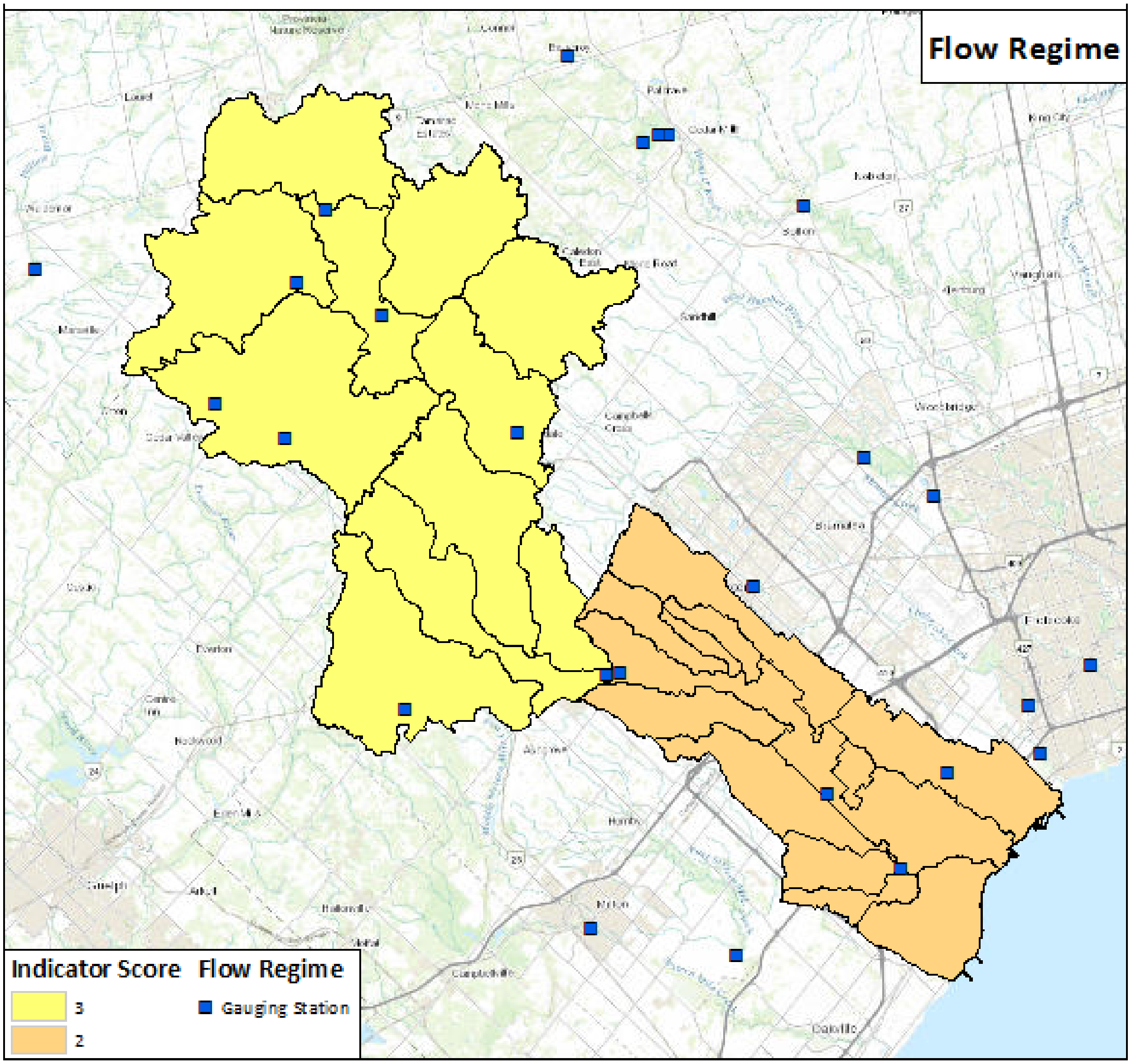

Figure 29: Habitat Integrity Indicator 5: Flow Regime.

Habitat Integrity Conditions Summary

Since all five indicators were available for testing (although some were very coarse), there is a maximum score of 5 and a minimum score of 0 for each indicator. As there were no Nulls, the total maximum aggregate score for Category 3 is **25**. The habitat integrity conditions utilize mostly small scaled, landscape type datasets and due to the differences in datasets available to the study area compared to the USA, there were some differences in scoring rules. However, where possible, TUC attempted to follow the original scoring rules. The summary scores and colours are shown in Figure 30 and the actual scores for each indicator by subwatershed can be found in Table 40.

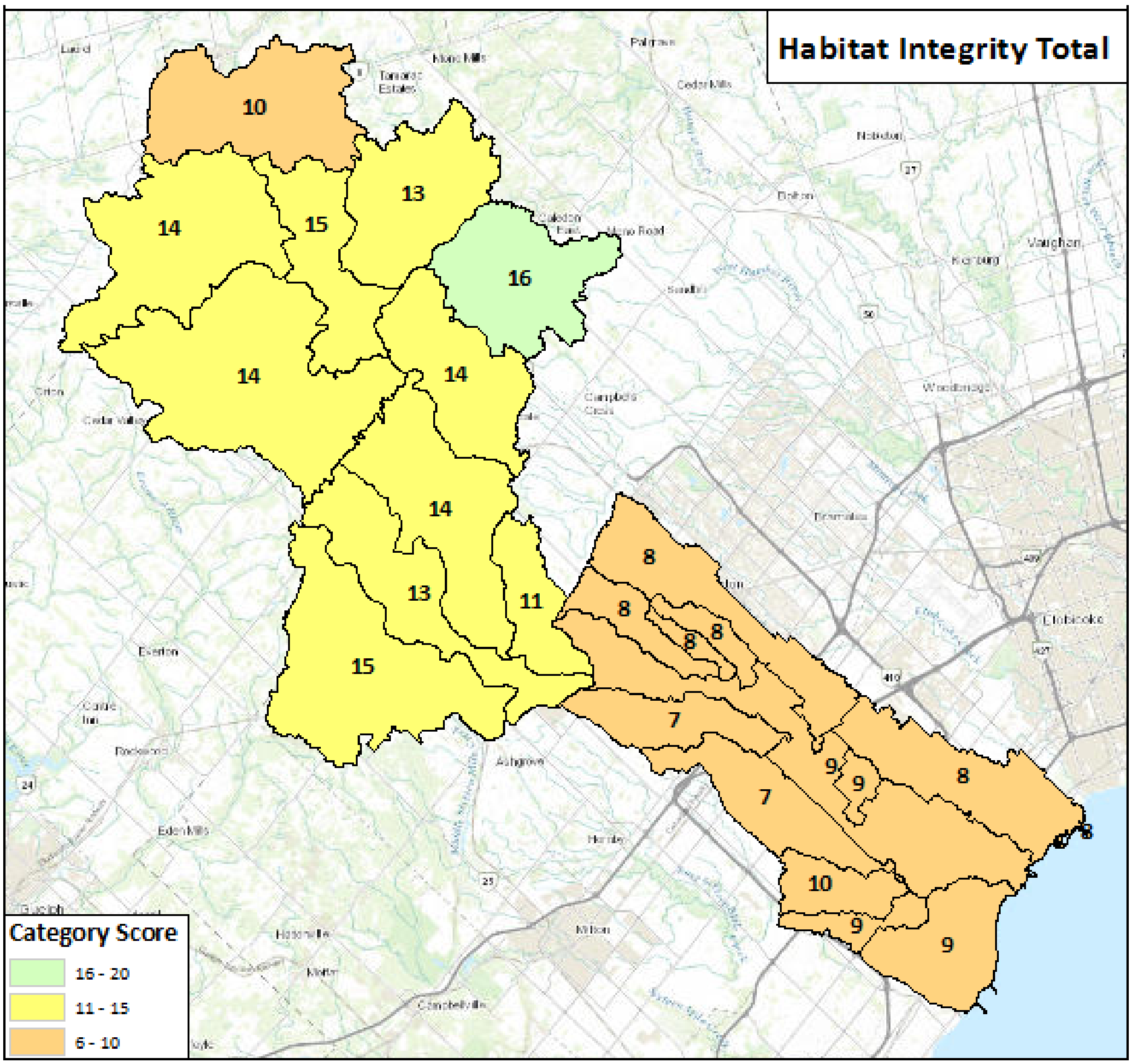

Figure 30: Aggregate Score for Category 3: Habitat Integrity Conditions

Table 40: Cumulative Scoring for Category 3: Habitat Integrity.

