**GLSE Mapping Methods**

**Abstract**

The Great Lakes is managed collaboratively by the Ontario, Canada and USA governments. Through the Canada Ontario Agreement (COA), the Ontario government has committed to a baseline mapping initiative by providing a high quality spatial ecological inventory for the Great Lakes shoreline. The Great Lakes Shoreline Ecosystem (GLSE) meets this commitment by providing a detailed 1:10,000 scale digital mapping product of the Great Lakes and interconnecting waterways. The study area is a two-kilometer buffer from the shoreline and aims to map all natural and anthropogenic features larger than half a hectare. Mapping extends beyond two kilometers to include wetland features only when they are influenced by Great Lakes water level fluctuations. Digital map production was done in Geographic Information Systems (GIS) software using a multi-data remote interpretive approach, employing a digital stereo (three dimensional) viewing environment when necessary. Manual feature delineation and ecological attribution was completed in GIS following the interpretive cues and decision rules described in the GLSE *Ecosite Keys and Tables* (Lee et. al., in prep.). Data sources include pre-leaf and summer orthophotography, primary field data and other supplementary data for geology, soils, elevation, and vegetation. After primary interpretation was completed, the digital map layer was thoroughly inspected and corrected for both geospatial and interpretive errors. The final output consists of a single geospatial polygon layer with attributes describing detailed ecological information and field data summaries where collected.

**Introduction**

The Ontario government has ongoing collaborative relationships with national (Canada) and international (U.S.) governments aimed at managing our collective Great Lakes resources. The Canada Ontario Agreement (COA) is one example of a focused formal agreement aimed at ensuring the quantity and quality of the Great Lakes and its biota and ecosystems. Under this agreement the Ontario government committed to supporting a baseline habitat mapping initiative aimed at establishing a high quality spatial ecological inventory for the Great Lakes shoreline including aquatic, terrestrial, wetland and anthropogenic features.

The Ontario Ministry of Northern Development, Mines, Natural Resources and Forestry (MNDMNRF) is also currently exploring ways of reducing government red tape and more accurate and precise ecological mapping is one avenue being explored to accomplish this, with the hope an up-to-date inventory of boundaries with greater certainty will allow earlier identification of areas restricted from development and reduce time spent on boundary revision at time of natural resource development application. For example, Ontario’s wetland and natural heritage policies, planning and management are a couple key examples that would benefit from improved mapping.

The MNDMNRF’s Science and Research Branch has built up extensive experience in classification and large-scale mapping of ecologically based communities through implementation of their natural heritage policy and Forest Resource Inventory (FRI) programs. Staff involved in the science and technology delivery elements of these programs have extensive knowledge of, and experience with, Ontario’s Ecological Classification System (ELC) and modern mapping technology such as digital stereo (three dimensional) high resolution aerial imagery, the suite of mapping resources made available by Google and Light Detection And Ranging (LiDAR). This, and their extensive knowledge of available existing supporting ecological data make them well suited to both develop and implement a modern ecological mapping legend and approach.

The Great Lakes Shoreline Ecosystem (GLSE) mapping project was therefore initiated to address the needs described above. This initiative required development of a Great Lakes shoreline focused ecological classification legend, field data collection to support legend development and mapping, interpretation keys and visual aids to guide on the ground and desktop mapping decisions and a technical desktop mapping guide.

**Document Objective**

The main objective of this document is to describe and illustrate the methods employed to develop and implement the GLSE desktop (GIS) mapping process.

**Study Area**

The focus area of this effort includes the entire Great Lakes shoreline from the outlet of the St. Lawrence at the Ontario border to the north-western location at which Lake Superior and the Ontario/U.S. border meet (Figure 1). The shoreline also includes all channels and lakes that connect the Great Lakes. The area also included all aquatic, terrestrial, wetland and anthropogenic features within two kilometers of this shoreline, with landward extents ending at natural feature boundaries and waterward extents ending where aquatic vegetation was no longer observable on any of the remotely sensed image sources consulted. A two kilometer buffer was selected to ensure mapping covered spatial criteria laid out by current provincial wetland policy and therefore relevant for potential future provincial use. Due to the time and resource intensive nature of this work, mapping of all Great Lakes islands, including large islands such as St. Joseph’s and Manitoulin, was not undertaken.



