On developing an unambiguous peatland classification using fusion of IKONOS and LiDAR DEM terrain derivatives – Victor Project, James Bay Lowlands.

by

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AUTHORS DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

Bogs and fens, which comprise > 90% of the landscape near the De Beers Victor diamond mine, 90 km west of Attawapiskat, ON, provide different hydrological functions in connecting water flow pathways to the regional drainage network. It is essential to define their distribution, area and arrangement to understand the impact of mine dewatering, which is expected to increase groundwater recharge. Classification was achieved by developing a technique that uses IKONOS satellite imagery coupled with LiDAR-derived DEM derivatives to identify peatland classes. A supervised maximum likelihood classification was performed on the 1 m resolution IKONOS Red/Green/Blue without the infrared (RGB) and with the infrared (IR_RGB) band to determine the overall accuracy prior to inclusion of the DEM derivatives. Confusion matrices indicated 62.9% and 65.8% overall accuracy for the RGB and IR_RGB, respectively. Terrain derivatives were computed from the DEM including slope, vertical distance to channel network (VDCN), deviation from mean elevation (DME), percentile (PER) and difference from mean elevation (DiME). These derivatives were computed at a local (15-cell grid size) and meso (250-cell grid size) scale to capture terrain morphology. The mesoscale 250-cell grid analysis produced the most accurate classifications for all derivatives. However, spectral confusion still occurred (regardless of scale) most frequently in the Fen Dense Conifer vs. Bog Dense Conifer classes and also in the Bog Lichen vs. Bog Lichen Conifer. Despite this confusion, by combining the larger scale LiDAR DEM derivatives and the IKONOS imagery it was found that the overall classification accuracy could be improved by 13%. Specifically, the DiME derivative combined with the multispectral IKONOS (IR_RGB) produced an overall accuracy of 76.5%, and increased to 83.7% when Bog Lichen and Bog Lichen Conifer were combined during a post hoc analysis. This classification revealed the landscape composition of the North Granny Creek subwatershed, which is divided into north and south. The north portion comprises 67.4% bog, 13.6% fen and 18.9% water class, while the south is 63.7% bog, 15.2% fen and 21.1% water class. These proportions provide insight into the hydrology of the landscape and are indicative of the storage and conveyance properties of the subwatershed based on the percentage of bog, fen, or open water.

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David Martindale, how could I leave you out of this. You and I are the last two members of "The House" in Waterloo. My education started in a house with you and it finished in a house with you. Thanks for all the great memories buddy and most of all thanks for being a great study partner during all those late nights!!

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Melanie, my university sweetheart, you have been unrelenting in your support, love, and encouragement throughout my tenure at UW. You're my drive to succeed and the most beautiful distraction I've encountered during this thesis. Thank you so much, I love you.

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Jon, last but by no means least. Your guidance and wisdom both as an advisor and as a friend throughout this experience, (especially in the home stretch) will not be forgotten. Like I said to you in the car on the ride home from UWO - a very big part of my motivation to finish was you. You taught me that there's more to being a "master" of something than just the research, it's taking hold of something and doing the best you can and never giving up. Thank you very much.

DEDICATION

I dedicate this thesis to those who doubted me (myself included) and especially to those who supported me (Mom that's you in case you missed it). Most of all I dedicate this to my father who showed me what hard work really means, and taught me that:

"They can take your house, your car, your job.....you can lose everything in the blink of an eye...but, they can never take your education away from you, so learn!"

This one's for you dad.

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1.0 INTRODUCTION

Peatlands cover 3% of Earth`s land surface (Harris & Bryant, 2008) and 12% of Canada's (Tarnocai, 2006), with most peatlands situated in remote, hard to access locations. The dynamic hydrological characteristics of peatlands, where the water table is at, near, or above the surface (NWWG, 1997) can often make field exploration for mapping and landscape classification purposes difficult. Remote Sensing enables the passive and active collection of data in peatlands without direct contact (Jensen, 2005). As early as the 1970's, researchers began with some success mapping and classifying wetlands communities of North America (Work and Gilnmer 1976 in Johnson and Barson 1993). Today remote sensing has developed into a tool that is used to both substitute and compliment the mapping and classification of peatlands that are difficult to access (Toyra & Pietroniro, 2005). Despite technological advancements it would seem that the same problems exist that did 30 years ago, in that two different landscapese can exhibit the same spectral response (Price, 1994; Cracknell, 1998).

Using Landsat MSS (Palylyk, 1987) and Belward et al., (1990) found that peatlands were too spectrally complex and lacked spectral discrimination between vegetation types, making the delineation of specific classes of bog and fen difficult. Features like open water bodies and marshes appear spectrally similar, causing a considerable degree of misclassification (Lee & Shan, 2003). Using Landsat, which collects at a relatively coarse (30 m) resolution, classification to the level observed by ecologists in the field can be nearly impossible, with broad scale regional studies being more realistic (Belward et al., 1990). Selecting a sensor that provides the appropriate resolution and selecting an appropriate classification method is necessary (Jensen, 2005). The sensors available today are abundant, ranging from very coarse broad scale resolution like MODIS (250 m to 1 km resolution depending on the band) to local microscale fine resolution IKONOS (1 m resolution). Despite the availability of data from various sensors, techniques for classification remain the same and the problem of spectral ambiguity continues. The most widely accepted basic methods of classification include: unsupervised, supervised or hybrid approaches which combine unsupervised or supervised (Ozesmi & Bauer, 2002; Jensen, 2005). Other techniques exist such as object oriented (i.e.: image segmentation), whereby the analyst controls the decomposition of the image into homogeneous segments or objects, grouping pixels to form one object (Jensen, 2005). Object oriented image analysis has provided encouraging results in more urban environments (Mathieu & Aryal, 2005). However, in these urban settings the confusion amongst spectrally similar landscapes most often occurred in the ecological or vegetation classes (Mathieu & Aryal, 2005; Mathieu et al., 2007a; Mathieu et al., 2007b). The advantage of using object oriented classification in these urban settings compared to a natural peatland is obvious in that there exists stark contrast (buildings, road edges) in urban settings compared to peatlands, thus conventional classification methods must be explored.

Unsupervised classifications, also known as clustering, can be well suited for use in wetlands that have a high degree of spectral variability, where a classified image can be achieved through the use of a higher number of classes to capture greater spectral variability (Ozesmi & Bauer, 2002). The process, known as "cluster busting", merges similar classes to achieve a final classification. More recently Brown et al., (2007) explored both the unsupervised and supervised classification techniques using Landsat data to classify types of blanket peatlands in Britain. The results confirmed those of earlier studies (Palylyk 1987; Belward et al., 1990) which demonstrated that in both unsupervised or supervised classifications the distinction between specific types of peatlands was difficult with broader scale regional data. Brown et al., (2007) recommends a higher resolution image (<10 m) to help distinguish the different peatland types.

The IKONOS satellite which collects very high spatial and spectral resolution data (panchromatic 0.82 m (B/W) and multispectral 3.2 m (R,G,B,NIR), can been used for peatland classifications (Jensen, 2005). However, the use of satellite imagery alone can produce inaccurate classifications when the spectral properties of different media are not unique (Price, 1994). Adding to this, peatlands are hard to classify because the transition between the different landscape classes (e.g. bog to fen) is not always abrupt, creating areas of spectral mixing or overlap in different landscape types (Belward et al., 1990; Russell et al., 1997; Ozesmi & Bauer, 2002). Peatlands, although typically flat and devoid of large-scale topographical relief (Mitsch & Gosselink, 2000), do have characteristic topography at a variety of scales that cannot be derived from spectral based classifications alone (Anderson et al., 2010). For example microscale hummock and hollow topography, bog and fen pools, surface patterning (broad vs. narrow flarks or ridges in bogs and fens), can all be ignored with large scale spectral based classifications. The fusion of topographical data such as that derived from LiDAR, with standard spectral based classifications improves the thematic distinction of peatland classifications (Anderson et al., 2010). Fusion combines two independent datasets such as IKONOS and LiDAR, to derive more information than if they were used individually (Pohl & Genderen, 1998). The fusion of LiDAR with even broad scale regional multispectral data such as Landsat can improve landcover classifications (Hudak et al., 2002; Bork & Su, 2007). The inclusion of LiDAR with high resolution multispectral IKONOS data can improve the separation of spectrally similar features like water and marsh and reduce misclassification by 50% (Lee & Shan, 2003). Most recently, Anderson et al., (2010) used LiDAR and IKONOS to test the possibility of ecohydrological mapping for an extensive 780 ha raised bog in Cumbria, UK. Results reveal that when LiDAR is combined with IKONOS, the peatland classification accuracy improve from 71.8% to 88.0%, respectively, corroborating earlier studies of Thomas et al., (2003). This recent trend of fusion of LiDAR with standard spectral based classification has proven useful in providing more accurate and detailed landscape classifications (Bork & Su, 2007). Although more recent, and not yet fully explored, the fusion of DEM terrain derivatives with spectral data has provided some promising results. In British Columbia, landslide inventories are monitored by a technique that utilizes the fusion of image segmentation (object oriented) and digital elevation data to identify mass movements (Barlow et al., 2006). In southern Ontario, derivatives are being incorporated into process-oriented ecohydrological modelling of peatlands to understand the influence of mesoscale topography on peatland hydrology and carbon dynamics (Sonnentag et al., 2008). However, the need to explore the capabilities of fusing LiDAR DEM terrain derivatives and high resolution multispectral data for use in classifying northern peatlands exists.

The discovery of a diamondiferous kimberlite pipe in a remote area of the Hudson/James Bay lowland 90 km west of Attawapiskat, Ontario has prompted the development of a diamond mine (Victor Project) within a peatland complex (Figure 1-1). The peatland was mapped during initial baseline studies by the project consultant through airphoto interpretation and ground truthing to produce a digitized (derived from hand drawn) map used for landscape inventory (AMEC, 2004). Classifications are an important tool for effective management but they must be accurate and continually updated or they will become historical (Johnston & Barson, 1993). In 2007, the University of Waterloo instrumented a complex assortment of peatland and non-peatland landscapes at this site. A classification of the peatland types is needed to determine how representative this area is compared to the regional peatland complex, and as a mapping tool essential to understanding the hydrological linkages in the landscape and patterns of peatland development.

Field investigation, air photos, and satellite imagery have identified that the area of interest around the Victor Mine is at the broadest level divided into ombrotrophic bogs and minerotrophic fens. These classes of wetland can be further subdivided into forms and then into types according to The Canadian Wetland Classification System (NWWG, 1997). Form and type are scale sensitive meaning they are dependant upon the scale at which the wetland is studied, and the level of detail required when classifying a wetland (Zoltai & Vitt, 1995). High resolution optical sensors like IKONOS which capture at 1m and 4m (more detail) are ideal for capturing both broad and microscale features of a landscape (Toyra & Pietroniro, 2005). Today there exists a multitude of satellite sensors available so that user defined preferences can allow for best suited spatial and spectral levels (Toyra & Pietroniro, 2005) to better explore the area of study.

The underlying goal of this research will be to combine field based knowledge of a peatland complex with remotely sensed LiDAR, and IKONOS data to work towards an unambiguous peatland landscape classification. The specific objectives are: 1) Develop a technique to improve spectral based landscape classifications of patterned peatlands in the Hudson/James Bay peatland complex by fusing IKONOS and LiDAR elevation terrain derivatives; 2) Classify the distribution and arrangement of peatlands in the North Granny Creek watershed a first-order sub-watershed of the Attawapiskat River); and 3) Identify the topographic characteristics of peatland forms within and between wetland classes.

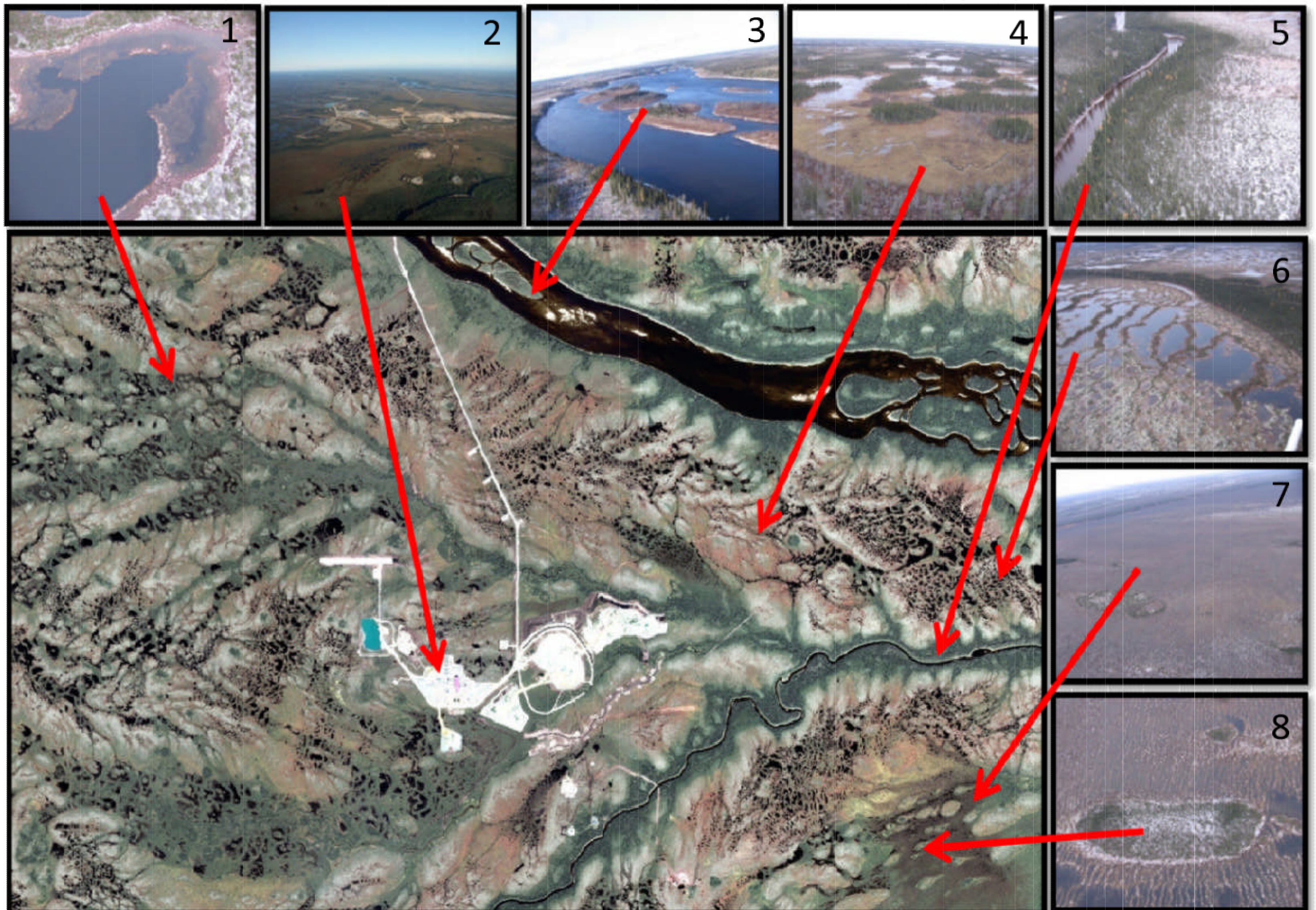


Figure 1-1 – Various Landscape types in a northern Ontario Peatland Complex (Top Left to Bottom Right)**:** 1.Open water with floating fen mat; 2. Victor Mine; 3. Bedrock Outcrop Islands of the Attawapiskat River; 4.Bog and fen complex; 5. Riparian Transition preceded by treed open bog; 6. Northern Ribbed Fen with broad flarks; 7. Large Northern Ribbed Fen with tear drop bogs ; 8. Tear Drop bog surrounded by northern ribbed fen.

2.0 STUDY SITE

The Victor Mine is situated in the James Bay lowland, 90 km west of Attawapiskat in the Nayshkootayaow River Watershed (2988992E 5858451N), a tributary of the Attawapiskat River (Figure 2-1). The area experiences long winters that typically last from October to late April, and short summers. Annual precipitation is approximately 680 to 720 mm per year (MOE 2010, AMEC 2004). Regional soils consist of thick deposits of marine clay and clay till that are overlain by peat deposits; averaging approximately 2 m in thickness, and are situated upon a locally karstic Silurian limestone aquifer known as the Attawapiskat formation (AMEC, 2004). The groundwater table is at near or above the surface in most areas and is associated with development of a patterned peatland complex with an array of bogs and fens. Minerotrophic fens (ribbed, riparian, ladder, etc.) are topographically low-lying, and typically portray directional seepage and/or convey water (NWWG, 1997; Mitch and Gosselink 2000; Quinton et al., 2003). Ombrotrophic bogs (domed, mound, flat) are marginally raised in elevation above the fens, thus receive precipitation as their sole source of water and act as water storage and release features (Sjörs, 1959; NWWG, 1997). Limestone bedrock outcrops (bioherms) exist sporadically around the landscape. Bioherms are ancient coral reef deposits that are round to irregular domed features (treed or untreed) that can rise up to 5 m metres out of the muskeg (Cowell, 1983; Figure 2-2). Palsas, which are ice-cored mounds (Seppala, 1986) similar in size, height and sometimes in vegetation cover to bioherms, also occur sporadically in the landscape. Bogs and fens occupy > 90% of the landscape (Tarnocai, 1998).

Two bioherms straddle the eastern margin of the North Granny Creek (NCG) subwatershed demarcating the start (south bioherm) and the end (north bioherm) of a research transect bisecting an array of peatland types (Figure 2-2). The transect shown in Figure 2-2 is where detailed hydrological measurements are being made as part of another study, and where detailed ground-truthing has been done for this research. The centre point of the transect is intersected by the easternmost edge of a domed bog. This domed bog is the watershed divide between the North-North Granny Creek (NNGC) and South-North Granny Creek (SNGC). NNGC and SNGC converge at Granny Creek, a small channel 1-2 m in width, <1 m deep with an average flow rate of ~20,000 m^3/day. Granny Creek meanders southeast (outside the NGC subwatershed) into the Nayshkootayaow River (~1,000,000 m^3/day), which flows into the Attawapiskat River (~50,000,000 m^3/day) and finally into James Bay. The NGC subwatershed is situated between the Attawapiskat River to the north and the Nayshkootayaow River to the south. The Victor Mine is located southeast of the NGC subwatershed, with the open pit mine for the project located immediately to the south (Figure 2-1).

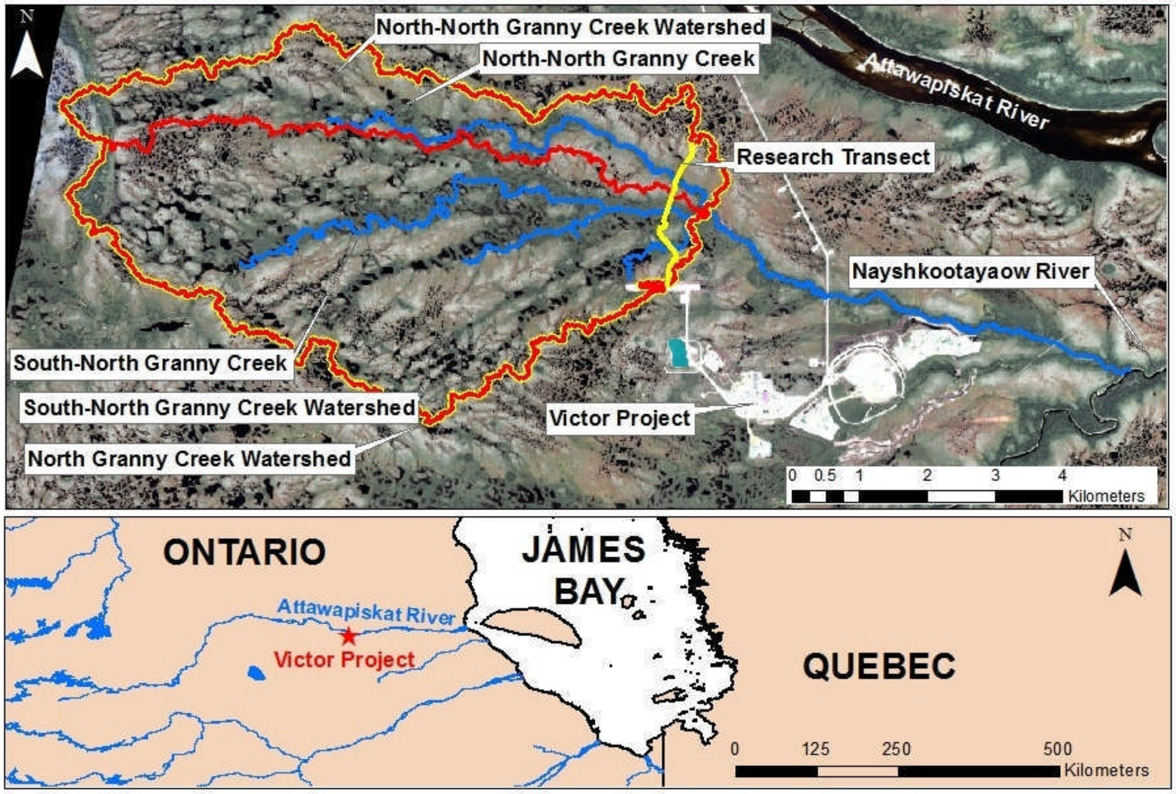


Figure 2-1 – North Granny Creek subwatershed located ~2km northwest of the Victor Project. Centroid Coordinates for the NGC: E298696 N5858884.

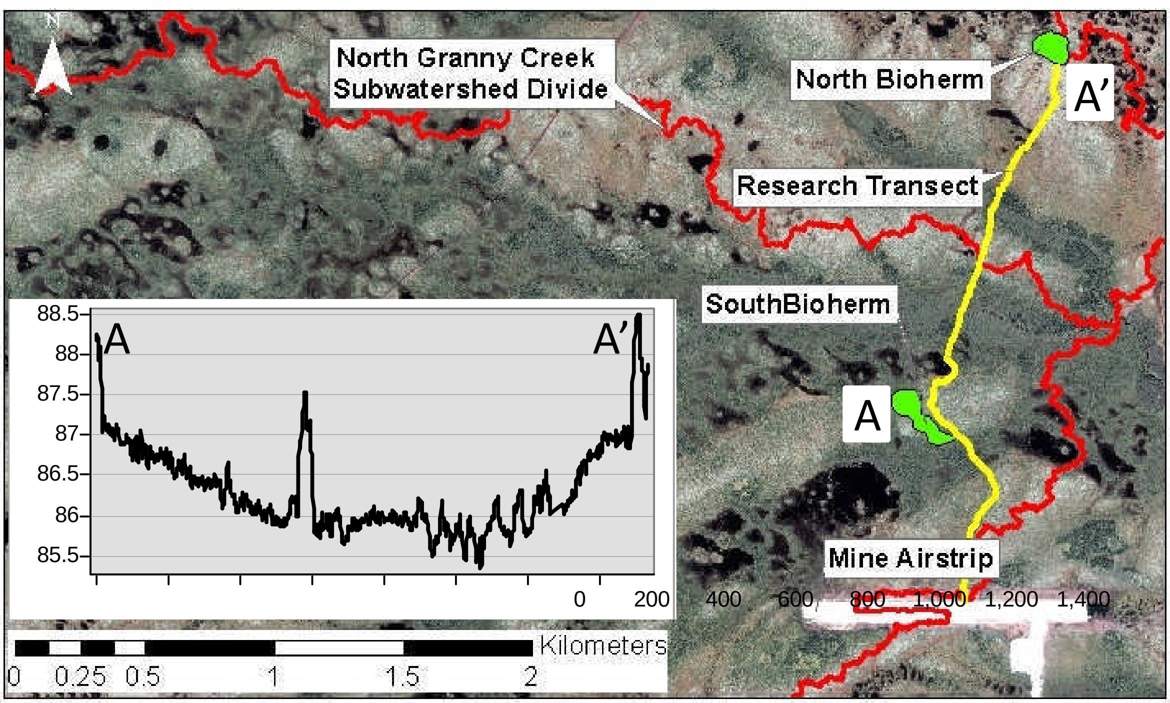


Figure 2-2: The Research study transect (yellow), with the North and South bioherms. Profile A to A' reveals the topography from the south to north bioherm along the yellow study transect.

3.0 METHODS

3.1 LiDAR Data Processing and Terrain Derivatives

The multispectral data used for this research was an August 2008 scene from Geoeye IKONOS®. The IKONOS data were provided in panchromatic 0.82 m, multispectral 3.2 m (IR/R/G/B) and a multispectral pansharpened 0.82 m true colour composite for visual purposes. The LiDAR data were from a 462 km^2 discrete-return airborne survey, conducted in July 2007 by Terrapoint Canada Inc. to produce a digital elevation model (DEM). Laser pulse returns were classified into bare-earth and vegetation classes by the LiDAR contractor and delivered as tiled, xyz ASCII files. A 1 m and 2.5 m pixel resolution DEM was interpolated from the classified bare earth returns using an inverse distance weighted (IDW) interpolator with a low weighting exponent (0.5), using a maximum of 4 neighbouring points. An accuracy assessment was conducted along the research transect using a Topcon HiPER GL RTK GPS system. The root mean square error (RMSE) was determined to be 4.5 cm (vertical accuracy) for surveyed versus LiDAR-derived elevations interpolated to 1m and 2.5 m grid spacing using the same parameters listed above. The LiDAR data were imported into SAGA, and clipped to the NGC watershed (watershed delineation and clipping discussed below). The LiDAR data were "gap filled" to remove depressions or sinks using the method of Wang and Liu (2006). This was necessary where LiDAR data were unavailable such as for open water, as a result of the laser pulse being absorbed into media. The DEM was finally smoothed three times using a Gaussian filter to remove the noise from the LiDAR (Figure 3-1). Further details regarding the IKONOS and LiDAR are provided in Table 3-1below.

Table 3-1: LiDAR data in nature are geometric range measurements, while IKONOS imagery records on a spectral level, spectral reflectance of the ground.

IKONOS	LiDAR
• Spectral resolution—4 bands (Near IR/R/G/B), 11 bits/pixel; • Spatial resolution—4 meters × 4 meters/pixel (trimmed to 2521 × 2028 pixels); • Preprocessing from Space Imaging, Inc.—Standard Geometrically Corrected, Mosaicked; • Horizontal positional accuracy (root mean square	• Spatial resolution (cell size)—3 m x 3m; •Horizontal positional accuracy—The ATM(Airborne Topographic Mapper) LiDAR elevation points are known to be horizontally accurate to +/− 0.8 m at an aircraft altitude of 700 m; • The ATM LiDAR elevation measurements have been found to be within+/−15 cm of each other in

error)—25 meters; and • Map projection—UTM Zone 18, WGS-84.	successive and overlapping passes of the same area; • Map projection—UTM Zone 18, WGS-84; and • Elevation reference—The vertical values in this data set have been converted to reference NGVD29, using the VERTCON software provided by the National Geodetic Survey.

Watershed Delineation

The watershed delineation was executed by Murray Richardson (2009) at Carleton University using SAGA. The previously discussed depression filling was necessary for this step so that a continuous topographic flow-routing is required for stream and watershed delineations. Digital stream networks were first derived from the LiDAR DEM using a deterministic-8 (single-flow direction- O'Callaghan and Mark 1984) algorithm in SAGA. Contributing area grids (CA) were computed using the parallel processing function in SAGA, and virtual stream segments were extracted using the channel network model by iteratively thresholding the CA grid with different initiation values and minimum segment lengths. The resulting stream network in the NGC subwatershed was compared to stream networks extracted from a 2008, 1.5m resolution IKONOS satellite image by manual interpretation and on-screen digitization (Figure 3-2). The resulting DEM was used to compute upslope contributing areas for the NNGC and the SNGC subwatershed.

Data Processing

In October of 2009, a field-based, ground-verification campaign was conducted, where predetermined locations of interest were visited and vegetation communities were characterized, providing a basis for the supervised classifications. Ten representative sites, including the research study transect were investigated, both within and outside the NGC subwatershed (Appendix A; Table 3-2). Using similar methods to those of earlier studies (Palyak, 1987; Belward et al., 1990; Ozesmi & Bauer, 2002; Brown et al., 2007) unsupervised and supervised classifications were carried out. Unsupervised (ISODATA) classification were conducted on a pansharpened 1 x 1 m pixel size August 2008 cloud free scene, in both ARC and SAGA. Different sample cluster sizing was explored at 3, 7, 12 and 20 group sample sizes, each with cluster busting. Supervised (maximum likelihood) classifications were executed next using the field data collected in 2009 (prior site visit knowledge also available) to produce a training data and a validation data set used for classification (Figure 3-3). In addition, a final training data set for the “water class” landscape unit was produced so that this landscape unit was masked and removed prior to any supervised classifications. The “water class” included open water and shallow pools. Shallow pools were typically shallow water with emergent sedge grass protruding from the surface of the water.

Table 3-2: Locations used as ground truthing locations, based on initial IKONOS image analysis.

Location	Easting	Northing	Class	Type	MASL	Qualitative Description
MS-1	313721	5862545	Bog	Domed	77.36	Contains abundance of lichen moss, ericacae shrubs, and trees and is raised 1.0 m above surrounding terrain. Surrounded by bioherms possibly palsas.
MS-7	299181	5862439	Bog	Domed	90.63	Relatively large domed bog part of a larger bog fen complex. Elevated only slightly above surrounding terrain.
MS-9-1	299199	5848134	Bog	Domed	91.22	Contains abundance of lichen moss, ericacae shrubs, and is raised 0.5 m above surrounding terrain. In an area where bioherms are present.
MS-9-2	308714	5847841	Bog	Domed	86.10	Contains abundance of lichen moss, ericacae shrubs, and trees and is raised 1.5 m above surrounding terrain.
MS-13	275894	5862882	Bog	Domed	n/a	Untreed bog, with concentric ring of trees at the exterior. No trees on the interior. Drops slightly in elevation and into open treed Bog.
MS-15	285217	5845425	Bog	Domed	n/a	Relatively large domed bog part contains directional flow paths which indicate surface drainage. Elevated only slightly above surrounding terrain.
Other 1	311688	5852695	Fen	Northern Ribbed	80.39	Large expanse of northern ribbed fen, with narrow parallel rides of tamarack and pool sequence. Tear-drop bogs dispersed intermittently amongst landscape.
Other 2	296066	5854495	Bog /Fen	LiDAR n/a	93.15	Landscape is mottled with bog and fen type landforms. Likely remnant flat bog. Contains large open pools of water.
Other 3	300716	5854195	Fen	Channel	88.29	Developed channel fen with ridges of tall standing conifers which are perched 1m above surrounding flowpaths.
Other 4	305066	5859510	Bog/ Fen	Channel Fen / Domed bog	84.29	Area of poorly developed fen intermixed with smaller areas of bog. Sequence of pools dictating direction of flow.

Prior to any supervised, classifications the training data in conjunction with the DEM was used to statistically evaluate how different terrain derivatives would improve classification results through fusion. The DEM landscape derivatives listed in Table 3-3 were each computed in SAGA and exported as an ASCII file into ARC GIS. In ARC GIS each derivative was converted to a raster and a signature file for each derivative was created from the training data classes created. The signature file was used to compute statistics for each derivative, whereby the area, min, max, range, mean, standard deviation and sum were calculated for individual classes of the training data.