Subwatershed Number	Name	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	CSI 3 Total
1	Loyalist Creek	1	5	0	1	2	**9**
2	Carolyn Creek	1	5	0	1	2	**9**
3	Sawmill Creek	1	5	1	1	2	**10**
4	Mullett Creek	1	3	0	1	2	**7**
5	Fletcher's Creek	1	4	0	1	2	**8**
6	Levi Creek	0	4	0	1	2	**7**
7	Huttonville Creek	1	4	0	1	2	**8**
8a	Springbrook Tributary	0	5	0	1	2	**8**
8b	Churchville Tributary	0	5	0	1	2	**8**
9	Norval to Port Credit	2	4	0	1	2	**9**
10	Black Creek	5	3	3	1	3	**15**
11	Silver Creek	5	1	3	1	3	**13**
12	Cheltenham to Glen Williams	5	2	2	2	3	**14**
13	East Credit River	5	4	3	1	3	**16**
14	Glen Williams to Norval	4	2	1	1	3	**11**
15	West Credit River	5	2	3	1	3	**14**
16	Caledon Creek	5	2	2	1	3	**13**
17	Shaw's Creek	5	2	3	1	3	**14**
18	Melville to Forks of the Credit	5	2	3	2	3	**15**
19	Orangeville	4	1	1	1	3	**10**
20	Forks of the Credit to Churchville	5	2	2	2	3	**14**
21	Lake Ontario Shoreline West	1	4	1	1	2	**9**
22	Lake Ontario Shoreline East	1	4	0	1	2	**8**

Future Security Risks Category

Indicator 1: % Land Conversion Vulnerability

Table 41: Input feature for category 4, indicator 1.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Digital Elevation Model (DEM)	Government of Canada	June 3, 2016
Crown Land Use Policy Atlas (CLUPA) Provincial	Land Information Ontario	October 14, 2016
Greenbelt Designation (Niagara Escarpment Plan and Oak Ridges Moraine Conservation Plan Only)	Land Information Ontario	October 14, 2016
Ontario National Road Network (NRN) Segments	Government of Canada	August 8, 2016
Canadian Named Place (City and Towns Only)	Government of Canada	October 14, 2016
Ecological Land Classification (ELC) Polygons	CVC	N/A

Table 42: Scoring Rules for category 4, indicator 1.

Scoring:

CSI Score	Rule (% Land Vulnerable to Conversion) As per TU USA
5	0% of Land Vulnerable to Conversion
4	> 0 - < 20%
3	20 - < 40%
2	40 - < 60%
1	60 - < 80%
0	80 - 100%

In this indicator, land susceptible to conversion is defined as those patches that are still classified as native by the ELC feature class. If land use has already been converted to a non-native type, it is removed from consideration, thus the analysis is assessed against the total remaining area and not the total area of the subwatershed boundary unit, which has been the normal unit area of assessment until this point. The input data is listed in Table 41 and the scoring is described in Table 42. The scoring rule follows the original CSI, except that it allows for a possible score of 0. The output of the analysis is radial looking because of the additive nature of the analysis and is the relationship between low/gentle slopes, proximity to population centres, proximity to roads, and protection by Crown or protected easements.

The results of the scoring are illustrated in Figure 31 including the distribution of both native lands and those patches at risk for conversion.

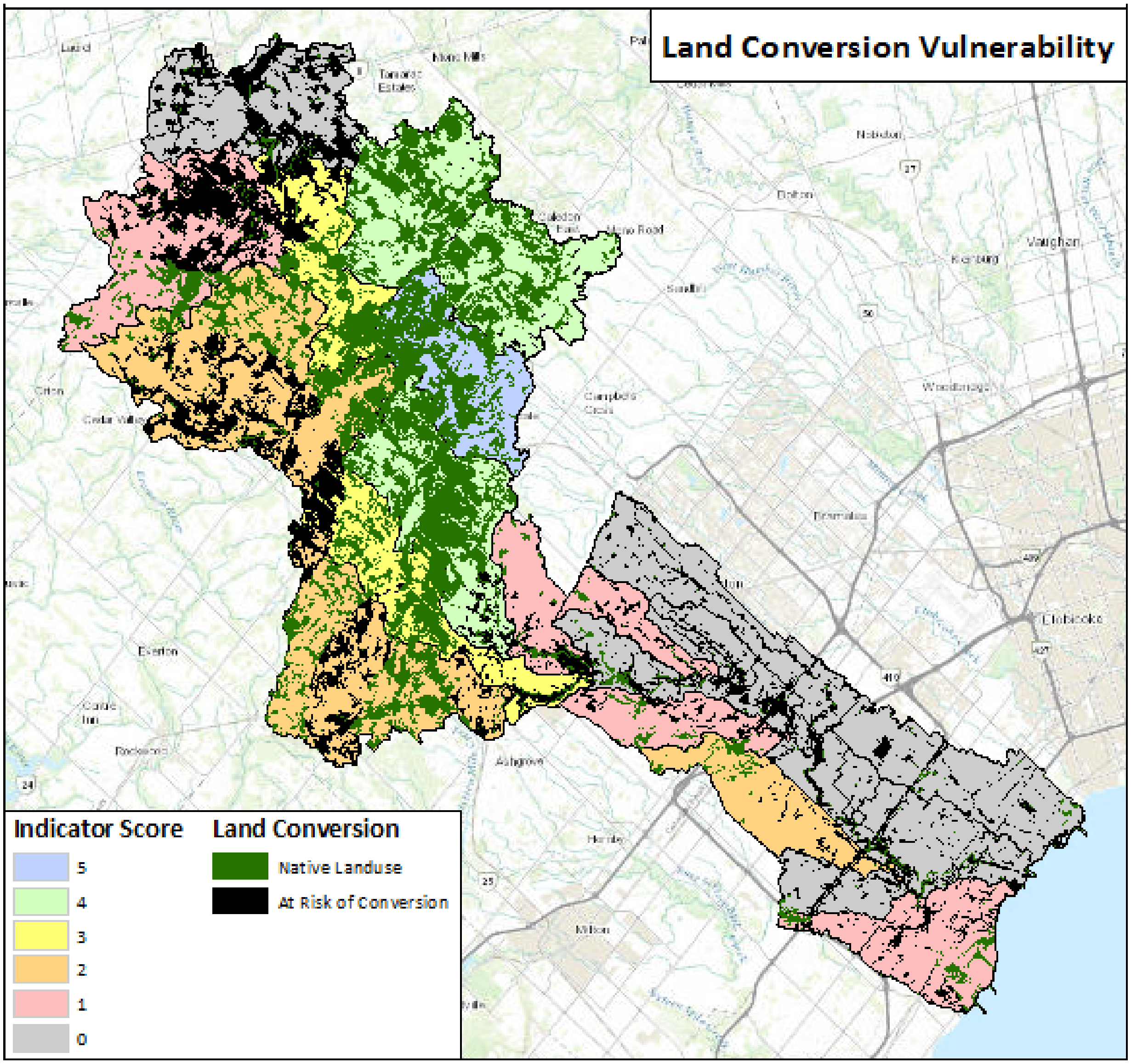

Figure 31: Future Security Indicator 1: Land Conversion Vulnerability.

Indicator 2: Resource Extraction

Table 43: Input feature for category 4, indicator 2.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Abandoned Mine	Government of Ontario: Ministry of Northern Development and Mines	August 17, 2016
Mineral Deposit Inventory (Not Including "Past Producing Mine Without Reserves")	Government of Ontario: Ministry of Northern Development and Mines	August 17, 2016
Ontario Geological Survey (OGS) Pits	Government of Ontario: Ministry of Northern Development and Mines	August 17, 2016

Table 44: Scoring Rules for category 4, indicator 2.

Scoring:

CSI Score	Rule (# Historical and Active Mines, Pits, Mineral Deposit)
5	0
4	1 - 3
3	4 - 6
2	7 - 9
1	10 - 12
0	13+

Table 45 below describes the original CSI Scoring Rule. Energy lease and detailed aggregate mapping datasets were not publicly available and were not assessed by the CSI. The original CSI scoring rules also do not have quantitative ranking which can be assessed and ranked easily. The current CSI ranking as shown in Table 44 for this indicator is based on equal break intervals of the observed data in the study area. These scores may be reranked at the provincial level or re-evaluated for future watershed areas. Figure 32 is the final score for this indicator and is scored regardless of whether Brook Trout populations are found in any subwatershed.

Table 45: TU USA CSI Scoring Rules from literature for category 4, indicator 2.

CSI Score	Rule (Land Vulnerable to Resource Extraction) As per TU USA
5	No Potential Development
4	No Active Development, Low Potential
3	No Active Development but Recoverable Deposits
2	Recoverable Deposits Present, Moderate Likelihood of Active Development
1	High Likelihood of Active Development