**Figure 1: Imagery map showing the spatial extent, in yellow, of GLSE mapping along with provincial and national administrative boundary lines (in black).**

Inland rivers and streams presented a unique challenge when considering the inland extent of the study area. Ontario provincial policy considered the great lakes shoreline as including all land inland two kilometers or up to the maximum potential influence of seasonal and storm related great lakes water fluctuation. This challenge was addressed by identifying the 100 year maximum above sea level water level elevation, for each of the five Great Lakes and Lake St. Clair, and identifying the location on inland stream and river shorelines at which this height occurred. The Ontario Digital Elevation Model was used to identify this location. Additionally, inland extents were terminated prior to upstream maximum height when anthropogenic barriers, such as dams, or natural barriers such as rapids, were observed on digital aerial photography to occur before, and end after, the respective lakes 100 year maximum height. Table 1 contains all above sea level height observations used for this work.

**Table 1:** All-Time Water Levels for Great Lakes from 1918 to 2018 (source Fisheries and Oceans Canada. Historical Monthly Mean Water Levels in meters referred to IGLD 1985).

|  |  |
| --- | --- |
| Lake | 100-Year Maximum Height Above Sea Level (meters) |
| Ontario | 75.37 |
| Erie | 174.9 |
| St. Clair | 175.85 |
| Huron | 177.29 |
| Superior | 183.73 |

**Methods**

The entire study area was broken up into numerous working study areas to accommodate technical and processing limitations associated with this type of work. The spatial extent of each study area was roughly 352 square kilometers. The study area boundary was created by selecting existing FRI polygon mapping adjacent to a Great Lakes waterbody, converting it to polyline data type. The great lakes shoreline polyline boundary was then buffered by two-kilometers inland and used to select FRI mapping beneath the buffer. The selected features were then exported to a new spatial layer and checked for topological errors.

Data was prepared for the mapping process by dividing the study area into individual blocks for interpreters to complete. A separate file geodatabase was created for each block. Geodatabases contained study area block boundary, an ecosite polygon feature class, a secondary ecosite point feature class, supplementary data, field data, and existing Forest Resources Inventory (FRI) classified polygons. The later was included as a potential source to copy and paste directly into the ecosite layer should interpreters determine a match between the two mapping approaches and decide to start with the FRI feature and modify if necessary. The FRI polygons and classification attributes were modified as needed to meet the GLSE standard. All data was in the projected Coordinate System “NAD 1983 CSRS Ontario MNR Lambert”, a Lambert Conformal Conic projection tailored to Ontario for which areas are best modeled for data covering large provincial extents.

The GLSE mapping product was approached in a developmental nature with an ongoing discussion over a couple years collaboratively developing the ecosite legend, keys and mapping process. Final methods were developed for the mixed wood plains by the middle of 2019 and applied to Lake Erie, Lake Ontario, and Lake Huron/Southern Georgian Bay. The methods for the Ontario shield portion of the shoreline were finalized in fall of 2020.

Supplementary data was used to provide input for nodal decisions to derive ecosite classifications. *Table 1: Supporting interpretation and delineation data sources* lists sources used with a description of how the data was applied. Where nodal decisions required substrate information, soil and geology layers were combined with landform observation as described in *Training Manual for Photo Interpretation of Ecosites in Northwestern Ontario* (Arnup et. al., 1999).

