Muskoka River Watershed IWM Natural Capital Inventory

Phase 2 Final Report: Data Enhancements, New Data & Verification

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TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

Realizing the ecological potential of every place

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Realizing the ecological potential of every place

1. INTRODUCTION

1.1 STUDY PURPOSE & SCOPE

The Muskoka River Watershed (the "Study Area") spans approximately 542,300 ha in central Ontario, commencing in headwaters emerging from springs and wetlands along the western slopes of Algonquin Provincial Park.

In 2008, 2013, 2016 and 2019, severe flooding events were experienced throughout the Watershed which contributed to significant damage of private property and municipal infrastructure. As an outcome of provincial funding and recommendations from the Muskoka Watershed Advisory Group in 2021, the District of Muskoka has moved forward with a series of projects aimed to reduce the impacts of flooding and describe existing biophysical conditions within the Watershed, with an overarching goal of moving towards a more integrated approach to Watershed management.

The Natural Capital Inventory is one of several projects focused on achieving this goal of integrated Watershed management (IWM). The objectives of this two-phased project are summarized below.

Phase 1: Data Collection & Gap Analysis

January – April 2022

Focused on collecting, consolidating, and integrating available spatial data from various background sources (including primary and grey literature), municipalities, agencies, and local experts to develop a comprehensive dataset of natural heritage features within the Watershed. The deliverable for this phase will be a data report which includes a gap analysis identifying key data gaps (spatial and type) and opportunities to enhance or update existing datasets.

Final Phase 1 report is dated August 8, 2022.

Phase 2: Data Enhancements, New Data & Verification

April – October 2022

Focused on improving existing datasets and filling gaps identified in Phase 1 through further desktop (remote sensing) analysis and scoped field verification specifically with regard to:

- **Wetlands:** Improving accuracy locations, extents, and community type; extending the enhanced wetland coverage to areas where data has not yet been collected (outside of the District boundary).
- **Watercourses, including 1st and 2nd order tributaries:** Improving accuracy of locations of features.
- **Vernal pools:** Field verification of those mapped previously and expansion of mapping to remainder of Watershed using an existing remote sensing model.
- **Ecologically significant areas:** identification by developing method/mapping to delineate areas that are key indicators of ecological function and contribute to ecological resiliency in the Watershed. Functions to consider will include:
    - o Habitat for rare species (e.g., S1-S3), including Species at Risk (O. Reg. 230/08);
    - o Uncommon land cover types (as defined by the Significant Wildlife Habitat Ecoregional Criteria Schedule for Ecoregion 5E: Rare Vegetation Communities (MNRF, 2015));
    - o Areas that contribute to storm water and spring runoff capacity; and

- Significant Wildlife Habitat (SWH).

This Phase 2 report summarizes the methodologies and results of the data enhancements, new data, and field verification efforts following Phase 1, and is intended to accompany the geospatial datasets made available on the Muskoka GeoHub.

1.2 STUDY AREA & ECOLOGICAL CONTEXT

The Muskoka River Watershed is subdivided into three subwatersheds, including the South Branch Muskoka River, North Branch Muskoka River, and Lower Muskoka. The Watershed contains extensive natural cover comprised of forests, wetlands, rock barrens, watercourses and waterbodies, many of which are undisturbed and represent key habitats for Species at Risk (SAR) and other significant plants and wildlife. The Watershed is primarily located within the District of Muskoka and spans a total of thirteen lower-tier and three upper-tier municipalities. In addition to the area municipalities within the District, the Watershed contains portions of the Town of Kearney, Township of Algonquin Highlands, Township of Dysart et al., Township of McMurrich/Monteith, Township of Perry, Township of Seguin, and Township of the Archipelago.

Lands within the Study Area and 2km buffer were included within the scope of data enhancements and field verification. Accessible lands targeted for field verification included District of Muskoka Properties, Conservation Reserve and Crown Land (within the District) which comprise 17,833 ha or 3.3% of the Study Area (Figure 1).

1.3 EXISTING DATA

Phase 1 focused on acquiring, reviewing and consolidating existing data related to natural heritage features within the Muskoka River Watershed, including spatial datasets, mapping resources, and additional primary and grey literature sources centralized around the following natural features and functions:

- Wetlands;
- Watercourses (1st and 2nd order streams);
- Vernal pools;
- Key Ecological Functions, including:
    - Rare species occurrences;
    - Uncommon landcover types;
    - Areas that contribute to stormwater capacity and spring runoff; and
    - Significant Wildlife Habitat (SWH).

Following data compilation, gaps were identified for further enhancement and/or field verification. For details on the data acquired for each of the listed features and functions, please refer to the *Phase 1: Data Compilation & Gap Analysis* report.

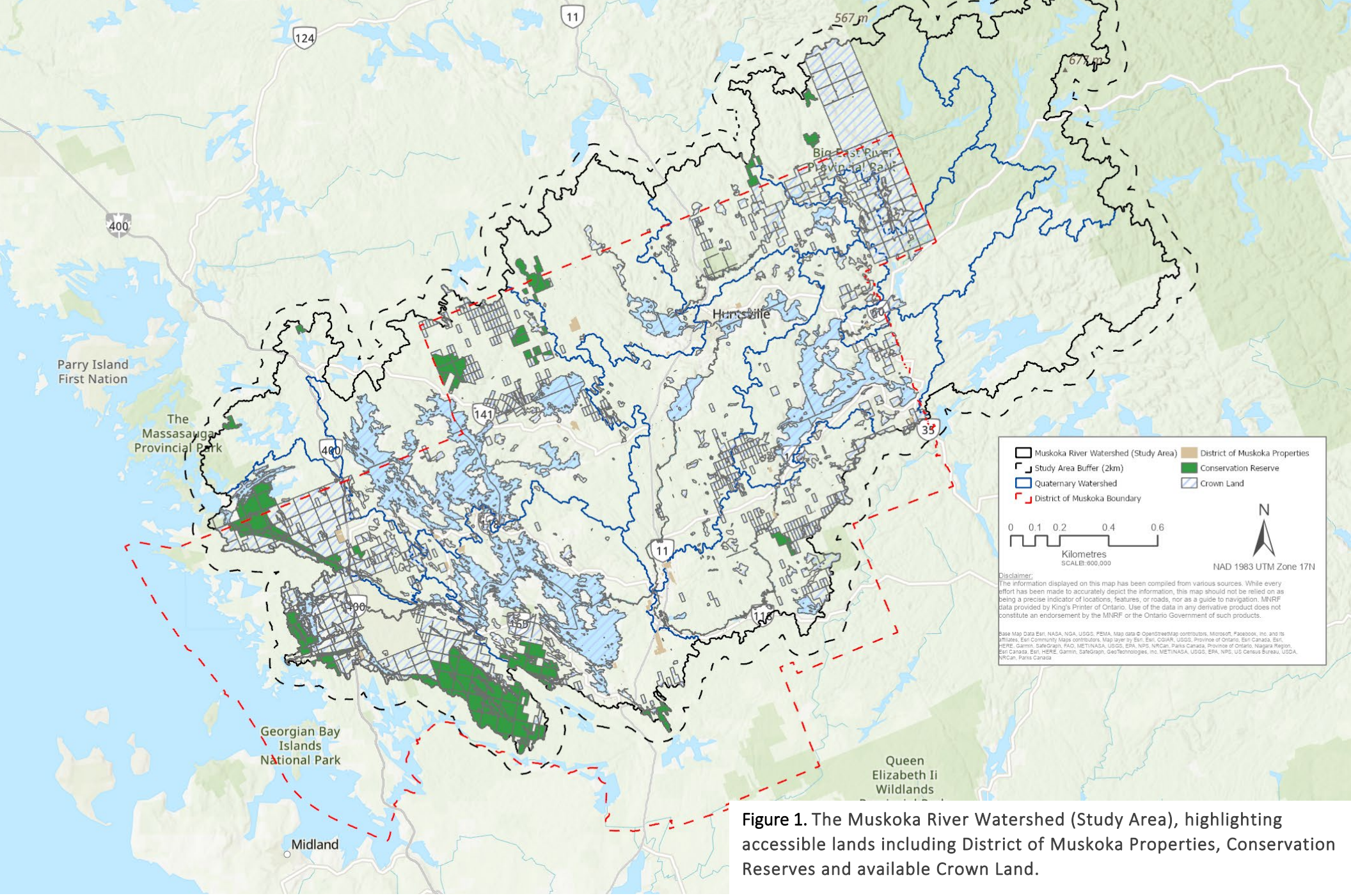


Figure 1. The Muskoka River Watershed (Study Area), highlighting accessible lands including District of Muskoka Properties, Conservation Reserves and available Crown Land.

2. METHODOLOGIES

2.1 DATA ENHANCEMENT

2.1.1 GIS MODELLING

2.1.1.1 REFINED LAND COVER MAPPING

Manually delineating land cover boundaries is a time-consuming and costly process. Remote sensing and machine learning have long been recognized as powerful tools for identifying wetlands and land cover (Environmental Laboratory, 1987) and allow for large areas to be mapped relatively quickly. In recent years, LiDAR (Light Detection and Ranging), which is a remote sensing technology, has been rapidly growing as a key dataset for mapping wetlands accurately (O'Neil et al. 2018). LiDAR provides detailed topographic information about the earth surface which can be interpolated to develop a high-resolution digital terrain model (DTM). Previous studies have shown that DTM derivatives can accurately model spatial extents of saturated area (O'Neil et al. 2018). These DTM derivatives include:

- Topographic Wetness Index (TWI) - indicates the tendency of an area to accumulate water or to drain water.
- Depth to Water Index (DTW) - developed by Murphy et al. (2007) and is a soil moisture index based on the assumption that soils closer to surface water are more likely to be saturated.
- Curvature - indicates the degree of convergence and acceleration of surface flow.
- Stochastic Depressions - indicates the probability of an area belonging to a topographic depression.

High resolution multispectral imagery is also an important dataset that can be used to create derivative inputs for predicting land cover. These imagery derivatives include:

- Normalized Difference Vegetation Index (NDVI) – indicator of green vegetation.
- Normalized Difference Water Index (NDWI) – indicator of moisture content.

These DTM and imagery derivatives paired with machine learning were used for modeling land cover within the Muskoka River Watershed. D&A employed a nested level approach to predict the location and extent of vegetation communities across the Muskoka River Watershed. The entire Watershed was first classified to the system level (terrestrial, wetland or aquatic) using deep learning processes which is a machine learning technique. Each system was then further refined using a combination of deep learning processes and existing data (Figure 2).

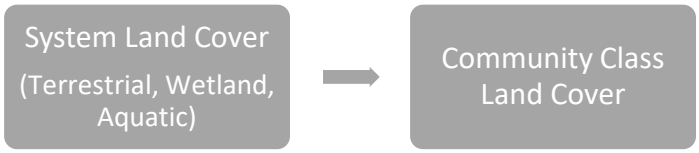


Figure 2. Nested level approach to land cover mapping

2.1.1.1.1 SYSTEM LAND COVER

Preprocessing:

The two main datasets used for modeling the system land cover was the 2018 South Central Ontario Orthophotography Project (SCOOP) and the 2019 MNRF Forest Resources Inventory (FRI) LiDAR digital terrain model (DTM) (Figure 3). The SCOOP 2018 orthophoto is a 16cm leaf-off colour-infrared product, captured between 22 March 2018, and 23 May 2018. Due to the large study area, resampling was necessary to increase processing speed. The orthophoto was resampled from 16cm to 1m resolution using the nearest neighbor algorithm. The normalized difference vegetation index (NDVI) was then calculated from the 1m orthophoto using the following equation:

$$\text{NDVI} = \frac{\text{Near Infrared Band} - \text{Red Band}}{\text{Near Infrared Band} + \text{Red Band}}$$

The normalized difference water index (NDWI) was also calculated from the 1m orthophoto using the following equation:

$$\text{NDWI} = \frac{\text{Green Band} - \text{Near Infrared Band}}{\text{Green Band} + \text{Near Infrared Band}}$$

Although these indices are typically used with leaf-on imagery to differentiate vegetated versus non-vegetated areas, they were incorporated into this analysis to help with classification of features with coniferous trees and wetland areas.

The 2019 Lidar DTM is a 50cm bare-earth terrain derived from a classified lidar point cloud. The Lidar DTM was used to derive topographic indices including curvature, depth to water index (DTW), and topographic wetness index (TWI). Prior to calculating these indices, the DTM was smoothed using the Perona Malik method with a smoothing width of 10m and 50 iterations. Smoothing was used to remove small changes in elevation (microtopographic noise) that are too small to indicate features of interest. Curvature was derived at 1m resolution from the smoothed DTM. DTW was calculated using the smoothed DTM, the Ontario Integrated Hydrology Network and ArcHydro's Depth to Water Index tool. Prior to running the TWI tool, the smoothed DTM was hydroconditioned to resolve topographic depressions using the fill method. ArcHydro's Topographic Wetness Index tool was then used to calculate TWI from the hydroconditioned DTM. The DTW and TWI were both derived to 5m resolution due to limitation in processing speed and pixel processing limitation.

The 2019 lidar DTM was also used to run the stochastic depression analysis tool from Whitebox Geospatial Analysis Tools (GAT). Whitebox GAT is an open-source software developed by Dr. John Lindsay at the University of Guelph. The stochastic depression analysis tool creates several temporary raster-based images in memory and therefore requires a large amount of memory to run. To enable the process, the DTM was split into 15km grids with a 200m overlap and resampled to 1m using a bilinear algorithm. The DTM was then smoothed to remove noise using the feature preserving smoothing tool from Whitebox GAT. This de-noising algorithm removes surface roughness while maintaining breaks-in-slope. The tool used 3 iterations with a filter size of 11 pixels, which is the default suggested by Whitebox GAT for high resolution DTM's. Lindsay et al. (2019) found that the degree of smoothing was less impacted by the filter size than it was either the normal difference threshold or the number of iterations. The normal difference threshold, which is the maximum degree of deviation in normal vectors, was set to 15 and a max elevation change of 0.5m. The stochastic depression analysis was then run on the smoothed DTM to calculate the probability

of each cell belonging to a depression. The DTM root-mean-square-error was set to 0.5m, the range of autocorrelation was set to 8 and the tool utilized 40 iterations.

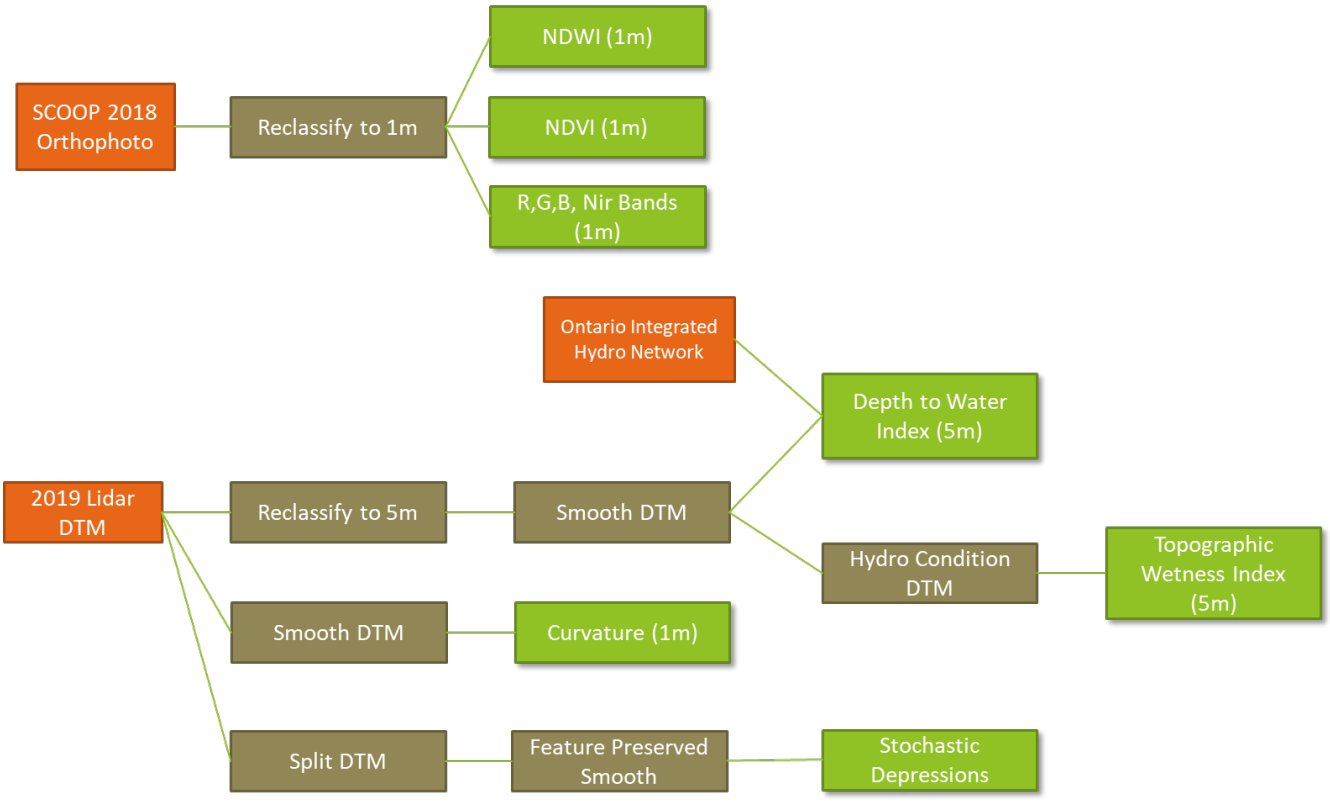


Figure 3. Data preprocessing workflow

Deep Learning:

When modeling land cover there are two types of potential errors: false positives, and false negatives. False positives incorrectly indicate the presence of a feature, while false negatives incorrectly indicate the absence of a feature. For this study and the mapping of wetland features, false positives were more acceptable than false negatives. The primary reason being that false positives can be candidate areas for field verification whereas features that are not mapped would not be identified as candidate areas to confirm during future study. Through multiple iterations of deep learning processing, it was determined that two methods mapped wetlands to a similar accuracy but identified different extents. To reduce the risk of false negative wetlands, the two wetland outputs were combined to create a final system land classification.

For the first method, the orthophoto bands, NDVI, TWI, DTW and curvature were combined into a single raster using ArcGIS's composite bands tool, resulting in an 8-band raster that could be used for deep learning. For the second method, the orthophoto bands, NDVI, NDWI and stochastic depression were combined into a single raster using ArcGIS's composite bands tool, resulting in a 7-band raster that could be used for deep learning.

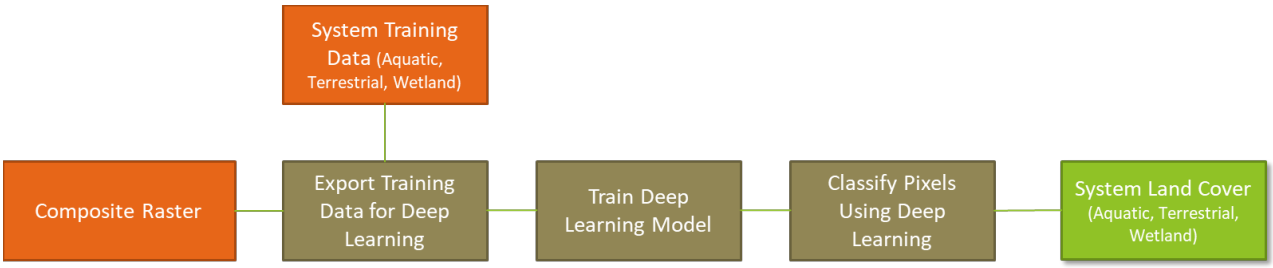


Figure 4. Deep learning workflow

Both composite rasters were classified using the same deep learning process as outlined in Figure 4. The first step in the deep learning process is exporting the training data for deep learning which converts the labeled vectors into learning training datasets. Our train dataset included 184 (1,506 ha) aquatic features, 388 (569 ha) wetland features, and 991 (1,368 ha) terrestrial features. The tool parameters were modified to set the tile size as 100m, the stride size as 80m, the reference system to map space, and the metadata format to classified tiles. The tile size is the size of the image chips exported and the stride size is the distance to move in the x and y direction when creating the next image chip. The next step was to train the deep learning model. The model was trained using the U-Net method[1] which is an architecture for semantic segmentation. The backbone model was ResNet-34[2]. A batch size[3] of 8 was utilized with a maximum of 35 epochs[4] and a 10% validation ratio (i.e. 10% of the data is used for validation purposes).