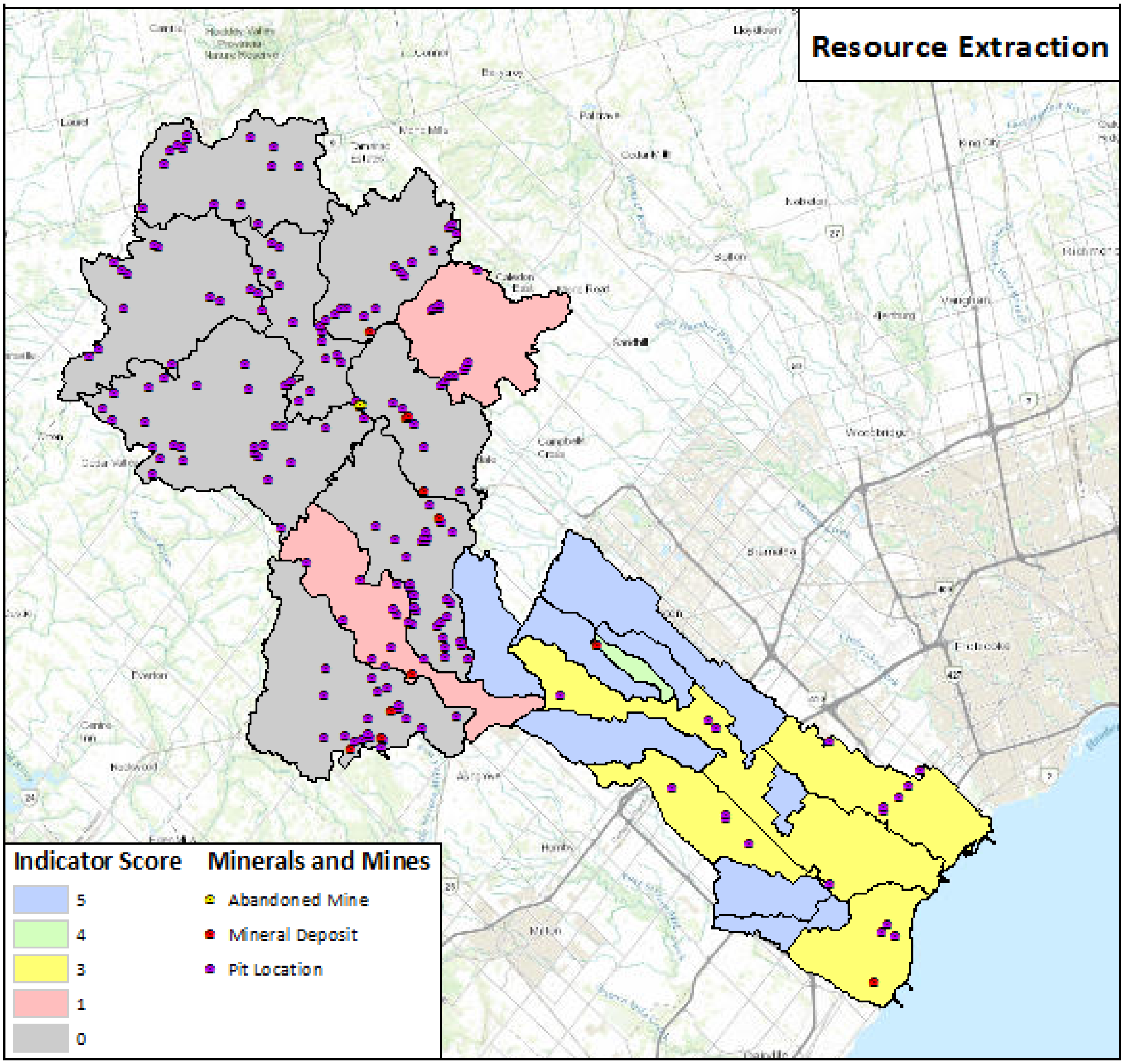

Figure 32: Future Security Indicator 2: Resource Extraction

Indicator 3: Flow Modification/Future Diversion and Development

Table 46: Input feature for category 4, indicator 3.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Renewable Energy Approval Projects (Focus on Water Power Development Only)	Land Information Ontario	August 23, 2016
Permit to Take Water Database (Potential)*	Land Information Ontario	March 13, 2017

Table 46 is the list of datasets used for this indicator. As of the production of this report, the Permit to Take Water (PTTW) Database has been acquired by Trout Unlimited Canada, however, the methodologies for assessing this dataset, assumptions, and scoring rules have not been developed for this iteration of the CSI model. The incorporation of the PTTW database will change the scoring rules described below.

Table 47: Scoring Rules for category 4, indicator 3.

Scoring:

CSI Score	Rule (# Potential Sites)
5	0
4	1
3	2 - 3
2	4 – 5
1	6 – 7
0	8+

Table 48 below is the original CSI Scoring Rule. Available datasets for potential sites of future development only identify geographic location of potential projects and not impact or modification potentials. The rules in Table 48 also do not contain quantifiable measurements that can be easily ranked and scored without some degree of interpretation. The scoring rules were modified from below as shown in Table 47 above.

Table 48: TU USA CSI Scoring Rules from literature for category 4, indicator 3.

CSI Score	Rule (Flow Modification) As per TU USA
5	No Known Vulnerability
4	One Site or Application
3	2 or 3 Sites or Applications
2	Multiple Sites or Applications Indicate Likely Modifications in significant portion of Subwatershed
1	Multiple Applications Indicate Like Modifications Throughout Watershed

As discussed above, the dataset available to this indicator only contains the geographic location of potential energy projects but does not discuss or indicate impact or modification potentials and as such the rules above were modified to be a simple count. Figure 33 demonstrates the results of this scoring and infers potential changes to flows as a result of any changes in landuse. This indicator requires further refinement and is considered a coarse estimate at this time only.

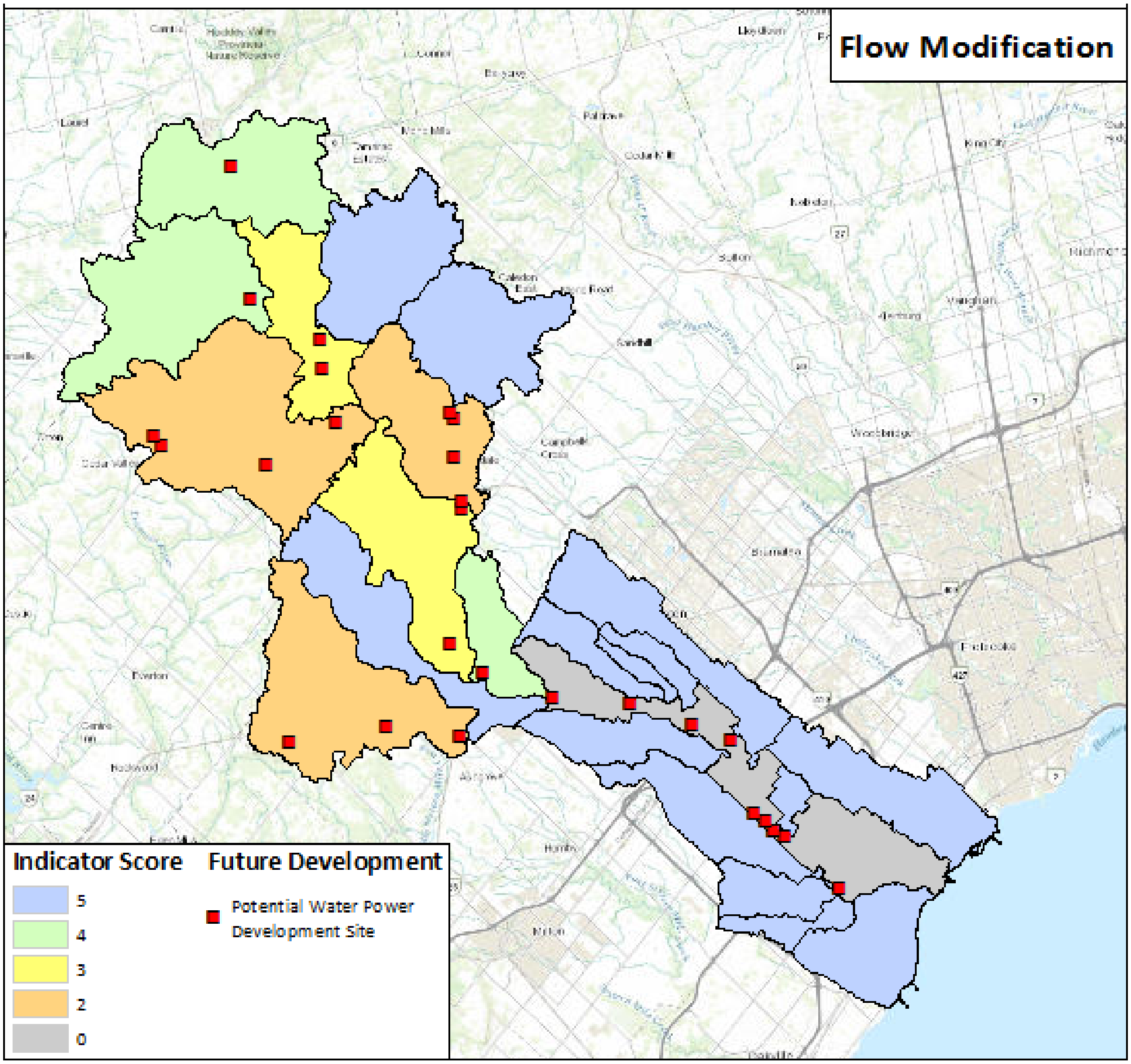

Figure 33: Future Security Indicator 3: Flow Modification/Future Diversion and Development.

Indicator 4: Climate Change (Thermal)

Table 49: Input feature for category 4, indicator 4.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Maximum Weekly Water Temperature (MWAT) datasets: Now, 2011a, 2041a, 2071a.	Government of Ontario (Dr. Cindy Chu, OMNRF)	November 22, 2016

Table 50: Previously considered modelling Inputs for category 4, indicator 4.

Previously Considered Inputs: (Potential backup if MWAT datasets are unavailable)

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Climate Data – High Resolution Projections	Land Information Ontario	August 15, 2016
Canada Drought Monitor (CDM)	Government of Canada	September 29, 2016

Table 51: Scoring Rules for category 4, indicator 4.

Scoring:

CSI Score	Rule (MWAT)
5	All MWAT Scenarios are Within Threshold for Survival
4	Only Current, 2011a, 2041a Scenarios are Within Threshold for Survival
3	Only Current and 2011a Scenarios are Within Threshold for Survival
2	Only Current (Now) Scenario Within Survival Threshold
1	All MWAT Scenarios exceed Threshold for Survival
0	N/A (Looking at scoring with threshold for maximum tolerance)

General Rules:

- Threshold temperature value for Brook Trout Survival is set at 21.2°C
- Threshold temperature value for maximum tolerance for Brook Trout is set at 25.6°C but not assessed currently.