Table 3-3: DEM Terrain Derivatives executed in SAGA.

Derivatives	Scale (metres)	Definition	SAGA Method
Slope	1,5,10,15	Slope measures the rate of change of elevation in the direction of the steepest decent (Wilson & Gallant, 2000).	Zevenbergen & Thorne 1987.
Aspect	1,5,10,15	The steepest downslope direction from each cell to its neighbours. Often thought of as slope direction or the compass direction a hill faces (ARC GIS, 2010).	Zevenbergen & Thorne 1987.
Curvature	1,5,10,15	Defined as a curvature tool that is a second derivative of the surface—for example, the slope of the slope. I.e. Curvature can be used to describe the physical characteristics of a drainage basin (ARC GIS, 2010).	Zevenbergen & Thorne 1987.
Difference from Mean Elevation	15,70,250	DiME is the difference between the elevation at the centre of the window and the mean elevation in the window, which is a measure of relative topographic position of the central point (Wilson & Gallant, 2000).	"Residual Analysis Function " Conrad, 2002.
Deviation from Mean Elevation	15,70,250	Deviation from the mean is the difference from the mean divided by the standard deviation, providing a measure of the relative topographic position as a fraction of the local relief and is measured from -1 to +1 (Wilson & Gallant, 2000).	"Residual Analysis Function " Conrad, 2002.
Percentile	15,70,250	Percentile is the ranking of the pixel at the center of the analysis window relative to all other pixel values in that window. It is calculated by counting the number of pixels lower than the central pixel and returning this value as a percentage (Wilson & Gallant, 2000).	"Residual Analysis Function " Conrad, 2002.
Vertical Distance to Channel Network	2.5	This derivative provides a resulting grid that identifies the altitude above the channel network in the same units as the data provided (i.e. MASL; Conrad, 2002 in SAGA).	"Terrain Analysis/ Channels Function" Conrad 2002.

Next, the supervised classifications were carried out. These classifications were carried out using the statistical data derived to identify which derivatives produced the most separability amongst the different classes. A composite image was created in ARC including the R,G,B,NIR plus any derivatives which were spectrally unique (had the highest degree of separability amongst classes), and a MLC was run to produce a landscape classification. To assess the accuracy of the classification, the polygon validation data layer was converted to a raster. From this raster, 750 pixels from each validation polygon delineated were randomly selected in ARC. The sample function in ARC is used to extract these pixels (randomly identified in the validation data) from the classified image, whereby the data is then reported in table format as a .csv file. The .csv file is opened in R (a program for statistical analysis), and the con function is used to produce the confusion matrix that identifies the classes that are being confused in the classification. For a complete layout of the work flow of the data and analysis performed, please see Figure 3-4.

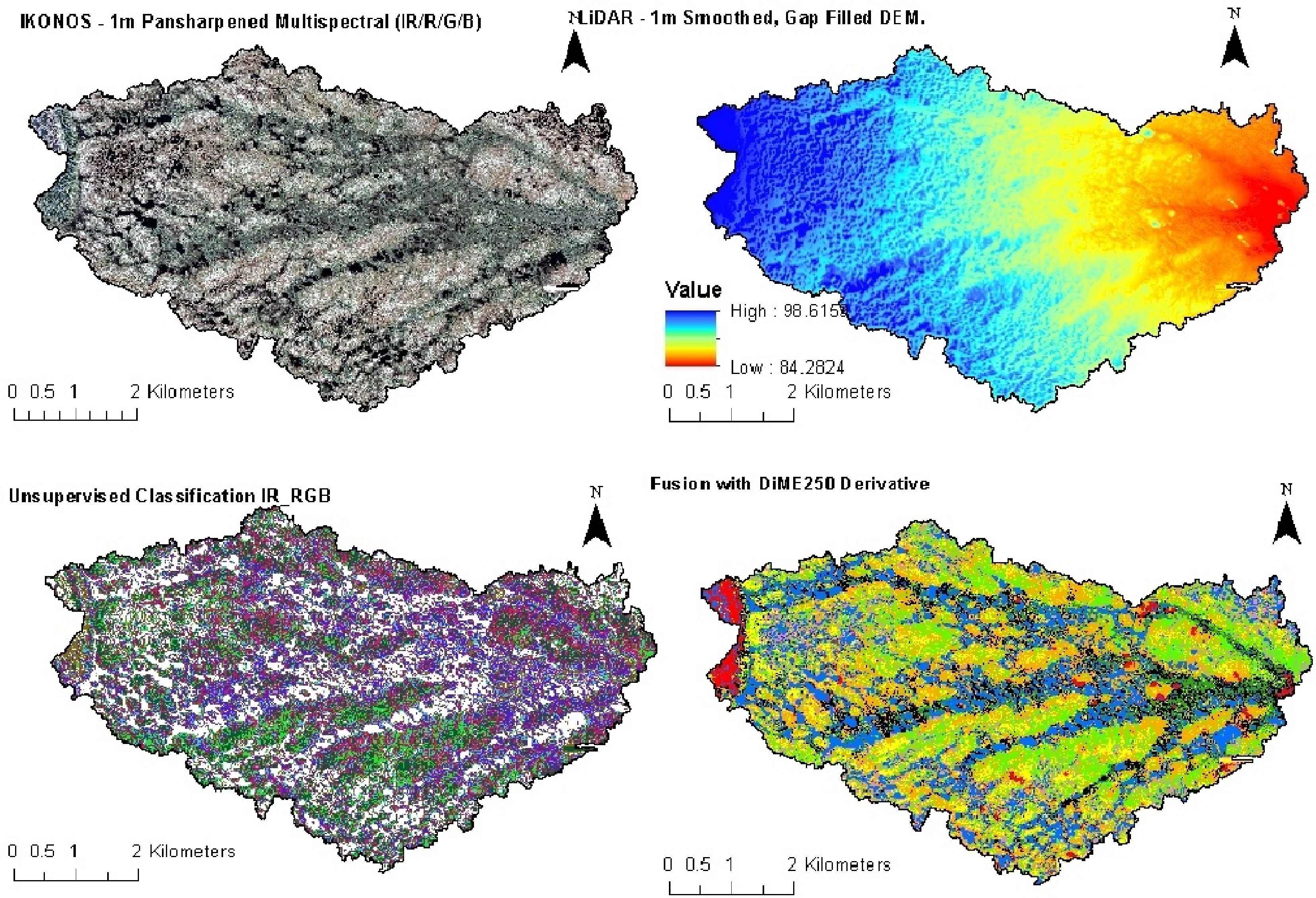


Figure 3-1: North Granny Creek Sub-watershed clip with general process layout layout.

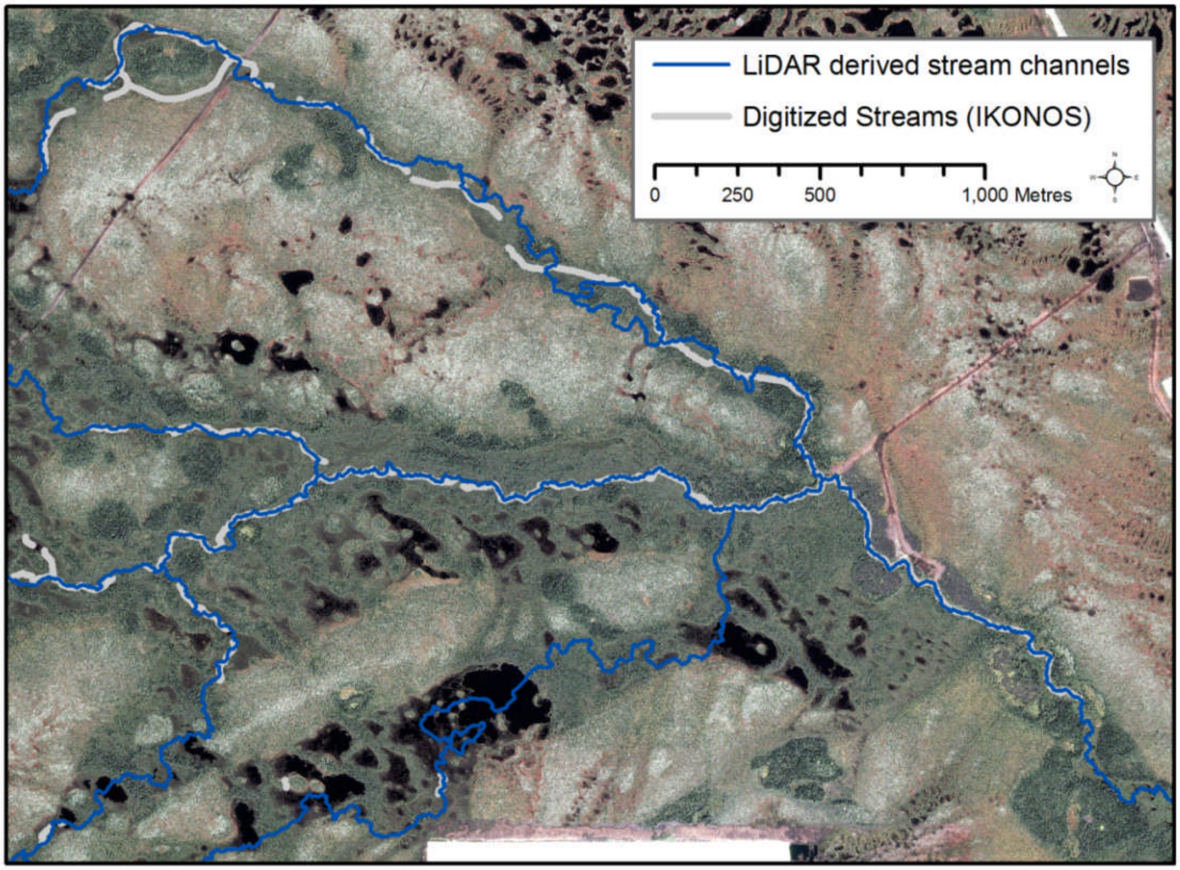
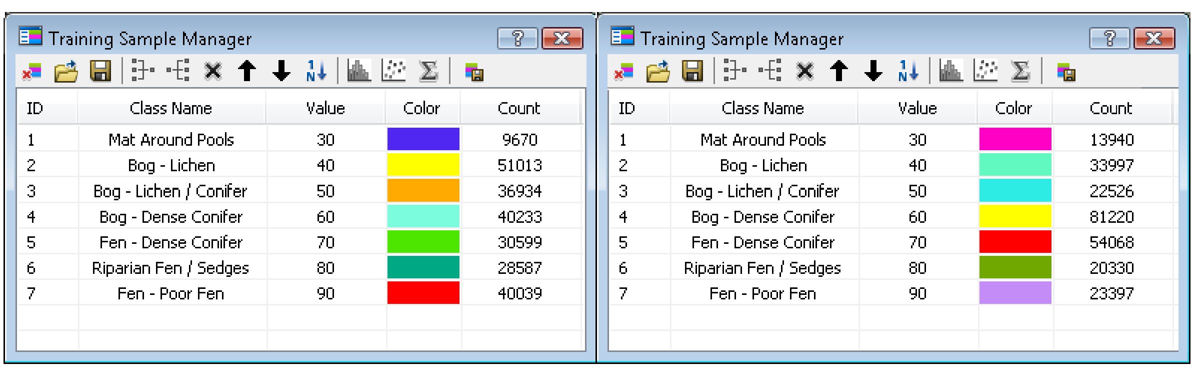


Figure 3-2: Digitized (light grey) versus LiDAR-derived virtual stream network (blue) for North Granny Creek watershed and nested sub-watersheds. Only stream segments visible in the 1.5 resolution IKONOS imagery were digitized for comparison with the LiDAR-derived network, and many additional stream segments were observed during field surveys (Richardson, 2009).



Training Sample Manager

ID	Class Name	Value	Color	Count
1	Mat Around Pools	30		9670
2	Bog - Lichen	40		51013
3	Bog - Lichen / Conifer	50		36934
4	Bog - Dense Conifer	60		40233
5	Fen - Dense Conifer	70		30599
6	Riparian Fen / Sedges	80		28587
7	Fen - Poor Fen	90		40039

Training Sample Manager

ID	Class Name	Value	Color	Count
1	Mat Around Pools	30		13940
2	Bog - Lichen	40		33997
3	Bog - Lichen / Conifer	50		22526
4	Bog - Dense Conifer	60		81220
5	Fen - Dense Conifer	70		54068
6	Riparian Fen / Sedges	80		20330
7	Fen - Poor Fen	90		23397

Figure 3-3: Left - Training Data; Right - Validation Data. Each class containing no less than 10 polygons for training.

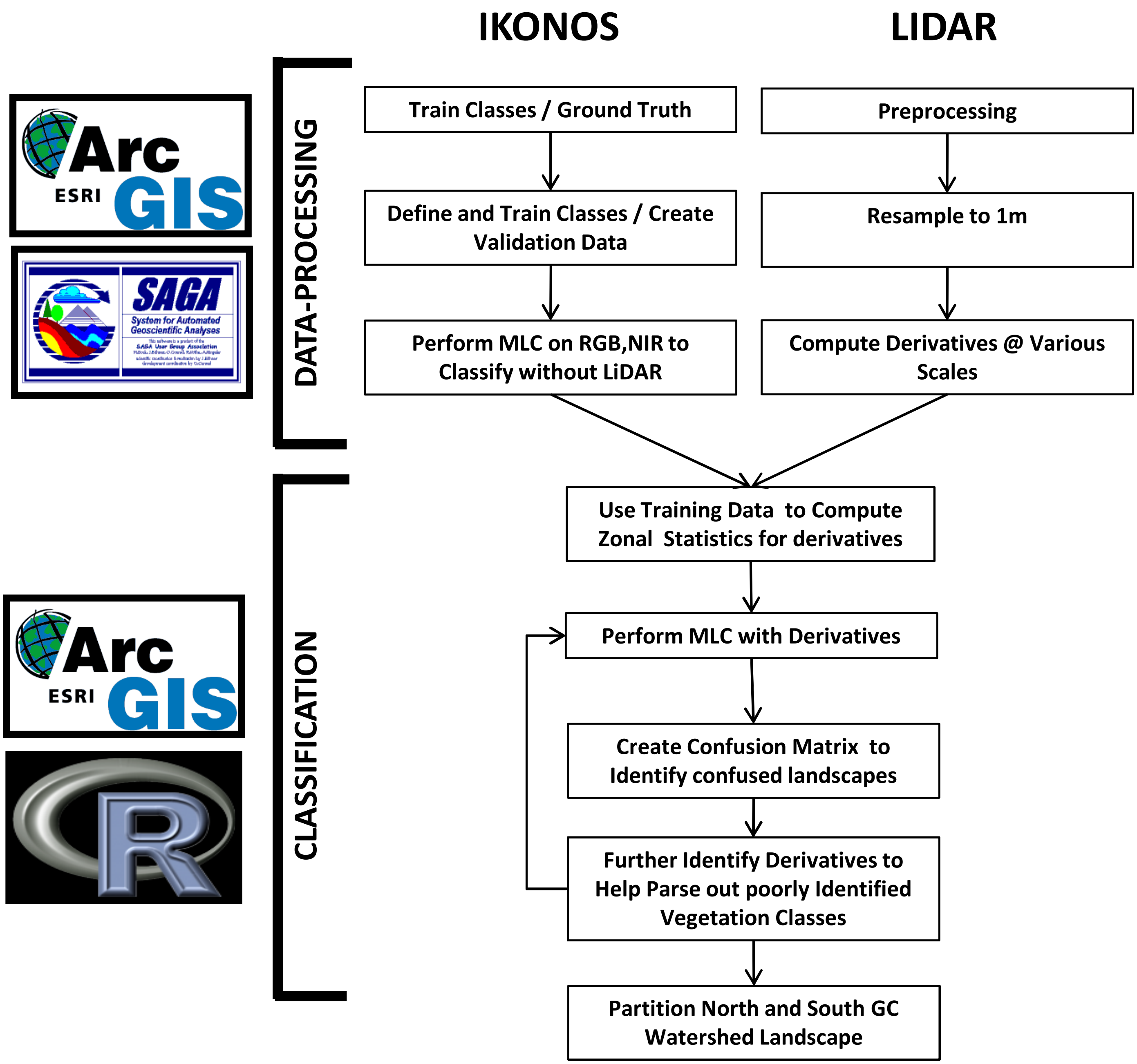


Figure 3-4: Work Flow for Data Processing.

4.0 RESULTS

The following sections will make reference to different landscape units or derivatives as per the following reference key:

Landscape Unit	Abbreviated Class Code
Mat Around Pools	MAP
Bog – Lichen	BL
Bog – Lichen / Conifer	BLC
Bog – Dense Conifer	BDC
Fen – Dense Conifer	FDC
Fen – Riparian Fen / Sedges	RFS
Fen – Poor / Fen	FPF

Derivative / Band	Abbreviation
DME	Deviation from Mean Elevation
DiME	Difference from Mean Elevation
PER	Percentile
SLP	Slope
VDCN	Vertical Distance to Channel Network
IR_RGB	Infrared, Red, Green, Blue Band of IKONOS
RGB	Red, Green, Blue band of IKONOS

4.1 Spectral Based Unsupervised Classifications

Unsupervised classifications were executed in ARC GIS with 3, 7, 12 and 20 clusters sizes for RGB and IR_RGB. The computer is required to group pixels with similar spectral characteristics into unique clusters, whereby the analyst then relabels and or combines the spectral clusters into information or landscape classes (Jensen, 2006). The 7-class cluster for both IR_RGB and RGB typically yielded a classification that was visually most agreeable with the IKONOS true colour composite. Misclassification still occurred where Riparian Fen Sedge (RFS) and Fen Poor Fen (FPF) exist. These areas of low relief throughout the stream networks appear spectrally different in the true colour composite but after a unsupervised classification become hard to separate. Figure 4-1 reveals that for both the IR_RGB and the RGB analysis there was a general confusion amongst Bog Dense Conifer (BDC) and Fen Dense Conifer (FDC), which was also confused with the RFS. Bog Lichen (BL), typically at the higher elevations in the bogs, was better separated when the near infrared band of the IKONOS was included for the 7-class cluster analysis. Overall, the addition of the IR band visually improved the results of the unsupervised classification, although misclassification still occurred. For example, pixels that were found adjacent to or surrounded by lighter coloured lichen moss were grouped under a different landscape designation. In some instances this may be a small water feature, some ericacae cover or a small tamarack. As a result, resampling resulted in a further degraded classification.

Resampling to group similar landscape units, as recommended for the larger 12 and 20 cluster sizes (Ozesmi & Bauer, 2002), was also explored with the IR_RGB. Results were similar to those of the smaller unsupervised classification at the 7 class size. The larger 12 and 20 class sizes did not resolve the spectral mixing or salt and pepper effect of the classifications. Pixels were classified as one vegetation class regardless of their location in a bog or fen, even though they are two distinctly different landscapes. For example, areas of dense conifer in the fens (FDC) contained a large proportion of other landscape vegetation / landscape types which were found in bogs and fens throughout the NGC watershed. Figure 4-2 reveals the spectral confusion and difficulty of using high resolution multispectral data for classifying patterned peatlands. The colour range of pixels in a small area can be found in abundance throughout the landscape. Cluster busting for both IR_RGB and RGB only confused the classification more, as it was near impossible to separate out or group pixels of similar classes. Grouping similar pixels perceived to be similar landscape units confused the classification because of the amount of spectral overlap in classes.

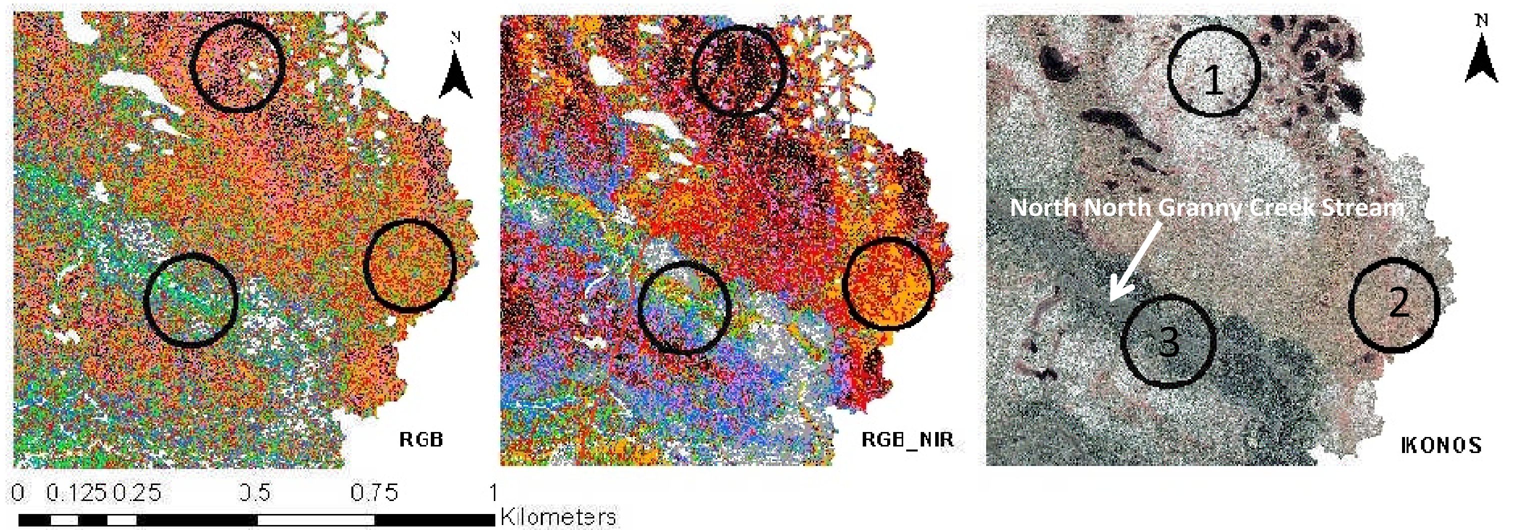


Figure 4-1: Unsupervised 7 Class with RGB (Left), IR_RGB (Centre) and True Colour Composite (Right) on the easternmost margin of the NGC subwatershed. Spectral confusion and overlap between landscape classes is shown in the areas circled above. Areas that appear spectrally unique in the IKONOS image on the right do not translate accordingly in the unsupervised classification. The addition of the IR band (centre image) reduces some of the "salt and pepper" effect of the unsupervised classification – but does not improve the spectral confusion of the classification. Circle 1: Bog Lichen Area; Circle2: Fen Poor Fen located on a Bog; Circle3: Riparian Fen Sedge and Dense Conifer.

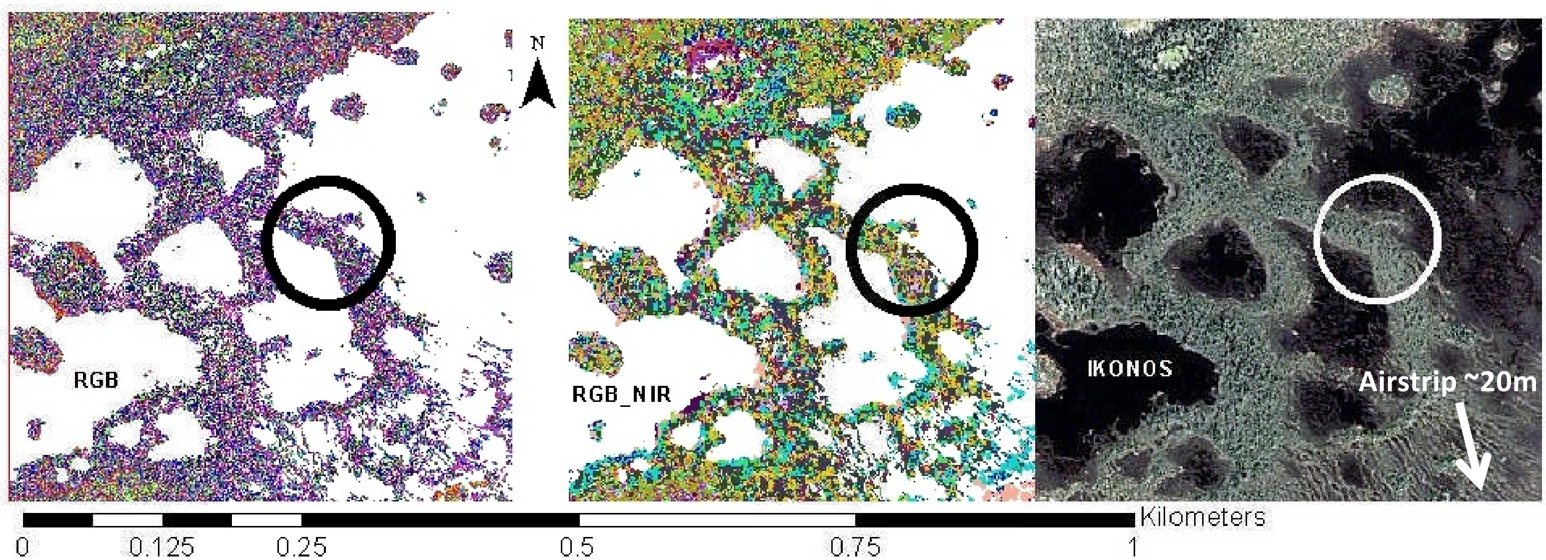


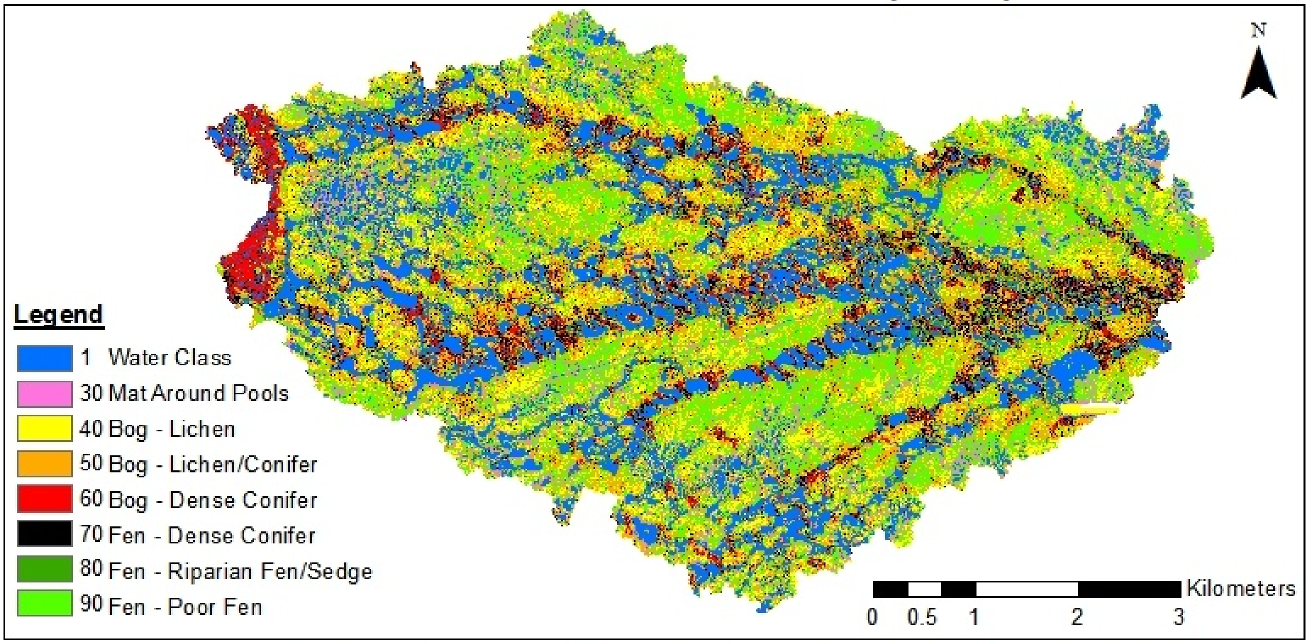
Figure 4-2: Fen Dense Conifer Spectral mixing with 12 class unsupervised cluster analysis immediately north of the Airstrip. The addition of the IR band to the unsupervised classification (centre) does not show any particular improvement over the RGB (left) 12 class cluster. The increase in cluster size only further complicates the classification efforts because of the degree of spectral variability in peatlands. Circle indicates and area of Fen Dens Conifer.

4.2 Spectral Based Supervised Classifications

RGB and the IR_RGB maximum likelihood classifications (MLC) provided for qualitative and quantitative representation superior to that of the unsupervised classifications. This can be assessed with confusion matrices, which are a means to identify the user's (rows) and producer's (columns) accuracy of the classification executed based on a selected sample size and validation data for each landscape unit identified. The vertical columns represent the validation data provided, while the rows indicate the accuracy of the classification generated from the data provided (Congalton, 1991). The overall accuracy is assessed by the sum of all the diagonals (top left to bottom right) divided by the total sample size. The confusion matrix produced for the RGB revealed an overall accuracy of 62.9% (Figure 4-3). Landscape classes MAP, RFS, and FPF were well separated and least confused amongst other classes as revealed by the higher users and producers accuracies shown in Figure 4-3. The remaining classes of BLC, BDC, and FDC all experienced confusion, with users and producers accuracies lower than 50%. The addition of the IR band increased the overall accuracy of the classification to 65.8% (Figure 4-4). As a result the users accuracy for all landscape units increased, except for the MAP class where the users accuracy decreased by only 1%. The producers accuracy for MAP, BLC and BDC all increased while for BL, FDC, RFS and FPF there was a decrease in accuracy with the addition of the IR band.

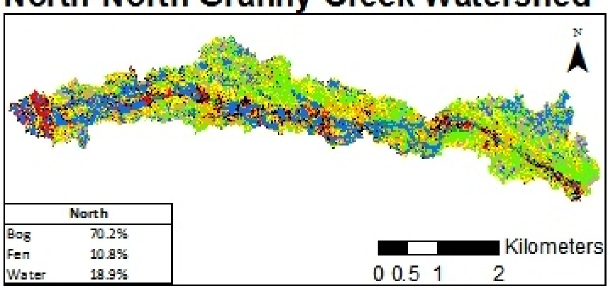
The landscape units for both supervised classifications with and without the IR band experienced similar confusion. This confusion typically occurred in the same landscape classes for both IR_RGB and the RGB alone, as expressed by the relatively similar user and producers accuracy for both tables shown in Figure 4-3 and Figure 4-4. There is however, a slight improvement in both the users and producers accuracy of BLC and BDC for the IR_RGB classification which contributed to the increased overall accuracy of the IR_RGB classification (Figure 4-4). FDC (in both classifications) above all other classes yielded the poorest results with confusion most amongst other classes with most confusion found in BL, BLC and RSF. The landscape unit MAP experienced least amount of confusion compared to all other classes with >96% percent users and producers accuracy for both RGB and IR_RGB classifications. FPF also exhibited a high degree of separation with >80% in both users and producers accuracy for both classification. Overall the importance of including the infrared band in the classification is evident as the increase in accuracy is obvious.