The accuracy of the deep learning model is summarized as 3 scores: Precision, Recall and F1.

- Precision – The ability of a model to identify only the relevant features. It is calculated by the number of true positives divided by the number of true positives plus the number of false positives. Generally, precision answers the question: given the model predicted a particular feature type, what is the probability that it is truly the given feature? Values will be high when false positives are low, and low when false positives are high. As noted previously, a lower precision is considered acceptable for this study, given that future site investigations can be undertaken to rule out potential false positives.

- Recall – The ability of a model to identify all relevant features. It is calculated by the number of true positives divided by the number of true positives plus the number of false negatives. Generally, recall answers the question: how well did the model do at representing the particular feature type in question. Values will be high when the model does a good job of predicting the presence of features that are actually present, and low when the model does a poor job of predicting the

[1] U-Net is a convolutional neural network that works with fewer training images and yields more precise segmentations than a fully convolutional network.
[2] ResNet-34 is an image classification model pre-trained on ImageNet dataset.
[3] The batch size is a hyperparameter of gradient descent that controls the number of training samples to work through before the model's internal parameters are updated.
[4] The number of epochs is a hyperparameter of gradient descent that controls the number of complete passes through the training dataset.

presence of features that are actually present. As minimizing false positives is preferred (i.e. minimizing the rate of features being potentially missed), this metric is used as the primary indicator of model effectiveness.

- F1 Score – F1 is the harmonic mean of precision and recall. Generally, F1 determines how well the model did overall at predicting feature type, assuming false positive and false negative errors are equally weighted. As the rate of false positive errors is considered to be more acceptable than false negatives, F1 scores were not used to evaluate model effectiveness. They do however, provide relevant information for potential improvements to model effectiveness that can be addressed through future study.

As noted above, recall was used as the primary summary statistic to evaluate model efficacy. Models were considered to have a high recall for scores equal to or above 0.8, moderate for scores between 0.6 and 0.8, and low for scores below 0.6. Across the various models run to classify land cover, recall ranged from a low of 0.16 (Mixed Swamps) to a high of 0.99 (Open Aquatic). The results of the classification models are presented below and summarized in Section 2.1.1.1.5.

The land cover models resulted in the following Precision, Recall and F1 scores (Table 1 and Table 2).

Table 1. Method 1 (Orthophoto, NDVI, TWI, DTW, curvature)

	Wetland	Terrestrial	Aquatic
precision	0.45	0.37	0.76
recall	0.86	0.92	0.98
f1	0.59	0.52	0.86

Table 2. Method 2 (Orthophoto, NDVI, NDWI, stochastic depressions)

	Wetland	Terrestrial	Aquatic
precision	0.40	0.37	0.76
recall	0.75	0.90	0.98
f1	0.52	0.52	0.86

The classify pixels using deep learning tool was then run using the trained model. A padding size of 25 and a batch size of 4 was utilized. The resulting outputs were 1m raster pixels classified to the system land cover. The raster calculator was then used to add the additional wetland extents mapped using method 2 to create a single system land classification raster.

Post-Processing:

A common occurrence during pixel classification is to have single or small groupings of cells that are misclassified that should belong to the same class that surrounds it. Another typical phenomenon occurring from pixel classification is boundaries that are jagged represent unrealistic feature boundaries. Pixel classifications needed to be translated/scaled to determine best estimate of features, including boundary and type. Post-processing tools were applied to the system land cover output raster to remove small

misclassifications (<15m^2) and smooth boundaries. The majority filter was run to remove the single, misclassified cells in the classified raster. The boundary clean tool was then run to smooth the boundaries between zones. The resulting raster was then converted to polygons and the simplify polygons tool was applied using the retain critical bends (Wang-Müller) algorithm. This creates a final systems land cover polygon dataset classified as wetland, aquatic or terrestrial (Figure 5).

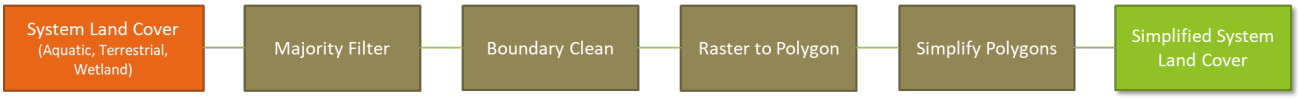


Figure 5. Data post-processing workflow

2.1.1.1.2 WETLAND COVER

Using the wetlands created from the systems land cover, a deep learning approach was utilized to classify wetland extents into community classes to facilitate mapping of wetland extent and type (Figure 6). Landcover predictions were also used to extract wetland features.

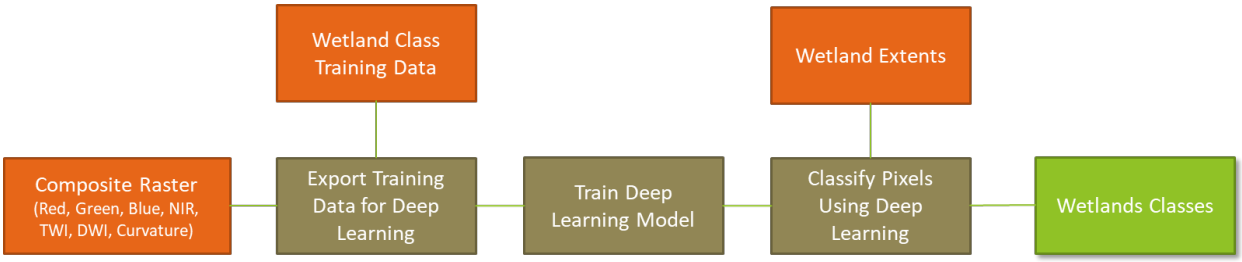


Figure 6. Deep learning process for identifying wetland classes

Training data contained the following six wetland classes (Table 3).

Table 3 Wetland classes (training dataset)

Wetland Class	No. Features	Area (ha)
Fen / Bog	31	61.3
Open Marsh	159	143.1
Coniferous Swamp	46	166.0
Deciduous Swamp	26	25.4
Mixed Swamp	36	85.1
Thicket Swamp	90	88.0

Export training data for deep learning tool was run using the composite raster as the input, a tile size of 100, a stride size of 80, the map space reference system, and the classified tiles metadata format. The model was then trained using the U-Net method which is an architecture for semantic segmentation and the backbone model was ResNet-34. A batch size of 8 was utilized with a maximum of 35 epochs and a 10% validation ratio. The model resulted in the following precision, recall and f1 scores (Table 4).

Table 4. Precision, recall and f1 scores for wetlands (modelling results)

	Bog / Fen	Open Marsh	Swamp Coniferous	Swamp Deciduous	Swamp Mixed	Swamp Thicket
precision	0.27	0.29	0.28	0.07	0.04	0.09
recall	0.65	0.91	0.90	0.36	0.16	0.40
f1	0.39	0.44	0.42	0.11	0.06	0.15

When comparing field verified wetlands that were detected in wetland modeling, models detected 93% of field verified wetlands (Table 5).

Table 5. Summary of field-verified wetlands detected using modeling

Type	Area (ha)	%
Field verified wetlands detected in wetland modeling	377.2	93%
Field verified wetlands not detected in wetland modeling	27.4	7%
Grand Total	404.7	100

The classify pixels using deep learning tool was then run using the trained model. A padding size of 25 and a batch size of 4 was utilized. The resulting output was a 1m raster containing wetland classes.

Post-processing was performed to remove small misclassifications and smooth boundaries. The majority filter was run to remove the single, misclassified cells and the boundary clean tool was then run to smooth the boundaries between zones. The region group tool was then run to identify connected regions with the same classification type. Regions smaller than 100m^2 were removed and the nibble tool was used to fill the areas based on the nearest neighbor classification type. The resulting raster was then converted to polygons to create the final wetland dataset which predicts wetland locations, extent, and type for the entire Muskoka River Watershed.

2.1.1.1.3 AQUATIC COVER

Mapping aquatic features was included as an additional feature type within the project scope to provide inputs for mapping significant wildlife habitat and species habitat distribution. Using the aquatic areas created from the systems land cover, a deep learning approach was utilized to classify the aquatic extents into community classes. Our training data contained two classes, shallow aquatic, and open aquatic. First the export training data for deep learning tool was run using the orthophoto (R, G, B, NIR) as the input with a tile size of 100, a stride size of 80, the map space reference system, and the classified tiles metadata format. The model was then trained using the U-Net method which is an architecture for semantic segmentation and the backbone model was ResNet-34. A batch size of 8 was utilized with a maximum of 35 epochs and a 10% validation ratio. The model resulted in the following precision, recall and f1 scores (Table 6).

Table 6. Precision, recall and f1 scores for aquatic cover (modelling results)

	Open Aquatic	Shallow Aquatic
precision	0.81	0.21
recall	0.99	0.57
f1	0.89	0.31

Post-processing was performed to remove small misclassifications and smooth boundaries. The majority filter was run to remove the single, misclassified cells and the boundary clean tool was then run to smooth the boundaries between zones. The region group tool was then run to identify connected regions with the same classification type. Regions smaller than 100m^2 were removed and the nibble tool was used to fill the areas based on the nearest neighbor classification type. The resulting raster was then converted to polygons to create the final aquatic dataset which predicts aquatic locations, extent, and type for the entire Muskoka River Watershed.

2.1.1.1.4 TERRESTRIAL COVER

Mapping terrestrial features was included as an additional feature type within the project scope to provide inputs for mapping significant wildlife habitat and species habitat distribution. This included development of models to update mapping of anthropogenic, barren, and forested features using existing data and deep learning processes.

Anthropogenic:

Esri's high resolution land cover classification pretrained deep learning model was applied to the orthoimage to map anthropogenic areas within the Watershed. This model was trained on the Chesapeake Bay high-resolution 7 class 2013/2014 NAIP Landcover dataset (produced by Chesapeake Conservancy with their partners University of Vermont Spatial Analysis Lab (UVM SAL), and Worldview Solutions, Inc. (WSI)) and other high-resolution imagery. Although the model is applicable in the United States and is expected to produce best results in the Chesapeake Bay Region the anthropogenic classes are less impacted by different landscape morphologies than other land classes. The Esri model was chosen to be used as the results were more accurate than creating custom anthropogenic training data within the Watershed (Table 7).

Table 7. Esri's anthropogenic landcover model accuracy

	Developed – Medium Intensity	Impervious Surfaces	Impervious Roads
precision	0.79	0.84	0.82
recall	0.69	0.84	0.83
f1	0.74	0.84	0.82

The output anthropogenic raster was reclassified to combine developed, medium intensity, impervious surfaces, and impervious roads then converted to polygons. Polygons were smoothed and generalized using a positive and negative 5m buffer. Existing road and building footprint data was integrated. MNRF roads were selected where Road Element Type was not equal to Virtual Road and Road Class was not equal to proposed, resource/recreational, service, trail, or trailer park. These roads were buffered by 3.5m to

create road polygons. Anthropogenic areas identified through deep learning, road buffer polygons and MNRF building footprints were combined to create an anthropogenic file (Figure 7).

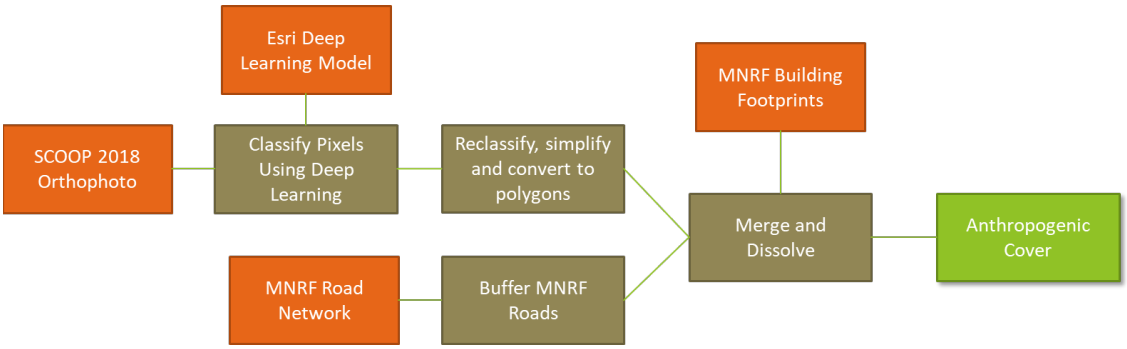


Figure 7. Anthropogenic mapping workflow

Barren:

Using the terrestrial areas created from the systems land cover, a deep learning approach was utilized to extract the barren areas. Export training data for deep learning tool was run using the orthophoto (R, G, B, NIR) as the input with a tile size of 100, a stride size of 80, the map space reference system, and the classified tiles metadata format. The model was then trained using the U-Net method which is an architecture for semantic segmentation and the backbone model was ResNet-34. A batch size of 8 was utilized with a maximum of 35 epochs and a 10% validation ratio. The model resulted in the following precision, recall and f1 scores (Table 8).

Table 8. Precision, recall and f1 scores for barren (modelling results)

	Barren
precision	0.11
recall	0.38
f1	0.17

The boundaries of the barren areas were smoothed by running the majority filter then the boundary clean tool. The resulting raster was converted to polygons. A positive and negative 4m buffer was applied to further smooth and clean the barren area boundaries. In some instances, the model detected anthropogenic areas as barren, these misclassifications were removed by erasing all anthropogenic and agriculture areas from the dataset. All barren features less than 100m^2 were assumed to be errors or insignificant features and therefore removed.

Forests:

The Forest Resource Inventory (FRI) provided by Westwind Forest Stewardship Inc is a dataset for detailed forest classification across the Watershed. The FRI dataset did not include certain smaller, discrete forest features, so an additional deep learning approach was used to detect these features. Our training data contained three classes, coniferous forest, deciduous forest, and mixed forest. Export training data for deep learning tool was run using the orthophoto (R, G, B, NIR) as the input with a tile size of 100, a stride size of 80, the map space reference system, and the classified tiles metadata format. The model was then trained using the U-Net method which is an architecture for semantic segmentation and the backbone model was

ResNet-34. A batch size of 8 was utilized with a maximum of 35 epochs and a 10% validation ratio. The model resulted in the following precision, recall and f1 scores (Table 9).

Table 9. Precision, recall and f1 scores for forests (modelling results)

	Coniferous Forest	Deciduous Forest	Mixed Forest
precision	0.32	0.35	0.23
recall	0.52	0.53	0.72
f1	0.40	0.42	0.35

The boundaries of the forested areas were smoothed by running the majority filter then the boundary clean tool. The resulting raster was converted to polygons and unionized with the FRI dataset.

2.1.1.1.5 SUMMARY

As outlined in the foregoing, the evaluation metric that was used to assess the efficacy of the land classification models relied primarily on 'recall'. As a reminder, recall evaluates the ability of the model to predict the occurrence of known feature types. This approach prioritizes the land class type irrespective of whether the resulting model predicts false positives. The rationale being that false positives are more acceptable and can be field verified in the future, whereas false negatives, which would be prioritized using 'precision' or f1 as an evaluation metric, are less acceptable.

The results from the deep learning land classification were broken into two stages. The first stage was a high-level classification of the watershed into either wetland, terrestrial, or aquatic. The second stage was a more refined classification of various land-class types.

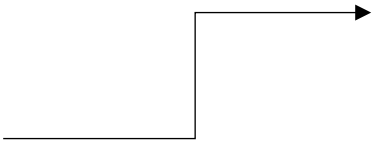
The high-level classification model resulted in a very acceptable prediction of the three classes (Table 1 and Table 2). This was the case for both methods that utilized a different combination of input parameters. For example, recall for wetlands was 0.86 and 0.75 (methods 1 and 2, respectively), for terrestrial was 0.92 and 0.90, and for aquatic was 0.98 and 0.98. Generally, the results are indicative of a relatively high probability that the models able to correctly identify existing features within the field verified dataset.

The lower scores for precision and F1 for these classes indicate that, for the predicted dataset, there did tend to be a high rate of false positives, particularly for wetland and terrestrial classes.

Among wetland features coniferous swamp and open marsh had the highest recall scores (both were over 0.9) this was followed by bog/fen (0.65), swamp thicket (0.40), deciduous swamp (0.36), and mixed swamp (0.16) (Table 4). Recall scores for aquatic features was extremely high for open aquatic (0.99) and low for shallow aquatic (0.57) (Table 6). Recall scores for impervious surfaces and roads were relatively high (over 0.84 and 0.83, respectively), and lower for developed areas (0.69) (Table 7). Recall for rock barrens was relatively low (0.38) (Table 8). Recall for forested features was highest for mixed forests (0.72) and lower for coniferous and deciduous forests (0.52 and 0.53) respectively (Table 9).

Given the results of the modeling approach validated using the field verified data, the final land cover map included a consolidation of data from the FRI data set and the predicted cover types from the various deep learning classification models. The following order of priority was used in determining the ultimate land cover type to include:

- Anthropogenic
- Agriculture Fields
- Modeled Wetlands
- Modeled Aquatic



- FRI Forest
- FRI Meadow/Shrub
- Modeled Barren
- Modeled Forests

2.1.1.2 VERNAL POOLS

The potential location of vernal pools were mapped by McMaster University researchers as published in the 2021 article *Detection of potential vernal pools on the Canadian Shield (Ontario) using object-based image analysis in combination with machine learning* (Luymes and Chow-Fraser 2021). The accuracy of Luymes and Chow-Fraser (2021) vernal pool modeling was assessed through targeted field verification. A total of 443 vernal pools were visited with 209 (47%) being present and 234 (52%) not present. Luymes and Chow-Fraser ran their vernal pool model on a 1m stereo-derived digital elevation model (DEM). Although the factors responsible for the over-estimation of vernal pool occurrences using this model was not explored in detail, it was anticipated that a revised modeling approach that combined high resolution LiDAR data and aerial imagery would provide improved prediction accuracy.

The workflow for this study used similar methods as outlined in the article *An Effective Method for Detecting Potential Woodland Vernal Pools Using High-Resolution LiDAR Data and Aerial Imagery* (Wu, Lane, and Liu 2014). Potential vernal pools were identified by locating surface depressions in the lidar DTM then further refined using land cover information. To extract depressions the stochastic depression analysis tool from Whitebox Geospatial Analysis Tools (GAT) was utilized. The stochastic depression analysis tool creates several temporary rasters in memory and therefore requires a large amount of memory to run. To enable the process to run, the DTM was split into 15km grids with a 200m overlap and resampled to 1m using a bilinear algorithm. The DTM was then smoothed to remove noise using the feature preserving smoothing tool from Whitebox GAT. This de-noising algorithm removes surface roughness while maintaining breaks-in-slope. The tool used 3 iterations with a filter size of 11, normal difference threshold of 15, and a max elevation change of 0.5m for optimal smoothing.

The stochastic depression analysis was then run on the smoothed DTM to calculate the probability of each cell belonging to a depression. The DTM root-mean-square-error was set to 0.5m, the range of autocorrelation was set to 8 and the tool utilized 40 iterations. The output from this process is a raster with values ranging from 0-1 with 1 being most likely to be a depression and 0 being least likely. We determined that a critical value of ≥0.40 was representative of "true surface depressions" which is consistent with the value used by Wu et al (2014). These areas were then extracted and converted to polygons for the watershed (Figure 8).

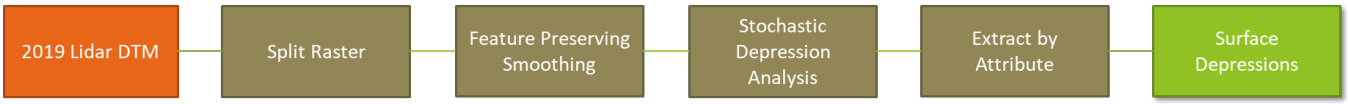


Figure 8. Workflow to identify surface depressions

Given their small size, features less than 25m^2 were removed as they were assumed to have resulted from overfitting and represent false positives occurrences. As well, depressions located within anthropogenic and agricultural land cover were removed as they were assumed to not have the associated ecological values and/or characteristics to be considered a vernal pool. Depressions located within 10m of a watercourse or waterbody feature were also removed as their hydrology and ecology was assumed to be more influenced by the associated water resource feature, than 'isolated' localized drainage.

Vernal pool boundaries within the updated layer were then smoothed, and small holes were filled by applying a positive, and then negative buffer of 2 meters.