The original CSI scoring rule developed by TU USA is shown in Table 52 for this indicator. However, it does not contain quantitative rankings which can be assessed and ranked easily without interpretation. Furthermore, TUC does not have the corresponding datasets to score climate change in this fashion nor the methodologies that were used to perform the analysis. Instead, TUC was supplied with climate change datasets which represents A2 emission “worse case” scenarios with Average Maximum Weekly Water Temperature (MWAT) into four temporal classes. Now (1971-2000), 2011a (2011-2040), 2041a (2041-2070), and 2071a (2071-2100). The scoring rules outlined in Table 51 above closely follows the modelled MWAT datasets. These most recent projections were provided by an MNR Aquatic Scientist with Aquatic Research and Monitoring Section as identified in Table 50 above.

Figure 34 is the results of the application of scoring using the most recent temperature projections from OMNRF and applying the scoring in Table 51 above.

Table 52: TU USA CSI Scoring Rules from literature for category 4, indicator 4.

CSI Score	Rule (Function of Watershed Connectivity, Habitat Conditions, Elevation Gradient) As per TU USA
5	High Condition, High Connectivity
4	Moderate Condition, Moderate Connectivity
3	Moderate Conditions but Low Connectivity
2	Low Conditions and Low Connectivity
1	Very Low Conditions

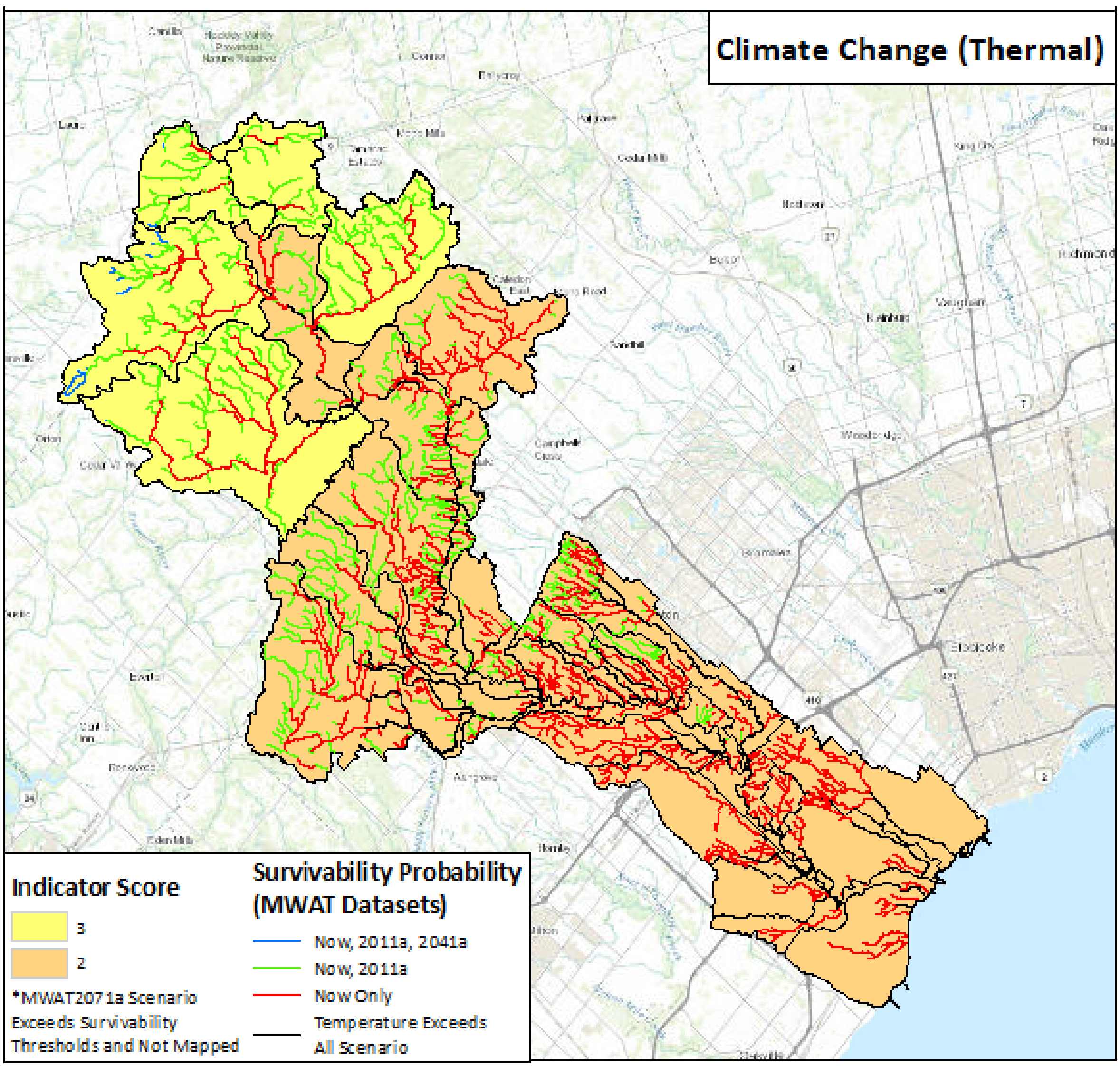

Figure 34 : Future Security Indicator 4: Climate Change (Thermal).

Indicator 5: Introduced and Invasive Species

Table 53: Input feature for category 4, indicator 5.

Inputs:

Dataset Name	Source Location	Most Recent Acquisition/Update Date
Brook Trout Range/Reach Current	Trout Unlimited Canada	Derived: January 11, 2017
Invasive Species Report	Government of Ontario	June 6, 2016

Table 54: Scoring Rules for category 4, indicator 5.

Scoring:

CSI Score	Rule (Competition Strength)
5	0%
4	>0 - <10%
3	10 – 19%
2	20 – 34%
1	35 – 49%
0	>50%
Penalty	**Rule (Invasive/Introduced Presence)**
-1	Positive Presence

Table 55 below is the original CSI Scoring Rule from TU USA. In the original CSI literature, the definition for this indicator is "future vulnerability to introduced species determined as a function of roads in riparian corridors, human population density, and occurrences of introduced species." However, the general scoring rules and relevance to conservation did not specifically indicate how population density, roads and riparian corridors were assessed. Furthermore, road density and riparian functions were assessed in indicator 3-3. After reviewing the rule, we determined that this indicator should be focused on invasive and non-native fish species threats. As a result, through working with our technical committee, we revised the scoring as shown in Table 54 above.

Table 55: TU USA CSI Scoring Rules from literature for category 4, indicator 5.

CSI Score	Rule (As a Function of Roads, Human Population Density, Introduced Species) As per TU USA
5	Threats Minor/Nonexistent
4	Non-natives Present in Larger Watershed, Chance of Spread Low
3	Non-natives Present in Watershed, Chance of Spread Moderate
2	Non-natives in Watershed, Spread High
1	Non-natives Present in Subwatershed, Spread High

Currently the competition data is derived from the ARA and OHN datasets. Instead of picking and choosing one specific species to test against, the current model tests for competition amongst all known competitor observations. However, the ARA datasets do not indicate native versus non-native status, therefore the analysis is based on a presence or lack of presence. The minimum score that this indicator can receive is 0, even if the penalty applied is larger than the riparian health score as the CSI does not include negative scoring. Figure 35 illustrates the resulting score including a display of the reaches of stream that either do or do not have a competitor non-native species.