**Table 1: Supporting interpretation and delineation data sources**

|  |  |
| --- | --- |
| **Data Layer Themes** | **Description** |
| Wetland\_Evaluated | **Potential Polygon Features:** A compilation of field calibrated and desktop mapped wetlands as part of an extensive ground based wetland evaluation process.  Quality of mapping varies, various mapping approaches dating back to digitizing from photocopied hard copy air photos.  Review outer boundary using wetland boundary delineation document. |
| SoilSurveyComplex (OMAFRA) | Polygon used to derive general soil texture (loam, sand, silt, clay, organic) and drainage (poor, well, rapid, imperfect) to determine soil texture for ecosite substrate. |
| Northern Ontario Engineering Geology Terrain Survey (NOEGTS) | Near-surface geological conditions, landforms, soil texture and drainage (wet, moist, dry) to determine soil texture for ecosite substrate. |
| QuaternaryGeology 50k (MNDM) | Polygon used to determine mode of deposition (e.g. glacial lacustrine plain) to aid in ecosite moisture regime designation and provide additional organic (i.e. peat/muck) feature mapping |
| PrismSweeps | Georeferenced prism sweep points following the FRI reporting format, used for interpretation calibration. |
| DataCards | GPS locations of GLSE ecosite samples with GLSE ecosite field survey sheets. Attribution for polygons intersecting these points should reflect the information in these samples. |
| Photos | GPS’d ground photos for vegetation identification |
| Plant Community Element Occurrence | **Polygon Features:** Plant Community Element Occurrence polygon mapping rare habitat communities (i.e. savannah’s, prairies, alvars, dunes, wetlands etc). |
| Ontario Parks and Parks Canada ecosite Mapping | **Polygon Features:** Varies by park, polygon mapping attributed with varying levels of detail in ecosite classification ranging from community series down to ecosite, possibly vegetation type. |
| ANSI | **Ecosite Interpretation Aid:** Polygonal information representative of Areas of Natural Scientific Interest.  Detail of report varies but usually contains physiographic description, soils and vegetative descriptions along with a list of vegetation species. |
| Lake Ontario Coastal Wetland Mapping | **Polygon Features:** Contains detailed wetland mapping to GLSE ecosite standard down to community class level for 16 wetlands along the coast of Lake Ontario. |
| SOLRIS | **Ecosite Interpretation Aid:** the Southern Ontario Land Resource Information System is a orthophoto/satellite image/DEM based land cover map with classes reflecting southern Ontario ecosite community series level classes.  Identified unmapped wetlands using radar imagery, soils and topographic moisture models.  Also identifies land use change up to 2010.  Useful for identifying additional potential wetlands sites and cause of recent anthropogenic related ecosite feature loss. |
| Conservation Authority ELC Mapping | **Ecosite Interpretation Aid, Potential Polygon Features:** ELC mapping varies by conservation authority area, polygon mapping attributed with varying levels of detail in ecosite classification ranging from community series down to ecosite. |
| Environment Canada Coastal Sensitivity Mapping | **Ecosite Interpretation Aid:** Line dataset attributed with the geological features (e.g. cliff, bedrock shelving) and substrates (rock, sand, cobble, gravel etc.) for the great lakes shoreline.  Scale is 1:50,000. |
| Forest Resources Inventory (FRI) calibration plots | **Ecosite Interpretation Aid:** Georeferenced 200 meter lines following the FRI reporting format, used for interpretation calibration. |

**Imagery** utilized to interpret the GLSE included SWOOP ortho images, FRI ortho or stereo imagery, Land Information Ontario Imagery (LIO) ortho imagery, LIO Web Imagery, World Imagery, Google Earth and Google Street View. The year of imagery acquisition varied; however the intent was to approximate 2015 lake levels by using multiple imagery products.  Image resolution also varied and the best possible was always used. Imagery was acquired from Ontario GeoHUB <https://geohub.lio.gov.on.ca/search?tags=imagery%20and%20base%20maps> and the best available in a location was used for classification.

An Ecosite Mapping Process for classification was implemented for photo interpreters using a Geographic Information System (GIS) consisting of a computer and GIS software (ESRI ArcMAP 10.3, ESRI ArcMAP 10.6, ArcGIS Pro and Stereo Analyst). The GLSE interpreter delineated and classified on the GIS window with all required imagery and data displayed spatially.

The minimum mapping unit for delineation was 0.5 Ha for this project with all lands classified into terrestrial, wetland, aquatic and anthropogenic ecosites. The study area boundaries spanned inland two kilometers from the Great Lakes shorelines buffer following natural ecosystem features or boundaries. Chains of contiguous wetlands were classified beyond the 2km boundary until they were beyond the vertical influence of Great Lakes level fluctuation. Anthropogenic polygons were clipped at the two-kilometer boundary. Wetlands and islands were mapped into the Great Lakes if contiguous with the shore. Delineation and ecosite attribution were primarily guided by the GLSE *Ecosite Keys and Tables* (Lee et. al., in prep.) which provided guidance regarding separation of substrate type, moisture, wetland type, vegetation cover, tree cover species, hardwood softwood or mixedwood, active versus dynamic shorelines, vertical cliffs and bluffs, and as otherwise defined in the legend.

Further to the documented GLSE legend, additional mapping and attribution methods were incorporated. Wetland features were delineated into open water if vegetation at any depth was visible in the water. If the provided OHN water boundary was observed on the imagery to be more than 10 m from the actual location, then the line work was corrected to reflect the shoreline representative of the imagery used, with the aim of a 2015 baseline. Water bodies more than 10 m wide and greater than 0.5 ha in area were delineated if not otherwise provided. Polygons were considered plantations if the vegetation was managed, in rows and contained greater than 70% of the planted tree species. Plantations were considered naturalized if they contained more than 30% non-planted species. In large urban areas, residential and industrial areas were not separated. In urban or rural areas where green space greater than 0.5 ha is mixed with buildings, parking lots, walkways; the green space is mapped as Anthropogenic Constructed Default. All green spaces associated with medians, right of ways or major intersections are classified as Anthropogenic Transportation and Related Surfaces. Any recently bulldozed areas, that show actual construction of anthropogenic structures beyond 2015, are classified as anthropogenic constructed default. In Ontario Shield, where FRI polygons are available as source data, GLSE polygons are not identified as “provided data” unless FRI calibration plot (field data) was available for that polygon. Secondary ecosites are identified with a point within the polygon.