Normalized difference water index (NDWI) was calculated using the 2018 orthophoto and the following equation:

$$\text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}}$$

The resultant NDWI raster ranged from -1 to 1 with water features being positive values while soil and vegetation are zero or negative values. NDWI was used by Wu et al. (2014) to further refine vernal pools by using the maximum and mean NDWI values. ESRI's zonal statistic tool was used to calculate the maximum, minimum, mean, and median NDWI values for each field surveyed vernal pools. No statistical difference in NDWI values were found between present and not present field verified vernal pools. Therefore, NDWI was not used to further refine vernal pool locations.

Field verification resulted in identification of 208 vernal pools. Of the vernal pools that were field-verified as present, the vernal pool modeling identified 53%, whereas wetland modeling detected 83%. The combined modeling approach (vernal pools and wetlands) detected 87% of field verified wetlands (Table 10).

Table 10. Summary of field-verified vernal pools detected using modeling

Mapping	No. Surveyed Vernal Pools Detected	% Detected
Vernal Pool Modeling	111	53%
Wetland Modeling	172	83%
Vernal Pool and Wetland Modeling	181	87%

2.1.1.3 WATERCOURSES (1st and 2nd ORDER STREAMS)

D&A explored a variety of workflows for modelling watercourses within the study area, ultimately choosing to combine the Ontario Integrated Hydrology (OIH) network with predicted watercourses derived from the 2019 FRI LiDAR DTM using ArcHydro.

2.1.1.3.1 WATERCOURSE PRE-PROCESSING

The main objective for this component of the study was to improve the extent and locational accuracy of 1st and 2nd order watercourses, which are often difficult to locate and map when working at a large scale such as the Muskoka River Watershed. The DTM used was 50cm bare-earth terrain derived from a classified lidar point cloud, which provided a much higher resolution picture of the study area's topography than previously available. To ensure the watercourse modelling was as detailed as possible the DTM was not resampled and was kept at the original 50cm resolution. Flow Direction was determined first using the D8 algorithm in ArcGIS Pro. This method tracks the direction of flow from each pixel to one of its 8 surrounding pixels. The Sink tool was then run in ArcGIS Pro to identify potential areas of internal drainage or "looping" flow which would impede modelling. Within the processed analysis area there were 179,585,869 unique sinks identified. Of these, approximately 95% were found to be 1m or less in diameter and 3m or less in depth. The Fill tool was run to remove sinks within the DTM, with multiple iterations being tested at 3m, 5m, 10m, and total fill. Outputs of the filled DTM were examined at locations of previously modelled sinks to evaluate success. Upon review, the 3m fill was found to be the most successful at removing sinks while ensuring that natural topographic features were not lost. Flow Direction was then re-run using the filled DTM, followed by Flow Accumulation, which calculates the accumulation of flow contributing to each downslope cell (Figure 9).

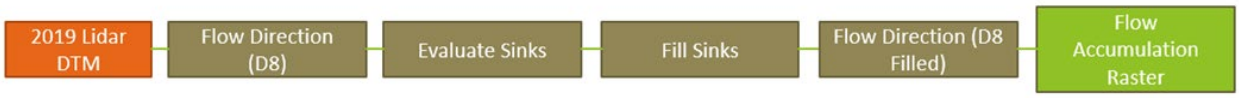


Figure 9. Pre-processing of 2019 Lidar DTM

2.1.1.3.2 PRELIMINARY WATERCOURSE DELINEATION

The output of the Flow Accumulation tool was used to determine areas of flow concentration which may indicate where watercourses are present. Classifications were applied at intervals of 10,000 pixels from 0 to 1,000,000. Each classification was examined at known locations of 1st order streams to determine what quantity of flow would be the most appropriate for modelling headwater features. Upon review a value of 175,000 pixels (43,750 m2) was found to match known extents of 1st order watercourses without overextending the upstream reach. The raster calculator was used to extract all pixels with a value greater than 175,000. The raster was then converted to line features using the Raster to Polyline tool (Figure 10).

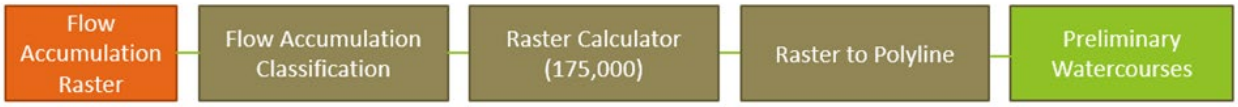


Figure 10. Preliminary watercourse mapping

2.1.1.3.3 FINAL HYDROLOGIC MODEL

The preliminary watercourses were refined by removing virtual flow segments and fragments of flow that did not contribute to the overall network. The OIH watercourse network was segmented by stream order and major features (3rd order and greater) were extracted. Extracted OIH features were merged with the refined lidar watercourse dataset. The two networks were aligned at merge points using the Snap tool, followed by segmentation at nodes via Dissolve. Stream Order (Strahler) was then determined for each feature, as well as length. Features were then exported as a complete hydrographic network for the entire Muskoka River Watershed (Figure 11).

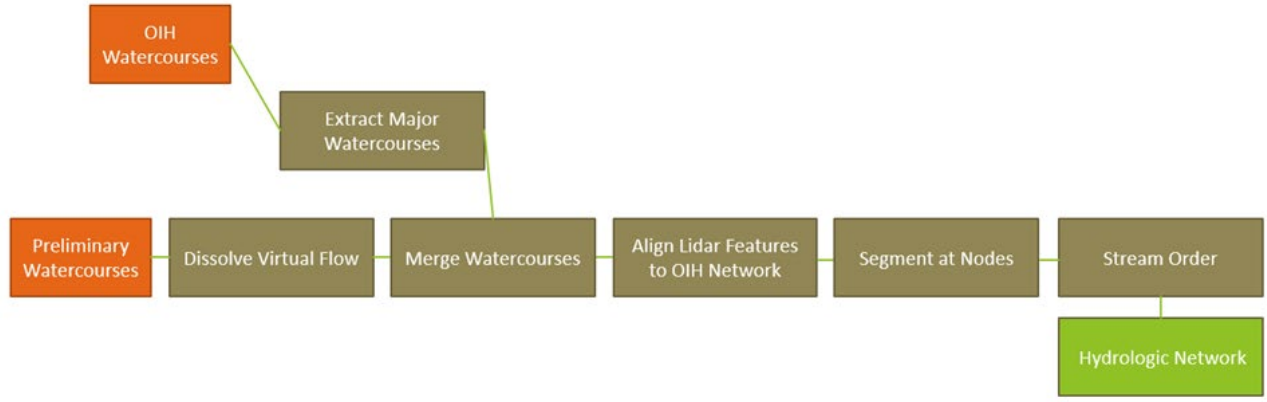


Figure 11. Final hydrologic model

2.1.1.4 KEY ECOLOGICAL FUNCTIONS

One of the overarching goals of the Natural Capital Inventory project was to identify areas within the Muskoka River watershed that provide important ecological functions. This included identifying areas that contain habitat for rare species, uncommon land-cover types, areas that contribute to stormwater and spring runoff capacity, and areas that are consistent with criteria for Significant Wildlife Habitat. For each of the key ecological function types, the following provides a summary of the data sources and/or methodologies used.

2.1.1.4.1 RARE SPECIES OCCURENCES

Rare species occurrence and observation data was obtained from the Natural Heritage Information Centre (NHIC), Global Biodiversity Information Facility (GBIF) including research-grade iNaturalist records, other available reports, and D&A's field observations in 2022. Rare species were defined as: Federal or Provincial Species at Risk (SAR) identified as Endangered, Threatened, or Special Concern, and/or species with an S-rank of S1-S3.

Open-source Species at Risk (SAR) records obtained through GBIF are often obscured due to sensitivity concerns and NHIC data is the most accurate with respect to location. A total of 24,369 observations were provided by NHIC within the study area including 148 species. The majority of records were reptiles (52%) and birds (42%), with insects, mammals, plants and amphibians accounting for a small percentage.

Additional data on Atlantic Coastal Plain plant species was obtained from *Atlantic Coastal Plain Flora Conservation in Ontario* (Keddy and Sharp 1989). Locations of rare coastal plant communities were digitized from field maps within the report and mapped as points in GIS. Additional species data was also extracted from the report to create a list of plant species associated with this habitat type.

Rare species records gathered from all sources, as defined above, were consolidated into a list and map of occurrences within the Watershed. This data was used for the Significant Wildlife Habitat (SWH) assessment for Special Concern and Rare Wildlife Species (i.e., Special Concern and S1-S3 species), and a select few species were identified and used in habitat modelling as described below (also ref. section 3.5.1).

Maximum Entropy (MaxEnt) Modelling

Modelling of select wildlife habitat within the study area was undertaken through two approaches, using a Maximum Entropy (MaxEnt) and Habitat Suitability Model. These approaches both utilize a variety of inputs including known and modelled landcover classes.

The ESRI integrated Presence-only Prediction (MaxEnt) tool was used to predict potential locations of select species occurrences within their current range. The tool works with three main inputs to create a model: known locations of species occurrences, range or study area where species may occur, and explanatory variables. Species were selected based on a number of criteria, including:

- current status as SAR;
- range within the study area; and
- number of high-quality presence locations.

After combining all data sources, the following species were selected for modelling with the MaxEnt approach:

- Blanding's turtle (*Emydoidea blandingii*)
- Common five-lined Skink (Southern Shield population) (*Plestiodon fasciatus*)
- Eastern hog-nosed snake (*Heterodon platirhinos*)
- Eastern ribbonsnake (*Thamnophis sauritus*)
- Eastern Massasauga (Great Lakes - St. Lawrence Population) (*Sistrurus catenatus*)
- Monarch (*Danaus plexippus*)
- Spotted turtle (*Clemmys guttata*)
- Wood thrush (*Hylocichla mustelina*)

These species and their general habitat preferences are summarized below (Table 11).

Species records were classified into "spatial accuracy" groups based on information included in the source datasets, with high accuracy records being used as inputs for the model. Landcover classifications and water features were converted to "distance-to" rasters at a resolution of 10 m using the Euclidean Distance tool to better capture species habitat preferences and reduce runtime. Spatial thinning (i.e. removal of nearby points) was applied to the input points based on known accuracy of the species class in order to reduce potential bias associated with sampling. Due to the large study area and input rasters the tool was run using a linear basis function rather than a step basis function. Resampling of the results was done using a Random Resampling Scheme with 10 iterations. Outputs were created in the form of prediction rasters showing areas where species were most and least likely to occur (Figure 12).

Table 11. Status and habitat preferences of MaxEnt modeled species.

Common Name	Species Group	SARA Schedule 1 Status	ESA Status	S Rank	General Habitat Preference
Blanding's turtle	Reptiles	THR	END	S3	Large wetlands and shallow waterbodies
Common five-lined Skink	Reptiles	SC	SC	S3	Rocky outcrops in coniferous or deciduous forest
Eastern hog-nosed snake	Reptiles	THR	THR	S3	Open woods or early successional habitat close to water
Eastern ribbonsnake	Reptiles	SC	SC	S4	Wetland and shoreline habitat
Eastern Massasauga	Reptiles	THR	THR	S3	Forest, meadow, shoreline riparian areas, wetland, rock barren, or grassland
Monarch	Butterflies	SC	SC	S2N,S4B	Prairie, meadow, marsh, forest
Spotted turtle	Reptiles	END	END	S2	Ponds, marshes, bogs
Wood thrush	Birds	THR	SC	S4B	Mature deciduous and mixed forest

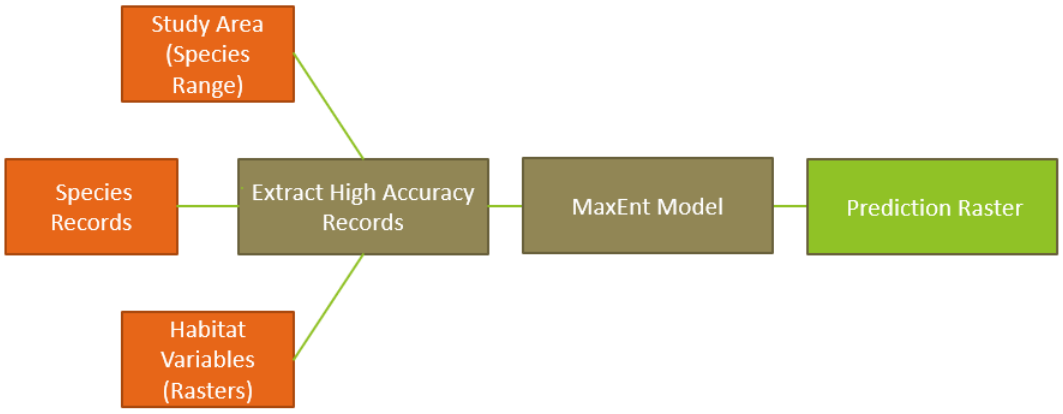


Figure 12. MaxEnt habitat modeling process.

The area under the curve (AUC) and omission rate were used to determine accuracy of the MaxEnt model. AUC is an evaluation diagnostic for how capable a model is at estimating known presence locations. Higher

AUC indicates a more appropriate model for predicting presence. Omission rate is used to assess the portion of known presence points that were misclassified as non-presence by the model, using a range of presence probability cutoff values between zero and one (Table 12).

Table 12. AUC and Omission Rate for Species Records

Species	AUC	Omission Rate
Blanding's Turtle	0.8935	0.1866
Common Five-lined Skink	0.8794	0.2562
Eastern Hog-nosed Snake	0.9186	0.4281
Eastern Ribbonsnake	0.8429	0.2105
Massasauga Rattlesnake	0.8138	0.2276
Monarch	0.9200	0.1847
Spotted Turtle	0.9662	0.2146
Wood Thrush	0.8699	0.1697

Habitat Suitability Model (HSM)

In addition to the MaxEnt approach, a Habitat Suitability Model (HSM) was generated for Little Brown Myotis habitat. Due to lack of accurate species records, the machine learning MaxEnt approach could not be employed for this species. The HSM complements the MaxEnt approach as it does not rely on species locations, instead using known habitat preferences to generate a weighted suitability map. All species included in the MaxEnt approach were also modelled using the HSM, as well as Little Brown Myotis (*Myotis lucifugus*) which did not have enough accurate species records to model using machine learning. Inputs for the habitat suitability model included previously modelled landcover classes, converted to "distance-to" rasters using the Euclidean Distance tool. Input rasters were transformed to a common suitability scale, with areas near preferred features being scored higher (). Exceptions to the suitability scale included anthropogenic areas, which were negatively scored and areas within an open aquatic environment.

Figure 13. HSM process.

Weights of the inputs for each species were determined by D&A wildlife ecologists based on known habitat preferences; Little Brown Myotis typically roost in trees or buildings during the summer months, and forage over water or fields (Table 13).

Table 13. Weighted habitat inputs for Little Brown Myotis.

Species	Anthropogenic	Shallow Aquatic	Open Aquatic	Barren	Fields	Forests	Open Marsh	Wetlands	South-facing Slopes	Watercourse
Little Brown Myotis	1	0	0	0	1	5	0	0	0	1

Generated habitat suitability maps were sampled at locations of known high-accuracy species occurrence points for a generalized assessment of the model. Each point was given a score of between 1 and 4 based on its relationship with the range of suitability values in the map (<25%, <50%, <75%, 100%). Due to the nature of the sample points available some inherent bias towards certain habitat types is assumed to be present (Table 14).

Table 14. HSM accuracy assessment using wildlife points.

Species	0.25	0.5	0.75	1		0.25 (%)	0.5 (%)	0.75 (%)	1 (%)
Little Brown Myotis	0	0	182	0		0.00	0.00	100.00	0.00

Summary statistics and area calculations were derived from the habitat suitability rasters using ArcGIS Pro. Each raster represented the habitat suitability score of a given wildlife species using pixel values expressed as decimal values between zero and one, with one pixel representing a 10 x 10 metre area.

Using the Raster Calculator tool, pixel values from each raster were multiplied by ten and converted from decimal to integer, resulting in a ranking of between one and ten. To summarize this data by subwatershed, the rasters were converted to vector data using the Raster to Polygon geoprocessing tool within ArcGIS Pro. This new data layer was then combined with an MNRF data layer representing quaternary watershed boundaries for the study area using the Intersect tool. Areas were calculated geometrically for each record, and the Summary Statistics tool was used to calculate the sum area for each ranking per watershed. Further formatting was done in Microsoft Excel.

2.1.1.4.2 UNCOMMON LANDCOVER TYPES

Uncommon landcover types have been identified based on the refined landcover mapping as part of the Significant Wildlife Habitat: Rare Vegetation Communities analysis. Please refer to section 3.5.3.3 for details.

2.1.1.4.3 AREAS THAT CONTRIBUTE TO STORMWATER & SPRING RUNOFF CAPACITY

The general goal of this component of the key ecological functions analysis involved identifying areas of the watershed that have the potential to play an important role in moderating flooding peaks associated with runoff resulting for storm events and/or the spring freshet.

The role of wetlands in providing such flooding attenuation functions has long been recognized (Keddy, 2016). As summarized in the Ontario Wetland Evaluation System (OWES) manual for northern Ontario, wetlands can play a role in flood attenuation through temporary storage, infiltration, and transpiration of water (OMNR, 2014) - the relative benefits of different wetlands are discussed based on the relationship with watercourse systems. For example, isolated wetlands (wetlands that are not connected to the watercourse system) are 100% efficient at attenuating flooding. Palustrine wetlands, wetlands associated with temporary/intermittent watercourses and riverine wetlands, associated with rivers, can provide important flood attenuation functions depending on their size and location in relation to the associated drainage basin. Similarly, lacustrine wetlands associated with lakes can provide important flood attention functions if wetlands have a large storage capacity relative to the associated lake.

The OWES methodology provides an explicit scoring approach to identify the relative benefits of flood attenuation provided by isolated, palustrine, riverine, and lacustrine wetlands. Therefore, categorizing all identified wetlands within the Muskoka River watershed as one of these types was used to provide a preliminary step in identifying areas within the watershed that contribute to stormwater and spring runoff capacity (i.e., flood attenuation). The analysis focused on classification of wetland type, with the intention that the results can be used to support the hydrologic benefits of wetlands for assessments that are more site-specific.

Modeled wetlands were evaluated to define their site type as lacustrine / riverine, palustrine, or isolated.

- Lacustrine / Riverine – Wetlands adjacent to modeled open aquatic or located on 3rd order or greater watercourses. Lacustrine and Riverine wetlands have been consolidated into the same class as the transition between wetland types was difficult to define with the available data and project scale.
- Palustrine – Wetlands located on 1st or 2nd order watercourses.
- Isolated – Wetlands with no mapped in or outflow.

2.1.1.4.4 SIGNIFICANT WILDLIFE HABITAT

Significant Wildlife Habitat (SWH) was assessed using the Criteria Schedules for Ecoregion 5E (MNRF, 2015) which contains 43 habitat categories and associated criteria for identifying candidate and confirmed SWH. The criteria schedules use a combination of ELC Ecosite Codes, indicator wildlife species and other habitat criteria and anecdotal information sources to identify candidate habitat. The criteria to confirm SWH typically involve extensive field verification exercises which often require multi-year study. Due to the scale of this study and lack of detailed field inventory, SWH has largely been identified as candidate unless confirming criteria were met.

A geoprocessing framework was developed to identify candidate SWH within the Watershed based on the ELC ecosite codes, size and proximity criteria, and indicator species listed in the SWH Ecoregional Criteria for Ecoregion 5E (MNRF, 2015). Forest Resource Inventory (FRI) mapping was used to evaluate the occurrence of the 43 SWH categories. Due to the scale of this project and lack of specificity with regard to

vegetation community data and wildlife surveys, SWH was largely identified to candidate level only; in few cases it was confirmed where suitable data was available (i.e. confirmed Old Growth forest data from FRI).

Detailed assessment criteria, methodologies, and (where appropriate) FRI vegetation codes used to identify each of the SWH categories are provided in Appendix G2.

2.2 NEW DATA & VERIFICATION

2.2.1 FIELD VERIFICATION

The 2022 field program involved rapid ecological assessments of 280 Study Sites (each of which being 4 ha in size) within the Muskoka River Watershed (Figure 14). Study Sites were identified in Phase 1 using a set of criteria based on **accessibility**, **number of target features** (i.e., wetlands, watercourses and vernal pools), and **consistent coverage** throughout the Watershed and each of the subwatersheds. Study Sites were each visited once by vegetation and wildlife ecologists between April 25 and July 1, 2022.