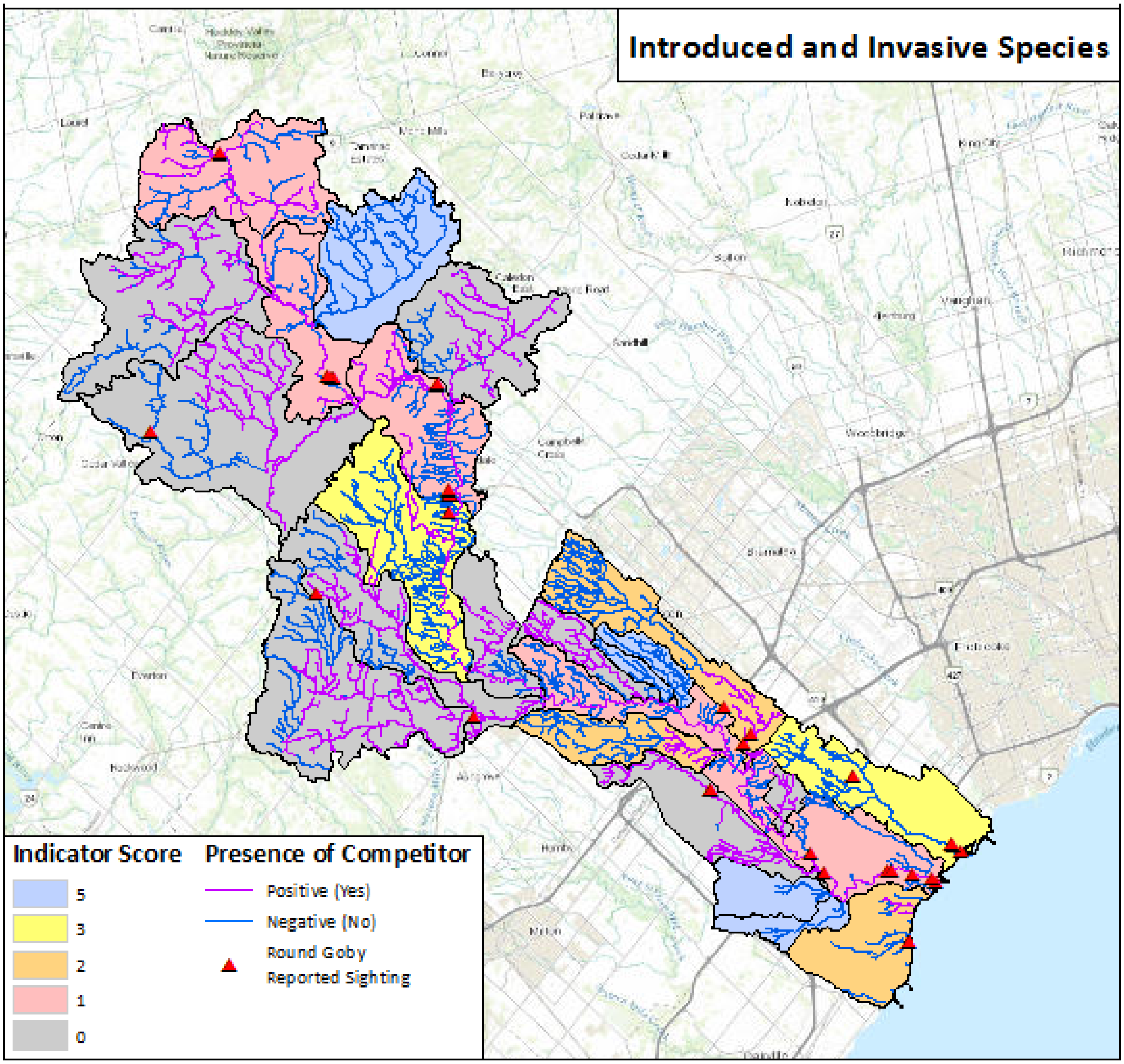

Figure 35: Future Security Indicator 5: Introduced and Invasive Species.

Future Security Risks Summary

Since all five indicators were available for testing, there is a maximum score of **5** and a minimum score of **0** for each indicator. As there are no Nulls, the total maximum aggregate score for Category 4 is **25**. The future security conditions shown in Figure 36 utilizes mostly small scaled, landscape type datasets and due to the differences in datasets available to the study area compared to the USA, there were some differences in scoring rules however, where possible, TUC attempted to follow the original scoring rules. The summary of the scoring variables for each indicator for the Future Security component by subwatershed are displayed in Table 56.

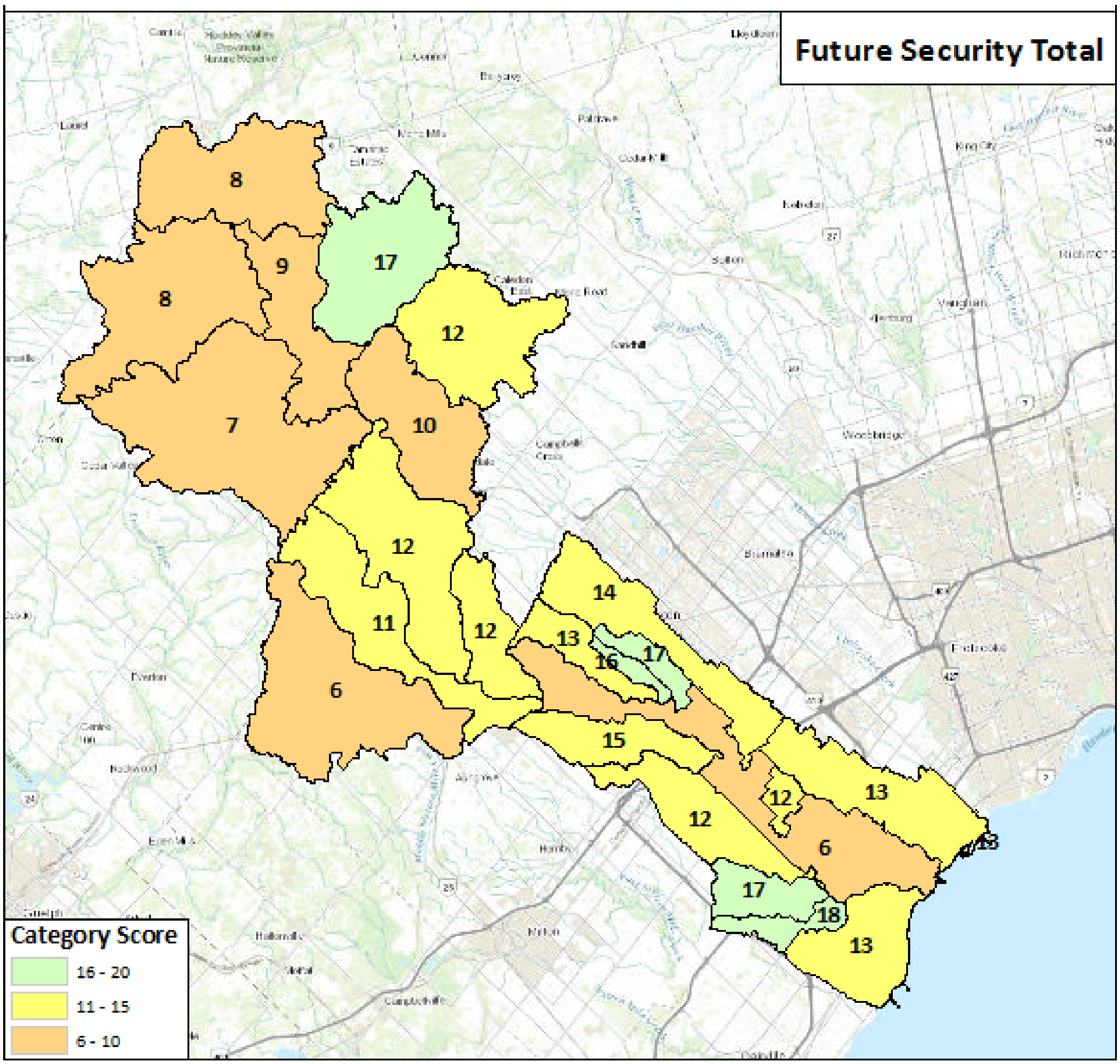

Figure 36: Aggregate Score for Category 4: Future Security Conditions

Table 56: Cumulative Scoring for Category 4: Future Security Risk.

Subwatershed Number	Name	Indicator 1	Indicator 2	Indicator 3	Indicator 4	Indicator 5	CSI 4 Total
1	Loyalist Creek	1	5	5	2	5	**18**
2	Carolyn Creek	0	5	5	2	0	**12**
3	Sawmill Creek	0	5	5	2	5	**17**
4	Mullett Creek	2	3	5	2	0	**12**
5	Fletcher's Creek	0	5	5	2	2	**14**
6	Levi Creek	1	5	5	2	2	**15**
7	Huttonville Creek	1	5	5	2	0	**13**
8a	Springbrook Tributary	0	4	5	2	5	**16**
8b	Churchville Tributary	0	5	5	2	5	**17**
9	Norval to Port Credit	0	3	0	2	1	**6**
10	Black Creek	2	0	2	2	0	**6**
11	Silver Creek	3	1	5	2	0	**11**
12	Cheltenham to Glen Williams	4	0	3	2	3	**12**
13	East Credit River	4	1	5	2	0	**12**
14	Glen Williams to Norval	1	5	4	2	0	**12**
15	West Credit River	2	0	2	3	0	**7**
16	Caledon Creek	4	0	5	3	5	**17**
17	Shaw's Creek	1	0	4	3	0	**8**
18	Melville to Forks of the Credit	3	0	3	2	1	**9**
19	Orangeville	0	0	4	3	1	**8**
20	Forks of the Credit to Churchville	5	0	2	2	1	**10**
21	Lake Ontario Shoreline West	1	3	5	2	2	**13**
22	Lake Ontario Shoreline East	0	3	5	2	3	**13**

Total CSI

The total CSI is an aggregation of all four categories explored above and shown in Figure 37 below. The current CSI maximum total is **100** for the Credit River watershed, which is the maximum score possible due to no null values or untestable parameters. All the summary scores by sub-watershed for each of the four categories is shown in Table 57.