SUPERVISED CLASSIFICATION (MLC): RGB

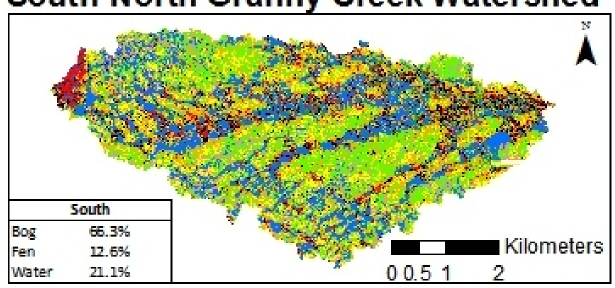


RGB	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	62.9%
30 - Mat Around Pools	**697**	1	0	0	0	0	11	98.31%
40 - Bog - Lichen	0	**525**	261	30	15	0	38	60.41%
50 - Bog - Lichen / Conifer	0	137	**366**	60	106	164	76	40.26%
60 - Bog - Dense Conifer	0	15	33	**316**	280	25	0	47.23%
70 - Fen - Dense Conifer	0	8	3	237	**262**	65	1	45.49%
80 - Riparian Fen / Sedges	0	6	16	16	35	**264**	6	76.97%
90 - Fen - Poor Fen	30	55	64	1	0	1	**613**	80.24%
	95.87%	70.28%	49.26%	47.88%	37.54%	50.87%	82.28%	

North-North Granny Creek Watershed



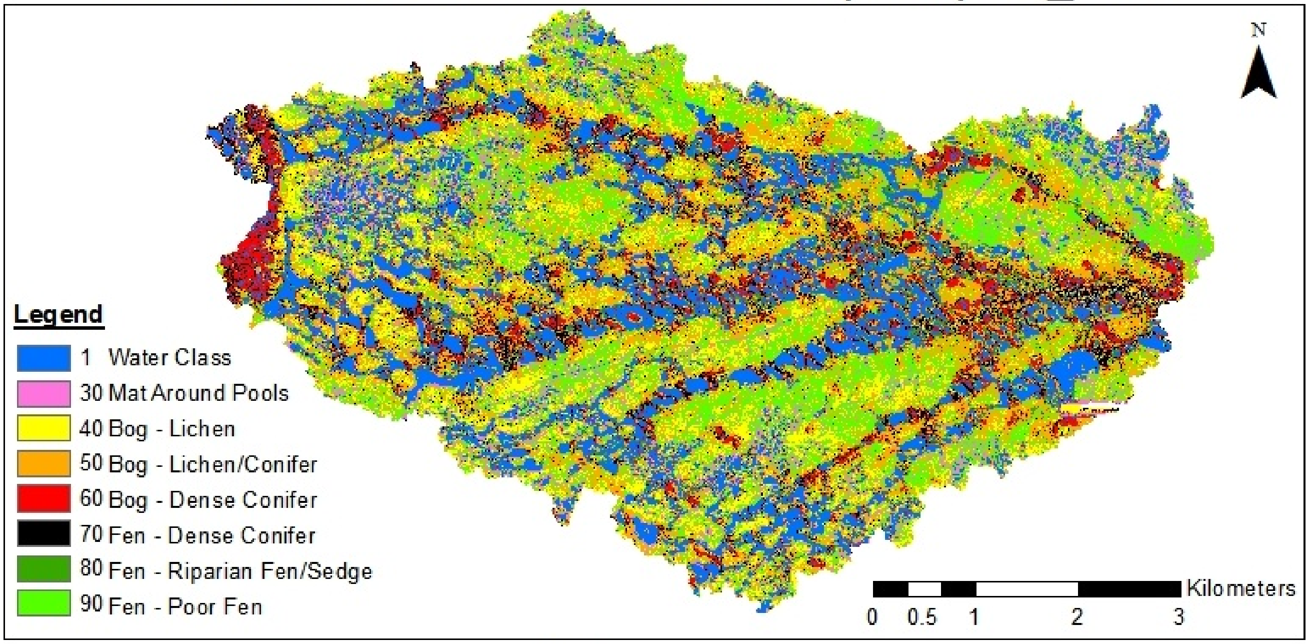
South-North Granny Creek Watershed



Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	490682	1047183	1,537,865	4.47%
40 - Bog - Lichen	1323117	3353226	4,676,343	13.58%
50 - Bog - Lichen / Conifer	1963084	5582995	7,546,079	21.92%
60 - Bog - Dense Conifer	513292	1519340	2,032,632	5.90%
70 - Fen - Dense Conifer	492820	1543452	2,036,272	5.92%
80 - Riparian Fen / Sedges	533818	1600805	2,134,623	6.20%
90 - Fen - Poor Fen	2356994	5049966	7,406,960	21.52%
Total	**9,465,556**	**24,958,052**	**34,423,608**	**100.00%**

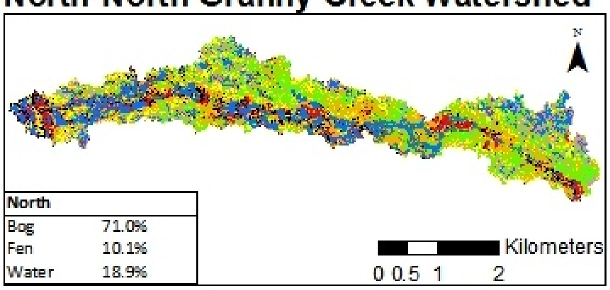
Figure 4-3: Maximum Likelihood Classification without the use of derivatives., and without the use of Infrared. Cells highlighted outside the diagonals (orange) in the confusion matrix indicate those landscape units that were misclassified greater than 10% of the time for that specific landscape unit.

SUPERVISED CLASSIFICATION (MLC): IR_RGB

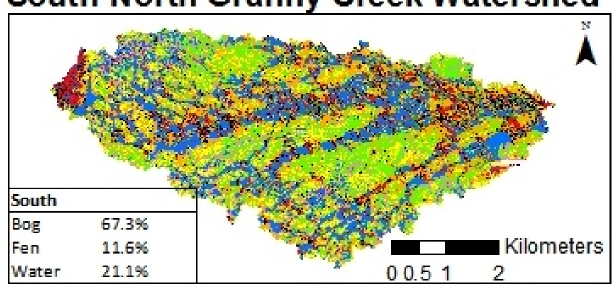


IR_RGB	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	65.8%
30 - Mat Around Pools	**705**	0	0	0	0	0	20	97.24%
40 - Bog - Lichen	0	**484**	154	8	7	15	56	66.85%
50 - Bog - Lichen / Conifer	0	193	**494**	46	101	180	64	45.83%
60 - Bog - Dense Conifer	0	1	1	**453**	306	21	0	57.93%
70 - Fen - Dense Conifer	0	19	19	158	**234**	79	1	45.88%
80 - Riparian Fen / Sedges	0	0	8	6	39	**214**	5	78.68%
90 - Fen - Poor Fen	25	48	69	3	1	2	**597**	80.13%
	96.58%	64.97%	66.31%	67.21%	34.01%	41.88%	80.35%	

North-North Granny Creek Watershed



South-North Granny Creek Watershed



Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	576329	1305724	1,882,053	5.47%
40 - Bog - Lichen	1090306	3099997	4,190,303	12.17%
50 - Bog - Lichen / Conifer	2318280	6027062	8,345,342	24.24%
60 - Bog - Dense Conifer	576191	1882812	2,459,003	7.14%
70 - Fen - Dense Conifer	523081	1591029	2,114,110	6.14%
80 - Riparian Fen / Sedges	428374	1313889	1,742,263	5.06%
90 - Fen - Poor Fen	2161246	4476454	6,637,700	19.28%
Total	**9,465,556**	**24,958,052**	**34,423,608**	**100.00%**

Figure 4-4: Maximum Likelihood Classification without the use of derivatives, and with the use of infrared. Cells highlighted outside the diagonals (orange) in the confusion matrix indicate those landscape units that were misclassified greater than 10% of the time for that specific landscape unit.

4.3 DEM Derivatives and Zonal Statistics

Slope

Slope measures the rate of change of elevation in the direction of the steepest decent (Wilson & Gallant, 2000). The slope derivative was executed in SAGA at 1 m, 10 m and 15 m grid resolution (see Appendix B for complete data). The 1 m grid resolution yielded good separability for each landscape class. The coefficient of variation (CV) is a measure of the data's variation from the mean. For each landscape class at the 1 m grid resolution the CV was greater than 0.52 for all landscape classes. FDC had the most variable spread in data with a CV at 1.06. BDC at all grid resolutions (1 m, 10 m, and 15 m) exhibited the highest separability among all other landscape units. At the 1 m grid resolution separability between MAP, BL and BLC is poor, all with mean values of ~0.02 m/m. At the 10 m grid cell analysis landscape classes begin to separate, and the CV for all classes decrease. At this scale there is a sharp decrease in CV for MAP and FDC from 1.01 to 0.34 and 1.06 to 0.79 respectively, and similarly all other classes experience this improvement in separability. At 15 m, the slope derivative for each landscape class begins to degrade as the separability remains relatively intact. While the CV for all classes at this scale increases, there is more confusion amongst the classes. As a result the 10 m grid cell analysis window (or less) is a suitable for use as a derivative.

Difference from Mean Elevation (DiME)

DiME is the difference between the elevation at the centre of the window and the mean elevation in the window, which is a measure of relative topographic position of the central point (Wilson & Gallant, 2000). This derivative was executed in SAGA at the 15, 70 and 250-cell grid size. The 15-cell grid size analysis produced poor separability amongst the different landscape classes. In addition the CV for all classes was high, with BL yielding a CV of 38. The limited separability, and the high CV for all landscape classes at the 15-cell grid size reveals a larger scale analysis is required. Thus, incorporating the DiME15 as a derivative would not be beneficial to landscape classifications. The 70-cell grid size analysis reveals a large reduction in the CV for each class. The CV for BL and BLC are reduced from 38.4 and 15.1 to 1.8 and 1.3, respectively. The remainder of the classes in the 70-cell grid size analysis experience a reduced CV. This reduction of CV provides for greater separability amongst the landscape classes reflecting a relatively smaller standard deviation. Although the CV for some classes increased using the 250-cell grid size, DiME250 revealed the most distinct results topographically. The bog classes were topographically elevated (as expected) above the fens, as shown in DiME250 (Appendix B). For DiME15 and DiME70 the mean elevation for some fens (i.e. FDC) were elevated above the Bogs landscape classes. As a result, the DiME250 derivative would be explored further for classifications purposes and would be expected to provide reasonable landscape classification results. See Appendix B for complete data.

Deviation from Mean Elevation (DME)

Deviation from the mean is the difference from the mean (elevation in the window) divided by the standard deviation, providing a measure of the relative topographic position as a fraction of the local relief and is measured from -1 to +1 (Wilson & Gallant, 2000). DME produced poor separability amongst the landscape classes for the 15-cell grid size analysis. Similar to DiME15, a high degree of variability and limited amount of separability existed. In addition the CV for all landscape classes was high (i.e. FPF had a CV of 41.5). As the grid size analysis window was increased to 70-cells, and finally to 250-cells, the separability amongst each of the classes increased for some classes and decreased for others. Overall, the 70-cell grid size analysis yielded a lower overall CV for the data. As a result the selection of the 70-cell and 250-cell analysis depended upon which other derivative it was paired with during the classification. For example the landscape class MAP has a CV of 0.9 for the 70-cell analysis and 1.4 for the 250-cell analysis. Consequently, if MAP is the landscape of interest, then the 70-cell grid analysis is favourable. The analyst however, does not have the option to separate out specific classes within derivatives, but it is possible to pair together multiple derivatives that have strong separability in classes where the other derivative is weak. While the 70-cell grid analysis contains the least overall variability between each dataset for the landscape units, the 250-cell grid analysis has mean elevations and topographic positions more representative of the landscapes, as a result the 250-cell is most suitable. For example, FDC and BLC class (shown in figures of Appendix B) are located at a lower mean elevation than that of BL. This is confirmed with field data that show these classes are typically found at the higher elevations of bogs. Thus, the most useful derivative is the 250-cell grid resolution. See Appendix B for complete data.

Vertical Distance to Channel Network (VDCN)

This derivative provides a resulting grid that identifies the altitude above the channel network in the same units as the data provided (i.e. MASL; Conrad, 2002). VDCN was calculated at a 2.5 m grid resolution. Overall, the CV for all landscape classes of this derivative were <0.6, BDC class being the highest (0.56). This derivative suggests that BL maintains the lowest mean distance to the channel network, contrary to logic. Intuitively, the fen class should experience a shorter mean vertical distance to a stream channel network. However, as shown in the data found in Appendix B, FDC is at a greater vertical distance to the channel than MAP, BL, and BLC. Despite this possible elevation discrepancy, the separation between landscape classes is good and this derivative may aid classification or separation of individual classes that are less separated in other derivatives. See Appendix B for complete data.

Percentile (PER)

Percentile is the ranking of the pixel at the center of the analysis window relative to all other pixel values in that window. It is calculated by counting the number of pixels lower than the central pixel and returning this value as a percentage. Similar to DiME and DME, the CV for the PER derivative decreases with a larger grid size window. However, the variability and separability for some of the landscape classes in PER degraded as the grid analysis scale increased. For example, the MAP landscape class CV increased from 0.39 to 0.51 as grid size increased from 15-cell to the 250-cell analysis, respectively. The 70-cell grid produced exceptionally good separability of only the RFS landscape class. In general, the 70-cell derivative yielded a lower overall CV for all landscape classes, but provided limited separability amongst classes, particularly BL and BLC. Overall, the 250-cell grid analysis compared to the results observed with all other grid cell analysis yielded a derivative with the least amount of variability amongst the classes, and the greatest amount of separability between classes. See Appendix B for complete data.

4.4 Fusion

Various combinations of the derivatives computed above were fused with the multispectral IKONOS data. These combinations were based upon separability and variability found within the statistics computed for each individual derivative as discussed above. As shown in Figure 4-3 and Figure 4-4, the addition of the IR band to the IKONOS while performing a supervised classification of the NGC watershed increased the accuracy of the classification from

62.9% to 65.8%. Preliminary classifications and accuracy assessments were performed for various derivatives fused with the RGB only. These results, where the IR band was not included into the classifications are organized in Appendix C. Any further discussion of fusion herein was completed with the IR band and the RGB combined.

Based on the separability and low overall CV for the different landscape units, the PER70 and PER250 were first fused with the IKONOS IR_RGB multispectral data. PER70 yielded an overall accuracy 66.7% when fused with the IR_RGB (Table 4-1). The users and producers accuracy for the classification was variable with a range of 40-95% for both. Commonly misclassified landscape units were BLC with BL, and FDC with BDC. In addition to confusion with BL, the BLC class was confused with FDC, and FPF, as a result BLC yielded a low users and producers accuracy.

When the PER70 derivative was removed and the PER250 derivative was added, the classification accuracy increased from 66.7% to 71.8%, respectively (Table 4-2). With PER250 confusion still remained with BL vs. BLC, and FDC vs. BDC. Interestingly RFS became slightly confused with FDC. This was experienced to a lesser extent with the PER70 derivative, however. In addition, the confusion with BLC vs. RFS was non-existent at the PER250 resolution. Both grids (PER70 and PER250) were then fused together with the IKONOS IR_RGB classification to produce an overall accuracy of 73.5% (Table 4-3). As a result, the common confusion previously observed between the landscape classes mentioned above, was slightly reduced for all those cells highlighted in Table 4-3. To help reduce confusion between FDC vs. BDC, the PER70 was removed and the slope derivative computed at 10 m grid resolution was incorporated with the PER250. The results of the fusion only degraded the classification and further reduced the overall accuracy to 70.2% (Table 4-4). Confusion amongst other classes also increased. BL became very confused with most other classes and returned a poor producers accuracy of 34.8%, which was the result of confusion associated with BLC. The users accuracy for BLC was also very low at 46.1%. Thus, slope at the 10 m grid size was removed from any further analysis.

The next derivative explored was the deviation from mean elevation (DME). The fusion of the DME250 derivative produced a classification with an overall accuracy of 75.3%. Confusion remained within the BLC landscape class, predominantly in the users accuracy at 55.2% (Table 4-5). BLC was still slightly confused with BL, FDC, and to a lesser extent FPF. When the DME70 derivative was added to the previous classification (Table 4-6), there was a reduction of .05% in the overall accuracy. Thus the inclusion of the DME70 derivative to the analysis did not further enhance the overall accuracy of the classification. The inclusion of this derivative also did not dramatically change the users and producers accuracy.

The VDCN derivative was next explored with various combinations of derivatives to try and separate the confusion of BLC with the various other classes. The VDCN derivative as discussed above maintained some misrepresentation in terms of elevation. However, the derivative provided for good separation amongst classes. When VDCN fused with both DME250 (Table 4-7) and PER70+DME250 (Table 4-8) the overall accuracy of the landscape classifications were 74.8% and 75.2%, respectively. The misclassification between landscape types were nearly identical. BLC still remained the most confused amongst other landscape units, generating a very low users accuracy (54.6%) but a relatively high producers accuracy (89.5%). Both classifications yielded a very low producers accuracy (~45% for both) for the BL class as a result of confusion with BLC. Overall, the addition of the VDCN derivative yielded better results than previous classifications. However, the confusion between different landscape classes increased. For example the confusion was spread out over various classes rather than confined to one or two particular classes.

The DiME derivative was finally fused with the IR_RGB. The DiME250 without any other derivative returned the best overall accuracy with 76.4% (Table 4-10). BLC was still confused with BL for both users and producers accuracy, in addition, BLC was again confused with FDC and FPF. The users accuracy as a result for BLC was low at 56%. When the PER70 was fused with the IR_RGB + DiME250 (Table 4-11), the overall accuracy of the classification reduced to 75.5%. The confusion amongst landscape units (especially BLC with other landscape units) remained the same, with the addition of confusion between BLC with FDC and RFS.

Misclassification commonly observed in all classifications executed and discussed above are shown in Table 4-12. Cells highlighted outside the diagonals (orange cells) indicate those landscape units that were misclassified greater than 10% of the time for that specific landscape unit. As shown BLC and FDC create the majority of the confusion in all classifications executed. Despite this the inclusion of the IR band of the IKONOS and the DiME250 derivative to the RGB bands of the IKONOS results in an increase from 62.9% (RGB) to 76.4% (IR_RGB_DiME250). Overall, the outcome of this analysis has shown a 13.5% increase in landscape classification accuracy for the NGC watershed when LiDAR derivatives are included.

Table 4-1: Supervised Classification - IR_RGB_PER70

IR_RGB_PER70	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**66.7%**
30 - Mat Around Pools	**718**	1	0	0	0	0	17	97.6%
40 - Bog - Lichen	0	**478**	156	6	10	19	61	65.5%
50 - Bog - Lichen / Conifer	0	205	**502**	51	88	175	68	46.1%
60 - Bog - Dense Conifer	0	0	3	**434**	330	12	0	55.7%
70 - Fen - Dense Conifer	0	17	26	242	**301**	68	3	45.8%
80 - Riparian Fen / Sedges	1	2	4	14	20	**470**	3	91.4%
90 - Fen - Poor Fen	31	47	59	3	1	6	**598**	80.3%
Total	95.7%	63.7%	66.9%	57.9%	40.1%	62.7%	79.7%	

Table 4-2: Supervised Classification - IR_RGB_PER250

IR_RGB_PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**71.8%**
30 - Mat Around Pools	**728**	2	0	0	1	0	22	96.7%
40 - Bog - Lichen	0	**387**	194	8	7	0	31	61.7%
50 - Bog - Lichen / Conifer	0	261	**500**	48	140	0	80	48.6%
60 - Bog - Dense Conifer	0	1	12	**468**	135	1	0	75.9%
70 - Fen - Dense Conifer	0	38	1	223	**458**	127	3	53.9%
80 - Riparian Fen / Sedges	1	3	0	3	5	**614**	0	98.1%
90 - Fen - Poor Fen	21	58	43	0	4	8	**614**	82.1%
Total	97.1%	51.6%	66.7%	62.4%	61.1%	81.9%	81.9%	

Table 4-3: Supervised Classification - IR_RGB_PER70_PER250

IR_RGB_PER70 _PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**73.5%**
30 - Mat Around Pools	**701**	2	0	1	0	0	19	97.0%
40 - Bog - Lichen	0	**383**	181	9	5	0	30	63.0%
50 - Bog - Lichen / Conifer	0	259	**511**	45	115	5	74	50.6%
60 - Bog - Dense Conifer	0	1	10	**480**	73	0	0	85.1%
70 - Fen - Dense Conifer	0	28	3	133	**476**	124	3	62.1%
80 - Riparian Fen / Sedges	1	4	0	6	7	**371**	0	95.4%
90 - Fen - Poor Fen	20	62	39	0	5	11	**615**	81.8%
Total	97.1%	51.8%	68.7%	71.2%	69.9%	72.6%	83.0%	

Table 4-4: Supervised Classification - IR_RGB_PER250_SLOPE10M

IR_RGB_PER250_ SLOPE10M	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Bog Conifer / Sphagnum	80 - Riparian Fen / Sedges	90 - Fen Dense Conifer	**70.2%**
30 - Mat Around Pools	**718**	0	0	2	0	0	3	99.3%
40 - Bog - Lichen	0	**441**	429	8	6	0	36	47.9%
50 - Bog - Lichen / Conifer	1	58	**259**	30	168	2	44	46.1%
60 - Bog - Dense Conifer	0	0	4	**458**	90	0	0	83.0%
70 - Fen - Dense Conifer	1	115	7	170	**404**	55	2	53.6%
80 - Riparian Fen / Sedges	1	7	0	6	5	**443**	0	95.9%
90 - Fen - Poor Fen	1	118	45	0	8	11	**656**	78.2%
	99.4%	59.7%	34.8%	68.0%	59.3%	86.7%	88.5%	

Table 4-5: Supervised Classification - IR_RGB_DME250

IR_RGB_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**75.3%**
30 - Mat Around Pools	**727**	2	0	0	1	0	21	96.8%
40 - Bog - Lichen	0	**491**	153	9	13	1	50	68.5%
50 - Bog - Lichen / Conifer	0	172	**544**	49	147	0	73	55.2%
60 - Bog - Dense Conifer	0	0	7	**446**	44	0	0	89.7%
70 - Fen - Dense Conifer	0	26	2	243	**534**	136	3	56.6%
80 - Riparian Fen / Sedges	0	2	0	3	7	**606**	0	98.1%
90 - Fen - Poor Fen	23	57	44	0	4	7	**603**	81.7%
Total	96.9%	65.5%	72.5%	59.5%	71.2%	80.8%	80.4%	

Table 4-6: Supervised Classification - IR_RGB_DME70_DME250

IR_RGB_DME70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**75.2%**
30 - Mat Around Pools	**701**	1	0	1	0	2	15	97.4%
40 - Bog - Lichen	0	**475**	135	7	12	1	45	70.4%
50 - Bog - Lichen / Conifer	0	186	**556**	52	129	0	73	55.8%
60 - Bog - Dense Conifer	0	2	7	**482**	71	7	1	84.6%
70 - Fen - Dense Conifer	0	19	9	127	**455**	146	2	60.0%
80 - Riparian Fen / Sedges	1	3	0	5	9	**345**	0	95.0%
90 - Fen - Poor Fen	20	53	37	0	5	10	**605**	82.9%
Total	97.1%	64.3%	74.7%	71.5%	66.8%	67.5%	81.6%	

Table 4-7: Supervised Classification - IR_RGB_VDCN_DME250

IR_RGB_VDCN _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**74.8%**
30 - Mat Around Pools	**739**	3	1	1	0	0	76	90.1%
40 - Bog - Lichen	0	**350**	29	8	2	0	45	80.6%
50 - Bog - Lichen / Conifer	1	301	**671**	79	68	0	109	54.6%
60 - Bog - Dense Conifer	0	2	18	**471**	56	1	0	85.9%
70 - Fen - Dense Conifer	0	41	19	188	**616**	175	3	59.1%
80 - Riparian Fen / Sedges	0	3	0	3	6	**564**	0	97.9%
90 - Fen - Poor Fen	10	50	12	0	2	10	**517**	86.0%
Total	98.5%	46.7%	89.5%	62.8%	82.1%	75.2%	68.9%	

Table 4-8: Supervised Classification - IR_RGB_VDCN_PER70_DME250

IR_RGB_VDCN_PER70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**75.2%**
30 - Mat Around Pools	**739**	3	1	3	0	3	85	88.6%
40 - Bog - Lichen	0	**341**	33	7	1	0	36	81.6%
50 - Bog - Lichen / Conifer	1	328	**677**	87	76	1	110	52.9%
60 - Bog - Dense Conifer	0	2	17	**497**	58	1	0	86.4%
70 - Fen - Dense Conifer	0	31	10	143	**593**	145	1	64.2%
80 - Riparian Fen / Sedges	2	4	0	10	20	**585**	0	94.2%
90 - Fen - Poor Fen	8	41	12	3	2	15	**518**	86.5%
Total	98.5%	45.5%	90.3%	66.3%	79.1%	78.0%	69.1%	

Table 4-9: Supervised Classification - IR_RGB_PER70_DME250

IR_RGB_PER70 _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**75.7%**
30 - Mat Around Pools	**726**	1	0	2	0	2	14	97.4%
40 - Bog - Lichen	0	**483**	147	8	16	1	49	68.6%
50 - Bog - Lichen / Conifer	0	189	**556**	62	135	1	75	54.6%
60 - Bog - Dense Conifer	0	1	6	**496**	40	0	0	91.3%
70 - Fen - Dense Conifer	0	17	4	177	**544**	173	2	59.3%
80 - Riparian Fen / Sedges	1	4	0	5	10	**559**	0	96.5%
90 - Fen - Poor Fen	23	55	37	0	5	14	**610**	82.0%
Total	96.8%	64.4%	74.1%	66.1%	72.5%	74.5%	81.3%	

Table 4-10: Supervised Classification - IR_RGB_DIME250

IR_RGB_DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**76.4%**
30 - Mat Around Pools	**695**	2	0	0	0	0	21	96.8%
40 - Bog - Lichen	0	**487**	136	6	13	4	48	70.2%
50 - Bog - Lichen / Conifer	0	186	**556**	46	128	0	75	56.1%
60 - Bog - Dense Conifer	0	0	5	**403**	39	0	0	90.2%
70 - Fen - Dense Conifer	0	14	2	218	**486**	51	3	62.8%
80 - Riparian Fen / Sedges	1	1	0	1	12	**454**	0	96.8%
90 - Fen - Poor Fen	26	49	45	0	3	2	**594**	82.6%
	96.3%	65.9%	74.7%	59.8%	71.4%	88.8%	80.2%	

Table 4-11: Supervised Classification - IR_RGB_PER70_DIME250

IR_RGB_PER70 _DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**75.5%**
30 - Mat Around Pools	**724**	2	0	0	0	2	19	96.9%
40 - Bog - Lichen	0	**482**	126	8	16	14	49	69.4%
50 - Bog - Lichen / Conifer	0	210	**574**	66	149	1	80	53.1%
60 - Bog - Dense Conifer	0	1	4	**498**	42	0	0	91.4%
70 - Fen - Dense Conifer	0	9	5	172	**529**	170	0	59.8%
80 - Riparian Fen / Sedges	1	1	0	5	11	**555**	0	96.9%
90 - Fen - Poor Fen	25	45	41	1	3	8	**602**	83.0%
	96.5%	64.3%	76.5%	66.4%	70.5%	74.0%	80.3%	

Table 4-12 - Most commonly misclassified landscape classes amongst all classifications performed. Orange cells indicate that >10% of pixels samples for the 750 sample size from the validation data was misclassified for all classifications.

	MAP	BL	BLC	BDC	FDC	RFS	FPF
MAP							
BL							
BLC							
BDC							
FDC							
RFS							
FPF							

5.0 DISCUSSION

The Canadian Wetlands Classification system (NWWG, 1997) was created to help the science community categorize and define the broad range of wetlands that exist across Canada. Theoretically it is based on hydrogeomorphic characteristics although practically, recognition of vegetation forms is critical to their identification (NWWG, 1988). GIS automation to partition the landscapes into those identified within the NWWG is difficult because an optical sensor cannot identify the smaller scale form and subform of the type of peatland that is included into a landscape classification as outlined by the NWWG 1997. For example, Figure 5-1 reveals a series of mound bogs (usually small, up to 3 m in diameter and 1 m high) which are a subform of bog. These landscape types cannot inherently be identified by spectral based classification without a priori knowledge due to the similar spectral properties of other bog features across the landscape. Because we as the analyst understand they are bog subform features, we can identify them but, an object based approach may be more suitable to parse out and identify these features based on their distinct size and location (i.e. surrounded by water). Classification of patterned peatlands can be fraught with this type of misclassification due to the spectral similarities, but mostly as a result of the spectral overlap between landscapes (Scott & Jones, 1995).

At a regional scale the spectral overlap between landscapes is typically neglected by standard spectral based classifications (Brown et al., 2007; Thomas et al., 2003) resulting in a classification suitable only for general regional pattern analysis (Figure 5-2). At a mesoscale (NGC watershed) the use of standard spectral based classifications in peatlands for accurate classification purposes can be problematic (Ozesmi & Bauer, 2002). This research has demonstrated that the accuracy of spectral based classifications for mesoscale patterned peatland analysis in the James Bay Lowlands (JBL) is less than 65.8% accurate (Figure 4-3 and Figure 4-4). This misclassification can be attributed to the complex arrangement of bog and fen communities that exist in the JBL and the degree of spectral similarity in the landscapes. Lee & Shan, 2003 considered the spectral confusion that arises from a road and a roof-top which have similar spectral signatures, but which could be separated on the basis of their elevation difference. In the patterned peatlands areas of dense conifer in bog and fen are spectrally similar, but their different topographic position offers an opportunity to distinguish them through fusion of multispectral data with LiDAR (Lee & Shan, 2003; Anderson et al., 2010).