The results from the field program have not been explicitly summarized or discussed for the purposes of this report; field data was used for model training and validation purposes incorporated into the final consolidated dataset.

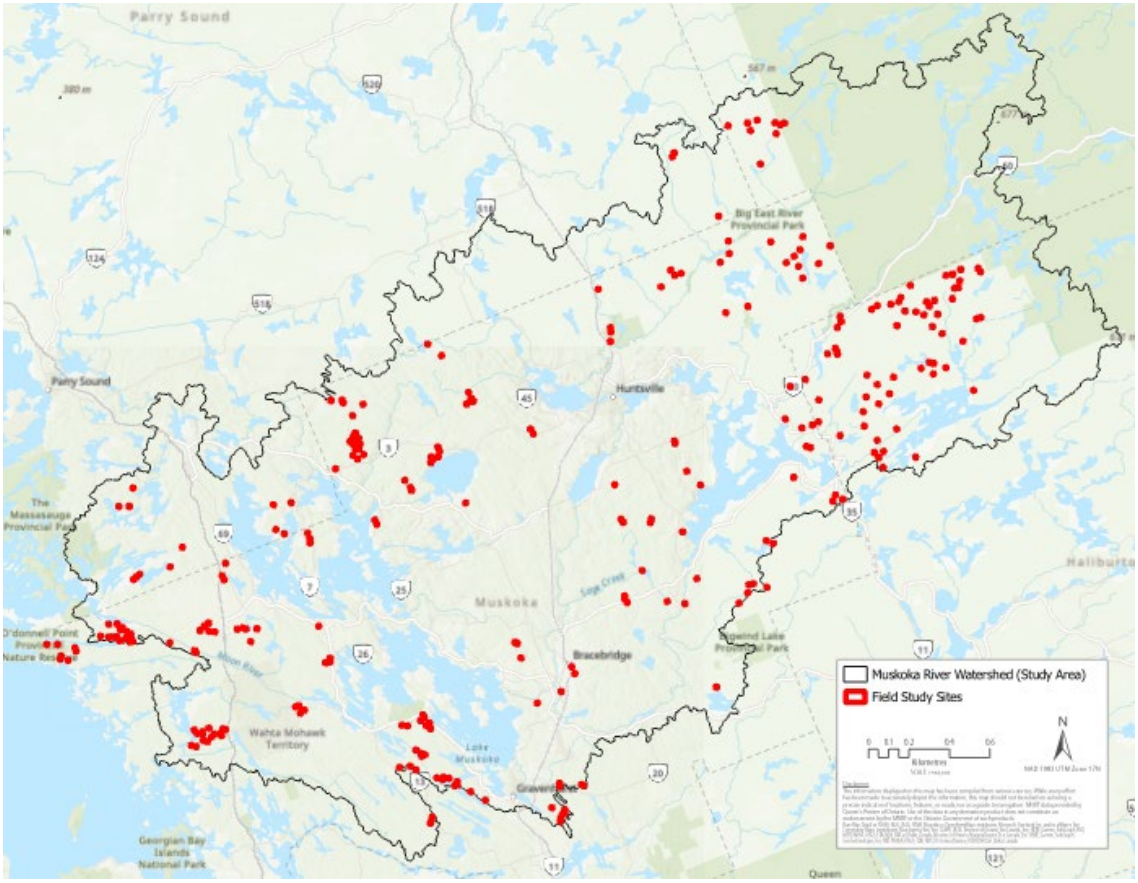


Figure 14. Study Site locations surveyed in 2022

Data was collected digitally at each Study Site using customized ESRI Survey123 forms; the data parameters collected at each site are summarized below.

2.2.1.1 REFINED LANDCOVER MAPPING

Landcover within each 4-ha Study Site was assessed using a list of vegetation community types generated from the following classification systems (Appendix A):

- Ecosites of Ontario (Banton et al., 2009);
- Great Lakes-St. Lawrence Ecosite Fact sheets (third draft) (Wester et. al, 2015);
- ELC for Southern Ontario (Lee et al., 1998); and
- Forest Ecosystem of Central Ontario Classification (FEC; Chambers, 2012).

A rapid assessment was undertaken by ecologists traversing each Study Site to confirm and delineate the landcover type(s) present. Vegetation community polygons were geolocated and delineated on field maps, attributed with unique IDs, and were ascribed the following data:

- Canopy cover (%, range);
- Dominant vascular plant species in each layer (canopy, sub-canopy, understory, and ground);
- Landcover type (open wetland, treed wetland, forest, meadow/field, thicket/successional, rock barren, or aquatic);
- ELC ecosite or vegetation community code (best-fitting code using either: FEC, Central Ontario ELC or Southern Ontario ELC); and
- Photographs.

Confirmed landcover/vegetation community data from Study Sites were then used to contribute verified data to the landcover training dataset.

2.2.1.2 WETLANDS

All wetlands encountered in the Study Sites were assessed for presence, location, extent, and type. This included wetlands previously mapped or modelled, and any additional unmapped wetlands encountered during fieldwork. Wetland polygons were geolocated and delineated on field maps, attributed with unique IDs, and assessed for landcover type. Wetlands were also assessed using the rapid ELC methods described above (2.2.1.1) to determine the best-fitting ELC code and dominant vascular plant species. The following data was recorded specifically for wetlands:

- Present/Not Present (for mapped wetlands);
- Wetland Type – Bog, Fen, Marsh, Swamp; and
- Photographs.

Confirmed wetlands within the Study Sites were used to contribute verified data to the landcover, wetlands, and stormwater/spring runoff capacity training datasets. It should be noted that while bogs and fens were

split into separate community types during field verification, GIS modelling did not have the required accuracy to split these communities. Therefore, the final dataset includes bogs and fens as a single class.

2.2.1.3 VERNAL POOLS

All vernal pools encountered within the Study Sites, including those previously mapped or modelled, and any additional unmapped vernal pools were verified for presence, location and extent. Vernal pools were geolocated and delineated on field maps, attributed with unique IDs, and assessed for other key attributes to indicate habitat function. The following data was collected for vernal pools within the Study Sites:

- Present/Not Present (for mapped vernal pools);
- GPS location;
- Photo(s);
- Presence of:
    - Moss on the forest floor or on tree root flares;
    - Emergent vegetation;
    - Wood debris;
- Maximum water depth:
    - 1-24 cm;
    - 25-50 cm;
    - 51-75cm;
    - 76-100cm;
    - >100cm.

The data collected on vernal pools was used to contribute verified data to vernal pool training models, potential for habitat suitability and potential to aid in stormwater and spring runoff capacity.

2.2.1.4 WATERCOURSES (1st and 2nd ORDER STREAMS)

Confluence points of 1st and 2nd order streams mapped by the Ontario Integrated Hydrology (OIH) identified during Phase 1 were targeted for field verification where they intersected with Study Sites. Field efforts confirmed if mapped confluence points were present, their location, and other key attributes that are predictive of stream permanency. Specific data recorded at 1st and 2nd order stream confluence points within Study Sites included the following based on parameters outlined in the Stream Permanency Handbook for South-central Ontario (MNR, 2005):

- Present/Not Present (for mapped confluences);
- GPS location of 1st/2nd order confluence points;
- Photo(s);
- Bank stability (eroding or stable);
- Channel Type (defined or ill-defined);
- Presence of in-stream terrestrial vegetation or root mats;
- Presence of standing water;

- Presence of fish;
- Water depth (cm);
- Channel width (cm); and
- Stream width (cm).

Data collected in the field were used to improve the accuracy of 1st and 2nd order streams/confluences, predict permanency, and potential to aid in stormwater and spring runoff capacity.

2.2.1.5 KEY ECOLOGICAL FUNCTIONS

2.2.1.5.1 RARE SPECIES OCCURENCES

At each Study Site, incidental plant and wildlife records were documented digitally with specific attention to any rare or significant species. Attributes collected included species name, location and relative abundance. Following field data collection, species lists were attributed with provincial and federal statuses and habitat details. For plant and wildlife species, this information included:

- Federal *Species at Risk Act* (SARA Schedule A) status (NHIC, 2021a,b);
- Provincial *Endangered Species Act* (ESA) status (NHIC, 2021a,b);
- Provincial S-rank (NHIC, 2021b); and
- SWH Indicator Species (MNRF, 2015).

Additional attributes documented for wildlife species included:

- Area Sensitivity (OMNR, 2000); and
- Habitat Category (OBBA, 2007).

The above data was used to contribute to SWH models and habitat suitability models.

2.2.1.5.2 UNCOMMON LANDCOVER TYPES

Uncommon landcover types have been identified based on the refined landcover mapping as part of the Significant Wildlife Habitat: Rare Vegetation Communities analysis. Please refer to section 3.5.3.3 for details.

2.2.1.5.3 AREAS THAT CONTRIBUTE TO STORMWATER & SPRING RUNOFF CAPACITY

Areas that contribute to stormwater and spring runoff capacity were identified based on a combined analysis of the field data collected on wetlands, vernal pools, watercourses and landcover.

2.2.1.5.4 SIGNIFICANT WILDLIFE HABITAT

Field-verified vegetation communities combined with confirmed species records at each Study Site were used to evaluate the occurrence of candidate Significant Wildlife Habitat (SWH) based on the criteria listed in the SWH Criteria Schedules for Ecoregion 5E (MNRF, 2015). For details on the criteria used in this analysis, please refer to Appendix G2.

3. RESULTS

The sections below provide a summary of results for each of the target ecological features and functions including:

- Landcover;
- Wetlands;
- Watercourses (1st and 2nd order streams);
- Vernal Pools;
- Key Ecological Functions:
    - Rare species occurrences;
    - Uncommon landcover types;
    - Areas that contribute to stormwater and spring runoff capacity; and
    - Significant Wildlife Habitat.

Where relevant and applicable, each section includes a framework outlining a summary of key results based on the compiled dataset; the accuracy of the modeled data based on a comparison with field-verified data; and a comparison of the background data vs. modeling data results. For data summaries that include breakdown by the 14 quaternary watersheds within the Muskoka River Watershed, please note that the terms 'subwatershed' and 'quaternary watershed' are used interchangeably.

3.1 REFINED LANDCOVER MAPPING

Land cover across the watershed was represented by eight broad types: aquatic, forest, wetland, shrub, barren, meadow, agriculture, and anthropogenic (Figure 15). Based on the combination of modeled land classification and FRI data, natural and aquatic class types cover approximately 96% of the watershed, with anthropogenic and agricultural classes being approximately 4%. Forest was the highest class covering approximately 63% of the landscape, followed by wetlands (18%), aquatic (15%), agriculture and anthropogenic (4%), and shrub, barren, and meadow (<1%).

A detailed breakdown of land cover class among subwatersheds is presented in Appendix A-2. Among subwatersheds, forest cover ranged between 47% and 77%. The highest forest cover occurring in Distress Pond-Big East River (77%), Hollow River (73%), and Oxtongue River Outlet (73%); the lowest forest cover occurring in Lake Muskoka-Muskoka River (47%) and Lake Rosseau (55%). The remaining subwatersheds having forest cover ranging between 60%-70%. Wetland cover ranged between 11% and 26%. The highest wetland cover occurred in Lake Vernon (26%), Moon River (23%), and Musquash River (23%); the lowest wetland cover occurring in Hollow River (11%), Baysville Narrows-South Branch Muskoka River (13%), Tea Lake-Oxtongue River (14%), Distress Pond (15%), and Lake Muskoka-Muskoka River (15%). The remaining subwatersheds ranged between 16% to 22%. Aquatic cover ranged between 7% and 28%. The highest aquatic cover occurred in Lake Muskoka-Muskoka River (28%), Little East River-Big East River (23%), Tea Lake-Oxtongue River (23%); the lowest aquatic cover occurred in Hollow River (7%), Lake Rosseau (8%),

Lake Vernon (9%), Musquash River (9%), North Branch Muskoka River (9%), and Blackstone Harbour. The remaining subwatersheds ranged between 13% and 18% aquatic cover.

A more detailed breakdown of the consolidated forest cover class is provided in Appendix A-4. This includes 75 forest types that were identified based on either the FRI data set or through the deep learning model classification. The information is not presented here, however the data was used to further identify forest type into coniferous, deciduous, and mixed forest classes; in turn, these were used as part of the consolidated land cover data set, habitat modeling, and Significant Wildlife Habitat interpretation.

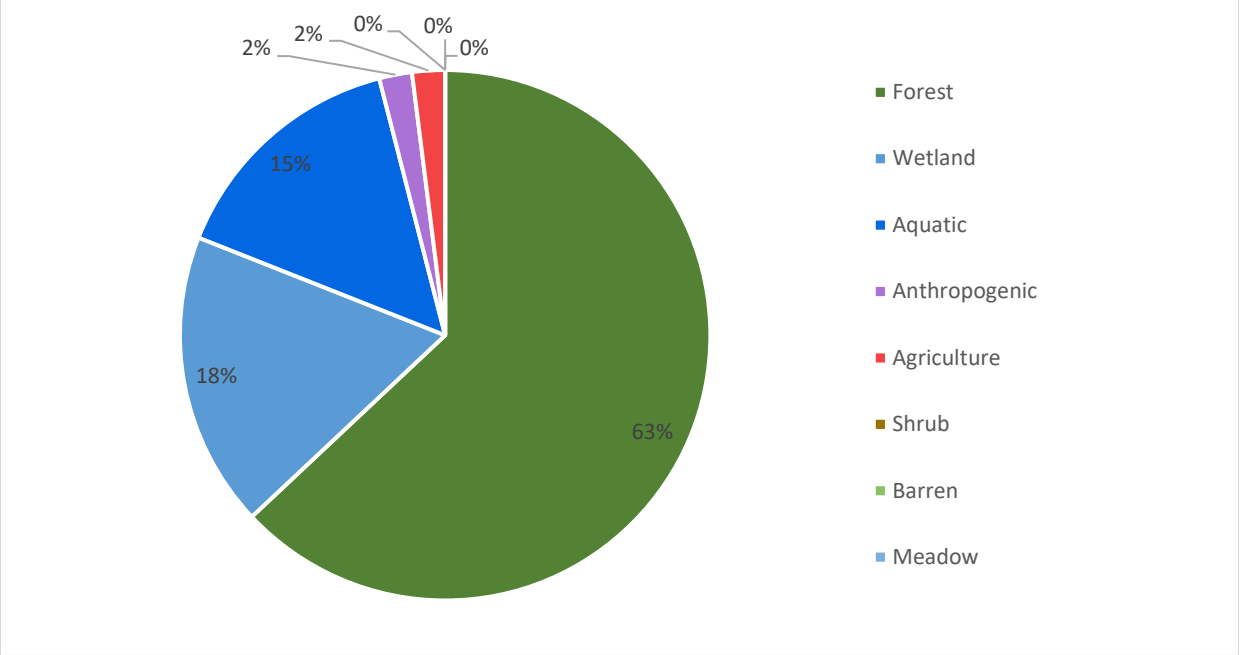


Figure 15. Muskoka River Watershed land cover

3.2 WETLANDS

Wetlands within the Watershed comprise over 94,000 ha, with the Lake Rosseau and Lake Vernon subwatersheds containing the largest wetland areas: approximately 12,600 ha (13%) and 9,700 ha (10%) of the Watershed's wetland coverage, respectively.

A total of six wetland classes were identified within the Watershed, predominantly comprised of Coniferous Swamp (36%) and Open Marsh (29%). The least represented wetland types were Deciduous Swamp (5%) and Bog / Fen (7%) (Figure 16).

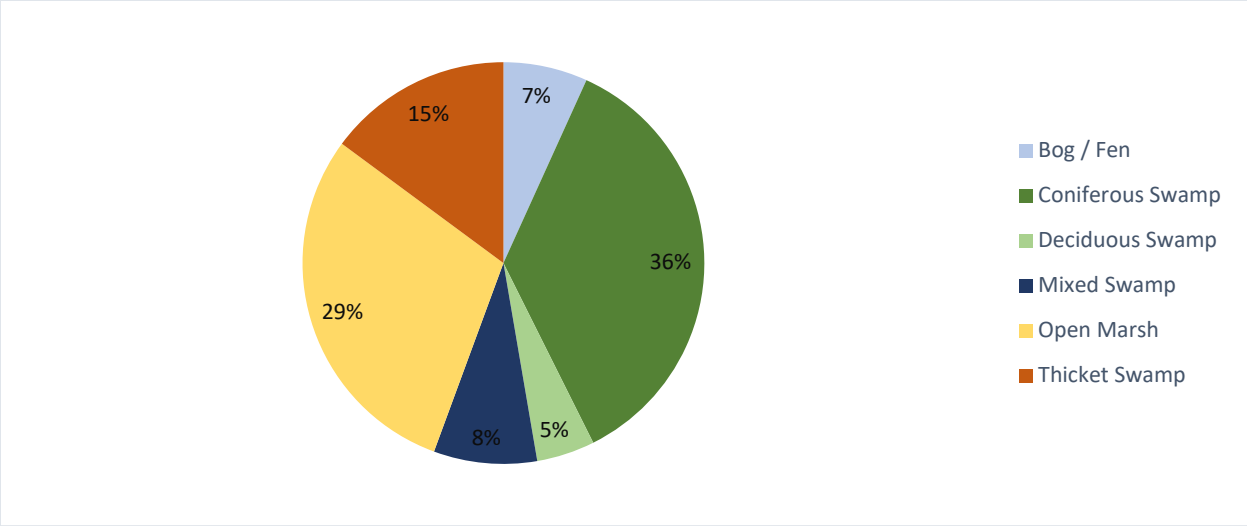


Figure 16. Modeled wetland classes within the Muskoka River Watershed

The wetland classes derived for this study differed slightly from the existing class types used by the District of Muskoka. The following provides a summary of the District classes related to the classes used for this study:

- Brush Alder = Swamp Thicket
- Fen/Bog = Fen/Bog
- Marsh = Open Marsh
- Open Water Marsh = Open Marsh
- Swamp = Coniferous Swamp, Deciduous Swamp, Mixed Swamp

A detailed breakdown of wetland class among subwatersheds is presented in Appendix B-2. The six wetland classes are represented in all of the 14 subwatersheds; coverage within subwatersheds ranged from 2,600 ha to 12,600 ha. Wetland cover is highest in Lake Rosseau (12,600 ha) and Lake Vernon (9,700 ha) while the lowest cover occurs in Blackstone Harbour (2,800 ha) and Hollow River (4,600 ha) (Table 15).

Table 15. Wetland classes and coverage (ha) by subwatershed.

Quaternary Watershed	Bog / Fen	Coniferous Swamp	Deciduous Swamp	Mixed Swamp	Open Marsh	Thicket Swamp	Grand Total
Baysville Narrows - South Branch Muskoka River	328.4	1754.0	295.9	403.5	1591.3	632.8	5006.0
Blackstone Harbour	189.5	681.7	148.2	190.1	1063.9	529.0	2802.4
Distress Pond - Big East River	220.9	2414.3	438.1	475.5	2241.6	1059.7	6850.1
Hollow River	104.2	1208.8	632.3	485.7	1679.1	518.8	4628.9
Lake Muskoka - Muskoka River	620.3	2187.2	270.5	802.4	2180.3	1526.3	7587.0
Lake Rosseau	1122.5	3918.4	656.2	880.1	4168.3	1836.2	12581.7
Lake Vernon	706.1	5009.2	222.3	685.6	2087.7	997.8	9708.7
Little East River - Big East River	289.4	2349.6	207.7	301.5	1421.8	536.9	5106.9
Moon River Bay	642.4	1269.8	85.7	263.9	2178.7	970.1	5410.5
Musquash River	562.1	2047.7	152.5	722.1	1816.2	1957.9	7258.4
North Branch Muskoka River	661.2	4174.9	350.1	787.3	2498.5	1065.8	9537.8
Oxtongue River Outlet	269.9	2015.8	213.1	265.1	1656.8	719.3	5139.9
South Branch Muskoka River Outlet	481.9	3037.7	420.6	1080.8	1751.9	985.1	7758.0
Tea Lake - Oxtongue River	194.9	1719.7	322.3	494.5	1484.2	687.0	4902.5
Grand Total	6393.8	33788.6	4415.5	7838.1	27820.4	14022.7	94279.0

When comparing the newly modeled wetland layer to the original background data (i.e. FRI, MNRF, and District), over 49,000 ha of wetlands were added based on the work conducted as part of this study. Within each subwatershed, additional wetland areas ranged from 1,789 ha (Blackstone Harbour) to 6,380 ha (Lake Rosseau) (Table 16).