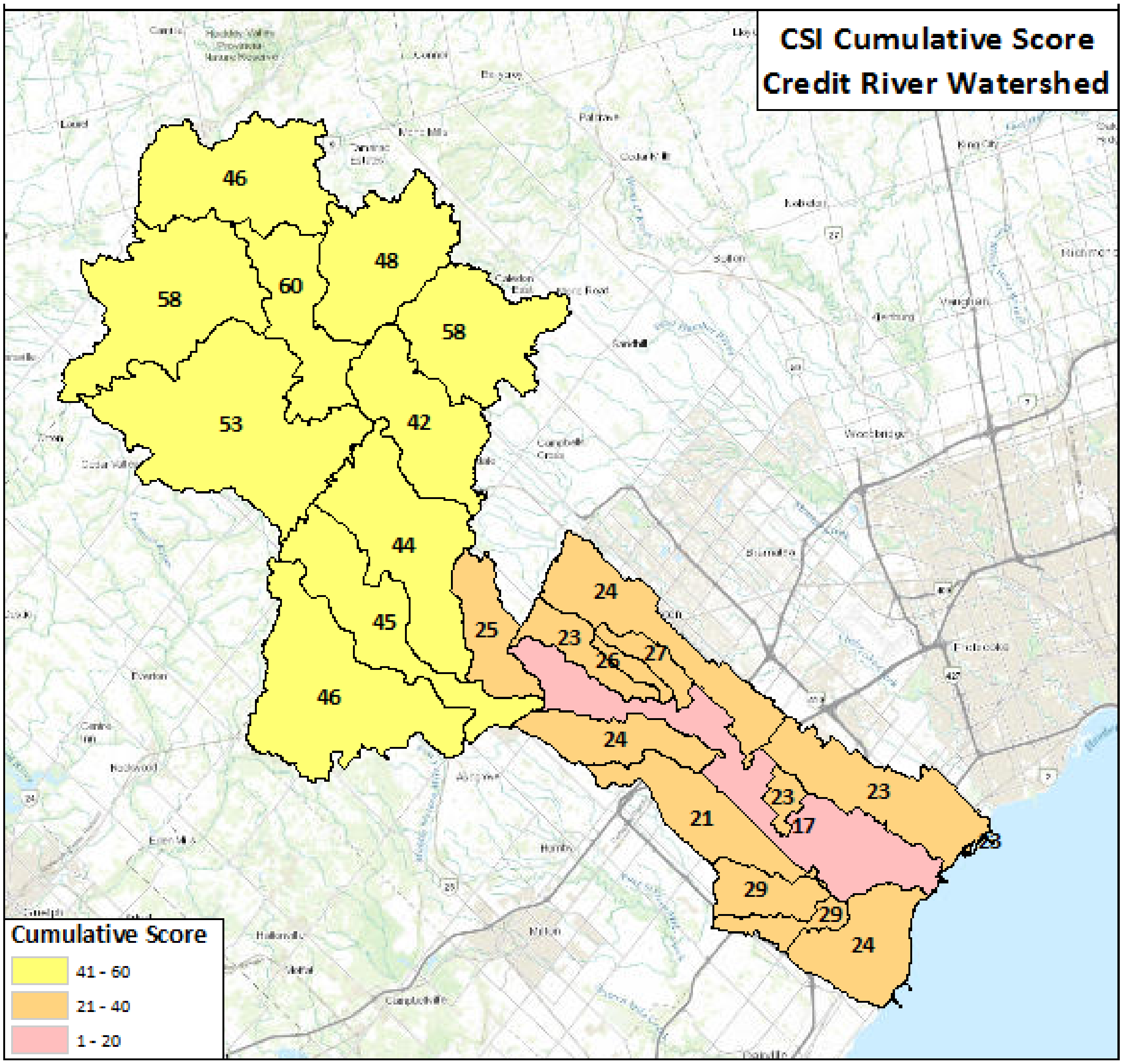

Figure 37: Total CSI score from the Aggregation of Categories 1 – 4. Maximum Score = 100.

Table 57: Total CSI Scores for each Credit River Subwatershed Division.

Subwatershed Number	Name	CAT 1 Score	CAT 2 Score	CAT 3 Score	CAT 4 Score	Total Score
1	Loyalist Creek	0	2	9	18	**29**
2	Carolyn Creek	0	2	9	12	**23**
3	Sawmill Creek	0	2	10	17	**29**
4	Mullett Creek	0	2	7	12	**21**
5	Fletcher's Creek	0	2	8	14	**24**
6	Levi Creek	0	2	7	15	**24**
7	Huttonville Creek	0	2	8	13	**23**
8a	Springbrook Tributary	0	2	8	16	**26**
8b	Churchville Tributary	0	2	8	17	**27**
9	Norval to Port Credit	0	2	9	6	**17**
10	Black Creek	7	18	15	6	**46**
11	Silver Creek	5	16	13	11	**45**
12	Cheltenham to Glen Williams	4	14	14	12	**44**
13	East Credit River	11	19	16	12	**58**
14	Glen Williams to Norval	0	2	11	12	**25**
15	West Credit River	13	19	14	7	**53**
16	Caledon Creek	4	14	13	17	**48**
17	Shaw's Creek	16	20	14	8	**58**
18	Melville to Forks of the Credit	18	18	15	9	**60**
19	Orangeville	11	17	10	8	**46**
20	Forks of the Credit to Churchville	4	14	14	10	**42**
21	Lake Ontario Shoreline West	0	2	9	13	**24**
22	Lake Ontario Shoreline East	0	2	8	13	**23**

For the Credit River watershed CSI analysis, one subwatershed (Subwatershed 9 – Norval to Port Credit) was ranked with a 1 and has the lowest cumulative score in the study area. Twelve subwatersheds (Subwatershed 1, 2, 3, 4, 5, 6, 7, 14, 21, 22, 8a, and 8b) were ranked with a 2. Finally, ten subwatersheds (Subwatershed 10, 11, 12, 13, 15, 16, 17, 18, 19, and 20) were ranked with a 3. No subwatersheds scored sufficiently high enough to be ranked as a 4 or 5, and there were no subwatersheds ranked as 0.

Management Priorities

The information derived from the CSI analysis is useful in determining the most efficient and effective management priorities for a given study area. For the Credit River watershed, the subwatershed boundaries was utilized to break down this large area into more practical and manageable fragments, as well as amalgamate reach level information. Table 58 below is a recreated version of the CSI Matrix developed by TU USA as a guide to determine best management options given the final, cumulative score for a watershed. The management options include: protecting, restoring, monitoring, and reintroduction of a target species. Our CSI analysis attempted to closely emulate the work, assumptions, and scoring that was developed by TU USA, therefore, the outcome from our CSI work uses Table 58 to prioritize the Credit River subwatersheds based on the management matrix below. (N.B. this is primarily a guide and recommendation to allow for further discussions towards specific management options by subwatershed.)

Table 58: Management Priority Matrix.

Management Priority Matrix		Vulnerability (Future Security Risk)				
		Low	Moderate Low	Moderate High	High	Priority
Habitat and Population Integrity*	High	2	2	1	1	Protection
		2	2	1	1	Monitoring
	Habitat Only	1	1			Reintroduction
	Moderately High	4	4	3	3	Protection
		3	3	2	2	Monitoring
		1	1	2	2	Restoration
	Habitat Only	1	2			Reintroduction
	Moderately Low	6	6	5	5	Protection
		4	4	3	3	Monitoring
		3	3	4	4	Restoration
	Low	5	5	4	4	Monitoring
		5	5	6	6	Restoration

* Range Wide Conditions scores are not directly assessed in the Matrix. If the target fish has been extirpated, reintroduction is determined by comparing habitat integrity against future security vulnerability.

	Priority Rank					
	1	2	3	4	5	6
Protection						
Restoration						
Monitoring						
Reintroduction						

Based on the management priority matrix and the categoric scoring from Table 58, the CSI scoring has been evaluated in Table 59 below:

Table 59: Cumulative CSI Scores Evaluated by the Management Priority Matrix.

Subwatershed Number	Name	CAT 1 Score	CAT 2 Score	CAT 3 Score	CAT 4 Score	Matrix Analysis
1	Loyalist Creek	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
2	Carolyn Creek	Extirpated	N/A	Mod Low	Mod High	Mod Low / Mod High
3	Sawmill Creek	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
4	Mullett Creek	Extirpated	N/A	Mod Low	Mod High	Mod Low / Mod High
5	Fletcher's Creek	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
6	Levi Creek	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
7	Huttonville Creek	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
8a	Springbrook Tributary	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
8b	Churchville Tributary	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
9	Norval to Port Credit	Extirpated	N/A	Mod Low	Mod High	Mod Low / Mod High
10	Black Creek	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
11	Silver Creek	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
12	Cheltenham to Glen Williams	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
13	East Credit River	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
14	Glen Williams to Norval	Extirpated	N/A	Mod Low	Mod High	Mod Low / Mod High
15	West Credit River	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
16	Caledon Creek	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod Low	Mod High / Mod Low
17	Shaw's Creek	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
18	Melville to Forks of the Credit	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High
19	Orangeville	**Use Both Cat 2 and 3**	Mod High	Mod Low	Mod High	Mod High / Mod High
20	Forks of the Credit to Churchville	**Use Both Cat 2 and 3**	Mod High	Mod High	Mod High	Mod High / Mod High

Subwatershed Number	Name	CAT 1 Score	CAT 2 Score	CAT 3 Score	CAT 4 Score	Matrix Analysis
21	Lake Ontario Shoreline West	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low
22	Lake Ontario Shoreline East	Extirpated	N/A	Mod Low	Mod Low	Mod Low / Mod Low

Using the summary table above, Table 60 summarizes the recommended broad-scale management recommendations for each subwatershed. This table can then be used as a basis for strategic planning decisions for each subwatershed. As the broad-scale choices are made, the CSI database can be utilized to identify reaches that would provide the biggest benefit for the selected subwatershed and the recommended strategy to achieve that benefit. Figure 38 displays the broad recommendations for each subwatershed.

Table 60: Subwatershed Strategy Priority Based on Management Priority Matrix.