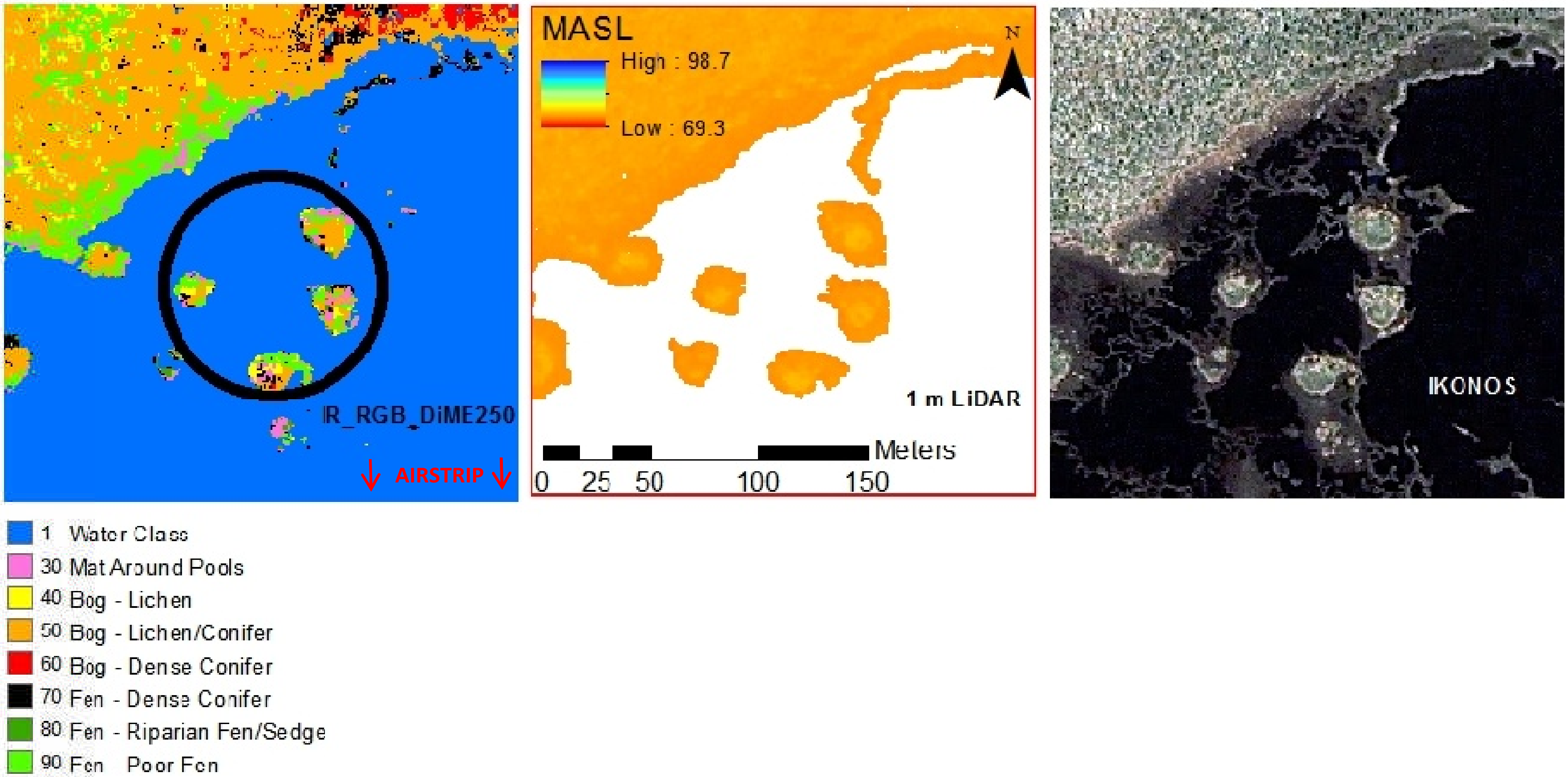


Figure 5-1: NGC Watershed Immediately North of Airstrip – Mound Bogs. These features become included into the classification and are identified as a different type of bog, not a mound bog. Shown on the left is a few small mound bogs that are divided into fen poor

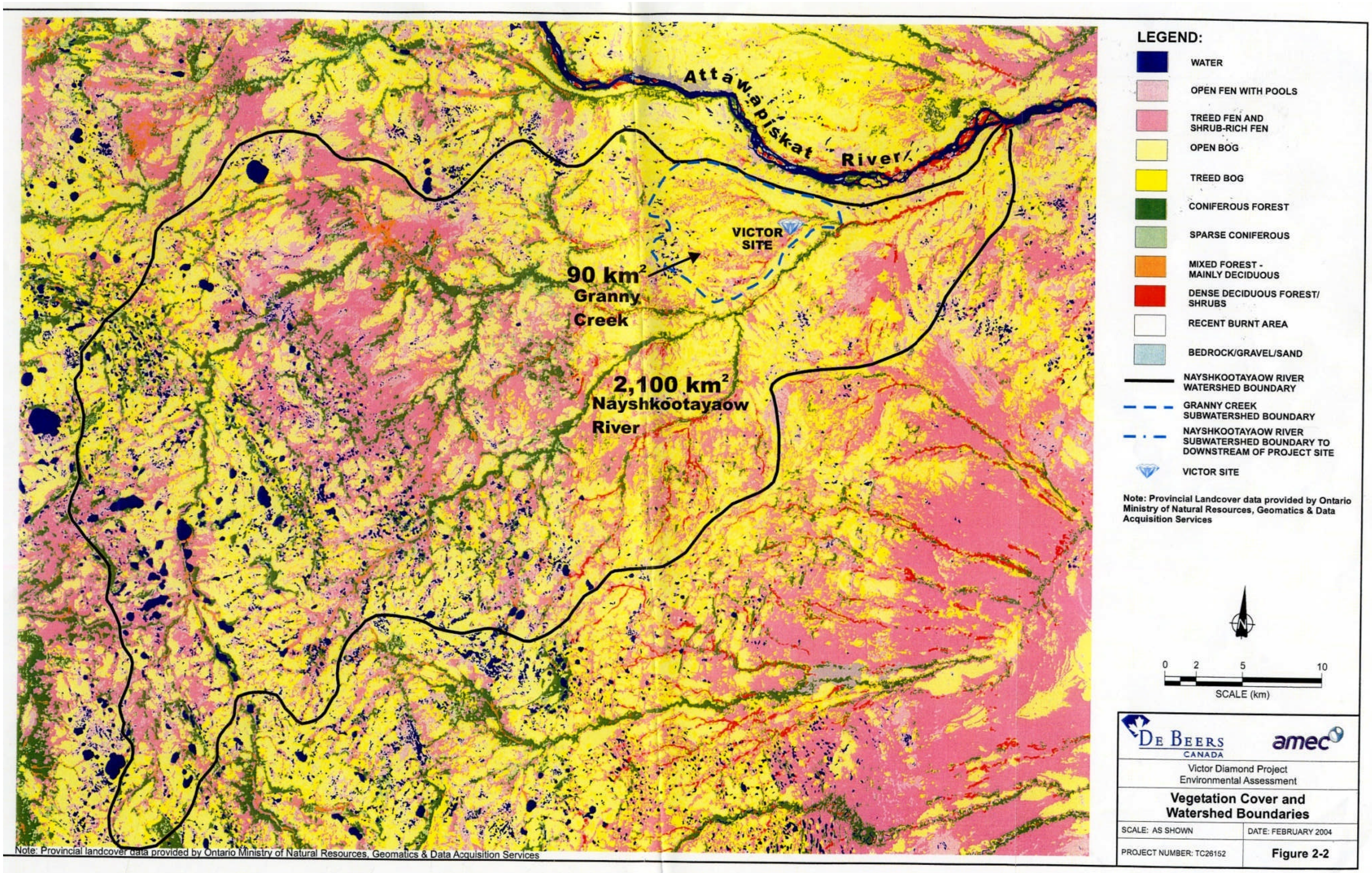


Figure 5-2: AMEC Map of Regional Vegetation cover and NGC watershed boundaries.

In peatlands however, large vertical gradients similar to those between a rooftop and asphalt surface do not typically exist. The general landscape of peatlands has low relief where gradual transition exists from one landscape type into the next (Sjörs 1959; Glaser et al., 2004; Figure 5-3). Not only is the topographic distinction gentle, its role on vegetation community type changes gradually, thus spectral confusion also occurs in these areas of transition (Ozesmi & Bauer, 2002).

This research has shown that spectral confusion in peatlands can be overcome by fusion of multispectral data with LiDAR based terrain derivatives that provide textural information (see also Barlow et al., 2006). DEM derivatives are useful at various scales, but the analyst must conceptually understand the processes and the physiography of the landscape to help separate the landscape classes. For example, bogs can be locally more elevated than fens. However, this relationship may not be apparent or captured in the analysis if the scale or computation window is too small. Figure 5-4 reveals this scale sensitivity, and the applicability of the same DEM derivative computed at three different scales where the information that can be extracted from each is distinctly different. Thus identifying what scale and what biophysical properties are of interest within the study area is a necessary and delicate endeavour.

In the NGC watershed bogs and fens coexist, and in some cases fen subforms (e.g. fen water tracks) exist within bogs. As discussed earlier mound bogs exist within the NGC watershed but to adequately identify these a microscale approach where a smaller grid size analysis for the DEM derivatives may be necessary. The approach used here was conducted at a scale that was incapable of identifying mound bogs (Figure 5-1). These, along with other subforms of bogs and fens (i.e. palsa bog, string bog, riparian fen, channel fen) were ignored resulting in training data that is representative of the broader scale arrangement of bogs and fens. Thus using a smaller grid size analysis of 15 m proved unsuccessful for classifications, because at this scale the grid size window is unable to generate a reference for mean elevation from a larger sample size (the landscape surrounding the pixel) during derivative computation. For example the bogs and fens across the NGC watershed are longer and wider where a bog can range 50-70 m in width to 2-3 kms in length. If the pixel under analysis is at the centre of the bog, and the window of analysis is large enough to capture where that bog pixel is relative to edge of the bog, then that pixel under analysis can better be identified or placed relative to the

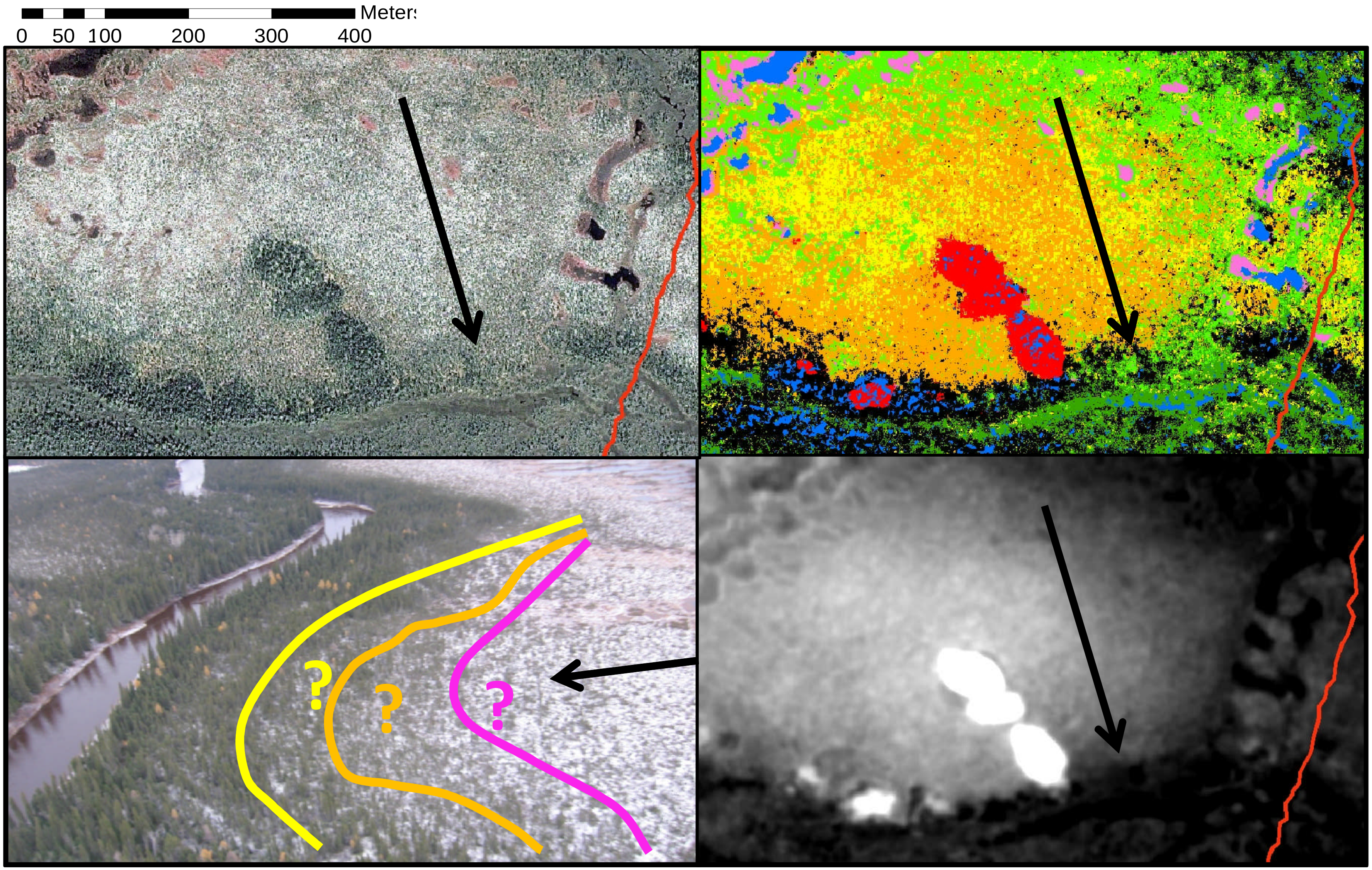


Figure 5-3: Bottom Left Picture and the direction of arrow indicates the gradual transition of Bog Lichen, into Bog Licehn/Conifer into a dense conifer riparian area, and the ambiguity in the division between each. Top Left: True Colour Composite; Top Right: Classified Image of IR_RGB_DiME250; Bottom Right DiME250 Derivative.

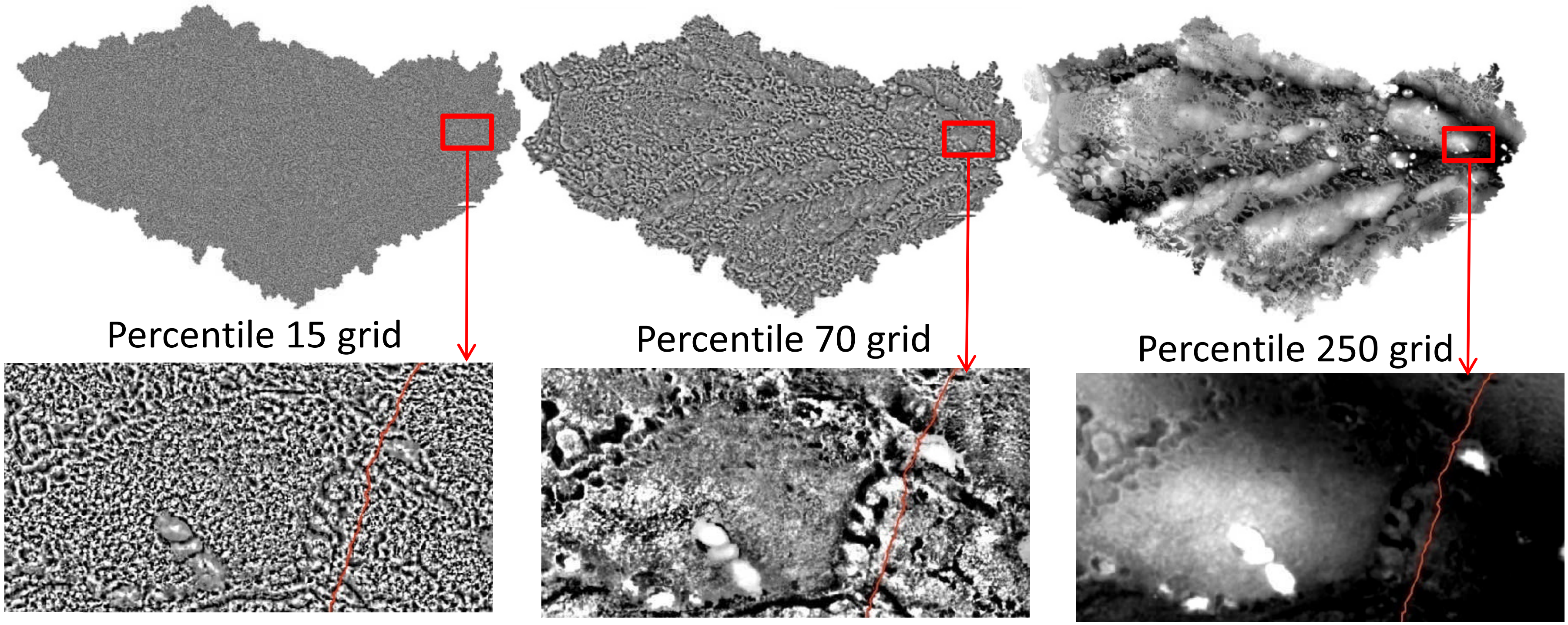


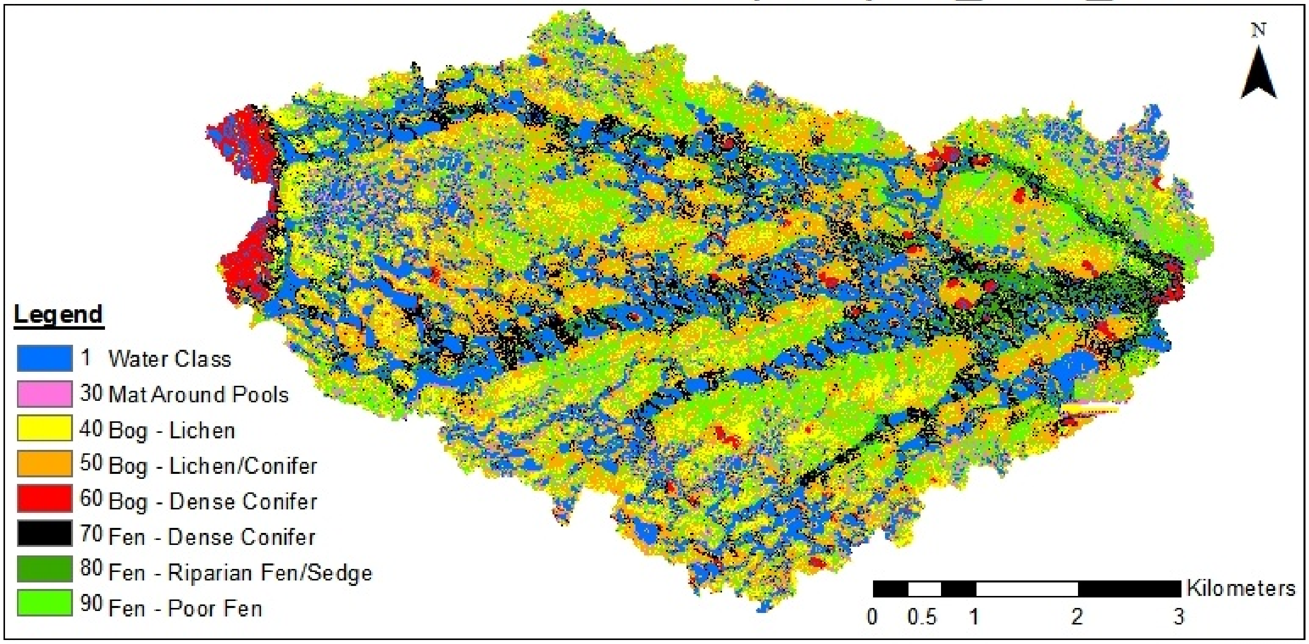
Figure 5-4: Comparison of small and large scale computation of derivatives. Left: Percentile 15-cell grid analysis; Centre: Percentile 70-cell grid analysis; Right: Percentile 250-cell grid analysis.

surrounding pixels. It is for this reason the larger 250-cell grid size terrain analyses performed were most successful. As shown in Figure 5-4, the larger 250-cell grid analysis helps clearly distinguish the form, or local relief of the NGC subwatershed better than both the intermediate 70-cell and smaller 15-cell grid analysis do. Fusion of multispectral IKONOS with all the individual (not together) 250-cell grid size derivatives enhanced the overall accuracy of landscape classifications in the NGC subwatershed by more than 10% (See Appendix C). Specifically the DiME250 derivative enhanced the overall accuracy of the classification by 13% from 62.9% to 76.4% (Table 4-10; Figure 5-5). Nevertheless, misclassification still occurred.

As shown earlier in Table 4-12 those cells highlighted outside the diagonals indicate the landscape units that were most commonly misclassified, where greater than 10% of the pixels in the sample size for that validation polygon was incorrectly classified. BLC created the majority of this confusion amongst other classes, but mainly with BL. It is not surprising that BLC and BL are confused as a result of their spectral similarity, but also because of the topographical characteristics they share. Both landscape units are found predominantly at the higher elevations (nearer the dome) in bogs thus distinguishing between them proved difficult. Figure 5-6 shows two transects across BL and BLC atop the same domed bog. The two profiles reveal that the differences in elevation between the two landscape classes are almost negligible. From A to A' the difference in elevation is less than 40 cm and from B to B' it is only 25 cm. Other areas and transects yielded similar results whereby elevation differences between BL and BLC were consistently < 50 cm. Thus, even though BL and BLC are different vegetation community types their appearance spectrally and their locations topographically are so similar that they become easily confused.

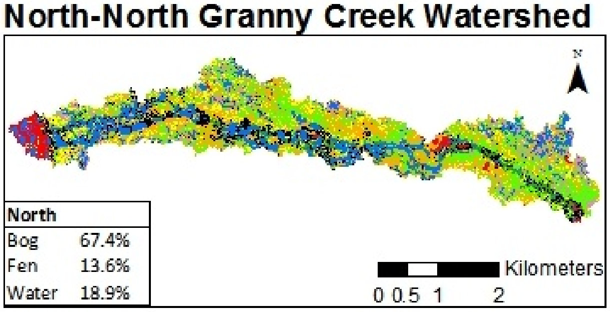
The outcome of this terrain analysis has shown that when LiDAR derived terrain derivatives were combined with IKONOS a 13.5% increase in landscape classification accuracy for the NGC watershed was achieved. Since much of the uncertainty was caused by the inability to distinguish between BL and BLC, a significant improvement in accuracy (from 76.3 to 83.7%) was achieved by combining these physiologically similar landscape classes (Table 5-1). This was done by merging the BLC with the BL class from the training and validation data and reiterating the same methods used in all previous analysis. This post-hoc analysis suggests BL and BLC should have been lumped during the training exercise; Table 5-1 merely provides a measure of

SUPERVISED CLASSIFICATION (MLC): IR_RGB_DiME250

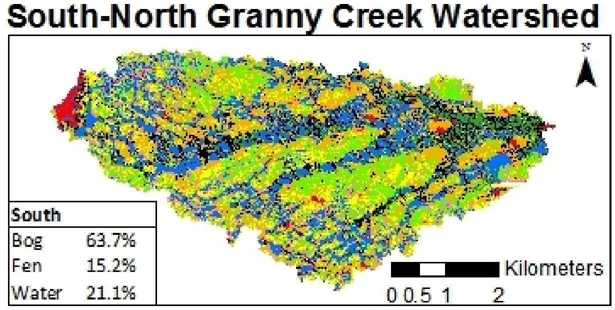


IR_RGB_DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	76.4%
30 - Mat Around Pools	695	2	0	0	0	0	21	96.8%
40 - Bog - Lichen	0	487	136	6	13	4	48	70.2%
50 - Bog - Lichen / Conifer	0	186	556	46	128	0	75	56.1%
60 - Bog - Dense Conifer	0	0	5	403	39	0	0	90.2%
70 - Fen - Dense Conifer	0	14	2	218	486	51	3	62.8%
80 - Riparian Fen / Sedges	1	1	0	1	12	454	0	96.8%
90 - Fen - Poor Fen	26	49	45	0	3	2	594	82.6%
	96.3%	65.9%	74.7%	59.8%	71.4%	88.8%	80.2%	

North-North Granny Creek Watershed



South-North Granny Creek Watershed



Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	570012	1229328	1,799,340	5.23%
40 - Bog - Lichen	1023486	2941638	3,965,124	11.52%
50 - Bog - Lichen / Conifer	2265922	6716473	8,982,395	26.09%
60 - Bog - Dense Conifer	330991	573428	904,419	2.63%
70 - Fen - Dense Conifer	808089	2642578	3,450,667	10.02%
80 - Riparian Fen / Sedges	483873	1147433	1,631,306	4.74%
90 - Fen - Poor Fen	2191422	4446089	6,637,511	19.28%
Total	9,465,544	24,958,052	34,423,596	100.00%

Figure 5-5: Maximum Likelihood Supervised Classification – Most successful overall accuracy when the DiME250 grid size analysis is included into the classification.

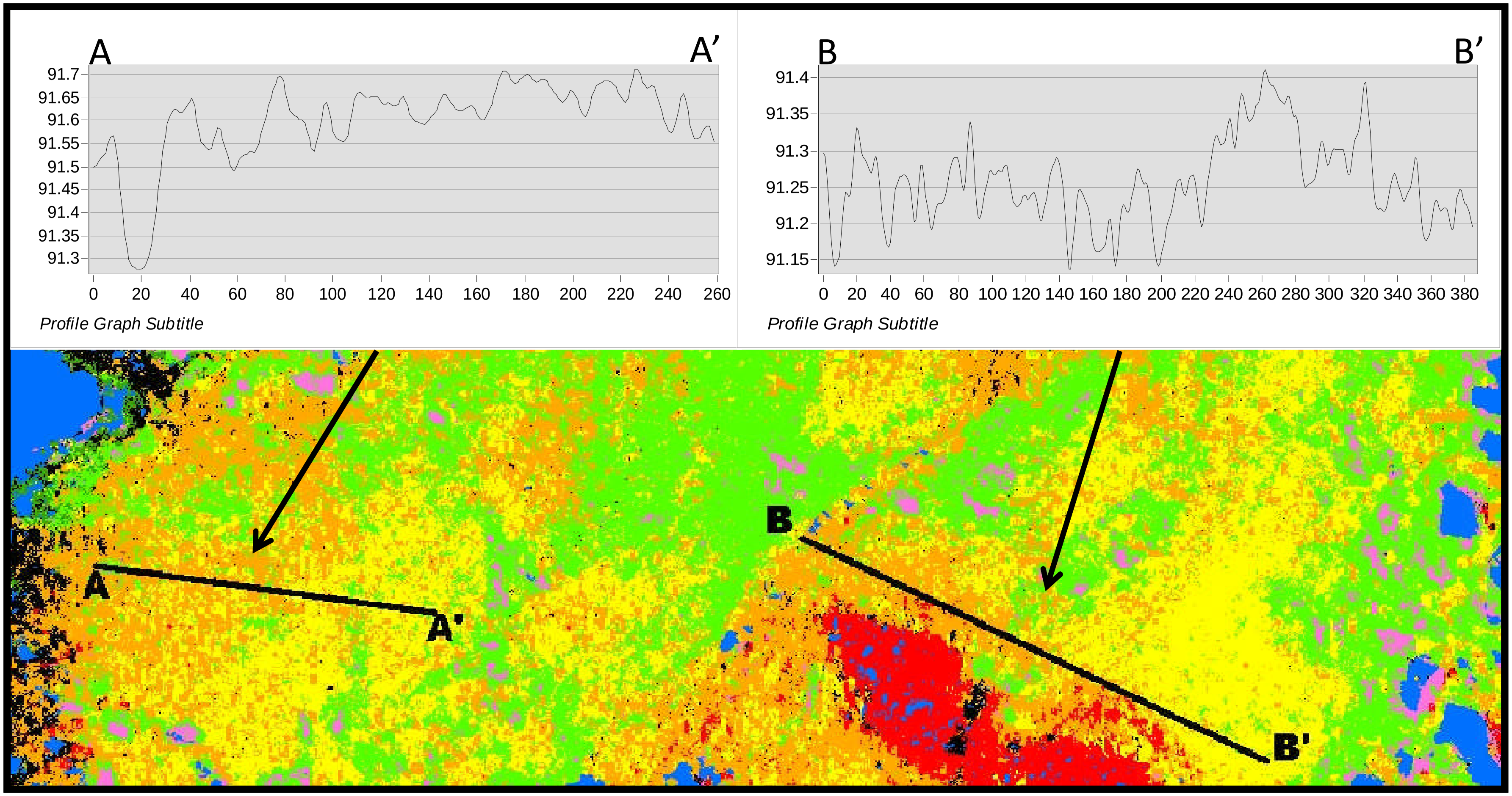


Figure 5-6: Cross sections across BLC (orange) and BL. (yellow).

relative increase and emphasizes the importance of accurately and appropriately training the data. A complete record of this post hoc analysis can be found in Appendix C.

Table 5-1: Combined Bog Lichen and Bog Lichen Conifer.

POST HOC: IR_RGB_DIME250B - MERGED BLC WITH BL	30 - Mat Around Pools	40 - Bog - Lichen	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	83.7%
30 - Mat Around Pools	**735**	0	0	0	0	19	97.48%
40 - Bog - Lichen	1	**677**	29	98	1	100	74.72%
60 - Bog - Dense Conifer	0	4	**418**	67	0	0	85.48%
70 - Fen - Dense Conifer	0	15	194	**524**	50	1	66.84%
80 - Riparian Fen / Sedges	0	1	5	8	**463**	0	97.06%
90 - Fen - Poor Fen	14	53	2	5	5	**630**	88.86%
	98.00%	90.27%	64.51%	74.64%	89.21%	84.00%	

The improved accuracy of classification with fusion of multispectral data with LiDAR DEM derivatives allows for a better understanding of the spatial arrangement of these landscape types, and the hydrological implications associated with their arrangement. It is understood that bogs typically store and release water relatively slowly, while fens act as conveyors (Quinton et al. 2003; Siegel and Glaser, 2006). Thus the proportion and arrangement of bog and fen in a watershed have implications for water storage and runoff efficiency of watersheds. The North Granny creek watershed is divided into the north and south as discussed earlier. The classification divides the north watershed into 67.4% bog and 13.6% fen with the remainder 18.9% as water features. The south slightly differs with 63.7% bog, 15.2% fen and 21.1% water. While the north and south subwatersheds are relatively similar in composition, the storage and conveyance function of each may differ, depending on the spatial arrangement of bogs, fens and pools, etc., and other watershed features such as shape, slope and microtopgraphic patterns. Figure 5-7 reveals the sequence of pools and ridges through two profiles, the northern transect having a larger gradient and lower microtopgraphic ridges separating fen-pools. Such an arrangement is expected to enhance discharge compared to the south which is flatter and with larger ridges.

Using the LiDAR and the derivatives one can further infer something about the arrangement and topographic characteristics of the bogs and fens in the NGC watershed. Three examples of different sized bogs are shown in Figure 5-8 that are all ~ 1 m in height. This elevation was typical across the watershed, when a variety of small and large bogs were profiled around the waterhsed, regardless of the domed bog base length. The domed bogs arrange themselves parallel (elongated) to the direction of flow, and typically straddle two streams or two larger channel fens. As shown in figure Figure 5-9 fens or smaller fen water tracks drain off of these bogs, usually into the streams or larger channel fens that straddle the domed bogs.