Table 16. Comparison of original and modeled wetland data by quaternary watershed.

Quaternary Watershed Name	Modeled Wetlands (ha)	Original Wetlands (FRI, MNR, District) (ha)	Wetlands Added (ha)	Wetlands Removed (ha)	Wetlands Remained the Same (ha)
Baysville Narrows - South Branch Muskoka River	5006.0	3235.3	2631.0	860.3	2375.0
Blackstone Harbour	2802.4	1629.4	1623.8	450.7	1178.7
Distress Pond - Big East River	6850.1	3152.9	4374.5	677.3	2475.6
Hollow River	4628.9	2135.8	2861.4	368.3	1767.5
Lake Muskoka - Muskoka River	7587.0	5409.9	3653.7	1476.6	3933.3
Lake Rosseau	12581.7	7979.9	6702.1	2100.2	5879.7
Lake Vernon	9708.7	6893.9	4082.0	1267.2	5626.7
Little East River - Big East River	5106.9	3399.9	2493.6	786.6	2613.3
Moon River Bay	5410.5	4479.8	2400.6	1469.8	3010.0
Musquash River	7258.4	5732.6	3404.7	1878.9	3853.7
North Branch Muskoka River	9537.8	5474.2	5332.9	1269.2	4205.0
Oxtongue River Outlet	5139.9	2746.8	2998.4	605.3	2141.5
South Branch Muskoka River Outlet	7758.0	5349.5	3682.1	1273.6	4075.9
Tea Lake - Oxtongue River	4902.5	2091.9	3153.8	343.2	1748.8
Grand Total	94279.0	59711.6	49394.4	14827.0	44884.6

Figure 17 provides a visual comparison of the original wetland layer (FRI, MNR, and District) versus the newly modeled wetlands.

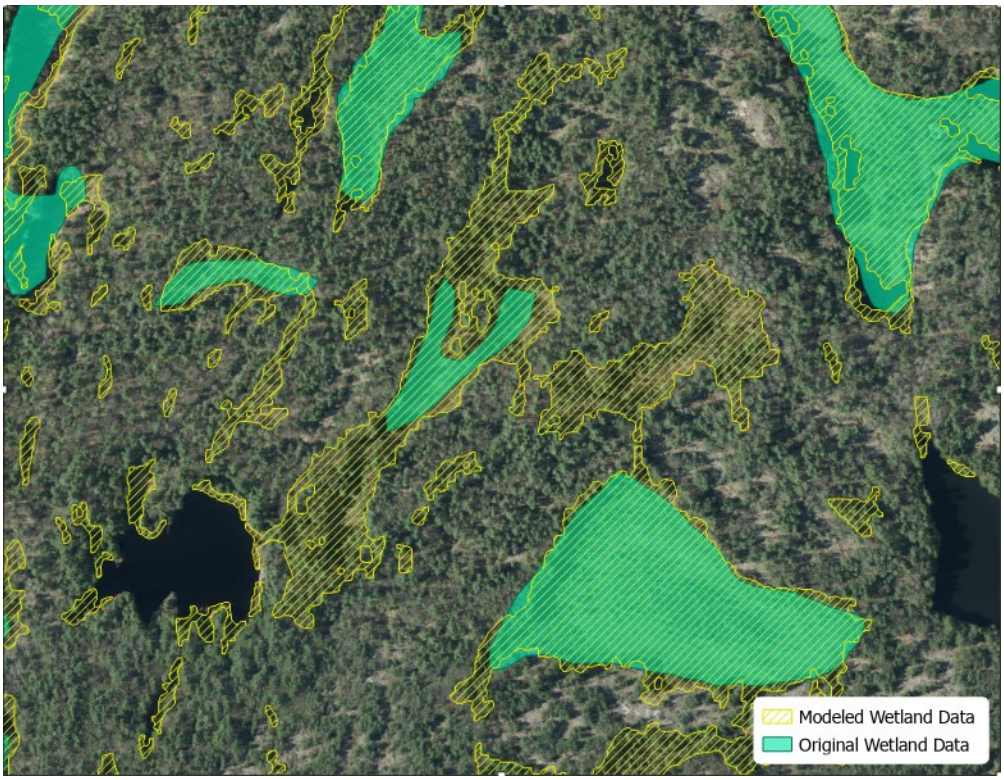


Figure 17. Visual comparison of original and modeled wetlands.

Please refer to Appendix B for detailed wetland data and mapping.

3.3 VERNAL POOLS

In total, over 439,000 vernal pools were modeled within the Watershed, comprising approximately 14,886 ha of land. The Lake Rosseau quaternary watershed contains the highest number (59,981) and largest area of vernal pools (2,124 ha, 14%) across the Watershed. Appendix C contains detailed vernal pool mapping (Table 17).

As the updated mapping of vernal pools was based on the high-resolution LiDAR data set, the analysis was completed after undertaking fieldwork. This precluded the ability to determine the accuracy of how well the model predicted the occurrence of vernal pool features. However, based on the vernal pool features that were confirmed during the field investigations, the model only predicted 53% of the features that were detected. When the model predictions from the stochastic depression analysis was combined with wetland prediction from the deep learning model however, 87% of the observed vernal pools was predicted. This indicates a combination of reviewing the stochastic depression analysis predictions and the wetland features prediction should be used when screening for the presence of vernal pools.

Table 17. Summary of vernal pools by quaternary watershed

Quaternary Watershed Name	No. Vernal Pools	Area (ha)	Percent area of mapped vernal pools (%)
Baysville Narrows - South Branch Muskoka River	25418	853.2	6%
Blackstone Harbour	14125	518.4	3%
Distress Pond - Big East River	33946	1033.1	7%
Hollow River	31829	1009.4	7%
Lake Muskoka - Muskoka River	36295	1218.2	8%
Lake Rosseau	59981	2124.7	14%
Lake Vernon	32712	1020.0	7%
Little East River - Big East River	23667	790.7	5%
Moon River Bay	21722	815.8	5%
Musquash River	37525	1420.9	10%
North Branch Muskoka River	42937	1418.6	10%
Oxtongue River Outlet	23838	767.1	5%
South Branch Muskoka River Outlet	31870	1138.8	8%
Tea Lake - Oxtongue River	24059	757.3	5%
Grand Total	439924	14886.2	100%

3.4 WATERCOURSES (1ST AND 2ND ORDER STREAMS)

In comparing the modeled watercourses and the existing Ontario Integrated Hydrology (OIH) data, modeling identified approximately 19,300 km of watercourse within the Watershed, compared to the OIH data which identified only 9,800 km; a difference of over 9,400 km (Table 18).

In terms of the aggregate total of the length of all identified watercourses in each subwatershed, Lake Rosseau and North Branch Muskoka River contain the longest total length of watercourses (2,625 km and 1,777 km respectively). Blackstone Harbour and Moon River Bay contain the least (550 km and 940 km respectively). The difference between OIH and modeled watercourse lengths ranges from 256 km (Blackstone Harbour) to 1237 km (Lake Rosseau) among subwatersheds, The remaining subwatersheds ranged from 445 km to 905 km of added watercourses. Refer to Appendix D for watercourse mapping.

Table 18. Comparison of OIH (original) and modeled watercourse lengths by quaternary watershed

Quaternary Watershed Name	Modeled Watercourses (km)	OIH Watercourses (km)	Difference (km)
Baysville Narrows - South Branch Muskoka River	1235.55	611.82	623.73
Blackstone Harbour	546.36	290.54	255.82
Distress Pond - Big East River	1700.22	979.13	721.09
Hollow River	1455.3	723.76	731.54
Lake Muskoka - Muskoka River	1624.04	794.97	829.07
Lake Rosseau	2625.15	1388.13	1237.02
Lake Vernon	1414.31	547.03	867.28
Little East River - Big East River	987.91	447.99	539.92
Moon River Bay	941.85	496.53	445.32
Musquash River	1237.58	777.64	459.94
North Branch Muskoka River	1776.85	978.35	798.5
Oxtongue River Outlet	1032.84	535.14	497.7
South Branch Muskoka River Outlet	1449.49	545.1	904.39
Tea Lake - Oxtongue River	1257.78	686.21	571.57
Grand Total	19285.23	9802.34	9482.89

3.5 KEY ECOLOGICAL FUNCTIONS

3.5.1 RARE SPECIES OCCURRENCES

A summary of the consolidated rare species occurrences gathered through the background and field investigations is provided below, including Species at Risk and Provincially Rare species (S1-S3). In addition, the results of the habitat modeling using the MaxEnt approach for targeted species is showcased in section 3.5.1.2. Appendix E contains further rare species and habitat suitability mapping and details.

3.5.1.1 SUMMARY OF KEY RESULTS

In total, 185 rare species representing 12 taxonomic groups were included in the various records that were compiled for the Watershed. As outlined in the methods section, species were considered 'rare' if there are identified as:

- Endangered, Threatened, or Special Concern Species at Risk (provincially per COSSARO and/or federally per SARA Schedule 1)
- S1, S2, or S3 based on Provincial rarity status

As indicated in Table 19 below, records for birds, vascular plants, invertebrates and reptiles had the highest representation of rare species. See Appendix E-2 for a detailed list of rare species.

Table 19. Rare species count by species group within the Watershed.

Species Group	Rare Species Count
BIRDS	57
VASCULAR PLANTS	56
INVERTEBRATES	34
REPTILES	18
BRYOPHYTES	8
MAMMALS	7
FISH	5
Grand Total	185

In total, over 40,000 rare species occurrences were identified in the Watershed, with the highest number of observations (12,846, 31%) occurring in the Lake Muskoka-Muskoka River subwatershed (Table 20).

Table 20. Rare species occurrences by subwatershed and species group.

Quaternary Watershed	Birds	Bryophytes	Fishes	Invertebrates	Mammals	Reptiles	Vascular Plants	Grand Total
Baysville Narrows - South Branch Muskoka River	913			66	2	148	37	1129
Blackstone Harbour	344		2	20	3	218	5	587
Distress Pond - Big East River	147	2		2	13	57	9	221
Hollow River	349	2		26	4	37	10	418
Lake Muskoka - Muskoka River	8952	2	5	226	138	3523	721	12846
Lake Rosseau	1701		2	72	9	1803	85	3587
Lake Vernon	617	2		44		67	52	730
Little East River - Big East River	1282			74	3	63	24	1422
Moon River Bay	95		7	7	176	5267	105	5552
Musquash River	344		4	20	136	2332	611	2836
North Branch Muskoka River	2091	4		227	1	227	24	2550
Oxtongue River Outlet	1854	2		168	14	122	31	2160
South Branch Muskoka River Outlet	1326			42		308	22	1676
Tea Lake - Oxtongue River	4785			80	52	334	532	5251
Grand Total	24800	14	20	1074	551	14506	2308	40965

3.5.1.2 HABITAT MODELING (MaxEnt)

For the purposes of this analysis, the following ranges of likelihood values were used to determine relative habitat suitability for each of the species modeled:

- 0: No suitable habitat
- 1-3: Low habitat suitability
- 4-6: Moderate habitat suitability

- 7-9: High habitat suitability

Within the Watershed, high habitat suitability was greatest for Little Brown Myotis (over 462,000 ha) followed by Wood Thrush (~127,600 ha) and Monarch (~99,700 ha) (Table 21).

Table 21. Highly suitable habitat (ha) within the Watershed by species.

Species	Highly suitable habitat (ha) within the Watershed
Little Brown Myotis*	462226.11
Wood Thrush	127602.33
Monarch	99675.68
Blanding's Turtle	55224.02
Ribbonsnake	27605.5
Eastern Hog-nosed Snake	26290.95
Massassauga	25061.8
Skink	20091.82
Spotted Turtle	13413.52

**Modeled using habitat suitability model instead of MaxEnt approach.*

A summary of habitat suitability determined through the MaxEnt approach for each species by subwatershed is provided below (Table 22).

Wood Thrush

Habitat for Wood Thrush exists in all 14 subwatersheds. Twelve of the subwatersheds (excluding Tea Lake-Oxtongue River and Hollow River) contain high habitat suitability (likelihood value of 7-9). Highly suitable habitat comprises approximately 127,600 ha within the Watershed. Of the highly suitable habitat identified, the Lake Rosseau and Lake Muskoka-Muskoka River subwatersheds contain the largest areas with approximately 29,300 ha (23%) and 23,700 ha (19%) respectively.

Spotted Turtle

Habitat for Spotted Turtle exists in 12 of the 14 subwatersheds (excluding Hollow River and Tea Lake-Oxtongue Lake). Highly suitable habitat is present in 11 of the watersheds, comprising approximately 13,400 ha. Of the highly suitable habitat identified, Moon River Bay and Lake Rosseau contain the largest areas, comprising approximately 3,600 ha (27%) and 3,000 ha (22%) respectively.

Table 22. Total area (ha) of highly suitable habitat (likelihood value 7-9) by species and subwatershed.

Quaternary Watershed	Area (ha) of highly suitable habitat by species								
	Wood Thrush	Spotted Turtle	Common Five-Lined Skink	Eastern Ribbonsnake	Monarch	Massassauga	Eastern Hog-nosed Snake	Blanding's Turtle	Little Brown Myotis*
Baysville Narrows - South Branch Muskoka River	4991	707	0	0	6638	0	1239	2938	30405
Blackstone Harbour	6695	1571	2707	3043	5441	3401	1706	2127	14874
Distress Pond - Big East River	1157	0	0	0	1117	0	1014	3945	44042
Hollow River	0	0	0	0	188	0	1008	4542	35412
Lake Muskoka - Muskoka River	23660	2244	2222	4611	17026	2619	2676	4559	36982
Lake Rosseau	29259	2953	3363	5914	23072	4499	4166	6649	61265
Lake Vernon	17019	0	0	0	8885	0	1767	2831	32445
Little East River - Big East River	10482	3568	0	0	5966	0	1688	2943	24864
Moon River Bay	2674	1573	8357	7745	4338	10434	3231	3851	21446
Musquash River	5299	0	2108	4129	7718	4109	1208	2586	28962
North Branch Muskoka River	19121	0	0	0	11254	0	1117	4665	43045
Oxtongue River Outlet	1386	798	0	0	1673	0	1528	4530	25203
South Branch	5857	0	1334	2163	6358	0	1188	2797	32956

Area (ha) of highly suitable habitat by species									
Quaternary Watershed	Wood Thrush	Spotted Turtle	Common Five-Lined Skink	Eastern Ribbonsnake	Monarch	Massassauga	Eastern Hog-nosed Snake	Blanding's Turtle	Little Brown Myotis*
Muskoka River Outlet									
Tea Lake - Oxtongue River	0	0	0	0	0	0	2756	6262	30326
Grand Total	127602	13414	20092	27606	99676	25062	26291	55224	462226

**Modeled using HSM, not MaxEnt.*

Common Five-Lined Skink

Habitat for Common Five-Lined Skink is present in nine of the 14 subwatersheds. Throughout the Watershed, highly suitable habitat is present in eight subwatersheds, comprising approximately 20,000 ha. Of the highly suitable habitat identified, Moon River Bay and Lake Rosseau contain the largest areas, comprising approximately 8,400 ha (42%) and 3,400 ha (17%) respectively.

Eastern Ribbonsnake

Habitat for Eastern Ribbonsnake is present in nine of the 14 subwatersheds. Throughout the Watershed, highly suitable habitat comprises approximately 28,000 ha within nine subwatersheds. Of the highly suitable habitat identified, Moon River Bay and Lake Rosseau contain the largest areas, comprising approximately 7,700 ha (28%) and 5,900 ha (21%) respectively.

Monarch

Habitat for Monarch is present in all 14 subwatersheds. Highly suitable habitat is present in 13 subwatersheds and comprises approximately 99,700 ha. Of the highly suitable habitat identified, Lake Rosseau and Lake Muskoka-Muskoka River contain the largest areas, comprising approximately 23,000 ha (23%) and 17,000 ha (17%) respectively.

Massassauga

Habitat for Massassauga was identified in eight of the 14 subwatersheds; highly suitable habitat was identified in all eight of these subwatersheds, comprising approximately 25,000 ha. Of the highly suitable habitat identified, Moon River Bay and Lake Rosseau contain the largest areas, comprising approximately 10,400 ha (42%) and 4,500 ha (18%) respectively.

Eastern Hog-nosed Snake

Habitat for Eastern Hog-nosed Snake was identified in all 14 subwatersheds, each of which contain highly suitable habitat which comprise approximately 55,200 ha. Of the highly suitable habitat identified, Lake Rosseau and Tea Lake-Oxtongue River contain the largest areas, comprising approximately 4,200 ha (16%) and 3,200 ha (12%) respectively.

Blanding's Turtle

Habitat for Blanding's Turtle is present in all 14 subwatersheds, each of which contain highly suitable habitat comprising approximately 55,200 ha. Of the highly suitable habitat identified, Lake Rosseau and Tea Lake-Oxtongue River contain the largest areas, comprising approximately 6,600 ha (12%) and 6,300 ha (11%) respectively.

Little Brown Myotis*

Habitat for Little Brown Myotis was identified in all 14 subwatersheds, each containing highly suitable habitat which comprises a total area of approximately 462,200 ha. Of the highly suitable habitat identified, Lake Rosseau and Distress Pond-Big East River contain the largest areas, comprising approximately 61,300 ha (13%) and 44,000 ha (10%) respectively.

**Modeled using habitat suitability model instead of MaxEnt.*

3.5.2 AREAS THAT CONTRIBUTE TO STORMWATER AND SPRING RUNOFF CAPACITY

Areas that contribute to stormwater and spring runoff capacity were defined as flood attenuating wetlands identified as isolated, palustrine and lacustrine / riverine as defined by OWES (OMNR, 2014). Lacustrine and riverine wetlands have been grouped together due to similar form and function. Across the Watershed, lacustrine / riverine wetlands were the most dominant type, comprising 66% (61,830 ha) of the wetlands identified. Palustrine wetlands comprise 22% (20,691 ha) and isolated wetlands comprise 12% (11,750 ha).

At the subwatershed level, the percent area of flood attenuating wetlands varies from 3% (Blackstone Harbour) to 13% (Lake Rosseau) of the total area of flood attenuating wetlands within the Watershed (Figure 18).

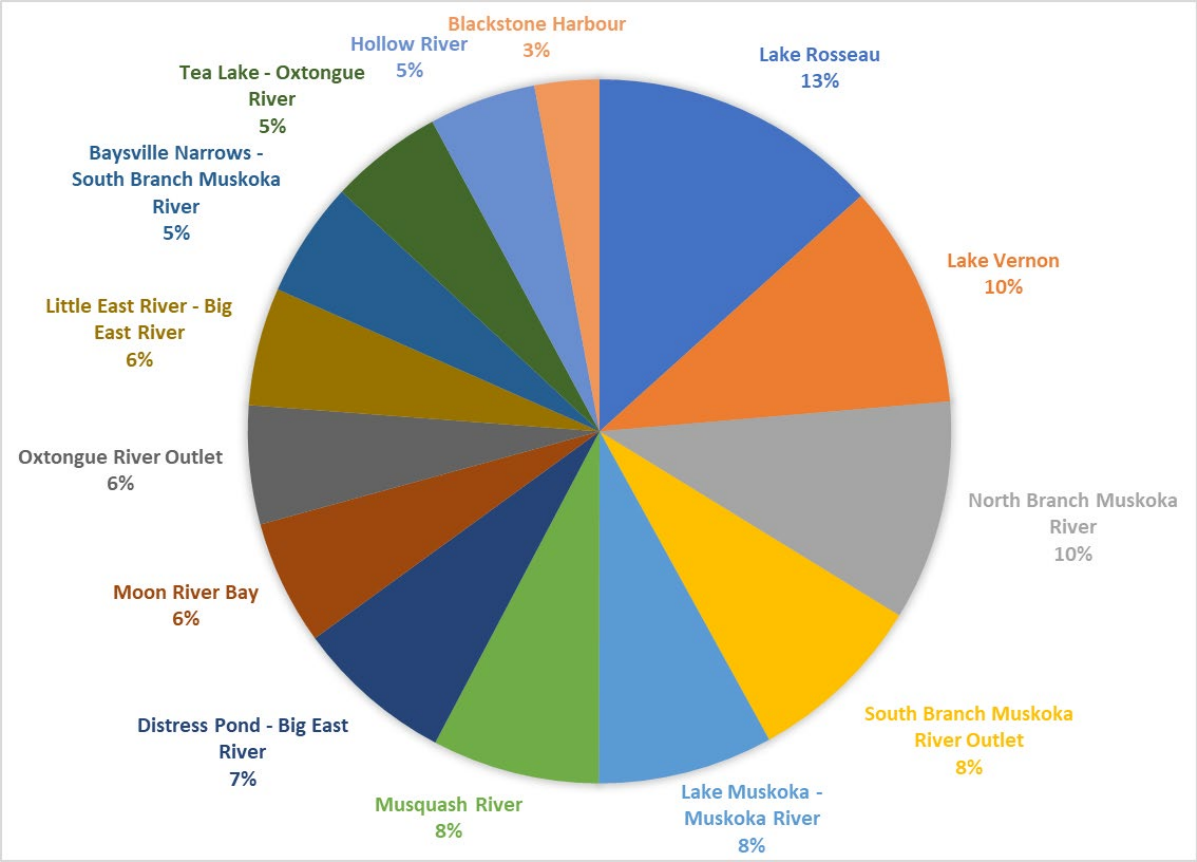


Figure 18. Total percent area contributing to stormwater and spring runoff capacity by subwatershed based on modeling.