Subwatershed Number	Name	Strategy Priority
1	Loyalist Creek	N/A
2	Carolyn Creek	N/A
3	Sawmill Creek	N/A
4	Mullett Creek	N/A
5	Fletcher's Creek	N/A
6	Levi Creek	N/A
7	Huttonville Creek	N/A
8a	Springbrook Tributary	N/A
8b	Churchville Tributary	N/A
9	Norval to Port Credit	N/A
10	Black Creek	Monitor and Restore
11	Silver Creek	Monitor and Restore
12	Cheltenham to Glen Williams	Monitor and Restore
13	East Credit River	Monitor and Restore
14	Glen Williams to Norval	N/A
15	West Credit River	Monitor and Restore
16	Caledon Creek	Restore
17	Shaw's Creek	Monitor and Restore
18	Melville to Forks of the Credit	Monitor and Restore
19	Orangeville	Monitor and Restore
20	Forks of the Credit to Churchville	Monitor and Restore
21	Lake Ontario Shoreline West	N/A
22	Lake Ontario Shoreline East	N/A

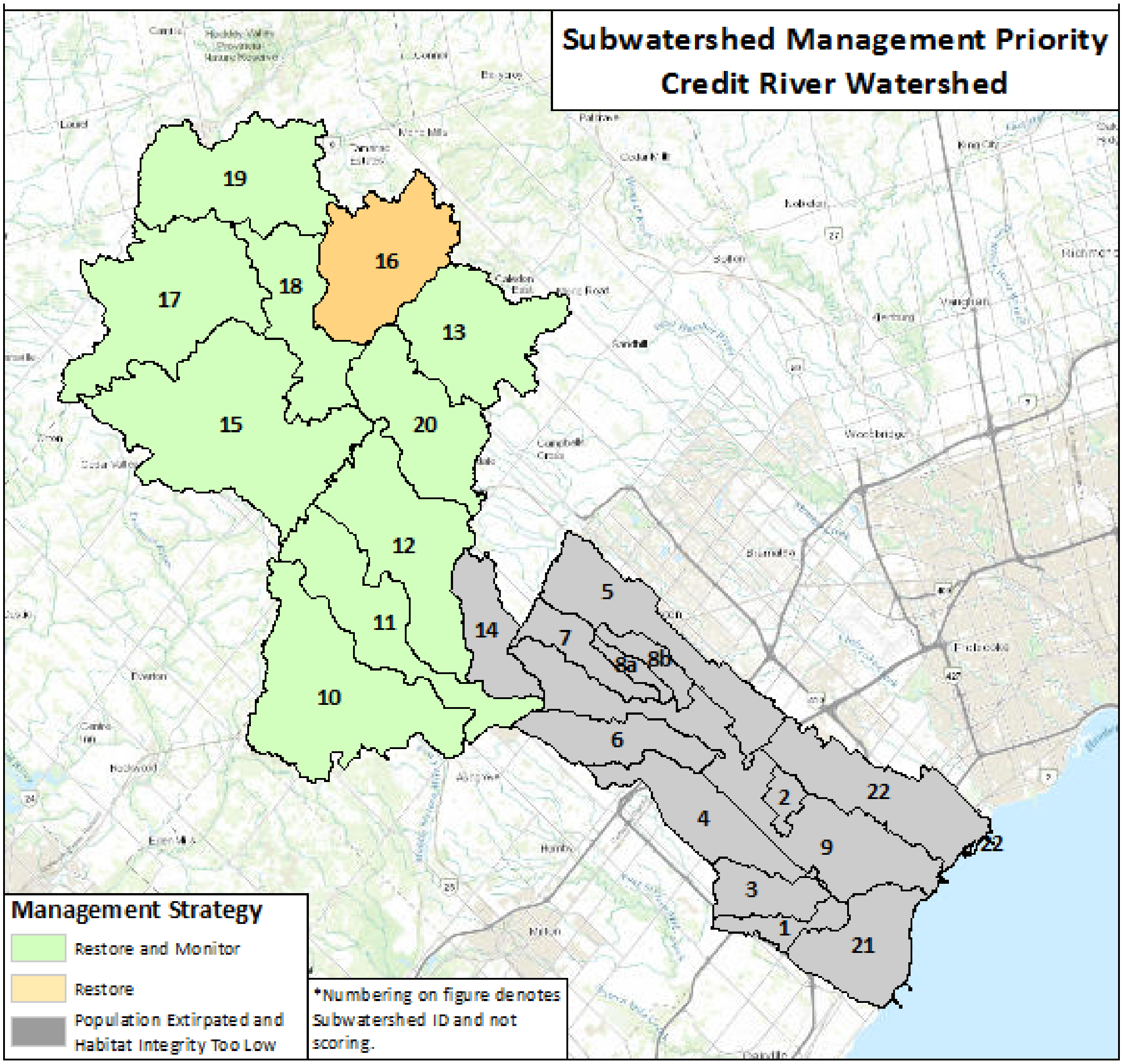

Figure 38: Management Strategy Priorities for the Credit River Watershed.

Discussion

The CSI has been used very successfully in the USA helping both NGO as well as State and Federal agencies better characterize the state of their watersheds in general and specifically targeting various coldwater fish species of concern. TUC has been working with TU USA to bring this approach for characterizing and prioritizing management options for coldwater communities in Canada.

In the last several decades, the decline of native Brook Trout in Ontario, and especially in southern Ontario has been very concerning. A great deal of research has been done to better understand the general risks and current distributions of Brook Trout, but the challenge is finding a practical and logical method to characterize watershed health and determine various courses of action to protect and restore Brook Trout populations. For this reason, TUC began working with TU USA to first better understand the CSI approach and then to assess its application for Canadian uses. Brook Trout populations in Ontario were chosen as the focal species to begin the testing of this approach. An initial grant from the Salamander Foundation several years ago helped TUC to begin the refinement of the indicator models for Canadian data and acquire training on the approach and methodology. A recent grant from the Ontario Trillium Foundation in 2016 has helped TUC to test the approach on a selected watershed with reliable data. The work was conducted with financial support from this OTF grant, seed grants and with support from the CVC, along with technical and financial support from the OMNRF.

There have been challenges with the modification of the CSI approach to Canadian data and data standards. The CSI developed by TUC overhauled much of the processes developed by TU USA. The results clearly reflect the issues facing Brook Trout in the Credit River watershed based upon review and input by fisheries and aquatic specialists with the CVC. A general recommendation for the next iteration of the CSI development will be converting all Imperial measurements to metric, and standardizing those measurements into the scoring parameters. As well as ensuring that the CSI model can adapt to the quality of datasets available as the CSI model is expanded to other watersheds.

One of the biggest challenges encountered while designing and developing the CSI for our test watershed, the Credit River, is the availability of historical and current distribution of the species of interest within the watershed. Distribution data is used as the input for several indicators within the range-wide condition, population integrity, and future security risk categories. One of the reasons that the Credit River watershed was chosen for our development work was the availability of up-to-date monitoring data within the watershed. However, even with this data availability, the finalization of the current and historical distribution data relied heavily on verification by fisheries experts with the CVC and additional discussions with OMNRF District staff. As the CSI program is expanded to other watersheds in southern Ontario, we anticipate there will be further challenges with getting current and historical information on the distribution of Brook Trout (and other species of interest) populations in the selected watersheds. One of the reasons for this challenge is that the province has not had a standardized monitoring program for rivers and streams since the early 1990s, although the provincial database is occasionally updated by OMNRF District staff. Other provincial programs such as the Ontario Stream Assessment Protocol has not been universally applied in Ontario. Therefore, as the program expands into watersheds with less empirical and current data, the program will have to draw in more expert opinion from both professionals and local NGO organizations. Older datasets and information were also used in the development of the historical distribution dataset, including old OMNRF data, and the reports by the Department of Planning and Development from the 1950s. Pre-European contact information was very sparse but in the case of the Credit River watershed, some historical, anecdotal information was provided by CVC.

The summary of the range-wide condition category utilizes several metrics, including not just population distribution within a watershed but also reaches of stream within the watershed. Included in the scoring are sections of streams that are 2nd Order and larger which are utilized by the species. The comparison between historically used and currently used stream size helps to determine: what we have lost and how far into the headwaters the species is being pushed, which can assist us in our understanding of vulnerability. In general, the summary for range-wide conditions suggest that the upper mainstem of the Credit River upstream of the Forks-of-the-Credit and up to Orangeville is still core to the range of Brook Trout. This area also acquires significant groundwater inputs that have helped protect Brook Trout populations in these subwatershed. Following these two subwatersheds, the West Credit is still the next best geographic area for range conditions. Somewhat surprising and disturbing is the lower value for the Black Creek subwatershed which historically had very high populations of Brook Trout.

By all measures, the population integrity condition category appears to demonstrate hope for the upper watershed. Here the population densities in healthier sections of the mainstem and West Credit helped to boost the values. Some of these good scores are tempered by the population extent scores that reflect a relatively high level of fragmentation in the watershed, creating many isolated and therefore vulnerable populations.

The fragmentation issue is a very significant concern for the Credit River watershed and may be the single most important indicator of long-term survivorship or population loss in the face of higher climate variability. The reason for this concern is that once populations are isolated and unable to flee to refuges in the face of higher climate variability, it is easier to lose these isolated populations as conditions within the fragments become unsuitable for the species.

Historically, as in many other watersheds in southern Ontario and throughout their native range, Brook Trout can exhibit a variety of life history strategies to avoid bad or non-ideal conditions, find refuges, and more food for survival and growth. There is some historical evidence of adfluvial or coaster Brook Trout in Lake Ontario pre-European contact, rivers such as the Credit may have had this additional life history variant. However, population fragmentation and warmer stream temperatures would have eliminated this life history strategy. Brook Trout in many locations in southern Ontario can also be inter-fluvial, moving out of small coldwater tributaries in the late fall after spawning and overwintering in larger cool to warm water streams until spring. There is compelling evidence of this ongoing strategy in watersheds such as the Saugeen and historically in the Grand. However, given the level of fragmentation observed presently in the Credit River watershed, this life history strategy is also likely not common or may no longer exist given the number of small on-line ponds and dams on small tributaries of the Credit and other watersheds in southern Ontario.