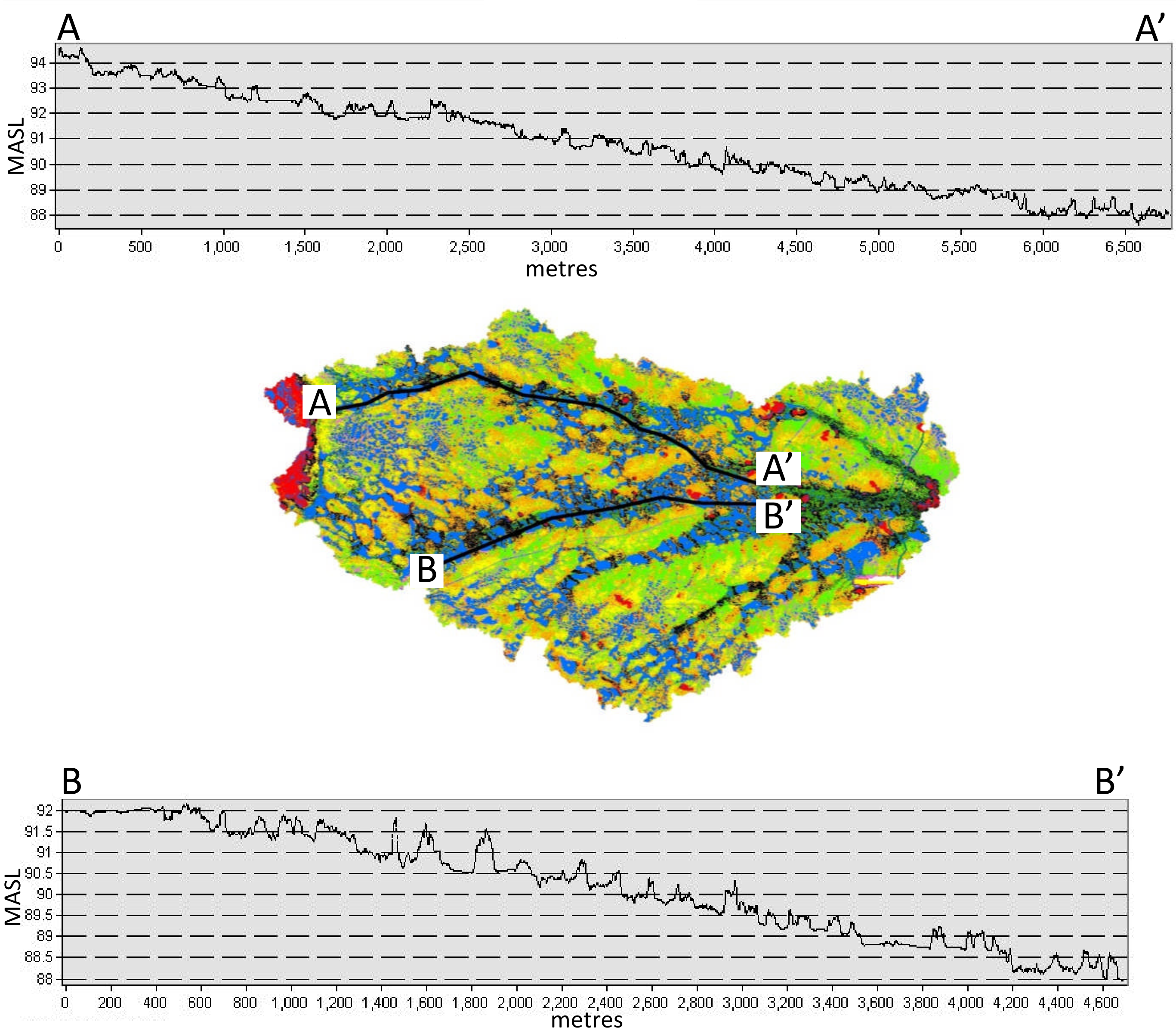


Figure 5-7: Transects through two fens, revel topographic relief, ridge height and pool length.

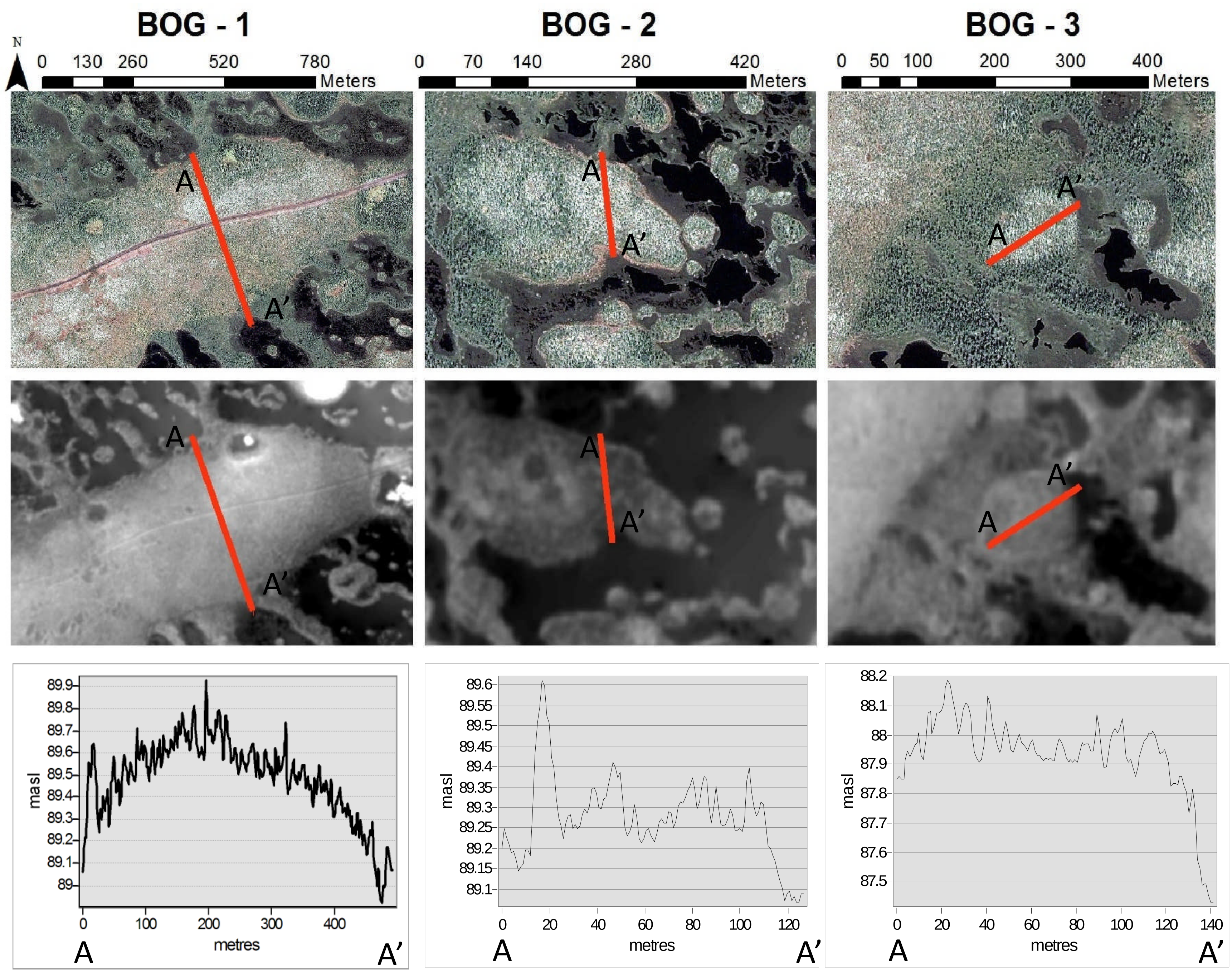


Figure 5-8: Shown above are three examples of domed bogs that are approximatley 1 m in height. This was typical across watershed regardless of the base length.

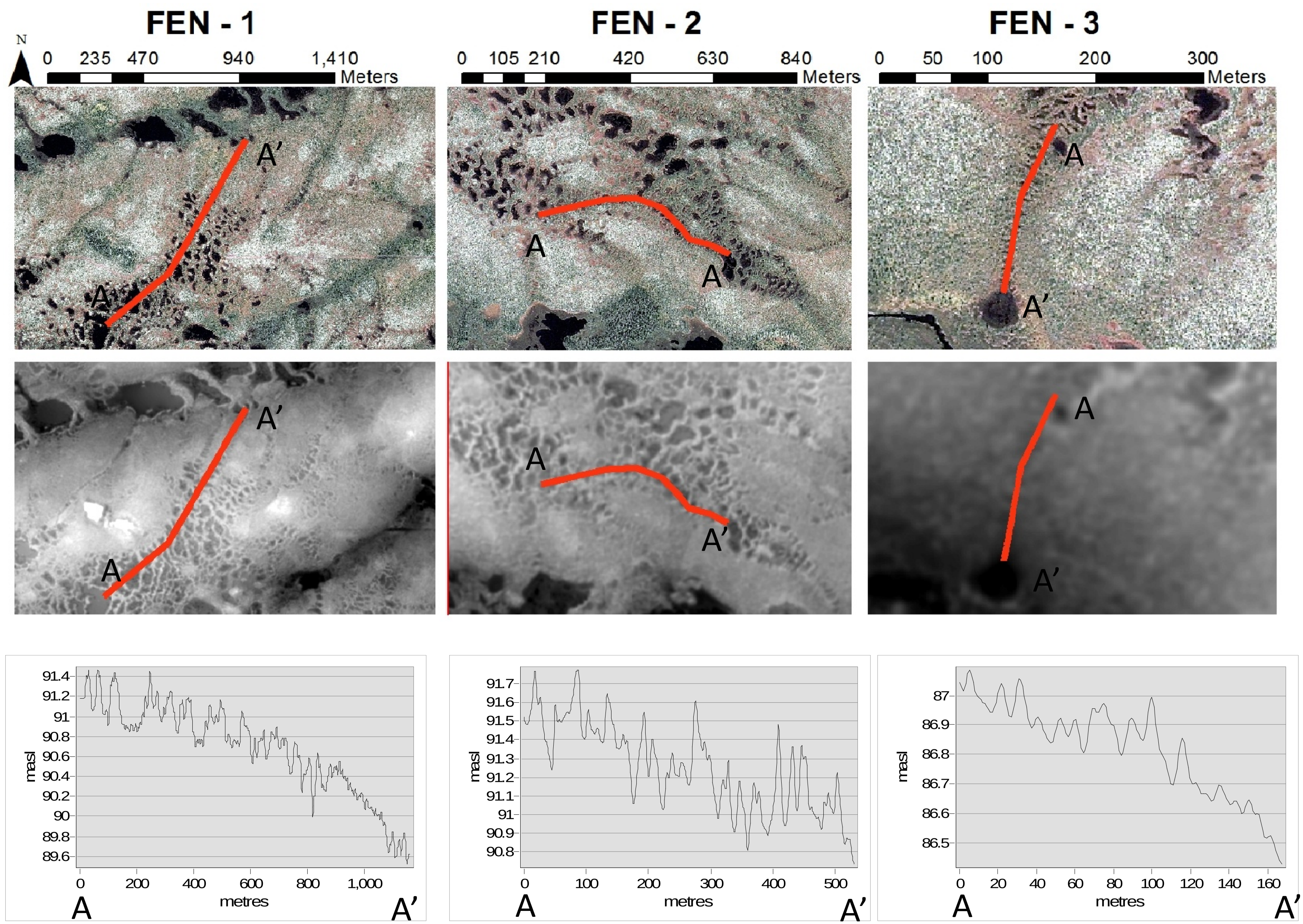


Figure 5-9: Right image: example (of various profiled throughout the watershed) where a 50 cm change in elevation over 160 m resulted in the development of a fen water track. These fen water tracts are prominent across the landscape and originate from nodes atop the domed bogs, connecting the domed bogs to the larger channel fens and streams that straddle the domed bogs as shown in the centre and left.

The smaller channel fens that originate on the surface of the larger domed bogs do not require a large flow gradient to drain. Figure 5-9 (right image) is one example (of various profiled throughout the watershed) where a 50 cm change in elevation over 160 m resulted in the development of a fen water track. These fen water tracts are prominent across the landscape and originate from nodes atop the domed bogs, connecting the domed bogs to the larger channel fens and streams that straddle the domed bogs. Because the elevation of the domed bogs in the NGC are only averaging 1 m in height, a 50 cm change in elevation over a relatively short distance seems to result in a fen water track. Specifically, in the larger domed bogs where a flatter top has developed and a sequence of bog pools form at the higher elevations **(**Figure 5-9; left image).

This type of analysis can also be used to quantify peatland topography within and between the wetland classes that have been delineated. This can be done with the use of the LiDAR (graphs in Figure 5-6) or as with the derivatives as shown in Figure 5-10. Using DiME250 the analyst can understand where these six landscape types lie physiographically in reference to the mesoscale mean elevation. For example the right image in Figure 5-10 reveals that the Fen Poor Fen class and riparian fen sedge class are generally found at ~0.5 m below the mean elevation, while both fen dense conifer and bog dense conifer peak at above ~1 m in elevation. This type of analysis allows for the user to conceptually understand where these peatland classes are located and how they may be affected physiographic changes in the landscape.

The benefits of including terrain based derivatives is obvious. Employing the use of these derivatives can aid the understanding of land use changes in northern peatlands that are affected by climate change or industrial activity (e.g. mining). Diamond extraction can physiologically and hydrologically alter the natural processes occurring at a micro and mesoscale. Specifically, under increased pumping rates due to mine dewatering there can be structural changes to the peatland caused by compression (Price, 1996) to drained peat soils which can affect hydraulic conductivity (Van Seters and Price, 2002). These structural changes have implications on both carbon storage and sequestration (Whittington & Price, 2006) and ultimately water storage and water balance within these systems (Price & Schlotzhauer, 1999; Price, 2003). The techniques demonstrated in this research have widespread applicability in watersheds both affected and unaffected by industry where naturally dry (or naturally wet) seasonal variations exist. The computation and inclusion of the appropriate terrain derivatives allow for an assessment of

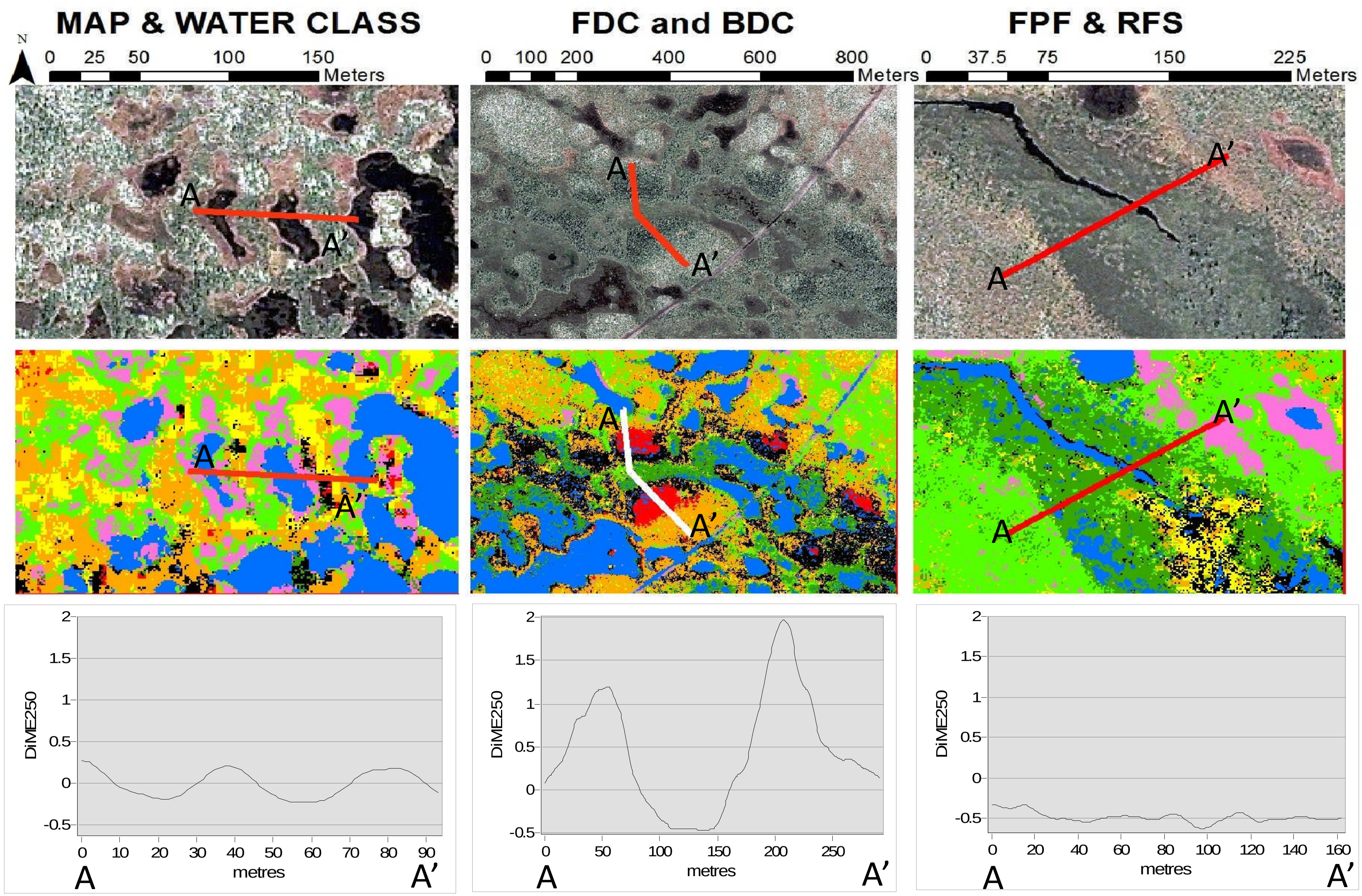


Figure 5-10: Topographic characteristics of peatland forms within and between wetland classes that have been delineated. Using DiME250 the analyst can understand where these six landscape types lie physiologically speaking in reference to the mesoscale mean elevation. For example the right image reveals that the Fen Poor Fen class and riparian fen sedge class are generally found at ~0.5 m below the mean elevation, while both fen dense conifer and bog dense conifer peak at above ~1 m in elevation

surface morphology and textural characteristics within and across patterned peatlands which enable hydrologists better understand peatland hydrology.

6.0 CONCLUSION

The results of this research reveal both the complexity and benefits of classifying patterned peatlands using GIS. The task of trying to train an image analysis program what we as scientists or analysts conceptually understand about a patterned peatland has proven difficult. Regardless, the analysis and classifications were useful because we learned that the relief between two landscapes at both the microscale (hummock and hollow) and mesoscale (peatland form) can be captured by the derivatives, with the larger mesoscale scale approach most suitable for classification purposes. The smaller grid scale analyses, however, are capable of enhancing our understanding of the microscale linkages within bogs or fens. Although this was not fully explored within this research the microscale topography derived from the smaller cell grid analysis is promising for the exploration of smaller surficial features at a more local scale. Without LiDAR derivatives the directional flow paths within a bog or fen cannot be determined from a spectral based classification alone.

Although a completely unambiguous classification (objective 1) was not achieved through this research, the results are very encouraging. With careful data training and some knowledge about these landscapes the fusion of IKONOS and terrain derivatives significantly improved classifications based on spectral characteristics of patterned peatlands. Refinement of the training data is necessary to explore the spectrally similar classes such as bog lichen and bog lichen conifer, and investigate if these classes can be better defined and better separated in the analysis if possible. The separation or merging of some landscape classes is part of this delicate exercise and leaves room for further inquiry and research. For example, within the water class, floating sedge was merged with open water because under increased water levels the sedges may become submerged, so grouping these two together allowed for complete separation of potential open water areas compared to land. Perhaps separation is necessary to further separate pools in bogs compared to pools in fens, since they likely have a different function. This can also be said for the merging of bog lichen and bog lichen conifer. As shown in Table 5-1 when bog lichen is merged with bog lichen conifer the overall accuracy of the landscape classification increases to 83.7%. It is for reasons just as these that peatland classification proved to be a delicate balance of user knowledge about the landscape and choosing the appropriate technique with which to convey the knowledge. For example if the analyst understands that the range of topographic relief across the watershed is only 5 m compared to 50 m, then it is this information that helps the analyst choose the grid size window during the calculation of derivatives.

This research has demonstrated the net benefits of providing the necessary textural (surface morphology) information about the landscape to help classify these landscapes with a spectral based approach. The resulting analysis was used to meet the second objective of this thesis and partition the NGC watershed into proportions of bog and fen where it was found that the north-north subwatershed comprises 67.4% bog and 13.6% fen with the remainder 18.9% as water features, while the south is 63.7% bog, 15.2% fen and 21.1% water (Figure 5-5). Finally this research has allowed for a greater understanding of the topographic characteristics of the peatlands forms within and between the wetland classes in the classification, thus meeting the third objective of this thesis. The inclusion of the derivatives allowed for exploration of the topographic characteristics of specific landscape classes (Figure 5-10), relative to one another but more importantly relative to mean elevation (of the window/scale chosen). Pairing the appropriate scale and computing the correct derivatives, can be a powerful tool to help hydrologist and ecologists understand the microscale and macroscale linkages in peatlands, or other landscapes. This research has clearly demonstrated that inclusion of terrain-based LiDAR derivatives, when combined with high resolution multispectral IKONOS data, improve the accuracy of landscape classifications in patterned peatlands of the James Bay Lowlands.

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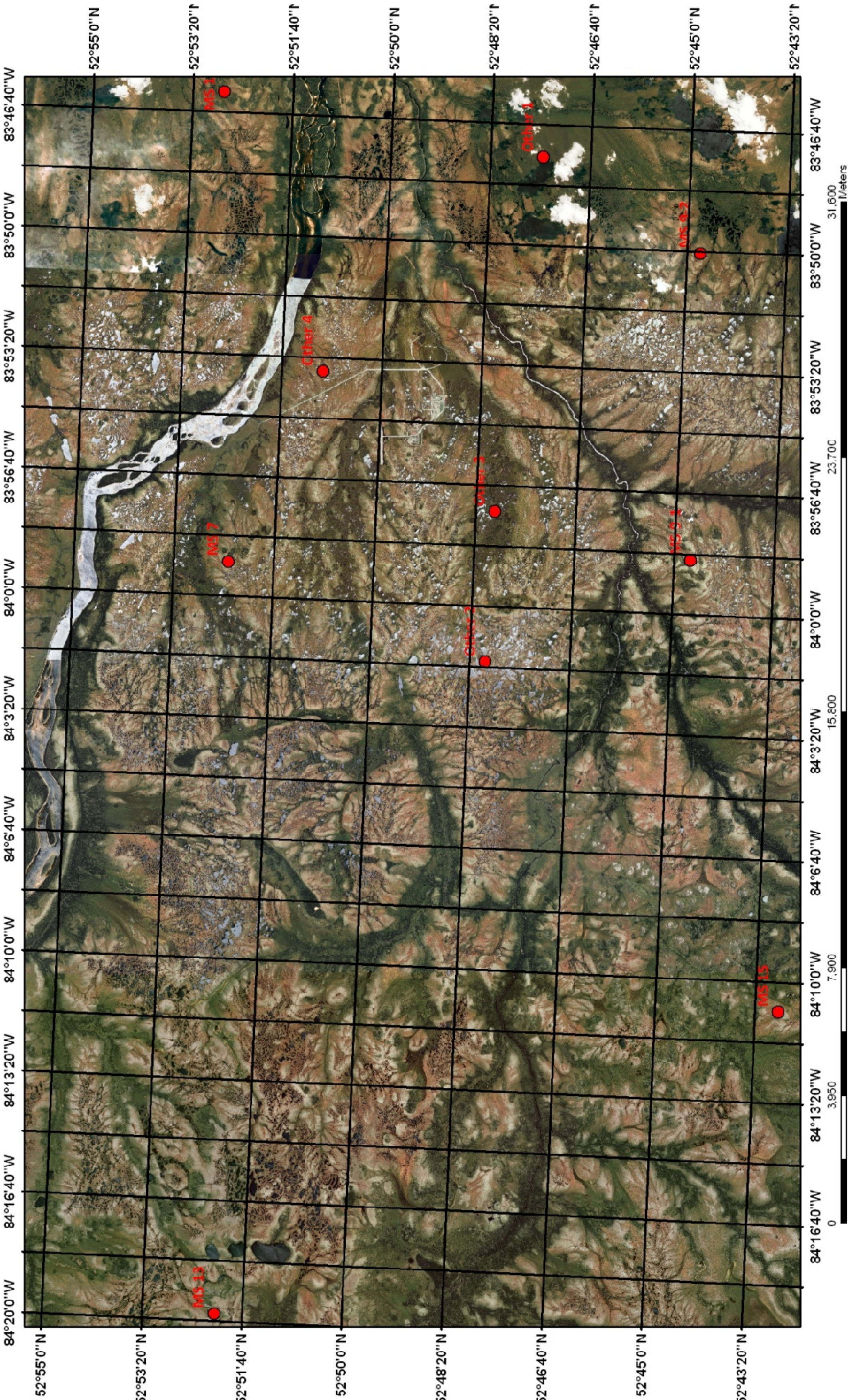
APPENDICES

APPENDIX A:

Ground Truthing Locations.



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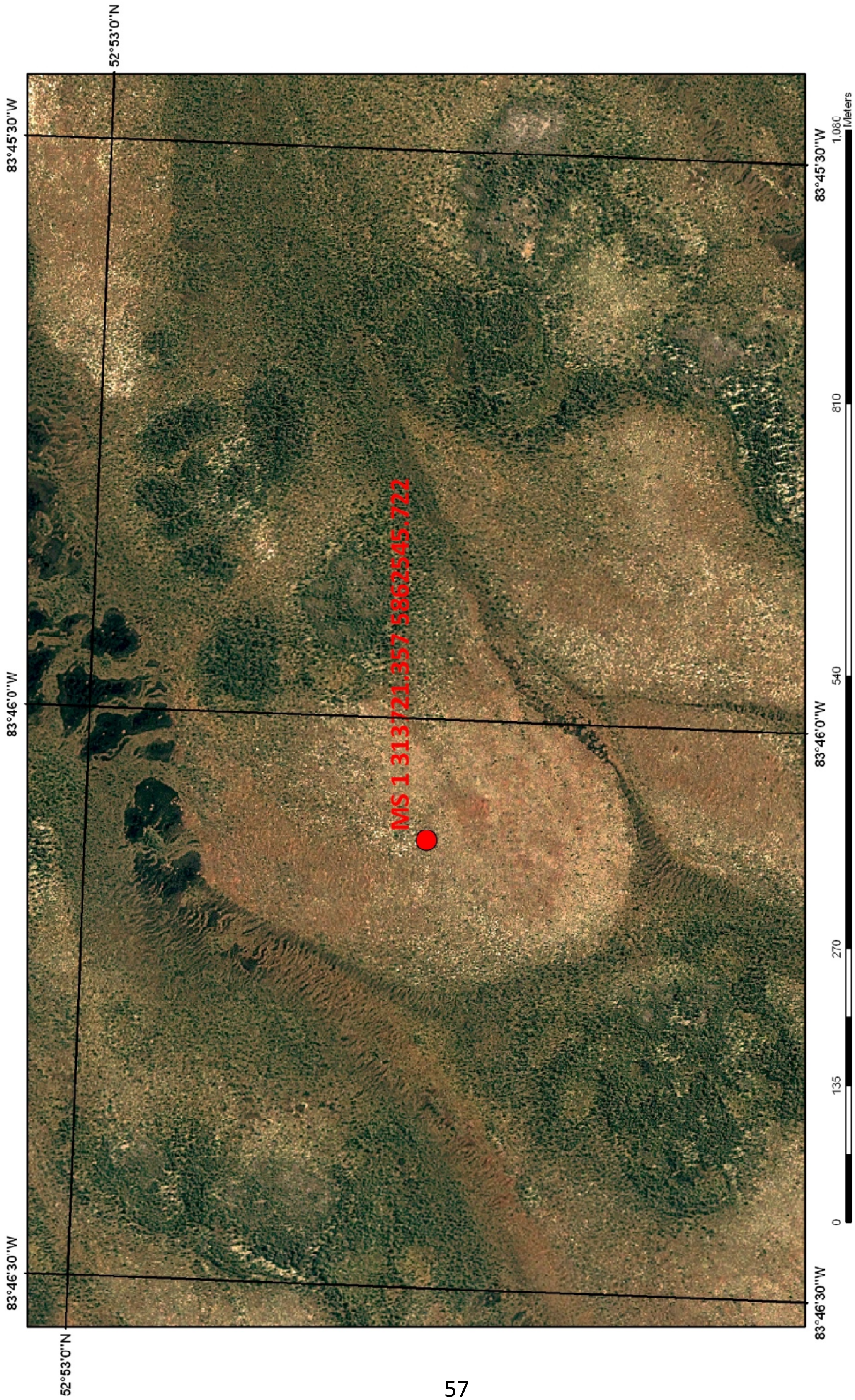
52°53'20"N
52°51'40"N
52°50'0"N
52°48'20"N
52°46'40"N
52°45'0"N
52°43'20"N
83°46'40"W
83°50'0"W
83°53'20"W
83°56'40"W
84°0'0"W
84°3'20"W
84°6'40"W
84°10'0"W
84°13'20"W
84°16'40"W
84°20'0"W
MS 1
Other 4
Other 1
MS 7
Other 2
MS 15
MS 13
0
3,950
7,900
15,800
23,700
31,600
Meters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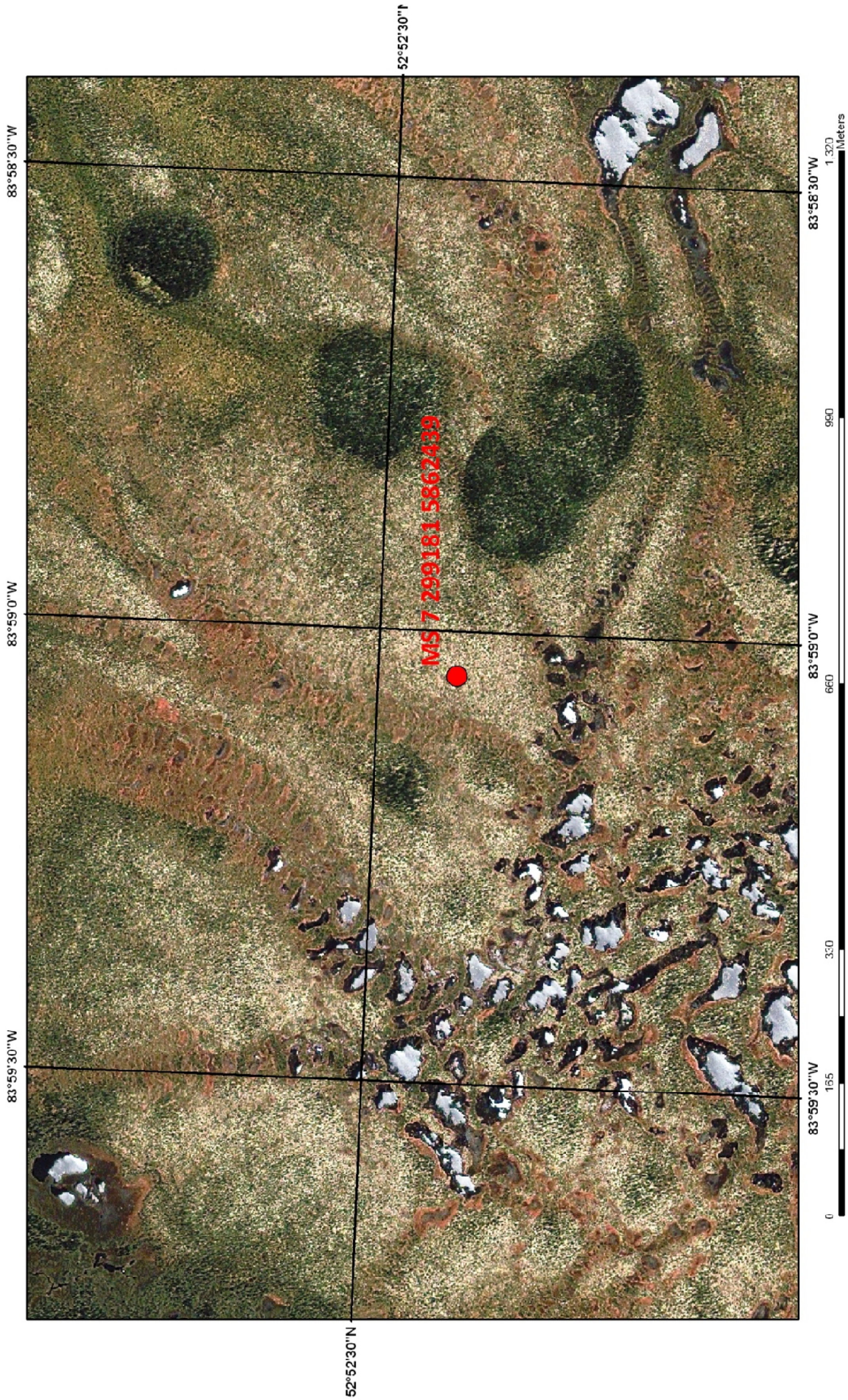
83°46'30"W
52°53'0"N
0
135
270
540
810
1,080
Meters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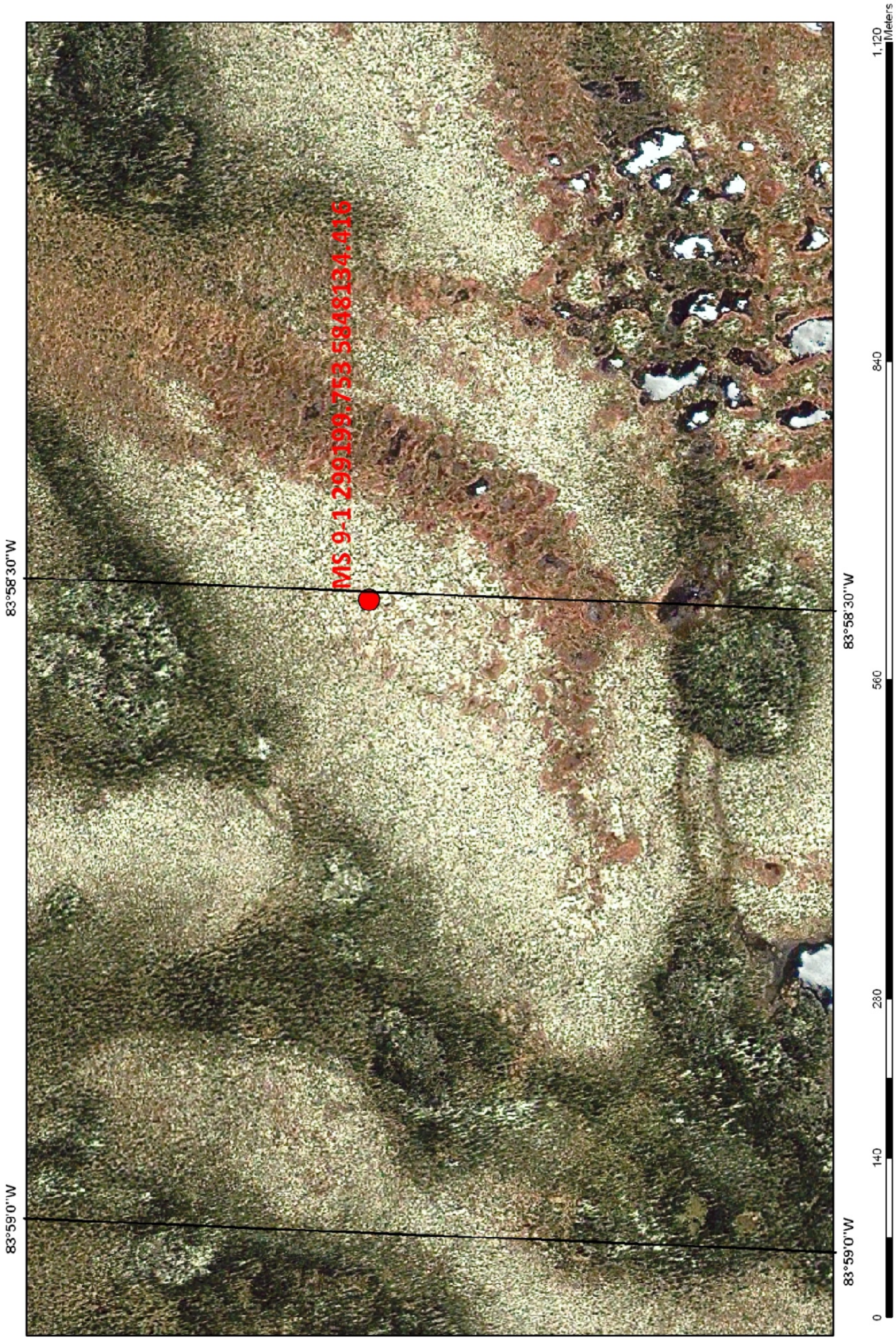
165
330
660
990
1,320
Meters