The Lake Rosseau, Lake Vernon and North Branch Muskoka River quaternary watersheds contain the most flood attenuating wetland area, ranging from 9,500 ha (North Branch Muskoka River) to 12,600 ha (Lake Vernon); Blackstone Harbour and Hollow River contain the least (2,800 ha and 4,600 ha respectively). The remaining subwatersheds range from 4,900 ha to 7,800 ha (Table 23).

Table 23. Flood attenuating wetland summary by quaternary watershed.

Quaternary watershed	Isolated Wetlands		Palustrine Wetlands		Lacustrine / Riverine Wetlands		Total	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Baysville Narrows - South Branch Muskoka River	628.4	13	1177.3	24	3200.3	64	5006	5%
Blackstone Harbour	513.4	18	529.8	19	1759.2	63	2802.4	3%

Quaternary watershed	Isolated Wetlands		Palustrine Wetlands		Lacustrine / Riverine Wetlands		Total	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Distress Pond - Big East River	708.7	10	1310.3	19	4831	71	6850	7%
Hollow River	657.4	14	1249.9	27	2721.7	58	4629	5%
Lake Muskoka - Muskoka River	982.4	13	1602.1	21	5002.5	66	7587	8%
Lake Rosseau	1781.3	14	3401.7	27	7398.7	59	12581.7	13%
Lake Vernon	628.9	6	1418.9	15	7660.9	79	9708.7	10%
Little East River - Big East River	576.7	11	1141.4	22	3388.8	66	5106.9	5%
Moon River Bay	712.4	13	919.1	17	3778.9	69	5410.4	6%
Musquash River	1334.8	18	1563.1	22	4360.5	61	7258.4	8%
North Branch Muskoka River	1212.9	13	2475.4	26	5849.5	61	9537.8	10%
Oxtongue River Outlet	538.8	10	886.1	17	3714.9	73	5139.8	5%
South Branch Muskoka River Outlet	899.2	12	2229.8	29	4629	60	7758	8%
Tea Lake - Oxtongue River	574.5	12	793.1	16	3535	72	4902.6	5%
Grand Total	11749.8	12	20698.2	22	61831.1	66	94279.1	100%

In terms of wetland type, Lake Rosseau and Musquash River contain the largest area of isolated wetland (1,800 and 1,300 ha respectively); Blackstone Harbour and Oxtongue River Outlet contain the least (513 and 540 ha respectively). Lake Vernon and Lake Rosseau contain the largest area of lacustrine / riverine wetland (7,700 ha and 7,400 ha respectively); Blackstone Harbour and Hollow River contain the least (1,800 ha and 2,700 ha respectively). Lake Rosseau and North Branch Muskoka River contain the largest area of palustrine wetland (2,400 ha and 2,500 ha respectively); Blackstone Harbour and Tea Lake – Oxtongue River contain the least (539 ha and 800 ha respectively).

Please refer to Appendix F for mapping of flood attenuating wetlands.

3.5.3 SIGNIFICANT WILDLIFE HABITAT

A summary of the Significant Wildlife Habitat (SWH) types using Ecoregion 5E criteria schedules are presented in Appendix G. For each type, details regarding the criteria, methods, vegetation codes, FRI data, and/or other specific considerations are included in Appendix G-2. In total, this included mapping for 36 SWH types across the Muskoka River Watershed; six SWH types were not mapped including:

- Rare vegetation communities:
  - Tallgrass Prairie;
  - Savannah; and
  - Alvar.
- Animal Movement Corridors:
  - Amphibian Movement Corridors;
  - Cervid movement corridors; and
  - Furbearer movement corridors.

Tallgrass Prairie, Savannah, and Alvar communities were not mapped in the FRI dataset, likely because they do not exist within the Watershed. Animal movement corridors were not mapped because these categories require confirmation of various other types of SWH (e.g. Amphibian breeding habitat) in order to be considered as candidate; confirmation of SWH was not completed for this project due to extensive and targeted field investigation requirements.

As outlined in the methods section, where SWH types are mapped, they are considered candidate (not confirmed) given the broad scale nature of the evaluation. The distribution of SWH types that were mapped can be viewed on Maps 6-1 through 6-37, Appendix G-1. A general summary of the number of SWH units and the associated area coverage is provided in the following subsections for each SWH category.

Throughout the Muskoka River Watershed, a total of 170,483 candidate SWH polygons were identified, comprising approximately 3,782,600 ha. Overall, Lake Rosseau and Distress Pond-Big East River contain the highest frequency of occurrence, and largest areas of candidate SWH (Table 24).

Table 24. Consolidated candidate SWH summary by subwatershed.

Quaternary Watershed	Number of Polygons -FRI	Area (ha)-FRI	Number of Polygons-MNRF	Area (ha)- MNRF	Total Number of Polygons	Total area (ha)
Baysville Narrows - South Branch Muskoka River	8197	248819.3	74	13579.3	8271	262398.6

Quaternary Watershed	Number of Polygons -FRI	Area (ha)-FRI	Number of Polygons-MNRF	Area (ha)- MNRF	Total Number of Polygons	Total area (ha)
Blackstone Harbour	7817	121648.9	105	6023.3	7922	127672.2
Distress Pond - Big East River	14843	378117.1	176	2459.6	15019	380576.7
Hollow River	9043	304937.2	174	2063.3	9217	307000.6
Lake Muskoka - Muskoka River	13986	269381.2	137	8105.5	14123	277486.7
Lake Rosseau	25567	489045.1	192	8552.9	25759	497598.1
Lake Vernon	12473	258105.6	30	5196.1	12503	263301.8
Little East River - Big East River	8969	190098.2	31	3571.3	9000	193669.4
Moon River Bay	12294	171136.8	115	3171.0	12409	174307.8
Musquash River	11763	227118.2	77	7251.6	11840	234369.8
North Branch Muskoka River	14067	309307.0	36	7581.3	14103	316888.3
Oxtongue River Outlet	9928	213998.2	97	3314.8	10025	217313.0
South Branch Muskoka River Outlet	8885	266189.4	37	1445.2	8922	267634.6
Tea Lake - Oxtongue River	11263	261471.1	107	871.3	11370	262342.4
Grand Total	169095	3709373.3	1388	73186.7	170483	3782560.0

Further details on occurrence frequency (i.e. number of unique polygons) and area (ha) of each candidate SWH category assessed by subwatershed is provided below.

3.5.3.1 SEASONAL CONCENTRATION AREAS OF ANIMALS

3.5.3.1.1 Waterfowl stopover and staging areas (terrestrial)

This habitat type is represented primarily by fields that tend to be flooded during the spring and support important foraging locations for migrating waterfowl. The total number of habitat polygons (30) is limited to only four subwatersheds and totals approximately 331 ha (Table 25).

Table 25. Candidate waterfowl stopover and staging areas (terrestrial) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Lake Muskoka - Muskoka River	23	275.6
Lake Rosseau	2	4.5
Musquash River	3	45.5
North Branch Muskoka River	2	5.1
Grand Total	30	330.7

3.5.3.1.2 Waterfowl stopover and staging areas (aquatic)

This habitat type is represented by a variety of aquatic and wetland feature types that support important foraging areas of local and migratory waterfowl. Given the extensive occurrence of these feature types, waterfowl stopover and staging areas are prevalent across the watershed, occurring in all 14 subwatersheds. In total 6,956 polygons were identified, representing approximately 93,355 ha (Table 26).

Table 26. Candidate waterfowl stopover and staging areas (aquatic) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	448	9434.8
Blackstone Harbour	224	3447.8
Distress Pond - Big East River	764	4490.2
Hollow River	508	7364.4
Lake Muskoka - Muskoka River	510	15813.0
Lake Rosseau	898	19131.3
Lake Vernon	447	4212.8
Little East River - Big East River	402	2641.7
Moon River Bay	311	4276.9
Musquash River	544	5305.5
North Branch Muskoka River	485	5163.6
Oxtongue River Outlet	502	2488.2
South Branch Muskoka River Outlet	357	3856.6
Tea Lake - Oxtongue River	556	5727.7
Grand Total	6956	93354.5

3.5.3.1.3 Shorebird migratory stopover areas

This habitat type is represented by a variety of shoreline areas associated with lakes, rivers, wetlands, and includes beach areas, bars and seasonally flooded mud flats and un-vegetated shoreline areas. The habitat type is restricted to nine subwatersheds. In total 69 polygons were identified, representing approximately 110 ha (Table 27).

Table 27. Candidate shorebird migratory stopover areas SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	1	1.1
Lake Muskoka - Muskoka River	11	16.4
Lake Rosseau	1	1.0
Lake Vernon	1	0.4
Little East River - Big East River	4	3.1
Moon River Bay	37	79.1
Musquash River	11	6.3
North Branch Muskoka River	2	2.2
South Branch Muskoka River Outlet	1	0.1
Grand Total	69	109.6

3.5.3.1.4 Raptor wintering areas

Raptor wintering areas provide roosting, foraging, and resting habitat for wintering raptors. These areas need to be >20 ha with a combination of forest and upland meadow/field habitat. This habitat type was identified in eight subwatersheds, including 462 polygons comprising approximately 8,031 ha (Table 28).

Table 28. Candidate raptor wintering area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Blackstone Harbour	18	149.3
Lake Muskoka - Muskoka River	120	2144.1
Lake Rosseau	158	3100.2
Lake Vernon	28	608.2
Little East River - Big East River	15	186.0
Musquash River	8	68.0
North Branch Muskoka River	95	1428.6
South Branch Muskoka River Outlet	20	346.2
Grand Total	462	8030.6

3.5.3.1.5 Bat hibernacula

This habitat type is represented by a variety of caves, mine shafts, underground foundations, and Karst topography. The habitat type occurs in 12 subwatersheds, represented by 1,241 polygons, covering approximately 4,241 ha (Table 29).

Table 29. Candidate bat hibernacula SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Blackstone Harbour	127	287.7
Distress Pond - Big East River	1	4.4
Hollow River	6	16.0
Lake Muskoka - Muskoka River	337	1235.2
Lake Rosseau	253	757.4
Lake Vernon	12	25.7
Little East River - Big East River	3	5.2
Moon River Bay	299	851.4
Musquash River	164	1009.2
North Branch Muskoka River	28	38.4
Oxtongue River Outlet	1	1.5
South Branch Muskoka River Outlet	10	8.5
Grand Total	1241	4240.5

3.5.3.1.6 Bat maternity colonies

This habitat type is represented by tree cavities and suitable vegetation. Typically, forests that contain mature trees that are large diameter and have a higher density of snags (standing dead trees) or trees with cavities. Given the extensive occurrence of treed areas in the watershed, this type of habitat is prevalent. The habitat is present in all 14 subwatersheds, occurring in 2,400 polygons comprising approximately 277,741 ha (Table 30).

Table 30. Candidate bat maternity colony SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	145	20089.3
Blackstone Harbour	114	9053.4
Distress Pond - Big East River	98	32201.0
Hollow River	116	24184.8
Lake Muskoka - Muskoka River	263	15129.4
Lake Rosseau	404	34766.3
Lake Vernon	176	20844.7
Little East River - Big East River	123	16673.4
Moon River Bay	153	10010.3
Musquash River	186	12380.1

North Branch Muskoka River	250	23743.5
Oxtongue River Outlet	97	17209.1
South Branch Muskoka River Outlet	175	20424.0
Tea Lake - Oxtongue River	100	21032.0
Grand Total	2400	277741.4

3.5.3.1.7 Turtle wintering areas

This type of habitat is represented by permanent waterbodies, large wetlands, bogs and fens with substrates that provide suitable overwintering habitat for turtles. The habitat is present in all 14 subwatersheds, represented by 7,757 polygons, covering approximately 115,345 ha (Table 31).

Table 31. Candidate turtle wintering area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	452	10699.1
Blackstone Harbour	254	3798.6
Distress Pond - Big East River	802	5861.6
Hollow River	511	8063.4
Lake Muskoka - Muskoka River	579	17158.9
Lake Rosseau	1037	22413.3
Lake Vernon	461	7664.6
Little East River - Big East River	404	4376.3
Moon River Bay	401	5131.4
Musquash River	670	6140.5
North Branch Muskoka River	592	7463.0
Oxtongue River Outlet	504	3927.8
South Branch Muskoka River Outlet	444	5776.4
Tea Lake - Oxtongue River	646	6870.6
Grand Total	7757	115345.4

3.5.3.1.8 Reptile hibernaculum

This type of habitat is represented by areas that allow access to places below the frost line such as burrows, rock crevices, and other natural/naturalized locations. The habitat is all 14 subwatersheds, and represented by 5,047 polygons, covering approximately 383,038 ha (Table 32).

Table 32. Candidate reptile hibernaculum SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	206	25324.4
Blackstone Harbour	111	12290.3
Distress Pond - Big East River	758	39401.9
Hollow River	567	31930.5

Quaternary Watershed Name	Number of Polygons	Area (ha)
Lake Muskoka - Muskoka River	501	27168.0
Lake Rosseau	516	50414.7
Lake Vernon	140	26536.6
Little East River - Big East River	159	20751.4
Moon River Bay	230	16925.9
Musquash River	375	22261.4
North Branch Muskoka River	251	34257.9
Oxtongue River Outlet	369	21987.6
South Branch Muskoka River Outlet	160	27434.4
Tea Lake - Oxtongue River	704	26352.9
Grand Total	5047	383037.7

3.5.3.1.9 Colonially-nesting bird breeding habitat (bank and cliff)

This type of habitat is represented by a variety of topographical areas and substrates such as soils banks, sandy hills, borrow pits, steep slopes, and sand piles that support nesting of different species of swallows. The habitat is present in all 14 subwatersheds, represented by 4,280 polygons, covering approximately 83,385 ha (Table 33).

Table 33. Candidate colonially-nesting bird breeding habitat (bank and cliff) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	142	205.5
Blackstone Harbour	58	144.2
Distress Pond - Big East River	730	88.4
Hollow River	548	95.7
Lake Muskoka - Muskoka River	441	2484.1
Lake Rosseau	371	1911.5
Lake Vernon	121	607.5
Little East River - Big East River	114	239.8
Moon River Bay	129	121.6
Musquash River	264	200.6
North Branch Muskoka River	241	1653.7
Oxtongue River Outlet	343	56.8
South Branch Muskoka River Outlet	115	481.8
Tea Lake - Oxtongue River	663	93.7
Grand Total	4280	8384.7

3.5.3.1.10 Colonially-nesting bird breeding habitat (tree and shrub)

This type of habitat is represented by live or dead standing trees in wetlands, lakes, islands and/or peninsulas. Shrubs and some emergent vegetation types may also support this habitat type. The habitat is present in all 14 subwatersheds. Based on the FRI land-cover modeling, the habitat is represented by 7,370 polygons, covering approximately 58,333 ha. Based on the MNRF confirmed locations of nests, the habitat is represented by 191 polygons comprising approximately 5,141 ha (Table 34).

Table 34. Candidate colonially-nesting bird breeding habitat (tree and shrub) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons - FRI	Area (ha) - FRI	Number of Polygons - MNRF	Area (ha) - MNRF
Baysville Narrows - South Branch Muskoka River	263	2566.1	12	263.9
Blackstone Harbour	147	1243.9	17	488.4
Distress Pond - Big East River	1049	7299.8	13	417.8
Hollow River	798	5352.2	7	212.5
Lake Muskoka - Muskoka River	561	3730.1	16	374.9
Lake Rosseau	685	4658.2	21	529.4
Lake Vernon	318	5717.2	6	152.7
Little East River - Big East River	281	3024.1	13	286.4
Moon River Bay	376	3025.8	15	450.9
Musquash River	585	3404.9	27	740.9
North Branch Muskoka River	397	5046.8	15	406.8
Oxtongue River Outlet	516	3871.9	10	229.0
South Branch Muskoka River Outlet	347	4279.3	9	286.6
Tea Lake - Oxtongue River	1047	5112.3	10	301.4
Grand Total	7370	58332.7	191	5141.4

3.5.3.1.11 Colonially-nesting bird breeding habitat (ground)

This type of habitat is represented by islands and/or peninsulas that support gull and/or tern nesting areas and are associated with open water, marshy areas of lakes, lakes, and/or large rivers . As well, it supports nesting of Brewer's Blackbird in shrub areas that are in close proximity to streams and irrigation ditches. The habitat is present in all 14 subwatersheds, represented by 6,398 polygons, covering approximately 16,738 ha (Table 35).

Table 35. Candidate colonially-nesting bird breeding habitat (ground) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	252	680.4

Quaternary Watershed Name	Number of Polygons	Area (ha)
Blackstone Harbour	138	462.3
Distress Pond - Big East River	851	332.8
Hollow River	728	561.2
Lake Muskoka - Muskoka River	666	3297.8
Lake Rosseau	609	2872.0
Lake Vernon	311	1450.4
Little East River - Big East River	166	417.6
Moon River Bay	366	1381.5
Musquash River	584	1627.0
North Branch Muskoka River	371	2235.2
Oxtongue River Outlet	399	167.9
South Branch Muskoka River Outlet	270	1081.7
Tea Lake - Oxtongue River	687	170.5
Grand Total	6398	16738.3

3.5.3.1.12 Deer yarding areas

This type of habitat is represented by two strata types and is mapped by MNRF. The broadest type is Stratum II that is inclusive of the entire Deer yarding area and typically includes mixed or deciduous forest that is used for browsing. This may also include agricultural areas. Stratum I is a subset of Stratum II and represents the inner core areas of the Deer yarding area and is critical during harsh winter weather; typically it is dominated by forest stands with a high density of conifer trees. Existing MNRF data identified 461 polygons covering approximately 57,852 ha. The FRI model detected an additional 26,000 ha of habitat, represented by 5,007 polygons and covering approximately 84,114 ha (Table 36).

Table 36. FRI vs. MNRF identified deer yarding area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons - FRI	Area (ha) - FRI	Number of Polygons - MNRF	Area (ha) - MNRF
Baysville Narrows - South Branch Muskoka River	256	3500.3	37	12941.9
Blackstone Harbour	446	1239.3	29	4530.4
Distress Pond - Big East River	340	8204.1	2	178.5
Hollow River	375	7694.1	53	999.8
Lake Muskoka - Muskoka River	371	6099.3	92	6344.5
Lake Rosseau	684	10106.8	114	6529.8
Lake Vernon	295	6457.1	20	4980.7
Little East River - Big East River	213	4318.9	7	3181.3
Moon River Bay	410	4178.9	43	1987.3

Quaternary Watershed Name	Number of Polygons - FRI	Area (ha) - FRI	Number of Polygons - MNRF	Area (ha) - MNRF
Musquash River	316	5207.2	18	6212.1
North Branch Muskoka River	371	8256.8	16	7016.3
Oxtongue River Outlet	227	5607.4	19	2314.7
South Branch Muskoka River Outlet	285	7127.1	9	616.2
Tea Lake - Oxtongue River	418	6116.8	2	18.3
Grand Total	5007	84114.2	461	57851.9

3.5.3.2 RARE VEGETATION COMMUNITIES

3.5.3.2.1 Beach/beach ridge/bar/sand dunes

This type of habitat is represented by unstable sands present in beaches, beach ridges, or sand dunes. The habitat is extremely rare and localized occurring in only four subwatersheds, and represented by 7 polygons, covering approximately 10 ha (Table 37).