In general, the population integrity conditions category is modestly good, despite fragmentation to the subwatersheds upstream of Georgetown. The best subwatersheds for population integrity are: the mainstem Credit from the Forks up to Orangeville, the West Credit, Little East Credit and Black Creek.

Habitat Integrity was quite variable amongst subwatershed units. The first indicator, land stewardship, demonstrates that a substantial amount of the upper watershed has some form of protection, whether it is designated as Niagara Escarpment Planning Area, ANSI, Provincial Park, Conservation Area, or a combination of these factors. This indicator suggests that there is hope for the upper watershed for habitat protection.

Watershed connectivity as it relates to the level of fragmentation, had some of the best data available on the connectivity or lack thereof in the subwatersheds. Given the amount of available information, a step-by-step validation and analysis process was performed to tie in various barrier types to movement including dams, culverts and natural waterfalls. Figure 23 shows clear issues and concerns regarding connectivity and fragmentation in the most vulnerable areas of the watershed where populations still exist. This fragmentation, when combined with barriers to movement and climate change demonstrate an enormous risk of loss of populations isolated in these reaches. The challenge, based on the results of the scoring is that those subwatersheds that still have the best population integrity are vulnerable to high levels of fragmentation which could mean that more isolated populations may be lost if the fragmentation is not resolved.

The watershed condition score focused on the quality of the riparian zone, both in width and contiguousness in comparison with a penalty based upon the level of road density within the subwatershed. Road density can seriously affect contiguousness and impact riparian health resulting in a variety of problems to the landscape, river structure and health and ultimately to the fish population. The results of this scoring suggest that the quality of riparian zones within the upper watershed is fair to poor at best. This is a metric that can be offset by improved riparian management and restoration.

Percent converted land was used as a surrogate indicator to infer relative impacts to water quality in various reaches and subwatersheds of the Credit River. The implication of this scoring is that there are real environmental consequences to water quality resulting from land conversion from natural to human use. These changes usually result in poor quality of the environment and negative impacts on the fish. The challenge with this metric is that not all landuse change is the same in its consequences to water quality.

Though flow regime was considered, the resulting metric is very coarse and demonstrates a need to further refine this indicator. At this point it primarily scores those portions of the overall watershed that are dominated by urban or urbanizing run-off versus the more rural portions of the landscape. It is definite that more work needs to be done to strengthen the quality of this metric.

The total score for the habitat integrity category demonstrates that some subwatersheds, such as the Little East Credit and upper main Credit still have relatively good levels of habitat available. The remaining subwatersheds range from fair to poor overall, suggesting that watershed condition and connectivity issues due to fragmentation are key issues on the upper watershed for Brook Trout in this watershed.

Under the future security risks category, the two most important indicators appear to be % land conversion vulnerability and climate change. Future land conversion risk is tempered by the amount of land in protected status based on provincial legislation or public ownership. However, the upper watershed is very attractive for future development and communities such as Georgetown, Acton, Erin, Hillsburgh, Inglewood and Orangeville certainly appear to be growth areas, especially under pressure from the province's Places to Grow Act. Because of these conditions, it is no surprise that the subwatersheds that score the highest (i.e. least likely at risk of conversion) are those within the Niagara Escarpment Commission (NEC) or Green Belt designation. The remainder of the higher quality subwatersheds fared more poorly and therefore exhibit higher risk or threat to environmental health.

The climate change indicator used the most recent results from analysis runs performed by aquatic researchers from OMNRF. This indicator demonstrates that based upon the modelling, the entire Credit River watershed falls within the situation where Brook Trout survivability occurs currently and in the 2011a climate/temperature scenarios and not beyond. This assumes no change in connectivity and removal of online ponds and dams that are influencing or exacerbating the impacts of greater climate warming.

The introduced and invasive species indicator also demonstrates a relatively poor score for many of the subwatersheds including those that still have good population integrity. The information portrayed in this indicator needs to be carefully assessed to determine the best course of action to reduce negative impacts of introduced or invasive species.

In general, the overall future security risks appear to be relatively high for the upper Credit River subwatersheds that still contain or could contain Brook Trout populations. A fair amount of work will be required to confirm the specific critical issues to help inform good decisions on restoration works in the future. The only upper subwatershed that scored well (good vs excellent) was the Caledon Creek subwatershed that has active aggregate extraction in many locations but the remaining areas are protected from development under the Green Belt Designation.

The cumulative CSI Score for the Credit River watershed indicates that there is certainly work to be completed in conserving and protecting Brook Trout. From a Brook Trout's perspective, the entire upper watershed has a moderate to high level of risk of loss if nothing is done. Management strategies that may help to improve Brook Trout populations, based on previous actions undertaken or completed to date, revolve around connectivity, habitat restoration and keeping invasive and non-native fish from critical portions of the watershed. From the CSI summary information, we found that ten subwatersheds (Subwatershed 10, 11, 12, 13, 15, 16, 17, 18, 19, and 20) were ranked with a 3. These are the highest scored watersheds as no subwatersheds ranked as a 4 or 5, and twelve were ranked a 2 (Subwatershed 1, 2, 3, 4, 5, 6, 7, 14, 21, 22, 8a, and 8b), a lone subwatershed (Subwatershed 9) was ranked as a 1.

Management Opportunities

One final product from this analysis was the preparation of the potential priority management plan for the Credit River and its subwatersheds. This ranking examines the results of the interaction between the habitat and population integrity categories in relation to their risk vulnerabilities. A set of management actions are identified as a sliding scale and each subwatershed was compared in this matrix resulting in Table 60 and Figures 37. As noted earlier, the specific techniques or approaches appropriate to fulfilling the various management options will have to be assessed by restoration specialists and agency staff to ensure that the methodologies used will get to the key controlling variables holding back or helping to ensure the perpetuation of Brook Trout populations in the watershed.

For example, ten subwatersheds of the entire watershed were identified as having a fair potential for restoration. Of these, the greatest opportunity for restoration and monitoring for restoration of Brook Trout were:

- Subwatershed 10 – Black Creek
- Subwatershed 11 – Silver Creek
- Subwatershed 12 – Cheltenham to Glen Williams

- Subwatershed 13 – East Credit River
- Subwatershed 15 – West Credit
- Subwatershed 17 – Shaw's Creek
- Subwatershed 18 – Melville to Forks of the Credit

These subwatersheds constitute the best potential opportunities for restoration of Brook Trout populations given the status of habitat, population, watershed condition and future security. Caledon Creek, Subwatershed 16 is recommended for monitoring to determine if conditions for Brook Trout might change in the future.

The specific management applications specific restoration work can be derived from some of the indicators. For example, on the West Credit River, Range-wide conditions (Table 13) suggests that although stream habitat use is relatively good, subwatershed population distribution is considered poor. The degree of fragmentation identified under the habitat integrity category is likely the cause of poor subwatershed use. Therefore, management actions should focus on mitigating fragmentation (indicator 2) and water quality/land conversion issues (indicator 4), which scored the poorest for the Habitat Integrity category (Table 40). Based on the review of the various indicators, strategy management options can be determined. Management options for improvement in habitat integrity should likely focus on dam and pond modification or removal and culvert mitigation to reduce fragmentation and improve water temperatures. Land conversion risk is high and therefore outreach to landowners to encourage better stewardship of their landuse would be a second major management strategy on the West Credit River subwatershed.

One clear outcome from the developmental work for the CSI program within the Credit River watershed, is the need for ongoing monitoring and data capturing to ensure that the best information is available to manage the watershed for health and to help restore Brook Trout populations. Some of the work completed for this project can also be used to target specific monitoring needs that were not realized before work was undertaken on the CSI development.

Conclusions

The refinement and development of a CSI modeling and scoring approach for the Credit River has produced information that TUC and its partners believe will provide an additional resource for strategic management of the Credit River in general and for the protection and restoration of Brook Trout populations specifically. Given differences in the types of data available in the USA versus Canada, several of the indicators for the various categories have had to be modified. These modifications to the indicators and their underlying assumptions, appear to have produced reliable results that mirror and better explain issues of habitat, population and temporal conditions found within the watershed, its subwatersheds and their individual reaches. The various partners that have worked to improve the CSI for Brook Trout and for the overall conditions of the Credit River Watershed believe we have produced a very useful product that can be used by managers and non-government organizations such as TUC and its chapter to better manage the Credit River.

The next challenge in the further development of the CSI will be to determine if the new structured indicators and their underlying assumptions work equally as well in other small watersheds with similar robust data layers. After the CSI approach is tested on another small watershed, the next step after this will be to test the approach on larger Great Lakes watersheds that may have less rigorous and detailed data to draw upon. The ultimate goal being to produce CSI analyses for all the watersheds of the Ontario side of the Great Lakes, with a focus on Brook Trout populations.

This new analysis approach has produced a good product that demonstrates the loss and vulnerability of Brook Trout within a watershed in southern Ontario and points to the need to build a broader view and understanding of watershed conditions, habitat integrity, aquatic populations and future issues so that we can better manage our watersheds not only for particular species but for the overall watershed health as well.

Reference

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