Traditional air photo interpretation, and more recent orthophoto and digital stereo air photo interpretation, is a process that relies heavily on the skill, knowledge and experience of an individual interpreter. The Ministry of Natural Resources and Forestry’s Forest Resources Inventory (FRI) unit is composed of several staff that have extensive skill, knowledge, and experience with the air photo interpretation process. This group has developed standardized ecosite-based imagery interpretation methods over the last 70 years for forest management purposes, and ecosite classification/attribution over the last 25 years. When provided a project specification and keys for complex classification decisions, such as GLSE ecosites, the FRI unit produces a polygon-based product like previous efforts but with modifications made to align with new delineation and attribution criteria. The methods, techniques, experience and skills of imagery interpretation and classification have been developed through training in identifying landscapes, geology, surficial soils, forest growth patterns, wetlands and ecosites integrated with field mensuration experience to combine imagery to on-the-ground conditions to assign ecosystem classification attributes. This is described in detail in “Training Manual for Photo Interpretation of Ecosites in Northwestern Ontario” (Arnup et. al., 1998). Identification of tree species as needed for nodal decisions in the legend was based on experience, training and supporting literature describing tree species interpretation (Zsilinszky, 1966; Arnup et. al., 1999). These documents, training and experience were relied upon for delineation of the landscape to group conditions into relatively homogenous ecosites to provide a primary ecosite label. Where a secondary ecosite condition exists a vector point is created and classified appropriately.

Where the GLSE production encountered the Forest Resources Inventory (FRI) mapped portion of the province the methodology was adjusted to accept the FRI ecosite based polygons. The FRI was produced using the 2012 Ecosite Land Classification (ELC). The polygon delineation and labels were then modified as needed to meet the GLSE standards. GLSE codes were used for shoreline, rockland and wetland sites and ELC ecosite codes were retained for forested sites.

Lastly, all ecosite mapping was visually quality checked by independent reviewers with extensive ecosite mapping knowledge and skill, using all source material provided to FRI interpreters at the onset of this project. Corrections were made in the ArcMap editing environment using common spatial editing procedures if required. The following is a list of the most common standards compliance issues and the resolution applied:

**Table 2: List describing common standards compliance issues and resolutions**

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| --- | --- |
| **Compliance Issues** | **Resolution** |
| Identification of floating and submerged vegetation | Check existing wetland mapping and historical multi-season and multi-date MNRF and google imagery |
| Correction of open fen confused with meadow marsh | Review of ground conditions where possible (field data, google street view), multi-season imagery to identify saturation due to spring surface water, and false colour composite to highlight presence of moss. |
| Upland confused with wetland | Review of ground conditions where possible (field data, google street view), multi-season imagery to identify saturation due to spring surface water, stereo interpretation, high resolution digital elevation model (LiDAR, orthophoto interpreted with derived break lines) |
| Confusion of active and dynamic shorelines | Review summer colour infrared imagery to confirm presence of vegetation and recode active to dynamic shoreline. |
| Omitted or mis-aligned prairie, cliff, alvar, savannah, or great lakes coastal meadow marsh | Review and align with existing provided Natural Heritage Information Center mapping. |
| Valid ecological features greater than ½ a hectare omitted. | Review data with test shapes representative of ½ a hectare. Split out and attribute, as per methods, all unique ecosites greater than this area. |
| Valid ecological features less than ½ a hectare not captured as secondary ecosites. | Review data with test shapes representative of ½ a hectare. When a unique ecological feature is identified that is less than ½ a hectare, add a secondary ecosite point feature and appropriate attribution. |

Special focus was placed on wetland mapping using “A Guide to Desktop Outer Wetland Boundary Mapping and Standards for Southern Ontario” (Wetland Rapid Evaluation Team, 2013). Full citations for the additional material provided at the onset of the project can be found at the end of this document (Zsilinszky, 1966; Arnup et. al., 1999).

**Citations**

Arnup, R., G.D. Racey and R.E. Whaley. 1999. Training Manual for Photo Interpretation of Ecosites in Northwestern Ontario. Ont. Min. Natur. Resour., Northwest Sci & Technol. Thunder Bay, Ont.. 130 pp.

Wetland Rapid Evaluation Team (WRET). 2013. A Guide to Desktop Outer Wetland Boundary Mapping and Standards for Southern Ontario. Ont. Min. Natur. Resour., Internal report, 70 pp.

Zsilinszky, V. G.. 1966. Photographic Interpretation of Tree Species in Ontario. Department of Lands and Forests, Timber Branch, Second Edition, 86 pp.