Table 37. Candidate beach/beach ridge/bard/sand dunes SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	1	1.1
Hollow River	1	5.2
Little East River - Big East River	4	3.1
North Branch Muskoka River	1	0.4
Grand Total	7	9.8

3.5.3.2.2 Shallow Atlantic coastal marsh

This type of habitat is represented by shallow mineral (sand) or mineral organic (sandy peat) shoreline subject to low wave energy, on inland lakes and beaver ponds particularly those that experience fluctuating water levels from year to year (i.e. some years with exposed shorelines in summer/fall). The habitat supports a unique flora and is recognized as provincially rare. The habitat is present in 11 subwatersheds, represented by 364 polygons, covering approximately 1,332 ha (Table 38).

Table 38. Candidate shallow Atlantic coastal marsh SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	9	20.9
Distress Pond - Big East River	16	58.4
Hollow River	77	267.6

Quaternary Watershed Name	Number of Polygons	Area (ha)
Lake Muskoka - Muskoka River	90	296.1
Lake Rosseau	2	0.6
Moon River Bay	31	134.1
Musquash River	111	489.6
North Branch Muskoka River	1	3.4
Oxtongue River Outlet	13	31.3
South Branch Muskoka River Outlet	10	22.4
Tea Lake - Oxtongue River	4	7.1
Grand Total	364	1331.5

3.5.3.2.3 Cliffs and talus slopes

This type of habitat is represented by cliffs and talus areas that are primarily Precambrian rock and are typically sparsely vegetated. SWH cliff types were determined based on classification in the FRI dataset. Based on this data source, it suggests that the habitat is rare and restricted within the watershed being present in five subwatersheds, represented by seven polygons, covering approximately 20 ha (Table 39). Given the topography of the landscape, cliffs are likely under-represented, therefore additional investigation into this SWH type is warranted using the high-resolution LiDAR data and specific criteria that define a cliff based on topographical parameters.

Table 39. Candidate cliff and talus slope SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Hollow River	1	5.2
Moon River Bay	2	7.4
Musquash River	1	0.4
North Branch Muskoka River	1	4.6
South Branch Muskoka River Outlet	2	2.5
Grand Total	7	20.1

3.5.3.2.4 Precambrian rock barren

This type of habitat is represented by extensive areas of exposed granitic rock bedrock sparsely vegetated, with less than 60% tree cover, and greater than 1 ha. The habitat is present in 12 subwatersheds, represented by 1,264 polygons, covering approximately 5,000 ha (Table 40).

Table 40. Candidate Precambrian rock barren SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	6	10.0

Quaternary Watershed Name	Number of Polygons	Area (ha)
Blackstone Harbour	122	317.1
Distress Pond - Big East River	4	7.4
Hollow River	14	30.5
Lake Muskoka - Muskoka River	326	1381.6
Lake Rosseau	243	783.6
Lake Vernon	16	36.9
Little East River - Big East River	19	48.5
Moon River Bay	276	1155.7
Musquash River	192	1147.5
North Branch Muskoka River	28	50.3
Oxtongue River Outlet	8	14.4
South Branch Muskoka River Outlet	5	9.4
Tea Lake - Oxtongue River	5	7.0
Grand Total	1264	4999.8

3.5.3.2.5 Sand barren

This type of habitat is represented by exposed sand, generally sparsely vegetated and caused by lack of moisture, periodic fires and erosion. They have little or no soil and the underlying rock protrudes through the surface. Usually located within other types of natural habitat such as forest or savannah. The habitat is present in all 14 subwatersheds, represented by 209 polygons, covering approximately 1290 ha (Table 41).

Table 41. Candidate sand barren SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	9	58.6
Blackstone Harbour	12	42.9
Distress Pond - Big East River	6	6.7
Hollow River	18	28.0
Lake Muskoka - Muskoka River	31	294.5
Lake Rosseau	25	119.1
Lake Vernon	10	80.9
Little East River - Big East River	11	101.3
Moon River Bay	17	51.0
Musquash River	23	61.6
North Branch Muskoka River	25	350.9
Oxtongue River Outlet	6	13.4
South Branch Muskoka River Outlet	14	80.0
Tea Lake - Oxtongue River	2	1.3
Grand Total	209	1290.2

3.5.3.2.6 Old growth forest

This type of habitat is represented by exhibiting the greatest number of old-growth characteristics, such as mature forest with large trees that are undisturbed. They have a heavy mortality or turnover of over- story trees resulting in a mosaic of gaps that encourage development of a multi-layered canopy and an abundance of snags and downed woody debris. To meet the criteria, stands are 30 ha or greater in size or with at least 10 ha interior habitat (measured from a 100 m internal buffer from the forest edge. The habitat is present in all 14 subwatersheds, represented by 940 polygons, covering approximately 36,672 ha (Table 42).

Table 42. Candidate old growth forest SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	88	1804.8
Blackstone Harbour	24	792.8
Distress Pond - Big East River	137	9584.4
Hollow River	136	3726.4
Lake Muskoka - Muskoka River	20	573.1
Lake Rosseau	88	2711.2
Lake Vernon	24	491.1
Little East River - Big East River	49	918.9
Moon River Bay	31	922.2
Musquash River	20	421.6
North Branch Muskoka River	38	709.1
Oxtongue River Outlet	134	5883.4
South Branch Muskoka River Outlet	52	1222.3
Tea Lake - Oxtongue River	99	6911.0
Grand Total	940	36672.4

3.5.3.2.7 Bog

This type of habitat is represented by nutrient-poor, acid peatlands dominated by peat mosses (Sphagnum sp.), ericaceous shrubs and sedges (Cyperaceae). The water table is at or near the surface in spring and slightly lower the remainder of the year and is virtually isolated from mineral soil waters. Mapping for this SWH type included predictions from the land cover modeling and the FRI dataset, which also includes fen habitats. The habitat is present in all 14 subwatersheds, represented by 82,265 polygons, covering approximately 10,630 ha (Table 43).

Table 43. Candidate bog SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	3988	603.8
Blackstone Harbour	4618	193.7
Distress Pond - Big East River	5937	256.8

Quaternary Watershed Name	Number of Polygons	Area (ha)
Hollow River	1484	119.0
Lake Muskoka - Muskoka River	4920	1118.5
Lake Rosseau	14921	1728.2
Lake Vernon	8249	1018.5
Little East River - Big East River	5526	478.4
Moon River Bay	7153	1112.2
Musquash River	4593	1241.4
North Branch Muskoka River	7895	1113.7
Oxtongue River Outlet	5043	279.2
South Branch Muskoka River Outlet	4485	1169.0
Tea Lake - Oxtongue River	3453	197.8
Grand Total	82265	10630.3

3.5.3.2.8 Rare forest type: Red Spruce

This type of habitat is represented by forest stands where Red Spruce may be present. Red spruce is a shade tolerant conifer that evolved within tolerant hardwood forests. It typically grows in a cool, moist climate and is tolerant of a range of shallow soil types, including in areas of moderate drainage. The habitat is present in all 14 subwatersheds, represented by 1,245 polygons, covering approximately 25,614 ha (Table 44).

Table 44. Candidate Red Spruce rare forest type SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	107	1959.4
Blackstone Harbour	28	453.0
Distress Pond - Big East River	200	4346.0
Hollow River	224	5020.6
Lake Muskoka - Muskoka River	23	592.6
Lake Rosseau	91	2015.3
Lake Vernon	18	239.4
Little East River - Big East River	55	935.9
Moon River Bay	32	1052.6
Musquash River	24	770.6
North Branch Muskoka River	36	694.3
Oxtongue River Outlet	155	3804.7
South Branch Muskoka River Outlet	53	1113.3
Tea Lake - Oxtongue River	199	2616.2
Grand Total	1245	25614.0

3.5.3.2.9 Rare forest type: White Oak

This type of habitat is represented by forest stands with White Oak present. The habitat is present in 13 subwatersheds, represented by 612 polygons, covering approximately 15,773 ha (Table 45).

Table 45. Candidate White Oak rare forest type SWH based on modeled landcover by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	77	2131.7
Blackstone Harbour	66	1354.8
Hollow River	24	418.1
Lake Muskoka - Muskoka River	79	2463.2
Lake Rosseau	120	2595.5
Lake Vernon	11	171.6
Little East River - Big East River	13	354.6
Moon River Bay	51	1018.2
Musquash River	73	2686.4
North Branch Muskoka River	41	1259.9
Oxtongue River Outlet	5	106.0
South Branch Muskoka River Outlet	50	1202.2
Tea Lake - Oxtongue River	2	10.4
Grand Total	612	15772.5

3.5.3.2.10 Tallgrass prairie (not mapped)

This type of habitat is represented by an open vegetation with less than < 25% tree cover, and dominated by prairie species, including a variety of grasses. In Ecoregion 5E, there are few if any tallgrass prairie remnants. This vegetation type was not identified within the watershed.

3.5.3.2.11 Savannah (not mapped)

This type of habitat is related to tallgrass prairie, but includes trees, which vary from 25 – 60% canopy cover. The open areas between the trees are dominated by prairie species, while forest species are found beneath the tree canopy. This habitat type was not identified within the watershed.

3.5.3.2.12 Alvar (not mapped)

This type of habitat is represented by a relatively level, mostly unfractured calcareous bedrock feature with a mosaic of rock pavements and bedrock overlain by a thin veneer of soil. They also have a complex hydrology with alternative periods of inundation and drought. Vegetation is typically sparse with a mix of lichen-moss communities, grasslands, and/or shrub thicket areas. This habitat type was not identified within the watershed.

3.5.3.3 SPECIALIZED WILDLIFE HABITAT

3.5.3.3.1 Waterfowl nesting areas

Waterfowl nesting areas generally includes upland habitat adjacent to wetlands. This habitat type is present in all 14 subwatersheds including 6,912 polygons comprising approximately 66,353 ha (Table 46).

Table 46. Candidate waterfowl nesting area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	351	3795.3
Blackstone Harbour	293	3122.1
Distress Pond - Big East River	681	4823.2
Hollow River	638	4191.0
Lake Muskoka - Muskoka River	624	5906.2
Lake Rosseau	789	8597.9
Lake Vernon	460	4948.5
Little East River - Big East River	255	1981.2
Moon River Bay	456	5831.0
Musquash River	599	7410.0
North Branch Muskoka River	562	5063.6
Oxtongue River Outlet	402	3386.6
South Branch Muskoka River Outlet	435	5094.8
Tea Lake - Oxtongue River	367	2202.5
Grand Total	6912	66352.8

3.5.3.3.2 Bald Eagle and Osprey nesting, foraging, and perching habitat

Bald Eagle and Osprey nesting, foraging and perching habitat is generally found in forested communities directly adjacent to riparian areas including rivers, lakes, ponds and wetlands. Nests are associated with lakes, ponds, rivers or wetlands along forested shorelines, islands, or on structures over water. Candidate habitat was identified in all 14 subwatershed; MNRF has identified osprey nests in 12 of the watersheds, all of which were mapped. A total of 5,763 polygons comprising approximately 333,929 ha were identified through modeling and 34 polygons comprising approximately 941 ha were identified by MNRF (Table 47).

Table 47. Candidate Bald Eagle and Osprey nesting, foraging, and perching habitat SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons - FRI	Area (ha) - FRI	Number of Polygons - MNRF	Area (ha) - MNRF
Baysville Narrows - South Branch Muskoka River	255	22153.8	2	56.5
Blackstone Harbour	126	11410.9	--	--

Quaternary Watershed Name	Number of Polygons - FRI	Area (ha) - FRI	Number of Polygons - MNRF	Area (ha) - MNRF
Distress Pond - Big East River	767	36083.7	6	178.1
Hollow River	573	28512.7	2	56.5
Lake Muskoka - Muskoka River	600	21066.7	1	28.3
Lake Rosseau	671	42219.0	4	113.1
Lake Vernon	195	23609.0	2	56.5
Little East River - Big East River	232	17179.3	2	56.5
Moon River Bay	253	15187.4	2	56.5
Musquash River	403	20561.3	--	--
North Branch Muskoka River	413	25706.9	1	28.3
Oxtongue River Outlet	374	20702.6	1	26.8
South Branch Muskoka River Outlet	196	24317.9	6	169.6
Tea Lake - Oxtongue River	705	25217.5	5	114.5
Grand Total	5763	333928.8	34	941.4

3.5.3.3.3 Woodland raptor nesting habitat

Woodland raptor nesting habitat includes conifer forests and plantations and is highly prevalent in all subwatersheds. A total of 2,068 polygons were identified comprising approximately 383,457 ha (Table 48).

Table 48. Candidate woodland raptor nesting area SWH by quaternary watershed

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	114	26026.1
Blackstone Harbour	120	12099.1
Distress Pond - Big East River	85	40754.4
Hollow River	64	32384.9
Lake Muskoka - Muskoka River	353	24440.1
Lake Rosseau	373	48360.7
Lake Vernon	91	28333.0
Little East River - Big East River	87	21670.4
Moon River Bay	151	15991.9
Musquash River	173	21159.7
North Branch Muskoka River	193	33531.1

Quaternary Watershed Name	Number of Polygons	Area (ha)
Oxtongue River Outlet	66	23360.2
South Branch Muskoka River Outlet	130	28157.7
Tea Lake - Oxtongue River	68	27188.0
Grand Total	2068	383457.3

3.5.3.3.4 Turtle and lizard nesting areas

Lizard nesting habitat is identified in suitable wooded areas. Candidate lizard nesting SWH is identified in all 14 subwatersheds, with 2,615 polygons totaling approximately 239,109 ha (Table 49).

Table 49. Candidate lizard nesting area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	171	18079.5
Blackstone Harbour	127	7321.5
Distress Pond - Big East River	127	29745.0
Hollow River	136	22391.5
Lake Muskoka - Muskoka River	248	11764.8
Lake Rosseau	393	29132.7
Lake Vernon	224	18140.6
Little East River - Big East River	141	14853.7
Moon River Bay	130	5510.9
Musquash River	191	7829.7
North Branch Muskoka River	271	21545.0
Oxtongue River Outlet	99	15988.6
South Branch Muskoka River Outlet	188	18834.9
Tea Lake - Oxtongue River	169	17970.5
Grand Total	2615	239109.0

Turtle nesting habitat is identified where open habitat and suitable sandy and/or gravel soils were present within 100 m of a watercourse or suitable wetland communities. Candidate turtle nesting habitat is identified in 4,220 polygons across the 14 subwatersheds, comprising approximately 2,868 ha (Table 50).

Table 50. Candidate turtle nesting area SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	128	69.4
Blackstone Harbour	55	57.9
Distress Pond - Big East River	724	81.6
Hollow River	532	66.5
Lake Muskoka - Muskoka River	429	709.0
Lake Rosseau	400	791.3
Lake Vernon	109	147.9

Quaternary Watershed Name	Number of Polygons	Area (ha)
Little East River - Big East River	98	37.6
Moon River Bay	150	119.4
Musquash River	256	86.5
North Branch Muskoka River	250	469.8
Oxtongue River Outlet	336	23.2
South Branch Muskoka River Outlet	92	115.4
Tea Lake - Oxtongue River	661	92.4
Grand Total	4220	2868.0

3.5.3.3.5 Seeps and springs

Seeps and springs are typical of headwater areas and are often the source of coldwater streams; they are typically located in forested habitats. A total of 1,755 polygons were mapped throughout the 14 subwatersheds comprising approximately 402,430 ha (Table 51).

Table 51. Candidate seeps and springs SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	106	27333.8
Blackstone Harbour	76	13352.9
Distress Pond - Big East River	26	43785.2
Hollow River	34	35067.8
Lake Muskoka - Muskoka River	296	24746.1
Lake Rosseau	332	51014.0
Lake Vernon	121	26862.5
Little East River - Big East River	87	21731.6
Moon River Bay	131	18052.1
Musquash River	157	24038.4
North Branch Muskoka River	198	34274.6
Oxtongue River Outlet	39	23717.5
South Branch Muskoka River Outlet	117	28552.8
Tea Lake - Oxtongue River	35	29900.5
Grand Total	1755	402429.7

3.5.3.3.6 Aquatic feeding habitat

Aquatic feeding habitat is important for nutrient uptake by moose and other wildlife. The SWH criteria specifies that these habitats are identified and mapped by MNRF; as such, no additional modeling was undertaken for this habitat category based on the Ecoregion criteria. Aquatic feeding habitat is present in 432 polygons within 11 of the subwatersheds, comprising 2,124 ha (Table 52).

Table 52. Candidate aquatic feeding habitat SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	12	65.8
Blackstone Harbour	34	141.7
Distress Pond - Big East River	101	614.1
Hollow River	92	376.7
Lake Rosseau	24	90.9
Little East River - Big East River	2	24.1
Moon River Bay	40	277.2
Musquash River	23	97.8
Oxtongue River Outlet	41	149.3
South Branch Muskoka River Outlet	1	3.8
Tea Lake - Oxtongue River	62	282.7
Grand Total	432	2124.0

3.5.3.3.7 Mineral licks

Mineral licks are valuable and rare habitats found in upwelling groundwater and the soil around seepage areas where sedimentary and volcanic bedrock is present. Candidate habitat was identified in all 14 subwatersheds, and MNRF has identified mineral lick SWH in one of the watersheds (Lake Rosseau); combined, a total of 1,756 polygons comprising approximately 402,430 ha were identified in the Watershed (Table 53).

Table 53. Candidate mineral lick SWH by quaternary watershed.

Quaternary Watershed	Type	Number of Polygons	Area
Baysville Narrows - South Branch Muskoka River	Candidate	106	27333.8
Blackstone Harbour	Candidate	76	13352.9
Distress Pond - Big East River	Candidate	26	43785.2
Hollow River	Candidate	34	35067.8
Lake Muskoka - Muskoka River	Candidate	296	24746.1
Lake Rosseau	MNRF Identified	31	4.5
Lake Rosseau	Candidate	332	51009.5
Lake Vernon	Candidate	121	26862.5
Little East River - Big East River	Candidate	87	21731.6
Moon River Bay	Candidate	131	18052.1
Musquash River	Candidate	157	24038.4
North Branch Muskoka River	Candidate	198	34274.6
Oxtongue River Outlet	Candidate	39	23717.5

South Branch Muskoka River Outlet	Candidate	117	28552.8
Tea Lake - Oxtongue River	Candidate	35	29900.5
Grand Total		1756	402429.7

3.5.3.3.8 Denning sites for mink, otter, marten, fisher, and eastern wolf

Denning sites for fur-bearing mammals are generally associated coniferous or mixed forest types. A total of 1,755 candidate denning polygons are identified in all the subwatersheds, comprising approximately 402,430 ha (Table 54).

Table 54. Candidate denning sites for mink, otter, marten, fisher, and eastern wolf SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	106	27333.8
Blackstone Harbour	76	13352.9
Distress Pond - Big East River	26	43785.2
Hollow River	34	35067.8
Lake Muskoka - Muskoka River	296	24746.1
Lake Rosseau	332	51014.0
Lake Vernon	121	26862.5
Little East River - Big East River	87	21731.6
Moon River Bay	131	18052.1
Musquash River	157	24038.4
North Branch Muskoka River	198	34274.6
Oxtongue River Outlet	39	23717.5
South Branch Muskoka River Outlet	117	28552.8
Tea Lake - Oxtongue River	35	29900.5
Grand Total	1755	402429.7

3.5.3.3.9 Amphibian breeding habitat (woodland)

Woodland amphibian breeding habitat includes suitable breeding ponds or wetlands that are associated with forested communities. A total of 3,750 polygons were identified in the 14 subwatersheds, comprising approximately 249,139 ha (Table 55). Note that this SWH type was mapped based on existing data; modeled vernal pool data was not included in this assessment due to time restrictions.

Table 55. Candidate amphibian breeding habitat (woodland) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	217	13258.3

Quaternary Watershed Name	Number of Polygons	Area (ha)
Blackstone Harbour	187	8834.8
Distress Pond - Big East River	295	21789.4
Hollow River	258	14324.3
Lake Muskoka - Muskoka River	440	18767.7
Lake Rosseau	520	32744.0
Lake Vernon	247	21360.8
Little East River - Big East River	222	11691.0
Moon River Bay	199	15301.8
Musquash River	209	21405.2
North Branch Muskoka River	372	19845.4
Oxtongue River Outlet	212	12481.1
South Branch Muskoka River Outlet	198	20812.1
Tea Lake - Oxtongue River	174	16523.0
Grand Total	3750	249139.1

3.5.3.3.10 Amphibian breeding habitat (wetland)

Wetland amphibian breeding habitat includes suitable wetlands and pools that are > 500 m^2. Candidate habitat was identified in all 14 subwatersheds, with a total of 1,986 polygons comprising approximately 8,732 ha (Table 56).