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83°59'0"W
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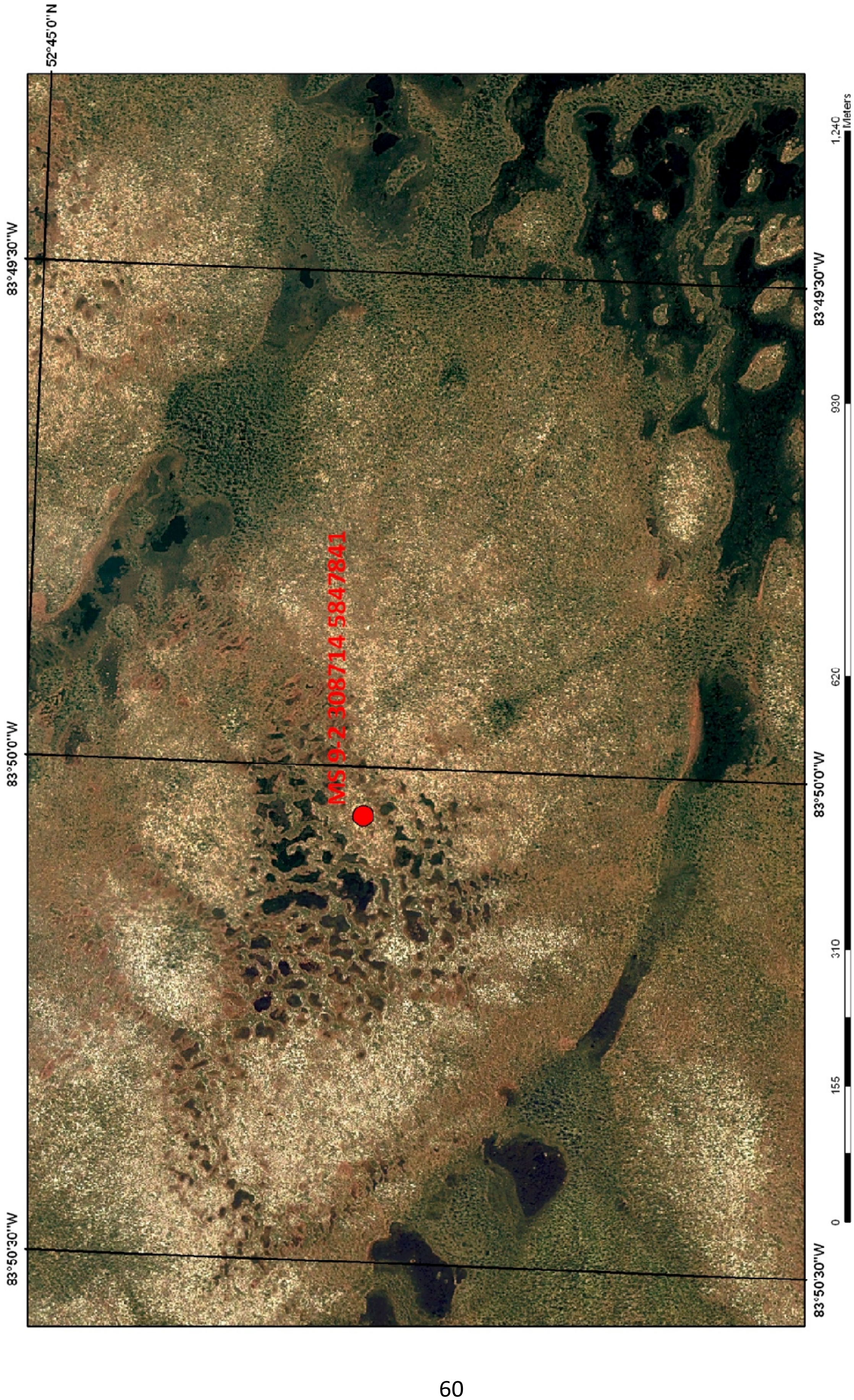
280
560
840
1,120
Meters



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83°49'30"W
83°50'0"W
83°50'30"W
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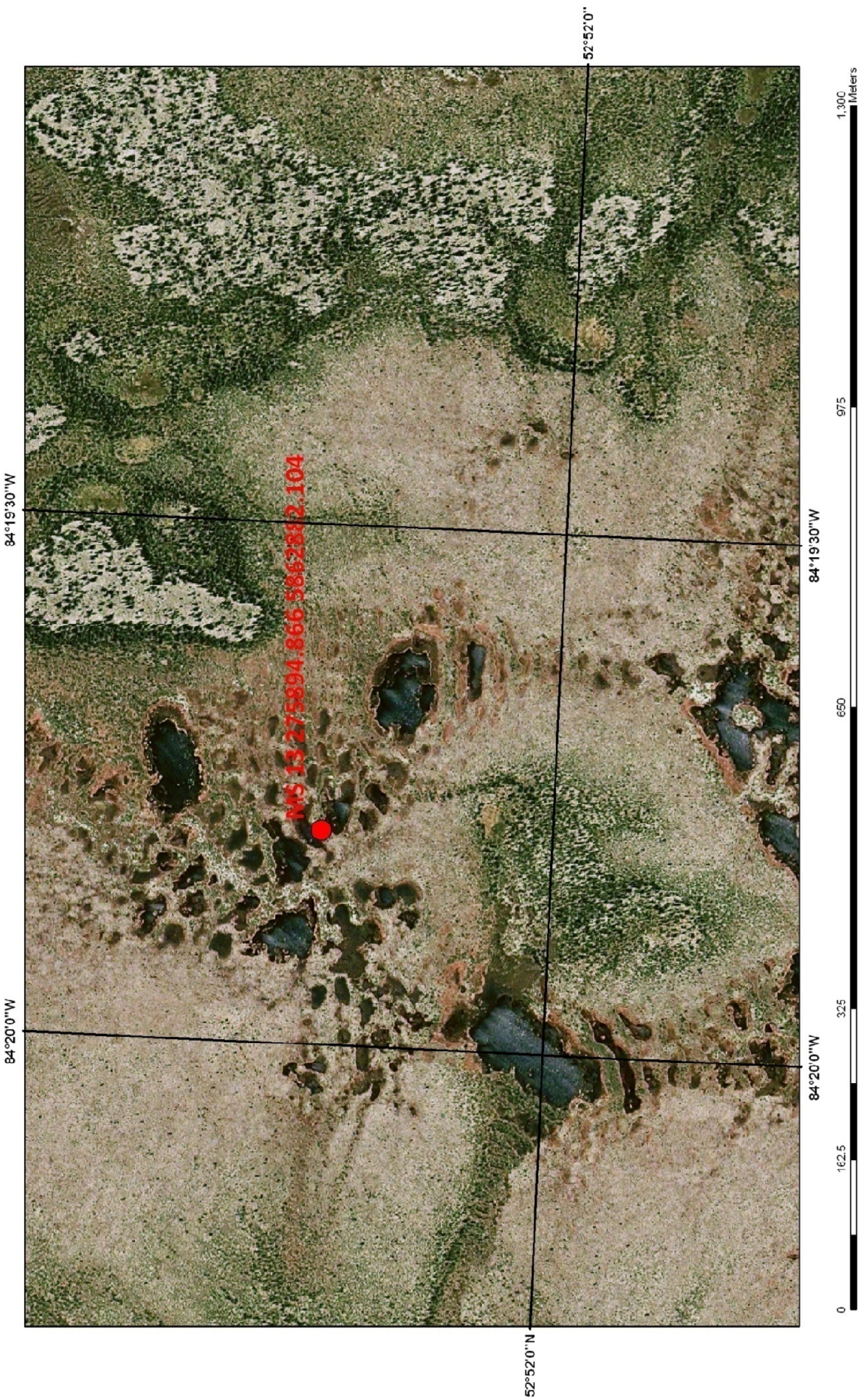
0
155
310
620
930
1,240
Meters



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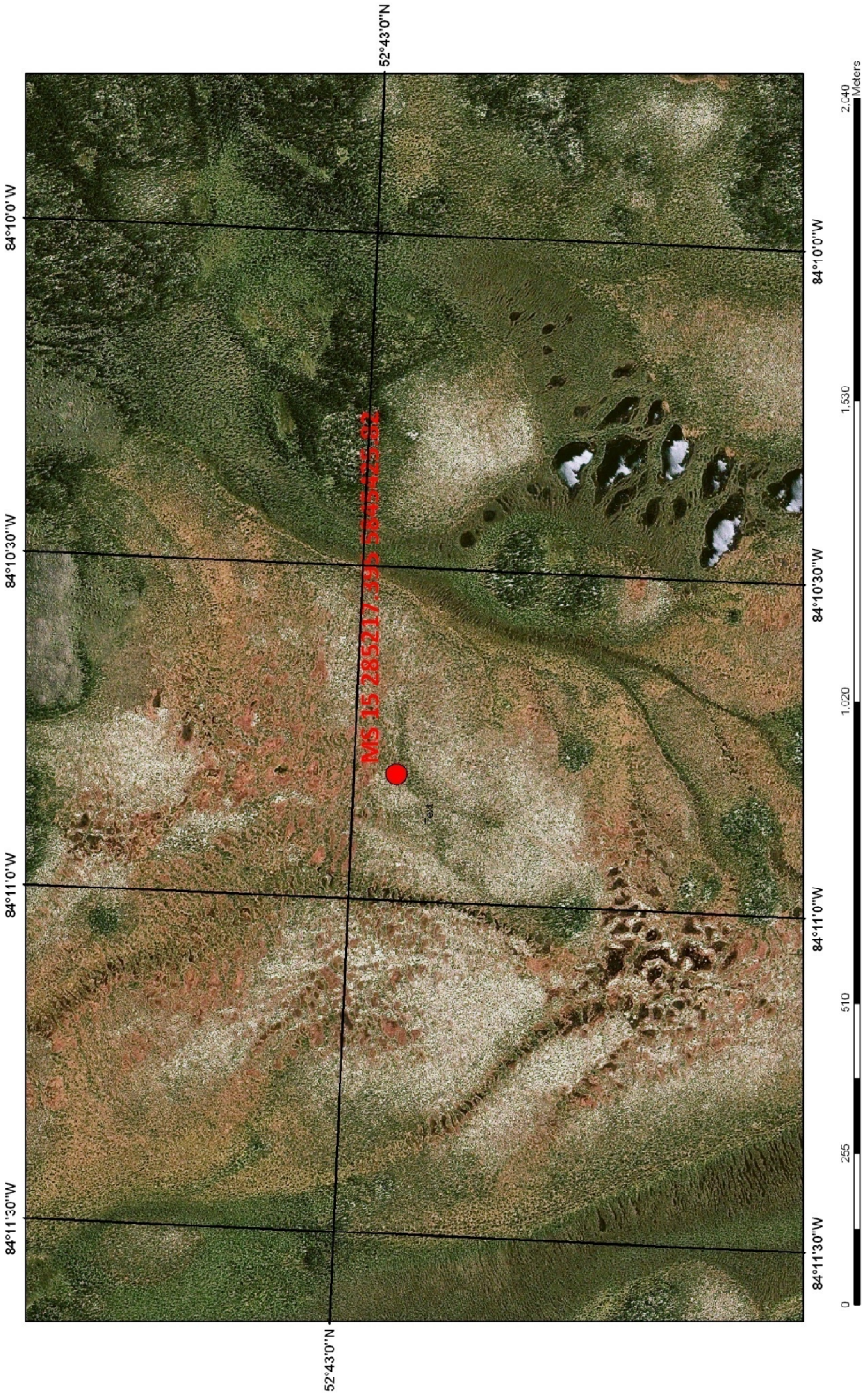
325
650
975
1,300
Meters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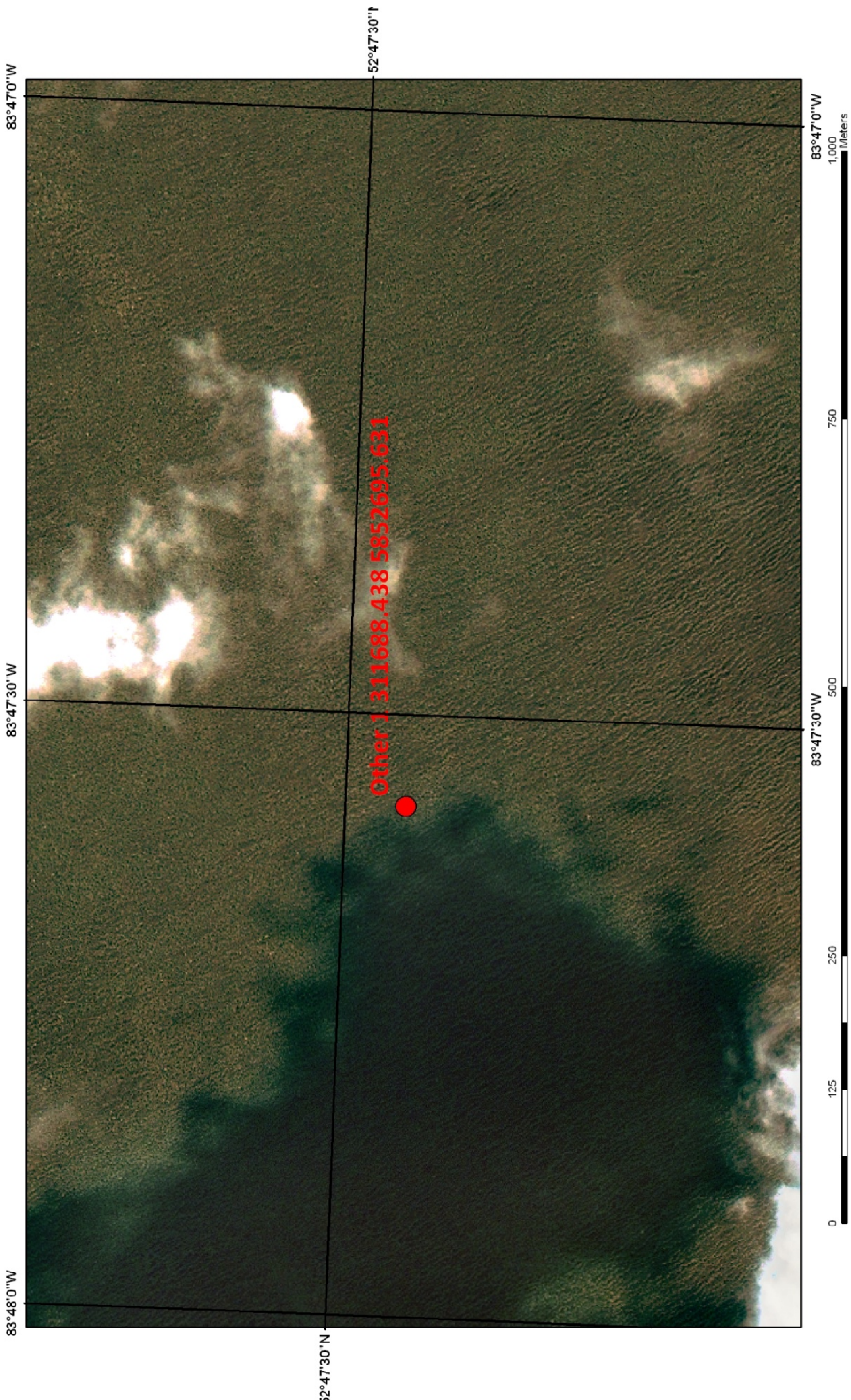
1,530
2,040
Meters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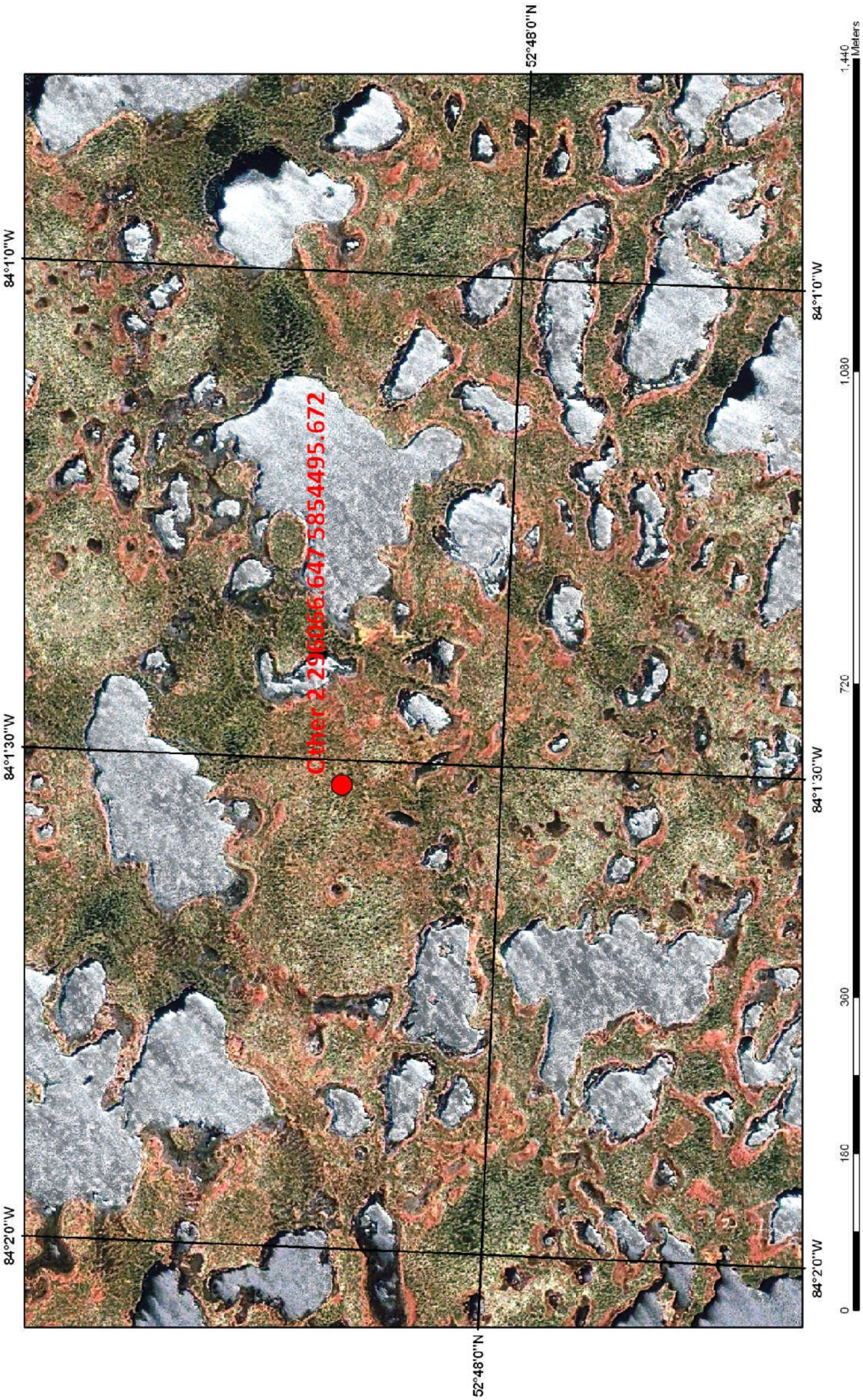
500
750
1,000
Meters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52°48'0"N
84°1'0"W
84°1'0"W
84°1'30"W
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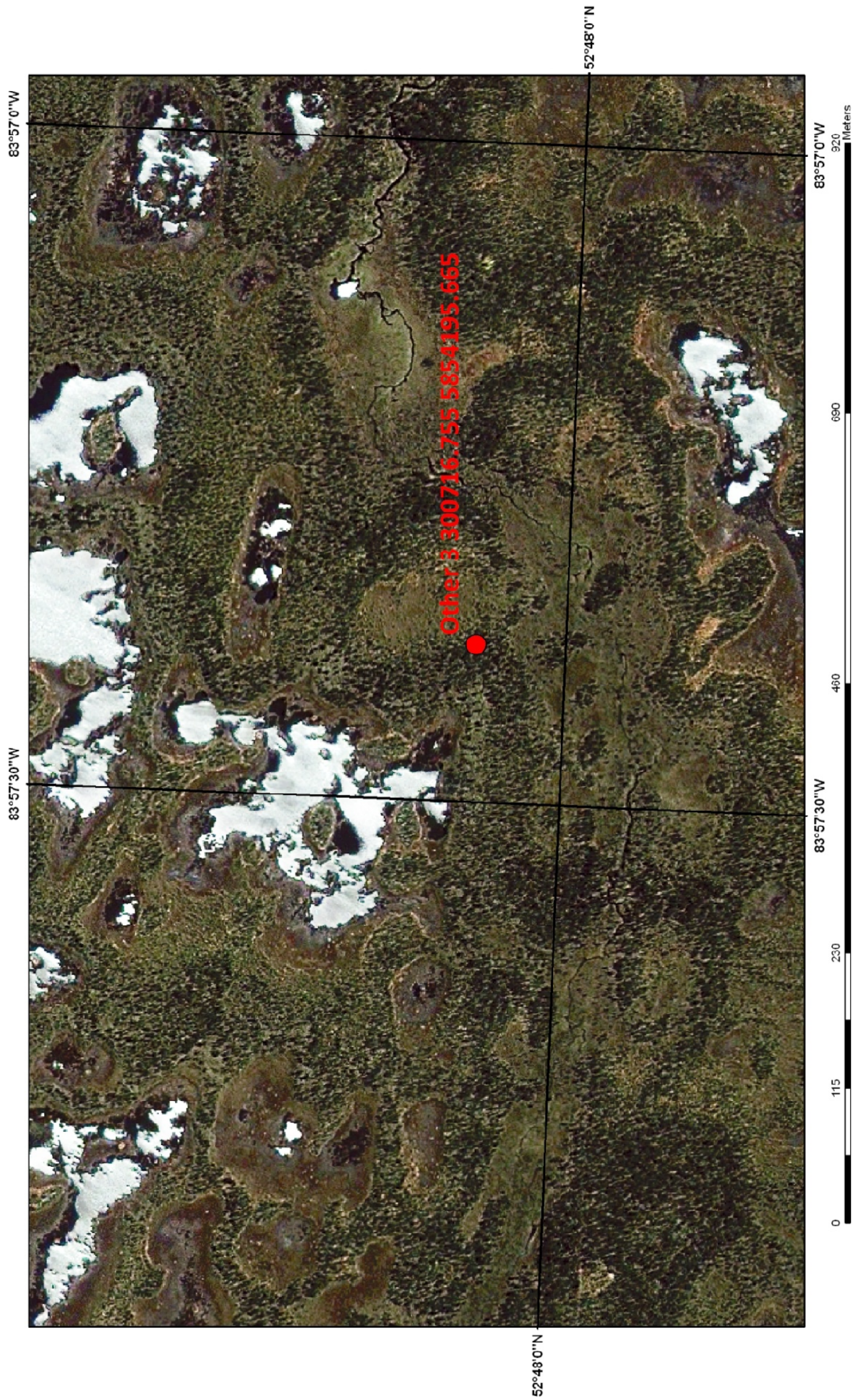
84°2'0"W
84°2'0"W
0
180
360
720
1,080
1,440
Meters



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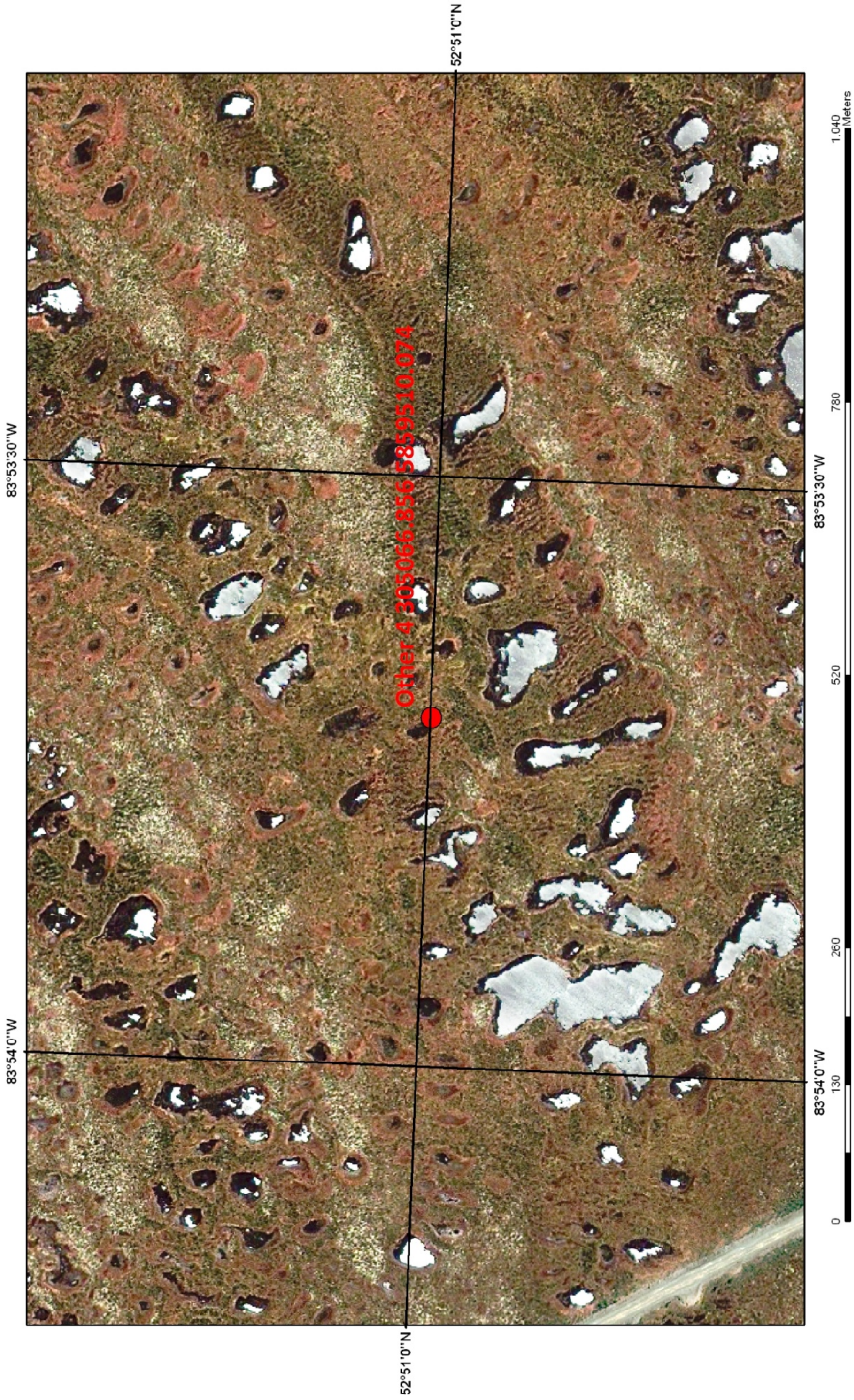
460
690
920
Meters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52°51'0"N
83°53'30"W
83°54'0"W
0
130
260
520
780
1,040
Meters

APPENDIX B:

Derivative Statistics.

Organization Within:

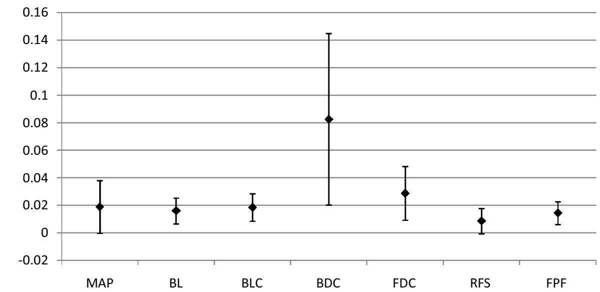
Slope
Difference From Mean Elevation (DiME)
Deviation From Mean Elevation (DME)
Vertical Distance to Channel Network (VDCN)
Percentile (PER)
Curvature
Aspect
R/G/B/NIR

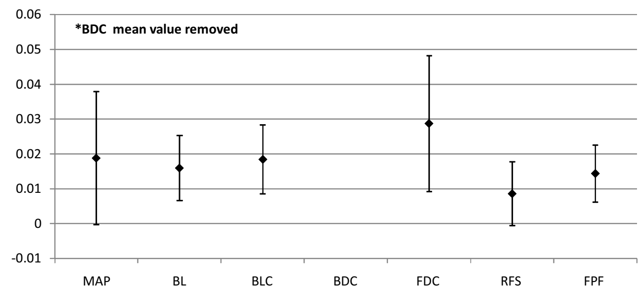
SLOPE

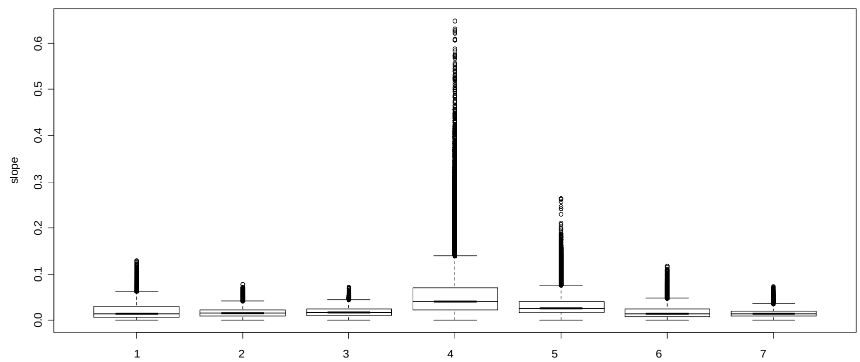
Difference From Mean Elevation (DiME)

1m_slope

ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	0.0002	0.1213	0.1211	0.018818	0.019092	182.5002	1.014560527
2	Bog - Lichen	40	51068	51068	0	0.0751	0.0751	0.015983	0.00934	816.2146	0.584370894
3	Bog - Lichen / Conifer	50	36939	36939	0	0.0654	0.0654	0.018462	0.009912	681.9834	0.536886578
4	Bog - Dense Conifer	60	40262	40262	0.0002	0.5696	0.5694	0.082481	0.062264	3320.8501	0.754889005
5	Fen - Dense Conifer	70	30581	30581	0.0003	0.1812	0.1809	0.028732	0.019489	878.6601	0.678302937
6	Riparian Fen / Sedges	80	28569	28569	0	0.1486	0.1486	0.008604	0.009151	245.81621	1.063575081
7	Fen - Poor Fen	90	40022	40022	0	0.0796	0.0796	0.014383	0.008181	575.61877	0.568796496

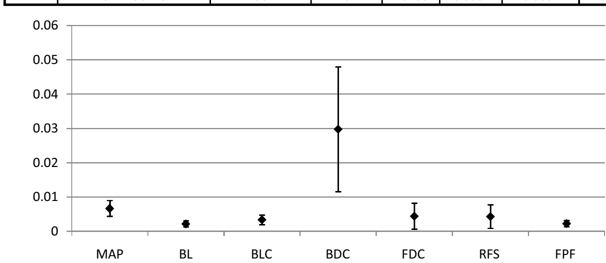


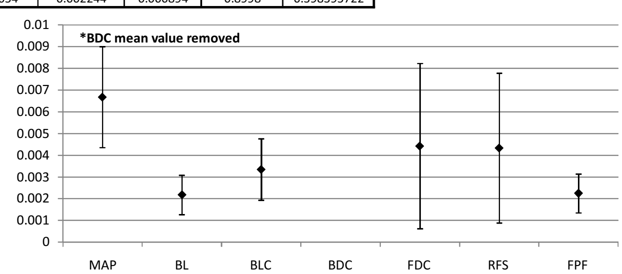


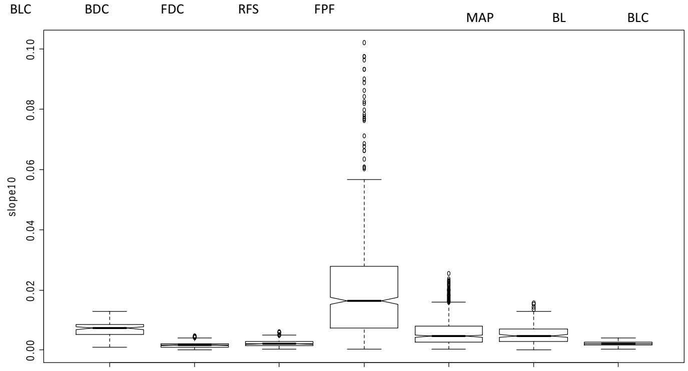


10m_slope

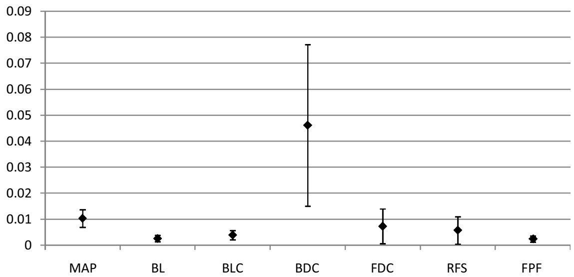
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	89	8900	0.0014	0.0113	0.0099	0.00668	0.002325	0.5945	0.348053892
2	Bog - Lichen	40	517	51700	0.0002	0.0048	0.0046	0.002179	0.000907	1.1266	0.416245984
3	Bog - Lichen / Conifer	50	369	36900	0.0005	0.0068	0.0063	0.003347	0.001418	1.2352	0.423662982
4	Bog - Dense Conifer	60	400	40000	0.0004	0.0975	0.0971	0.029771	0.018221	11.9084	0.612038561
5	Fen - Dense Conifer	70	296	29600	0.0003	0.0188	0.0185	0.004423	0.003805	1.3091	0.860275831
6	Riparian Fen / Sedges	80	278	27800	0.0001	0.0162	0.0161	0.004332	0.003442	1.2042	0.79455217
7	Fen - Poor Fen	90	401	40100	0.0007	0.0061	0.0054	0.002244	0.000894	0.8998	0.398395722

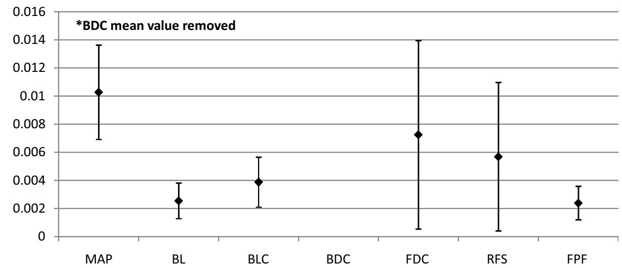


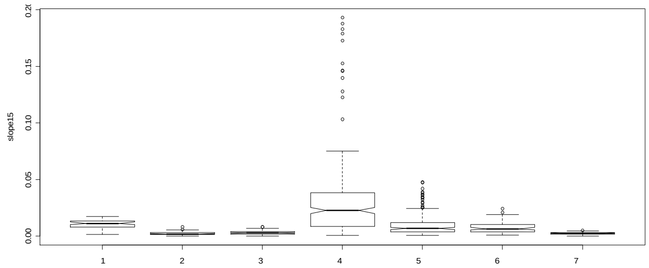




15m_slope											
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	46	10350	0.0013	0.0157	0.0144	0.01027	0.003357	0.4724	0.326874391
2	Bog - Lichen	40	228	51300	0.0002	0.0078	0.0076	0.002546	0.001266	0.5805	0.497250589
3	Bog - Lichen / Conifer	50	165	37125	0.0005	0.0089	0.0084	0.003879	0.001781	0.6401	0.459138953
4	Bog - Dense Conifer	60	187	42075	0.0033	0.1787	0.1754	0.04612	0.031112	8.6244	0.674588031
5	Fen - Dense Conifer	70	137	30825	0.0001	0.0342	0.0341	0.007244	0.006701	0.9924	0.925041414
6	Riparian Fen / Sedges	80	122	27450	0.0002	0.024	0.0238	0.00569	0.005285	0.6942	0.928822496
7	Fen - Poor Fen	90	171	38475	0	0.0075	0.0075	0.002394	0.001195	0.4093	0.499164578



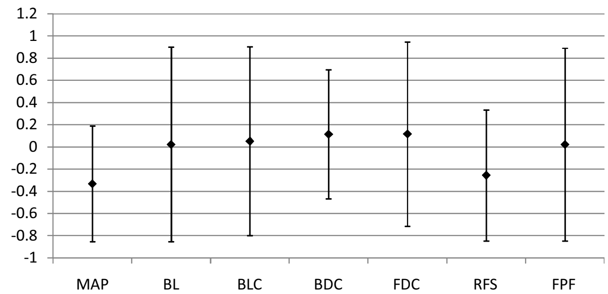


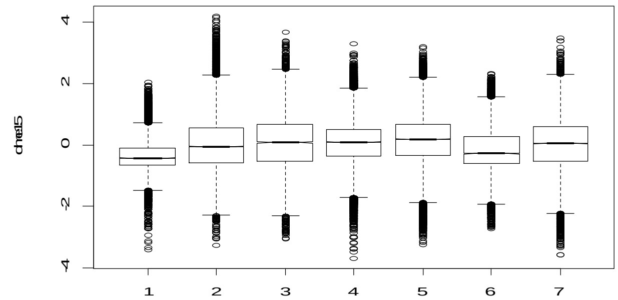


Deviation From Mean Elevation (DME)

dme15

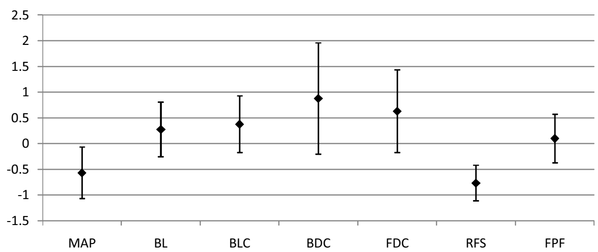
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	-3.4584	2.3839	5.8423	-0.332694	0.521594	-3226.4666	1.567789019
2	Bog - Lichen	40	51068	51068	-3.1426	4.3065	7.4491	0.022516	0.876994	1149.8218	38.94981347
3	Bog - Lichen / Conifer	50	36939	36939	-3.3999	3.5502	6.9501	0.05164	0.851441	1907.5376	16.48801317
4	Bog - Dense Conifer	60	40262	40262	-2.4308	3.4145	5.8453	0.113914	0.580956	4586.4009	5.099952596
5	Fen - Dense Conifer	70	30581	30581	-3.233	3.7323	6.9653	0.116375	0.83087	3558.8513	7.139591837
6	Riparian Fen / Sedges	80	28569	28569	-2.8957	4.4093	7.305	-0.256642	0.590155	-7332.0098	2.299526188
7	Fen - Poor Fen	90	40022	40022	-3.7736	4.6041	8.377701	0.02092	0.869287	837.26282	41.55291587

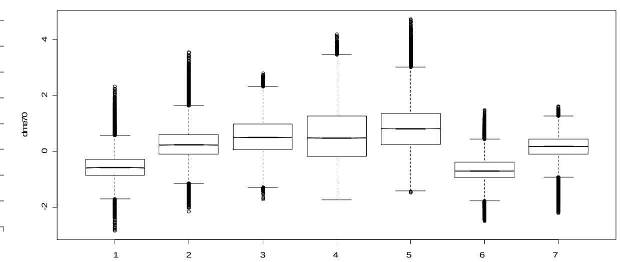




dme70

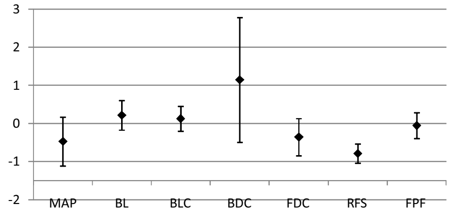
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	-1.606	2.3892	3.9952	-0.567794	0.502402	-5506.4678	0.884831471
2	Bog - Lichen	40	51068	51068	-2.1258	3.0227	5.1485	0.275824	0.530219	14085.787	1.922309154
3	Bog - Lichen / Conifer	50	36939	36939	-1.5093	2.9008	4.4101	0.377634	0.550769	13949.437	1.458473019
4	Bog - Dense Conifer	60	40262	40262	-1.218	4.7995	6.0175	0.877515	1.082172	35330.492	1.233223364
5	Fen - Dense Conifer	70	30581	30581	-2.0442	4.234	6.2782	0.631239	0.80468	19303.926	1.274762808
6	Riparian Fen / Sedges	80	28569	28569	-2.9361	0.9646	3.9007	-0.766391	0.346874	-21895.035	0.45260709
7	Fen - Poor Fen	90	40022	40022	-1.9637	3.6787	5.6424	0.099132	0.473232	3967.4575	4.773756204

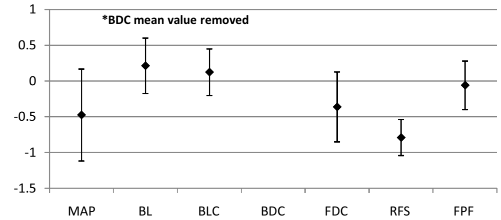


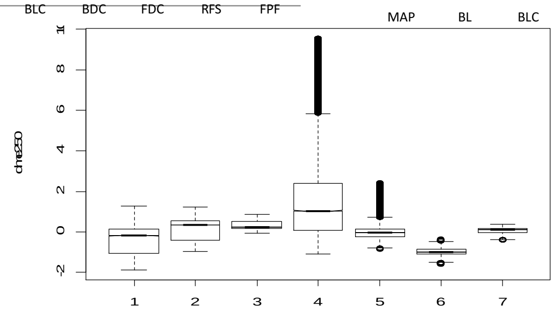


dme250

ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	-1.945	0.7878	2.7328	-0.47439	0.641788	-4600.6299	1.352870001
2	Bog - Lichen	40	51068	51068	-0.9494	0.902	1.8514	0.215178	0.38763	10988.715	1.801438809
3	Bog - Lichen / Conifer	50	36939	36939	-0.6801	0.7581	1.4382	0.124804	0.325905	4610.1362	2.611334573
4	Bog - Dense Conifer	60	40262	40262	-0.9247	9.5803	10.505	1.141656	1.636146	65487.531	1.433133974
5	Fen - Dense Conifer	70	30581	30581	-1.2301	2.1723	3.4024	-0.359782	0.487771	-11002.482	1.355740421
6	Riparian Fen / Sedges	80	28569	28569	-1.5072	-0.0128	1.4944	-0.789442	0.251335	-22553.564	0.318370444
7	Fen - Poor Fen	90	40022	40022	-0.8899	0.5186	1.4085	-0.057759	0.33848	-2311.6223	5.860212261



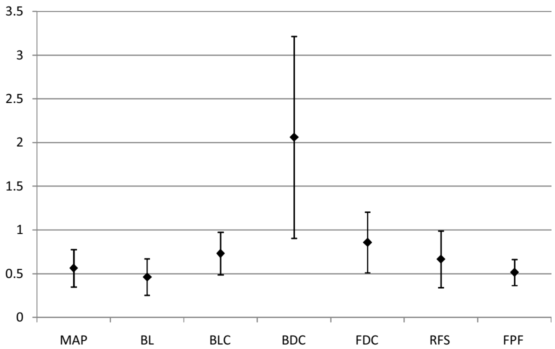


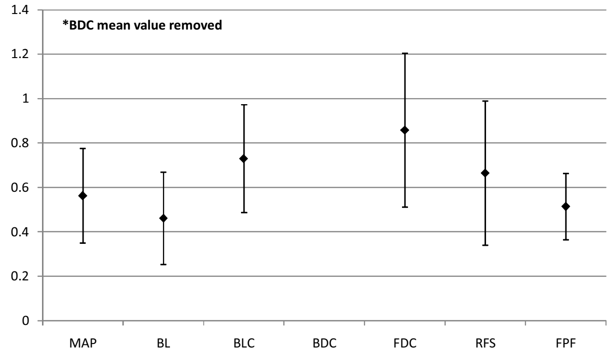


Vertical Distance to Channel Network (VDCN)

VDCN 2.5m

ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	0	1.3182	1.3182	0.562678	0.212883	5456.8545	0.378338943
2	Bog - Lichen	40	51068	51068	0	1.1182	1.1182	0.461374	0.20793	23561.451	0.450675591
3	Bog - Lichen / Conifer	50	36939	36939	0.1275	1.4129	1.2854	0.729787	0.243114	26957.604	0.333130078
4	Bog - Dense Conifer	60	40262	40262	0.3406	7.5567	7.2161	2.05962	1.15475	82924.406	0.560661675
5	Fen - Dense Conifer	70	30581	30581	0.1867	2.6136	2.4269	0.857701	0.346373	26229.361	0.403838867
6	Riparian Fen / Sedges	80	28569	28569	0	1.445	1.445	0.665022	0.324811	18999.008	0.488421436
7	Fen - Poor Fen	90	40022	40022	0	0.9412	0.9412	0.51393	0.148983	20568.498	0.289889674

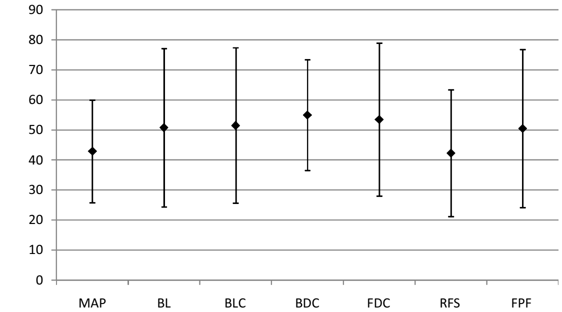


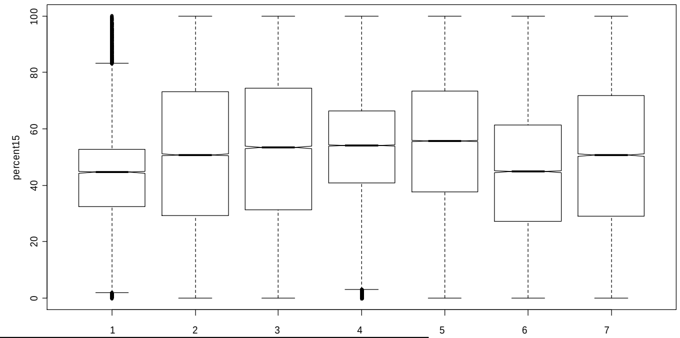


Percentile (PER)

percentile 15

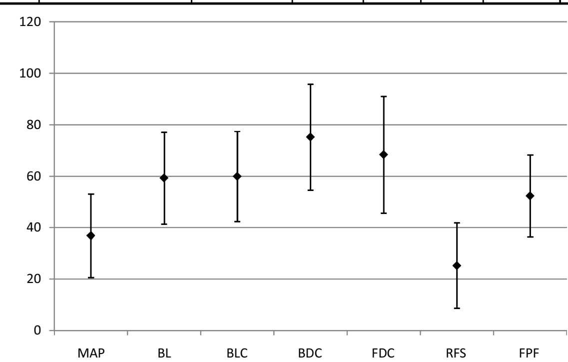
ID	CLASSNAME	ZONE_CODE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	1	9698	9698	0	99.434998	99.434998	42.866737	17.100698	415721.63	0.398926982
2	Bog - Lichen	2	51068	51068	0	100	100	50.763058	26.40217	2592367.8	0.520105979
3	Bog - Lichen / Conifer	3	36939	36939	0	100	100	51.506882	25.889975	1902612.8	0.502650791
4	Bog - Dense Conifer	4	40262	40262	0	100	100	54.987225	18.439453	2213895.5	0.335340672
5	Fen - Dense Conifer	5	30581	30581	0	100	100	53.479843	25.477896	1635467.1	0.476401847
6	Riparian Fen / Sedges	6	28569	28569	0	100	100	42.262177	21.105204	1207388.1	0.499387526
7	Fen - Poor Fen	7	40022	40022	0	100	100	50.516193	26.33783	2021759	0.521374008

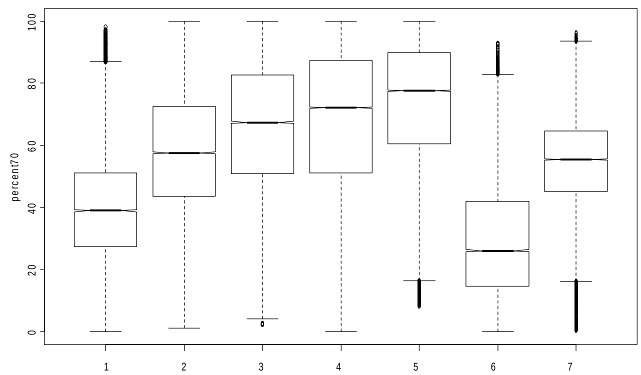




percentile 70

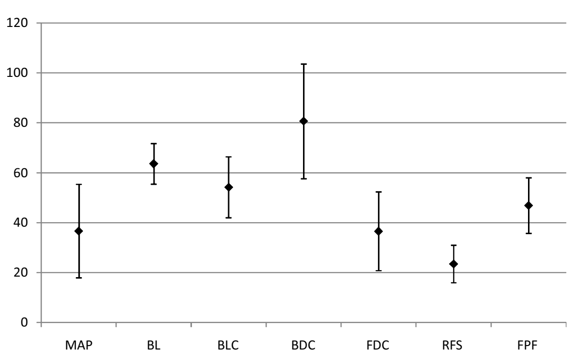
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	0.3968	97.677597	97.2808	36.875935	16.240143	357622.81	0.440399491
2	Bog - Lichen	40	51068	51068	0.2017	99.987	99.785301	59.252689	17.882185	3025916.3	0.301795333
3	Bog - Lichen / Conifer	50	36939	36939	4.8855	99.915398	95.0299	59.912022	17.501581	2213090.3	0.292121354
4	Bog - Dense Conifer	60	40262	40262	0	100	100	75.180962	20.625036	3026935.8	0.274338549
5	Fen - Dense Conifer	70	30581	30581	1.0539	100	98.946098	68.355637	22.706066	2090383.6	0.332175472
6	Riparian Fen / Sedges	80	28569	28569	0	82.559196	82.559196	25.277235	16.590689	722145.31	0.656349043
7	Fen - Poor Fen	90	40022	40022	1.776	100	98.223999	52.352577	15.936719	2095254.9	0.304411357

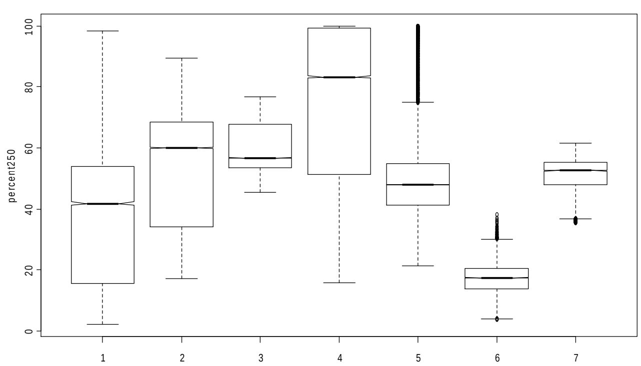




percentile 250

ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	1.6286	76.857399	75.228798	36.665115	18.736662	355578.28	0.511021498
2	Bog - Lichen	40	51068	51068	16.7759	78.492897	61.716995	63.574844	8.128328	3246640.3	0.12785447
3	Bog - Lichen / Conifer	50	36939	36939	23.8016	80.112297	56.310699	54.192081	12.218097	2001801.4	0.225459085
4	Bog - Dense Conifer	60	40262	40262	17.0728	99.9991	82.9263	80.617279	23.028229	3245813	0.2856488
5	Fen - Dense Conifer	70	30581	30581	12.095	99.630501	87.5355	36.579021	15.762191	1118623	0.430907951
6	Riparian Fen / Sedges	80	28569	28569	5.8376	47.739201	41.9016	23.498829	7.533619	671338.06	0.320595507
7	Fen - Poor Fen	90	40022	40022	17.6005	64.347298	46.746796	46.858742	11.150557	1875380.5	0.237961083

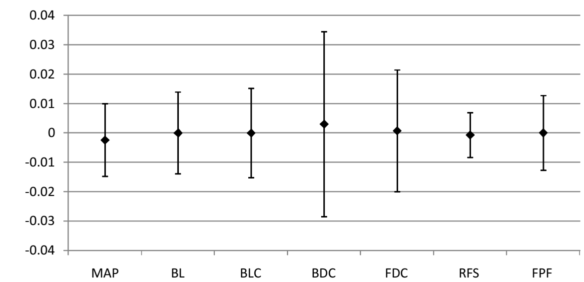


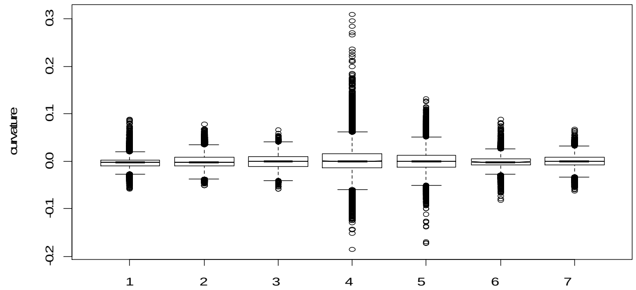


Curvature

Curvature 1m

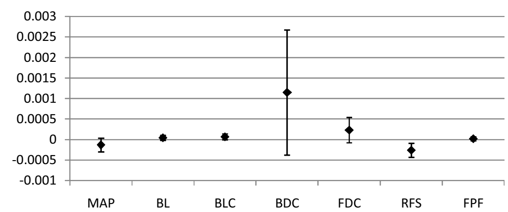
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	-0.0571	0.0896	0.1467	-0.002421	0.012371	-23.4778	5.109871954
2	Bog - Lichen	40	51068	51068	-0.0499	0.0863	0.1362	0.000005	0.013918	0.2407	2783.6
3	Bog - Lichen / Conifer	50	36939	36939	-0.0554	0.0709	0.1263	-0.000038	0.015197	-1.4088	399.9210526
4	Bog - Dense Conifer	60	40262	40262	-0.1615	0.3097	0.4712	0.002995	0.031462	120.5982	10.5048414
5	Fen - Dense Conifer	70	30581	30581	-0.0986	0.1045	0.2031	0.000723	0.020724	22.1168	28.66390041
6	Riparian Fen / Sedges	80	28569	28569	-0.0472	0.0629	0.1101	-0.00072	0.007644	-20.582399	10.61666667
7	Fen - Poor Fen	90	40022	40022	-0.0496	0.0803	0.1299	0.000014	0.012711	0.5514	907.9285714

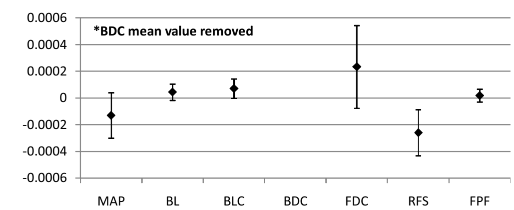


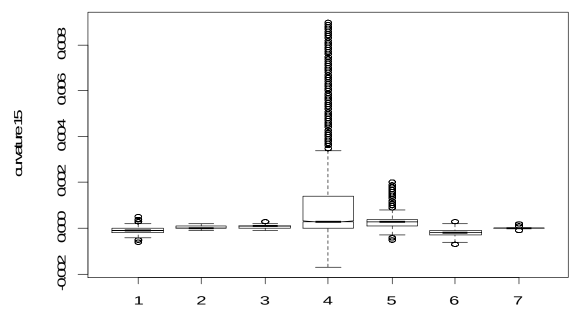


Curvature 15m Resample

ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	-0.0005	0.0004	0.0009	-0.000131	0.00017	-1.2737	1.297709924
2	Bog - Lichen	40	51068	51068	-0.0001	0.0002	0.0003	0.000044	0.000061	2.2695	1.386363636
3	Bog - Lichen / Conifer	50	36939	36939	-0.0001	0.0003	0.0004	0.00007	0.000072	2.5985	1.028571429
4	Bog - Dense Conifer	60	40262	40262	-0.002	0.009	0.011	0.001149	0.001524	46.252102	1.326370757
5	Fen - Dense Conifer	70	30581	30581	-0.0004	0.0018	0.0022	0.000233	0.000309	7.1131	1.326180258
6	Riparian Fen / Sedges	80	28569	28569	-0.0008	0.0003	0.0011	-0.000259	0.000173	-7.3944	0.667953668
7	Fen - Poor Fen	90	40022	40022	-0.0001	0.0002	0.0003	0.000018	0.000048	0.7282	2.666666667



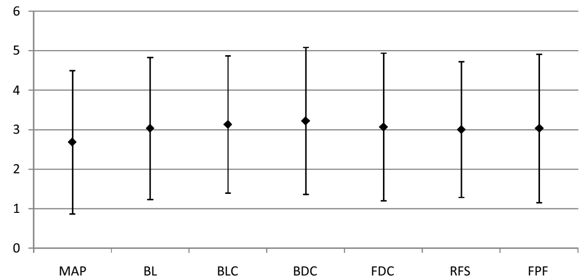


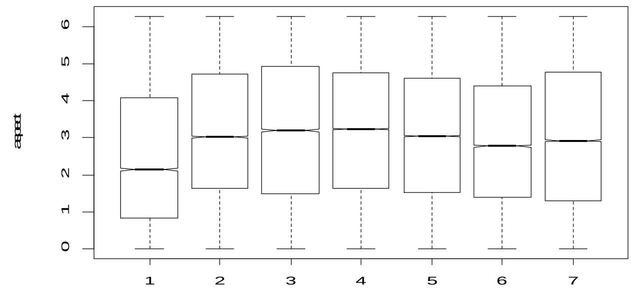


Aspect

Aspect

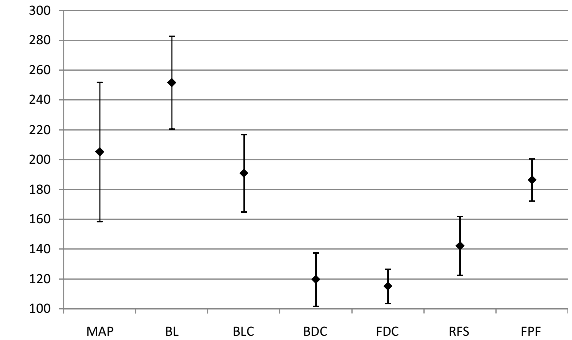
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	CV
1	Mat Around Pools	30	9698	9698	0.0045	6.2832	6.2787	2.685708	1.814212	26045.992	0.675506049
2	Bog - Lichen	40	51067	51067	0.0022	6.2832	6.281	3.034706	1.798829	154973.34	0.592752313
3	Bog - Lichen / Conifer	50	36938	36938	0.0021	6.2832	6.2811	3.132896	1.736989	115722.91	0.554435577
4	Bog - Dense Conifer	60	40262	40262	0.0006	6.2832	6.2826	3.225286	1.861278	129856.45	0.577089288
5	Fen - Dense Conifer	70	30581	30581	0.0012	6.2832	6.282	3.071562	1.868589	93931.438	0.608351386
6	Riparian Fen / Sedges	80	28565	28565	0.0022	6.2832	6.281	3.007298	1.719751	85903.461	0.571859191
7	Fen - Poor Fen	90	40022	40022	0.0019	6.2832	6.2813	3.034424	1.878751	121443.71	0.619145841