Table 56. Candidate amphibian breeding habitat (wetland) SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	109	522.4
Blackstone Harbour	87	351.0
Distress Pond - Big East River	106	258.7
Hollow River	140	317.3
Lake Muskoka - Muskoka River	185	876.8
Lake Rosseau	271	1317.8
Lake Vernon	207	1020.7
Little East River - Big East River	59	230.6
Moon River Bay	222	1246.8
Musquash River	235	1041.0
North Branch Muskoka River	145	680.7
Oxtongue River Outlet	43	105.8
South Branch Muskoka River Outlet	154	679.2
Tea Lake - Oxtongue River	23	83.3
Grand Total	1986	8732.1

3.5.3.3.11 Mast producing areas

Mast producing areas provide important food for many wildlife species, and generally are associated with forest habitat > 0.5 ha. One mast producing area has been identified by MNRF in the Blackstone Harbour subwatershed. In total, 1,151 polygons are identified throughout the 14 subwatersheds, comprising approximately 37,652 ha (Table 57).

Table 57. Candidate mast producing areas SWH by quaternary watershed.

Quaternary Watershed Name	Habitat Type	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	Candidate	86	2327.9
Blackstone Harbour	Candidate	86	2580.9
Blackstone Harbour	Identified by MNRF	1	3.1
Distress Pond - Big East River	Candidate	9	191.4
Hollow River	Candidate	98	1729.0
Lake Muskoka - Muskoka River	Candidate	164	6562.7
Lake Rosseau	Candidate	219	6508.2
Lake Vernon	Candidate	30	406.6
Little East River - Big East River	Candidate	16	395.0
Moon River Bay	Candidate	92	3367.5
Musquash River	Candidate	145	6797.4
North Branch Muskoka River	Candidate	95	2656.7
Oxtongue River Outlet	Candidate	12	172.8
South Branch Muskoka River Outlet	Candidate	94	3881.6
Tea Lake - Oxtongue River	Candidate	5	74.0
Grand Total		1151	37651.7

3.5.3.4 HABITAT OF SPECIES OF CONSERVATION CONCERN

3.5.3.4.1 Marsh bird breeding habitat

Marsh breeding bird habitat generally includes wetland habitat that contains shallow water and emergent aquatic vegetation. One indicator species, Green Heron, has slightly different habitat needs and is most commonly found at the edge of water sheltered by shrubs and trees. Marsh breeding bird habitat occurs in 8,199 polygons throughout the Watershed, comprising approximately 37,034 ha (Table 58).

Table 58. Candidate marsh breeding bird habitat SWH by quaternary watershed

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	327	1744.8
Blackstone Harbour	340	1400.9
Distress Pond - Big East River	740	1961.0
Hollow River	522	1351.7

Lake Muskoka - Muskoka River	670	3936.3
Lake Rosseau	1020	5256.5
Lake Vernon	485	3148.9
Little East River - Big East River	345	1336.2
Moon River Bay	630	3347.4
Musquash River	925	4395.7
North Branch Muskoka River	561	2825.5
Oxtongue River Outlet	391	1769.2
South Branch Muskoka River Outlet	567	3213.8
Tea Lake - Oxtongue River	676	1345.5
Grand Total	8199	37033.5

3.5.3.4.2 Open country bird breeding habitat

Open country bird breeding habitat includes large grasslands >30 ha, and includes agricultural areas (i.e. G code 044: Dry to Fresh, Coarse: Field) (MNRF, 2015). This habitat type is sparse and limited to seven subwatersheds, with 133 polygons comprising approximately 3,104 ha (Table 59).

Table 59. Candidate open country bird breeding habitat SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Lake Muskoka - Muskoka River	49	1186.3
Lake Rosseau	44	1020.0
Lake Vernon	6	130.9
Little East River - Big East River	1	36.8
Musquash River	2	42.1
North Branch Muskoka River	24	532.1
South Branch Muskoka River Outlet	7	155.3
Grand Total	133	3103.5

3.5.3.4.3 Shrub/early successional bird breeding habitat

Shrub and early successional bird breeding habitat includes large shrub / thicket habitats >30 ha in size. This habitat type was quite sparse with 77 polygons in six subwatersheds, comprising approximately 1,732 ha (Table 60).

Table 60. Candidate shrub/early successional bird breeding habitat SWH by quaternary watershed.

Quaternary Watershed	Number of Polygons	Area (ha)
Lake Muskoka - Muskoka River	2	12.4
Lake Rosseau	55	1254.2
Lake Vernon	6	113.9

Little East River - Big East River	1	36.3
Moon River Bay	1	39.2
North Branch Muskoka River	12	276.1
Grand Total	77	1732.1

3.5.3.4.4 Special concern and rare wildlife

As noted in section 3.5.1.1 and Appendix E-2, a total of 185 rare plant and wildlife species were recorded in the Watershed. In total, 7,432 occurrences were identified in grids comprising approximately 542,147 ha; the highest proportion of observations were in the Lake Muskoka – Muskoka River and Musquash River subwatersheds (Table 61).

Table 61. Special concern and rare wildlife SWH by quaternary watershed.

Quaternary Watershed Name	Number of Polygons	Area (ha)
Baysville Narrows - South Branch Muskoka River	294	39033.4
Blackstone Harbour	276	17446.1
Distress Pond - Big East River	88	46465.4
Hollow River	99	40922.4
Lake Muskoka - Muskoka River	1728	52465.8
Lake Rosseau	857	79531.1
Lake Vernon	261	36943.7
Little East River - Big East River	149	27558.1
Moon River Bay	513	23997.0
Musquash River	1174	31746.9
North Branch Muskoka River	716	48265.3
Oxtongue River Outlet	249	27020.0
South Branch Muskoka River Outlet	495	36383.3
Tea Lake - Oxtongue River	533	34369.1
Grand Total	7432	542147.8

3.5.3.5 ANIMAL MOVEMENT CORRIDORS

3.5.3.5.1 Amphibian movement corridors (not mapped)

Amphibian movement corridors provide opportunities for amphibians to move between terrestrial habitat and breeding habitat, and are identified when SWH for Amphibian Breeding Habitat is confirmed; for this reason, amphibian movement corridors were not mapped.

3.5.3.5.2 Cervid movement corridors (not mapped)

Cervid movement corridors provide important access to seasonally important habitats for moose and deer. Corridors can be identified when SWH for Deer Wintering Habitat, Moose Aquatic Feeding Areas, and Mineral Lick Habitat are confirmed; for this reason, cervid movement corridors were not mapped.

3.5.3.5.3 Furbearer movement corridors (not mapped)

Furbearer movement corridors provide important access between denning sites and habitat for Mink, Otter, Marten, Fisher and Eastern Wolf. Corridors are typically identified within riparian areas associated with confirmed denning sites; for this reason, furbearer movement corridors were not mapped.

4. DISCUSSION & RECOMMENDATIONS

4.1 GENERAL SUMMARY

The two-phased Natural Capital Inventory is one of several projects in support of integrated Watershed management (IWM) within the Muskoka River Watershed. *Phase 1: Data Consolidation and Gap Analysis* focused on review and consolidation of available data to identify gaps and opportunities to enhance and verify datasets as part of Phase 2. The primary data gap identified as part of Phase 1 was improved accuracy and coverage of landcover base mapping and Ecological Land Classification interpretation within the Muskoka River Watershed Study Area to address the primary objectives of the study related to improving wetland mapping, vernal pool mapping, identify areas/features that contribute to storm water capacity and spring runoff and ecologically significant areas (habitat for rare species/SAR, uncommon landcover types, and Significant Wildlife Habitat).

This report summarizes key findings and complements the data layers that were created and housed in an accompanying geodatabase to be curated by the District of Muskoka. The following provides a high level overview of the key findings and a series of recommendations and next steps.

The combination of collating existing contemporary data sets and undertaking advanced geospatial modeling using high resolution aerial imagery and LiDAR have been used to produce robust and comprehensive updates to the land cover classification, wetland occurrence and type, occurrence of vernal pools, head water drainage features, occurrence of rare species, and significant wildlife habitat mapping for the Muskoka River watershed.

Key findings related to the primary objectives of the study that are relevant to the entire watershed included:

- Consolidated base layer maps for the watershed that identify a) wetland, aquatic, and terrestrial features, and b) refined cover types for each of the broader land classes
- Addition of 49394.4 ha of potential wetland features compared to the existing wetland extent based on data derived from the MNRF, District, and FRI
- Addition of 9482.89 km of potential headwater drainage features (1st and 2nd order streams)
- Identification of over 439,000 potential vernal pool features across the entire watershed
- Collating and representing over 40,000 occurrence records of 185 rare species from a variety of government, citizen science, and field records

- Classification of wetland features to identify their role in flood attenuation following OWES protocols, including mapping to show extent of lacustrine/riverine, palustrine, and isolated wetland site types
- Detailed habitat suitability mapping for seven representative rare species within subwatershed in which they have confirmed records
- Mapping 36 candidate SWH types, including uncommon land cover types, following provincial criteria provided in the Ecoregion 5E Criteria Schedules

The following provides a general summary of suggested next steps and recommendations that are related to:

- How the mapping products can be used to monitor changes in natural capital over time
- Environmental policy, land-use and natural systems planning
- Process to assign values to natural capital features within the watershed
- Additional inventory actions and follow up studies

4.2 MONITORING CHANGES IN NATURAL CAPITAL

The resulting land classification approach resulted in a multi-stage approach to developing a collated landcover base that varied in the level of effectiveness to predict the presence of specific feature class types. At the coarsest classification scale, the model developed to predict wetland, aquatic, and terrestrial features performed very well. At the more refined classification scale, the wetland classification model coniferous swamp and open marsh types had the highest recall, whereas bog/fen and had moderately high recall, and swamp thicket, and mixed swamp had moderate to poor recall. For aquatic features, open aquatic had the highest recall, whereas shallow aquatic had only moderate recall. For terrestrial features, anthropogenic features had relatively high recall, whereas rock barren and forest features had only moderate or poor recall.

Therefore, it should be expected that there will be variation in feature class and boundaries when additional desktop and/or field confirmation is undertaken across the watershed to further validate the land cover class types that have been presented. In general, it is expected that the location and boundaries that discriminate among wetland, aquatic, and terrestrial features is reasonably accurate. Where the spatial data generated in this study is used for monitoring, it is recommended that the monitoring approach consider the following:

- Focus on feature types that had high to moderate/high recall – natural features such as coniferous swamp, open marsh, bog/fen, mixed forests; non-natural land cover such as impervious surfaces
- Identify opportunities to improve predictive accuracy of feature with moderate recall – swamp thicket, mixed swamp, shallow aquatic, rock barrens, coniferous forests, and deciduous forests
- Identify opportunities to integrate FRI data into monitoring to coordinate on-going forest harvesting regimes and management

- Continue to explore and utilize high-quality citizen science data sets (e.g. eBird available through GBIF) to monitor year to year and long-term variation in wildlife detection/occurrences

4.3 ENVIRONMENTAL POLICY, LAND-USE AND NATURAL SYSTEMS PLANNING

All of the data layers that were created for this study have important utility for a range of environmental policy, land-use, and natural systems planning undertakings. The following provides a summary of potential opportunities and uses:

- Explore land cover mapping for inputs to on-going Integrated Watershed Management studies where spatially explicit feature type mapping is required to assess functionality of water resource systems
- Utilize mapping to screen for potential environmental policy constraints and/or ecological sensitivities when developing terms of reference for technical studies including but not limited to watershed studies, subwatershed studies, and/or local-scale development applications/Environmental Impact Studies
- Utilize a variety of the products to undertake preliminary wetland evaluation using OWES procedures that can be completed via desktop analysis (e.g. wetland cover mapping, flood attenuation mapping, rare species mapping/occurrences)
- Identify potential need for headwater drainage feature, intermittent stream, and/or vernal pool surveys/confirmation based on the updated mapping for each of these feature types
- Identify potential Species at Risk surveys and permitting requirements using habitat models for rare species and/or consolidated rare species occurrence mapping.
- Identify potential Significant Wildlife Habitat survey and/or confirmation based on the SWH mapping

4.4 ASSIGN VALUES TO NATURAL CAPITAL FEATURES

Natural assets include the stocks of resources such as lakes, rivers, creeks, wetlands, forests, wildlife, soils and wide range of other natural features and functions that are critical to sustaining the health of our ecosystems. Recognizing the broad range of services and benefits that these natural assets provide to humans has long been recognized and is emerging as a central theme in holistic land-use planning initiatives. This is particularly critical for municipal governments, given their respective responsibility for financing and managing a range of built infrastructure and services that can be improved through implementation of a natural asset management framework (MNAI, 2022). As an example, wetlands, forests, and healthy soils can provide extensive economic value in the form of flood protection and mitigation when present at the right location and at the right amount within watersheds. A diverse array of other ecosystem services are provided by natural assets such as, but not limited to carbon sequestration,

pollination, recreation, water purification, renewable energy production, and erosion control. Where these services can be modelled, and the economic benefits they provide can be quantified, undertaking an natural asset valuation study sets the stage for a more holistic understanding of the importance of natural systems, features, and their functions.

One of the first stages in developing a natural asset management framework includes identifying the key natural heritage features that are present, the functions they provide, and how the combination of these features and functions relate to a variety of important 'services'. The data and mapping developed for this study can be utilized for such an undertaking. The next step will involve the District determining the appropriate next step with regard to the approaches they wish to undertake to identify and model the services that are provided by the vast array of natural assets. For example, open source natural capital modeling programs existing such as InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) (https://naturalcapitalproject.stanford.edu/software/invest). The models that are provided are spatially explicit and can be integrated with various GIS platforms to value a variety of ecosystem services provided by natural assets. As well, not-for-profit groups such as Municipal Natural Assets Initiative exist to help municipalities follow a comprehensive natural asset planning process (https://mnai.ca/). The services provided by such organizations go beyond the valuation of services however, and include a much more comprehensive planning process that involves developing natural asset registries, policy, and implementation plans.

4.5 RECOMMENDATION FOR ADDITIONAL INVENTORY ACTIONS AND FOLLOW UP STUDIES

Notwithstanding the extensive effort and updating to natural capital features and functions within the Muskoka River watershed that is provided in this study, what is provided represents a 'snap-shot' of conditions that exist using the data sources available. As well, the methods used to develop the updated information relied on innovative approaches to model and/or collate existing data. It is recognized throughout that the study that there is variability in the accuracy of the results that have been provided, therefore it is incumbent on any users of this information to validate its accuracy, particularly when using the information for interpretation and decision making at local scales.

As such, with the mapping products and associated data providing a baseline, additional field verification will be a critical to validating and updating the actual boundaries and types of natural features, wildlife, and habitat types that are present across the watershed. Certainly, additional field investigations that are undertaken specifically to further validate and refine the model prediction developed as part of this study would be valuable. This could include for example:

- Incorporating other remotely sensed imagery such as leaf on imagery to better classify terrestrial community types
- Exploring the use of Digital Surface Models and/or LiDAR point cloud data to better predict the structural characteristics of terrestrial and wetland features
- Expanding the habitat modeling workflows to include more rare species and/or species at risk
- Undertaking field investigations for rare species and/or species at risk where there are gaps in information within the watershed

As well, approaches to validate and/or update the data sets that have been created for this study could include incorporating data from formal studies that are undertaken by qualified professionals. This would involve developing a workflow that allows new information to be vetted and updated on a regular basis. For example, this could include updating feature boundaries and types based on a range of studies and/or data sharing with partners that includes but is not limited to:

- Technical studies undertaken by the District and/or local area municipalities such as subwatershed plans, official plan comprehensive reviews
- Data submitted for Environmental Assessment, Natural Environment Reports, and/or Environmental Impact studies
- Data provided by other government organizations (e.g. the Natural Heritage Information Centre)
- Data provided by land-trusts and land-conservancy organizations

Finally, other natural capital data sets that were not included as key components of the scope for this study that should be considered include, but are not limited to:

- Partnerships with First Nations and Indigenous Peoples to explore ways to recognize the value of traditional knowledge
- Fish habitat of lakes, watercourses, and streams
- Benthic invertebrate monitoring data
- Invasive species occurrence and habitat suitability/potential spread

Combined with the natural capital data updates developed for this study, the recommendations provided will help to ensure the District of Muskoka maintains a comprehensive and holistic understanding of the Muskoka River watershed. In turn, this will result in the District continuing to be at the forefront of sustainable and responsible land-use planning and management.

5. REFERENCES

Banton, E., J. Johnson, H. Lee, G. Racey, P. Uhlig, and **M. Webster. 2009.** Ecosites of Ontario: Operational Draft. April 20th, 2009.

Chambers, B., B.J. Naylor, J. Nieppola, B. Merchant and **P. Uhlig. 2012.** Field Guide to Forest Ecosystems of Ontario (Ministry of Natural Resources SCSS field guide FG-01). Queens Printer for Ontario, 1997.

Government of Canada. 2002. Species at Risk Act, Statutes of Canada (2002, c. 29). Retrieved from the Department of Justice Laws Website: http://laws-lois.justice.gc.ca/eng/acts/S-15.3/index.html

Government of Ontario. 2007. Endangered Species Act, Statutes of Ontario (2007, c. 6). Retrieved from the ServiceOntario e-Laws website: http://www.e-laws.gov.on.ca/html/statutes/english/elaws_statutes_07e06_e.htm

Keddy, P.A. Wetland Ecology, principles and conservation. Cambridge University Press, Cambridge, United Kingdom.

Lee, H., W. Bakowsky, J. Riley, J. Bowles, M. Puddister, P. Uhlig, and **S. McMurray. 1998.** Ecological Land Classification for Southern Ontario: First Approximation and its Application. Ontario Ministry of Natural Resources, Southcentral Sciences Section, Science Development and Transfer Branch, SCSS Field Guide FG-02.

Lindsay JB, Francioni A, Cockburn JMH. 2019. LiDAR DEM smoothing and the preservation of drainage features. Remote Sensing, 11(16), 1926; DOI: 10.3390/rs11161926.

MNAI, 2022. Primer on natural asset management. Available at URL: **https://mnai.ca/media/2019/06/MNAI-Org-Charts.pdf**

MNR (Ministry of Natural Resources). 2005. The Stream Permanency Handbook for South-Central Ontario. Southern Region Planning Unit, 2005.

NatureServe Explorer. 2022. National and Subnational Conservation Status Definitions web page. Available at: https://explorer.natureserve.org/AboutTheData/Statuses

NHIC (Natural Heritage Information Centre). 2021a. Ontario Vascular Plant Species List. Ontario Ministry of Natural Resources. https://www.ontario.ca/page/get-natural-heritage-information

NHIC (Natural Heritage Information Centre). 2021b. Ontario Wildlife Species List. Ontario Ministry of Natural Resources. https://www.ontario.ca/page/get-natural-heritage-information

OMNR (Ontario Ministry of Natural Resources). 2010. Natural Heritage Reference Manual. Available at: https://dr6j45jk9xcmk.cloudfront.net/documents/3270/natural-heritage-reference-manual-for-natural.pdf

OMNR (Ontario Ministry of Natural Resources). 2014. Ontario Wetland Evaluation System, Northern Manual, 1st Edition, Version 1.3. 280 pp.

OMNRF (Ontario Ministry of Natural Resources and Forestry). 2015. Significant Wildlife Habitat Criteria Schedules for Ecoregion 5E, January, 2015. Available at: https://docs.ontario.ca/documents/4774/schedule-5e-jan-2015-access-ver-final-s.pdf

O'Neil, Gina L., Goodall, Jonathan L.., Watson, Layne T., 2018. Evaluating the potential for site-specific modification of LiDAR DEM derivatives to improve environmental planning-scale wetland identification using Random Forest classification, Journal of Hydrology, Volume 559, 2018, Pages 192-208, ISSN 0022-1694, https://doi.org/10.1016/j.jhydrol.2018.02.009.

Wester, M., P. Uhlig, W. Bakowsky, and **Banton, E. 2015.** Great Lakes-St. Lawrence Ecosite Fact sheets (third draft). January 12, 2015.

Wu, Qiusheng & Lane, Charles & Liu, Hongxing. (2014). An Effective Method for Detecting Potential Woodland Vernal Pools Using High-Resolution LiDAR Data and Aerial Imagery. Remote Sensing. 6. 11444-11467. 10.3390/rs61111444.