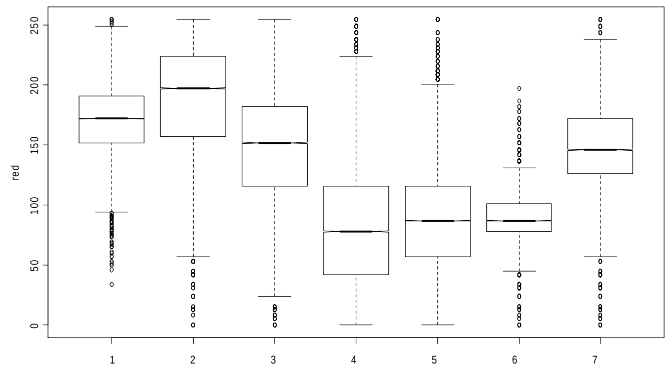




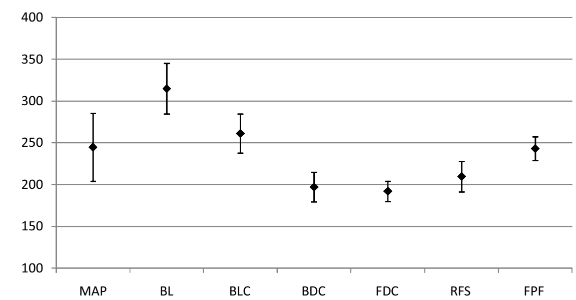
R/G/B/NIR

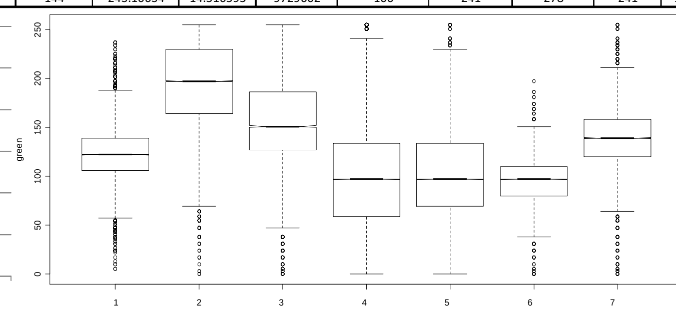
Red															
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN	CV
1	Mat Around Pools	30	9698	9698	93	778	685	205.19716	46.599991	1990002	155	225	143	203	0.6356
2	Bog - Lichen	40	51068	51068	148	367	219	251.6517	31.170582	12851349	188	253	367	251	1.4506
3	Bog - Lichen / Conifer	50	36939	36939	118	295	177	190.99007	25.939367	7054982	153	182	129	189	0.7088
4	Bog - Dense Conifer	60	40262	40262	78	237	159	119.58258	17.866907	4814634	124	110	83	117	0.7545
5	Fen - Dense Conifer	70	30581	30581	83	177	94	115.15104	11.480036	3521434	72	113	169	115	1.4956
6	Riparian Fen / Sedges	80	28569	28569	89	234	145	142.22223	19.739059	4063147	118	136	96	137	0.7059
7	Fen - Poor Fen	90	40022	40022	126	284	158	186.42828	14.091536	7461233	107	188	249	186	1.3245





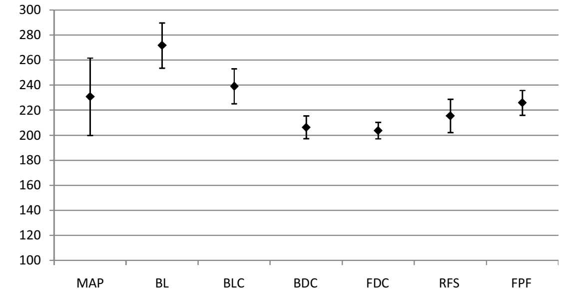
Green															
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN	CV
1	Mat Around Pools	30	9698	9698	149	772	623	244.76253	40.629246	2373707	120	238	482	240	2.0252
2	Bog - Lichen	40	51068	51068	220	435	215	314.88791	30.418886	16080696	183	315	229	315	0.7270
3	Bog - Lichen / Conifer	50	36939	36939	204	384	180	261.12839	23.281103	9645821	136	257	357	258	1.3891
4	Bog - Dense Conifer	60	40262	40262	151	319	168	197.09657	17.796598	7935502	119	195	246	195	1.2615
5	Fen - Dense Conifer	70	30581	30581	152	249	97	192.00746	12.076742	5871780	75	188	239	193	1.2713
6	Riparian Fen / Sedges	80	28569	28569	160	295	135	209.50989	18.169193	5985488	107	199	276	205	1.3869
7	Fen - Poor Fen	90	40022	40022	211	355	144	243.10634	14.316595	9729602	106	241	278	241	1.1535

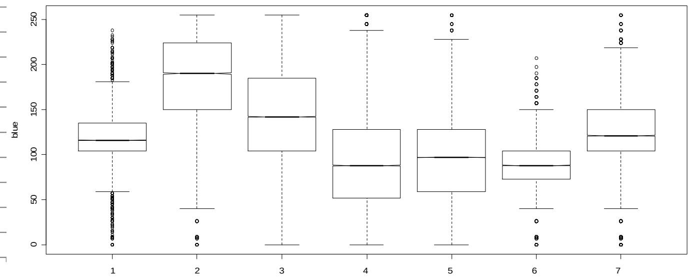




Blue

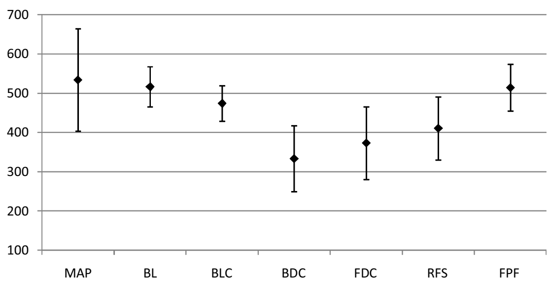
ID	CLASSNAME	CLASSVALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN	CV
1	Mat Around Pools	30	9698	9698	192	633	441	230.83409	30.899708	2238629	86	221	252	226	1.1403
2	Bog - Lichen	40	51068	51068	212	339	127	271.7157	18.029892	13875977	119	275	224	271	0.8145
3	Bog - Lichen / Conifer	50	36939	36939	204	302	98	239.15767	13.940698	8834245	88	233	284	238	1.2189
4	Bog - Dense Conifer	60	40262	40262	183	280	97	206.37787	9.128274	8309186	69	203	244	205	1.2020
5	Fen - Dense Conifer	70	30581	30581	183	233	50	203.81822	6.629962	6232965	44	205	231	204	1.1268
6	Riparian Fen / Sedges	80	28569	28569	189	284	95	215.52539	13.331803	6157345	80	212	191	212	0.9009
7	Fen - Poor Fen	90	40022	40022	205	304	99	225.96297	9.901697	9043490	71	222	254	224	1.1441

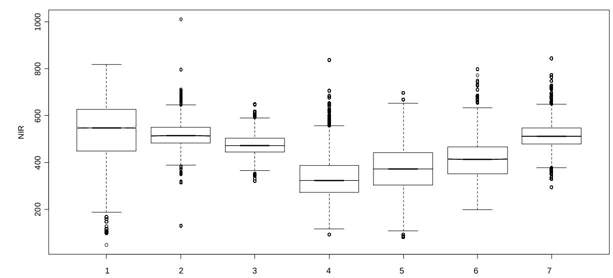




NIR

ID	CLASSNAME	VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	VARIETY	MAJORITY	MINORITY	MEDIAN	
1	Mat Around Pools	1	13954	13954	48	817	769	533.94	130.49422	7450599	479	509	48	546	
2	Bog - Lichen	2	34018	34018	130	1011	881	516.4798	51.294235	17569610	275	513	381	513	
3	Bog - Lichen / Conifer	3	22526	22526	320	647	327	474.01855	45.182743	10677742	224	464	541	472	
4	Bog - Dense Conifer	4	81177	81177	91	837	746	333.3317	83.933838	27058868	455	309	525	323	
5	Fen - Dense Conifer	5	54112	54112	80	696	616	373.01096	92.49855	20184368	451	264	189	371	
6	Riparian Fen / Sedges	6	20326	20326	197	798	601	410.479	80.4916	8343396	339	491	293	413	
7	Fen - Poor Fen	7	23412	23412	294	843	549	514.53436	59.545921	12046279	299	492	357	512	





APPENDIX C:

Classification Matrix and Results.

PERCENTILE

RGB_PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	70.2%
30 - Mat Around Pools	**706**	0	0	0	0	0	11	98.47%
40 - Bog - Lichen	0	**420**	318	16	11	0	14	53.92%
50 - Bog - Lichen / Conifer	0	213	**363**	64	164	0	64	41.82%
60 - Bog - Dense Conifer	0	4	18	**430**	93	0	0	78.90%
70 - Fen - Dense Conifer	0	44	13	154	**410**	92	1	57.42%
80 - Riparian Fen / Sedges	0	7	0	4	6	**408**	1	95.77%
90 - Fen - Poor Fen	15	55	34	3	10	10	**654**	83.74%
	97.92%	56.53%	48.66%	64.08%	59.08%	80.00%	87.79%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	499140	1063707	1,562,847	4.54%
40 - Bog - Lichen	1103110	3157676	4,260,786	12.38%
50 - Bog - Lichen / Conifer	2154809	6423502	8,578,311	24.92%
60 - Bog - Dense Conifer	360339	956458	1,316,797	3.83%
70 - Fen - Dense Conifer	759309	2311982	3,071,291	8.92%
80 - Riparian Fen / Sedges	387255	867000	1,254,255	3.64%
90 - Fen - Poor Fen	2409833	4916642	7,326,475	21.28%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		**North**	
Bog	**66.2%**	**Bog**	**69.0%**
Fen	**12.7%**	**Fen**	**12.1%**
Water	**21.1%**	**Water**	**18.9%**

IR_ RGB_PER250 _SLOPE10M	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	70.2%
30 - Mat Around Pools	**718**	0	0	2	0	0	3	99.31%
40 - Bog - Lichen	0	**441**	429	8	6	0	36	47.93%
50 - Bog - Lichen / Conifer	1	58	**259**	30	168	2	44	46.09%
60 - Bog - Dense Conifer	0	0	4	**458**	90	0	0	82.97%
70 - Fen - Dense Conifer	1	115	7	170	**404**	55	2	53.58%
80 - Riparian Fen / Sedges	1	7	0	6	5	**443**	0	95.89%
90 - Fen - Poor Fen	1	118	45	0	8	11	**656**	78.19%
	99.45%	59.68%	34.81%	67.95%	59.32%	86.69%	88.53%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.50%
30 - Mat Around Pools	513772	1345188	1,858,960	5.40%
40 - Bog - Lichen	1306045	3510998	4,817,043	14.00%
50 - Bog - Lichen / Conifer	1820726	5839120	7,659,846	22.26%
60 - Bog - Dense Conifer	381903	770525	1,152,428	3.35%
70 - Fen - Dense Conifer	813820	2745049	3,558,869	10.34%
80 - Riparian Fen / Sedges	407544	932326	1,339,870	3.89%
90 - Fen - Poor Fen	2428139	4544372	6,972,511	20.26%
Total	**9,463,698**	**24,948,663**	**34,412,361**	**100.00%**

South		**North**	
Bog	**64.2%**	**Bog**	**68.2%**
Fen	**14.7%**	**Fen**	**12.9%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_PER70	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	66.7%
30 - Mat Around Pools	**718**	1	0	0	0	0	17	97.55%
40 - Bog - Lichen	0	**478**	156	6	10	19	61	65.48%
50 - Bog - Lichen / Conifer	0	205	**502**	51	88	175	68	46.10%
60 - Bog - Dense Conifer	0	0	3	**434**	330	12	0	55.71%
70 - Fen - Dense Conifer	0	17	26	242	**301**	68	3	45.81%
80 - Riparian Fen / Sedges	1	2	4	14	20	**470**	3	91.44%
90 - Fen - Poor Fen	31	47	59	3	1	6	**598**	80.27%
	95.73%	63.73%	66.93%	57.87%	40.13%	62.67%	79.73%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	601922	1362346	1,964,268	5.71%
40 - Bog - Lichen	1101565	3122834	4,224,399	12.27%
50 - Bog - Lichen / Conifer	2328042	5983009	8,311,051	24.14%
60 - Bog - Dense Conifer	481943	1658156	2,140,099	6.22%
70 - Fen - Dense Conifer	645242	1927377	2,572,619	7.47%
80 - Riparian Fen / Sedges	415437	1278242	1,693,679	4.92%
90 - Fen - Poor Fen	2099656	4365003	6,464,659	18.78%
Total	**9,465,556**	**24,958,052**	**34,423,608**	**100.00%**

South		North	
Bog	**66.1%**	**Bog**	**69.9%**
Fen	**12.8%**	**Fen**	**11.2%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	71.8%
30 - Mat Around Pools	**728**	2	0	0	1	0	22	96.68%
40 - Bog - Lichen	0	**387**	194	8	7	0	31	61.72%
50 - Bog - Lichen / Conifer	0	261	**500**	48	140	0	80	48.59%
60 - Bog - Dense Conifer	0	1	12	**468**	135	1	0	75.85%
70 - Fen - Dense Conifer	0	38	1	223	**458**	127	3	53.88%
80 - Riparian Fen / Sedges	1	3	0	3	5	**614**	0	98.08%
90 - Fen - Poor Fen	21	58	43	0	4	8	**614**	82.09%
	97.07%	51.60%	66.67%	62.40%	61.07%	81.87%	81.87%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	601912	1361302	1,963,214	5.70%
40 - Bog - Lichen	945122	2846498	3,791,620	11.01%
50 - Bog - Lichen / Conifer	2374786	6667614	9,042,400	26.27%
60 - Bog - Dense Conifer	347477	1050379	1,397,856	4.06%
70 - Fen - Dense Conifer	815966	2529316	3,345,282	9.72%
80 - Riparian Fen / Sedges	347010	801457	1,148,467	3.34%
90 - Fen - Poor Fen	2241522	4440401	6,681,923	19.41%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	**65.6%**	**Bog**	**68.8%**
Fen	**13.3%**	**Fen**	**12.3%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_PER70 _PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	73.5%
30 - Mat Around Pools	**701**	2	0	1	0	0	19	96.96%
40 - Bog - Lichen	0	**383**	181	9	5	0	30	62.99%
50 - Bog - Lichen / Conifer	0	259	**511**	45	115	5	74	50.64%
60 - Bog - Dense Conifer	0	1	10	**480**	73	0	0	85.11%
70 - Fen - Dense Conifer	0	28	3	133	**476**	124	3	62.06%
80 - Riparian Fen / Sedges	1	4	0	6	7	**371**	0	95.37%
90 - Fen - Poor Fen	20	62	39	0	5	11	**615**	81.78%
	97.09%	51.83%	68.68%	71.22%	69.90%	72.60%	83.00%	

Landscape Type	**North**	**South**	**Total**	**% Total Coverage**
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	642841	1451231	2,094,072	6.08%
40 - Bog - Lichen	984666	2927047	3,911,713	11.36%
50 - Bog - Lichen / Conifer	2368153	6740527	9,108,680	26.46%
60 - Bog - Dense Conifer	390355	1165839	1,556,194	4.52%
70 - Fen - Dense Conifer	777972	2323753	3,101,725	9.01%
80 - Riparian Fen / Sedges	342242	850181	1,192,423	3.46%
90 - Fen - Poor Fen	2167566	4238389	6,405,955	18.61%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		**North**	
Bog	**66.2%**	**Bog**	**69.2%**
Fen	**12.7%**	**Fen**	**11.8%**
Water	**21.1%**	**Water**	**18.9%**

DME

RGB_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	73.4%
30 - Mat Around Pools	**727**	2	0	0	0	0	6	98.91%
40 - Bog - Lichen	0	**498**	249	20	19	0	34	60.73%
50 - Bog - Lichen / Conifer	0	141	**429**	53	176	0	81	48.75%
60 - Bog - Dense Conifer	0	4	13	**439**	38	0	0	88.87%
70 - Fen - Dense Conifer	0	38	12	232	**507**	117	0	55.96%
80 - Riparian Fen / Sedges	1	4	0	4	6	**627**	3	97.21%
90 - Fen - Poor Fen	22	63	47	2	4	6	**626**	81.30%
	96.93%	66.40%	57.20%	58.53%	67.60%	83.60%	83.47%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	489961	1040538	1,530,499	4.45%
40 - Bog - Lichen	1243621	3280367	4,523,988	13.14%
50 - Bog - Lichen / Conifer	2019343	6471827	8,491,170	24.67%
60 - Bog - Dense Conifer	292351	553222	845,573	2.46%
70 - Fen - Dense Conifer	807188	2524028	3,331,216	9.68%
80 - Riparian Fen / Sedges	399351	883752	1,283,103	3.73%
90 - Fen - Poor Fen	2421980	4943233	7,365,213	21.40%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	**65.3%**	**Bog**	**68.3%**
Fen	**13.7%**	**Fen**	**12.7%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.3%
30 - Mat Around Pools	**727**	2	0	0	1	0	21	96.80%
40 - Bog - Lichen	0	**491**	153	9	13	1	50	68.48%
50 - Bog - Lichen / Conifer	0	172	**544**	49	147	0	73	55.23%
60 - Bog - Dense Conifer	0	0	7	**446**	44	0	0	89.74%
70 - Fen - Dense Conifer	0	26	2	243	**534**	136	3	56.57%
80 - Riparian Fen / Sedges	0	2	0	3	7	**606**	0	98.06%
90 - Fen - Poor Fen	23	57	44	0	4	7	**603**	81.71%
	96.93%	65.47%	72.53%	59.47%	71.20%	80.80%	80.40%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	593938	1331506	1,925,444	5.59%
40 - Bog - Lichen	1049421	3064268	4,113,689	11.95%
50 - Bog - Lichen / Conifer	2298956	6670204	8,969,160	26.06%
60 - Bog - Dense Conifer	279309	603560	882,869	2.56%
70 - Fen - Dense Conifer	872646	2824235	3,696,881	10.74%
80 - Riparian Fen / Sedges	355701	817623	1,173,324	3.41%
90 - Fen - Poor Fen	2223824	4385571	6,609,395	19.20%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		**North**	
Bog	**64.3%**	**Bog**	**68.1%**
Fen	**14.6%**	**Fen**	**13.0%**
Water	**21.1%**	**Water**	**18.9%**

RGB_DME70 _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	73.6%
30 - Mat Around Pools	**704**	2	0	0	0	2	7	98.46%
40 - Bog - Lichen	0	**475**	226	24	9	0	32	62.01%
50 - Bog - Lichen / Conifer	0	161	**453**	46	147	0	80	51.07%
60 - Bog - Dense Conifer	0	8	12	**475**	50	7	0	86.05%
70 - Fen - Dense Conifer	0	29	14	117	**463**	140	1	60.60%
80 - Riparian Fen / Sedges	1	3	0	10	7	**353**	3	93.63%
90 - Fen - Poor Fen	17	61	39	2	5	9	**618**	82.29%
	97.51%	64.28%	60.89%	70.47%	67.99%	69.08%	83.40%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	555996	1184243	1,740,239	5.06%
40 - Bog - Lichen	1222204	3233752	4,455,956	12.94%
50 - Bog - Lichen / Conifer	2078272	6630572	8,708,844	25.30%
60 - Bog - Dense Conifer	404862	923365	1,328,227	3.86%
70 - Fen - Dense Conifer	785880	2237803	3,023,683	8.78%
80 - Riparian Fen / Sedges	344165	915732	1,259,897	3.66%
90 - Fen - Poor Fen	2282416	4570882	6,853,298	19.91%
Total	**9,465,544**	**24,957,434**	**34,422,978**	**100.00%**

South		North	
Bog	**66.3%**	**Bog**	**69.1%**
Fen	**12.6%**	**Fen**	**11.9%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_DME70 _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.2%
30 - Mat Around Pools	**701**	1	0	1	0	2	15	97.36%
40 - Bog - Lichen	0	**475**	135	7	12	1	45	70.37%
50 - Bog - Lichen / Conifer	0	186	**556**	52	129	0	73	55.82%
60 - Bog - Dense Conifer	0	2	7	**482**	71	7	1	84.56%
70 - Fen - Dense Conifer	0	19	9	127	**455**	146	2	60.03%
80 - Riparian Fen / Sedges	1	3	0	5	9	**345**	0	95.04%
90 - Fen - Poor Fen	20	53	37	0	5	10	**605**	82.88%
	97.09%	64.28%	74.73%	71.51%	66.81%	67.51%	81.65%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	640173	1440231	2,080,404	6.04%
40 - Bog - Lichen	1067613	3085040	4,152,653	12.06%
50 - Bog - Lichen / Conifer	2302153	6788090	9,090,243	26.41%
60 - Bog - Dense Conifer	422589	1071872	1,494,461	4.34%
70 - Fen - Dense Conifer	796033	2324776	3,120,809	9.07%
80 - Riparian Fen / Sedges	314718	846445	1,161,163	3.37%
90 - Fen - Poor Fen	2130516	4140513	6,271,029	18.22%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		**North**	
Bog	**66.2%**	**Bog**	**69.3%**
Fen	**12.7%**	**Fen**	**11.7%**
Water	**21.1%**	**Water**	**18.9%**

VDCN

IR_RGB_VDCN _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**74.8%**
30 - Mat Around Pools	**739**	3	1	1	0	0	76	90.12%
40 - Bog - Lichen	0	**350**	29	8	2	0	45	80.65%
50 - Bog - Lichen / Conifer	1	301	**671**	79	68	0	109	54.60%
60 - Bog - Dense Conifer	0	2	18	**471**	56	1	0	85.95%
70 - Fen - Dense Conifer	0	41	19	188	**616**	175	3	59.12%
80 - Riparian Fen / Sedges	0	3	0	3	6	**564**	0	97.92%
90 - Fen - Poor Fen	10	50	12	0	2	10	**517**	86.02%
	98.53%	46.67%	89.47%	62.80%	82.13%	75.20%	68.93%	

Landscape Type	**North**	**South**	**Total**	**% Total Coverage**
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	657000	1601517	2,258,517	6.56%
40 - Bog - Lichen	913917	2429941	3,343,858	9.72%
50 - Bog - Lichen / Conifer	2638000	7955821	10,593,821	30.78%
60 - Bog - Dense Conifer	302353	994471	1,296,824	3.77%
70 - Fen - Dense Conifer	754453	2273655	3,028,108	8.80%
80 - Riparian Fen / Sedges	293736	677322	971,058	2.82%
90 - Fen - Poor Fen	2110756	3757570	5,868,326	17.05%
Total	**9,461,964**	**24,951,382**	**34,413,346**	**100.00%**

South		**North**	
Bog	**67.1%**	**Bog**	**70.0%**
Fen	**11.8%**	**Fen**	**11.1%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_VDCN _DME70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	**74.1%**
30 - Mat Around Pools	**715**	2	1	3	0	2	84	88.60%
40 - Bog - Lichen	0	**344**	23	7	2	0	41	82.49%
50 - Bog - Lichen / Conifer	0	306	**685**	70	87	0	103	54.76%
60 - Bog - Dense Conifer	0	2	14	**473**	72	6	1	83.27%
70 - Fen - Dense Conifer	0	31	10	117	**504**	156	2	61.46%
80 - Riparian Fen / Sedges	1	4	0	4	14	**334**	0	93.56%
90 - Fen - Poor Fen	6	50	11	0	2	13	**510**	86.15%
	99.03%	46.55%	92.07%	70.18%	74.01%	65.36%	68.83%	

Landscape Type	**North**	**South**	**Total**	**% Total Coverage**
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	657000	1601517	2,258,517	6.56%
40 - Bog - Lichen	913917	2429941	3,343,858	9.72%
50 - Bog - Lichen / Conifer	2638000	7955821	10,593,821	30.78%
60 - Bog - Dense Conifer	302353	994471	1,296,824	3.77%
70 - Fen - Dense Conifer	754453	2273655	3,028,108	8.80%
80 - Riparian Fen / Sedges	293736	677322	971,058	2.82%
90 - Fen - Poor Fen	2110756	3757570	5,868,326	17.05%
Total	**9,461,964**	**24,951,382**	**34,413,346**	**100.00%**

South		**North**	
Bog	**67.1%**	**Bog**	**70.0%**
Fen	**11.8%**	**Fen**	**11.1%**
Water	**21.1%**	**Water**	**18.9%**

IR_RGB_VDCN _PER70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.2%
30 - Mat Around Pools	**739**	3	1	3	0	3	85	88.61%
40 - Bog - Lichen	0	**341**	33	7	1	0	36	81.58%
50 - Bog - Lichen / Conifer	1	328	**677**	87	76	1	110	52.89%
60 - Bog - Dense Conifer	0	2	17	**497**	58	1	0	86.43%
70 - Fen - Dense Conifer	0	31	10	143	**593**	145	1	64.25%
80 - Riparian Fen / Sedges	2	4	0	10	20	**585**	0	94.20%
90 - Fen - Poor Fen	8	41	12	3	2	15	**518**	86.48%
	98.53%	45.47%	90.27%	66.27%	79.07%	78.00%	69.07%	

Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	693720	1691206	2,384,926	6.93%
40 - Bog - Lichen	922147	2401786	3,323,933	9.66%
50 - Bog - Lichen / Conifer	2614398	8068760	10,683,158	31.04%
60 - Bog - Dense Conifer	296831	925246	1,222,077	3.55%
70 - Fen - Dense Conifer	783422	2233375	3,016,797	8.77%
80 - Riparian Fen / Sedges	292057	742284	1,034,341	3.01%
90 - Fen - Poor Fen	2067640	3627640	5,695,280	16.55%
Total	**9,461,964**	**24,951,382**	**34,413,346**	**100.00%**

South		North	
Bog	**67.0%**	**Bog**	**69.7%**
Fen	**11.9%**	**Fen**	**11.4%**
Water	**21.1%**	**Water**	**18.9%**

BEST RESULTS

IR_RGB_PER70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.7%
0	0	0	0	0	0	0	0	
30 - Mat Around Pools	**726**	1	0	2	0	2	14	97.45%
40 - Bog - Lichen	0	**483**	147	8	16	1	49	68.61%
50 - Bog - Lichen / Conifer	0	189	**556**	62	135	1	75	54.62%
60 - Bog - Dense Conifer	0	1	6	**496**	40	0	0	91.34%
70 - Fen - Dense Conifer	0	17	4	177	**544**	173	2	59.32%
80 - Riparian Fen / Sedges	1	4	0	5	10	**559**	0	96.55%
90 - Fen - Poor Fen	23	55	37	0	5	14	**610**	81.99%
	96.80%	64.40%	74.13%	66.13%	72.53%	74.53%	81.33%	

Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	631851	1414108	2,045,959	5.94%
40 - Bog - Lichen	1079659	3113458	4,193,117	12.18%
50 - Bog - Lichen / Conifer	2301723	6789830	9,091,553	26.41%
60 - Bog - Dense Conifer	320371	765550	1,085,921	3.15%
70 - Fen - Dense Conifer	829948	2511572	3,341,520	9.71%
80 - Riparian Fen / Sedges	356341	896514	1,252,855	3.64%
90 - Fen - Poor Fen	2153902	4205935	6,359,837	18.48%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	65.3%	Bog	68.5%
Fen	13.7%	Fen	12.5%
Water	21.1%	Water	20.5%

IR_RGB_PER70_DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.5%
30 - Mat Around Pools	724	2	0	0	0	2	19	96.92%
40 - Bog - Lichen	0	482	126	8	16	14	49	69.35%
50 - Bog - Lichen / Conifer	0	210	574	66	149	1	80	53.15%
60 - Bog - Dense Conifer	0	1	4	498	42	0	0	91.38%
70 - Fen - Dense Conifer	0	9	5	172	529	170	0	59.77%
80 - Riparian Fen / Sedges	1	1	0	5	11	555	0	96.86%
90 - Fen - Poor Fen	25	45	41	1	3	8	602	83.03%
	96.53%	64.27%	76.53%	66.40%	70.53%	74.00%	80.27%	

Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	629479	1380644	2,010,123	5.84%
40 - Bog - Lichen	1055745	2992299	4,048,044	11.76%
50 - Bog - Lichen / Conifer	2343440	7005247	9,348,687	27.16%
60 - Bog - Dense Conifer	359997	718550	1,078,547	3.13%
70 - Fen - Dense Conifer	801397	2417125	3,218,522	9.35%
80 - Riparian Fen / Sedges	355072	911205	1,266,277	3.68%
90 - Fen - Poor Fen	2128665	4271897	6,400,562	18.59%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	65.6%	Bog	68.9%
Fen	13.3%	Fen	12.2%
Water	21.1%	Water	18.9%

IR_RGB_DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	76.4%
30 - Mat Around Pools	**695**	2	0	0	0	0	21	96.80%
40 - Bog - Lichen	0	**487**	136	6	13	4	48	70.17%
50 - Bog - Lichen / Conifer	0	186	**556**	46	128	0	75	56.10%
60 - Bog - Dense Conifer	0	0	5	**403**	39	0	0	90.16%
70 - Fen - Dense Conifer	0	14	2	218	**486**	51	3	62.79%
80 - Riparian Fen / Sedges	1	1	0	1	12	**454**	0	96.80%
90 - Fen - Poor Fen	26	49	45	0	3	2	**594**	82.61%
	96.26%	65.90%	74.73%	59.79%	71.37%	88.85%	80.16%	

Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	570012	1229328	1,799,340	5.23%
40 - Bog - Lichen	1023486	2941638	3,965,124	11.52%
50 - Bog - Lichen / Conifer	2265922	6716473	8,982,395	26.09%
60 - Bog - Dense Conifer	330991	573428	904,419	2.63%
70 - Fen - Dense Conifer	808089	2642578	3,450,667	10.02%
80 - Riparian Fen / Sedges	483873	1147433	1,631,306	4.74%
90 - Fen - Poor Fen	2191422	4446089	6,637,511	19.28%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	63.7%	Bog	67.4%
Fen	15.2%	Fen	13.6%
Water	21.1%	Water	18.9%

POST HOC: IR_RGB_DIME250B - REMOVED "50-BLC" CLASS	30 - Mat Around Pools	40 - Bog - Lichen	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	83.9%
30 - Mat Around Pools	740	0	0	1	0	26	96.48%
40 - Bog - Lichen	0	642	13	30	3	55	86.41%
60 - Bog - Dense Conifer	0	4	422	49	0	0	88.84%
70 - Fen - Dense Conifer	0	21	221	594	102	2	63.19%
80 - Riparian Fen / Sedges	0	2	5	3	401	1	97.33%
90 - Fen - Poor Fen	10	81	11	21	4	666	83.98%
	0	0	78	52	240	0	

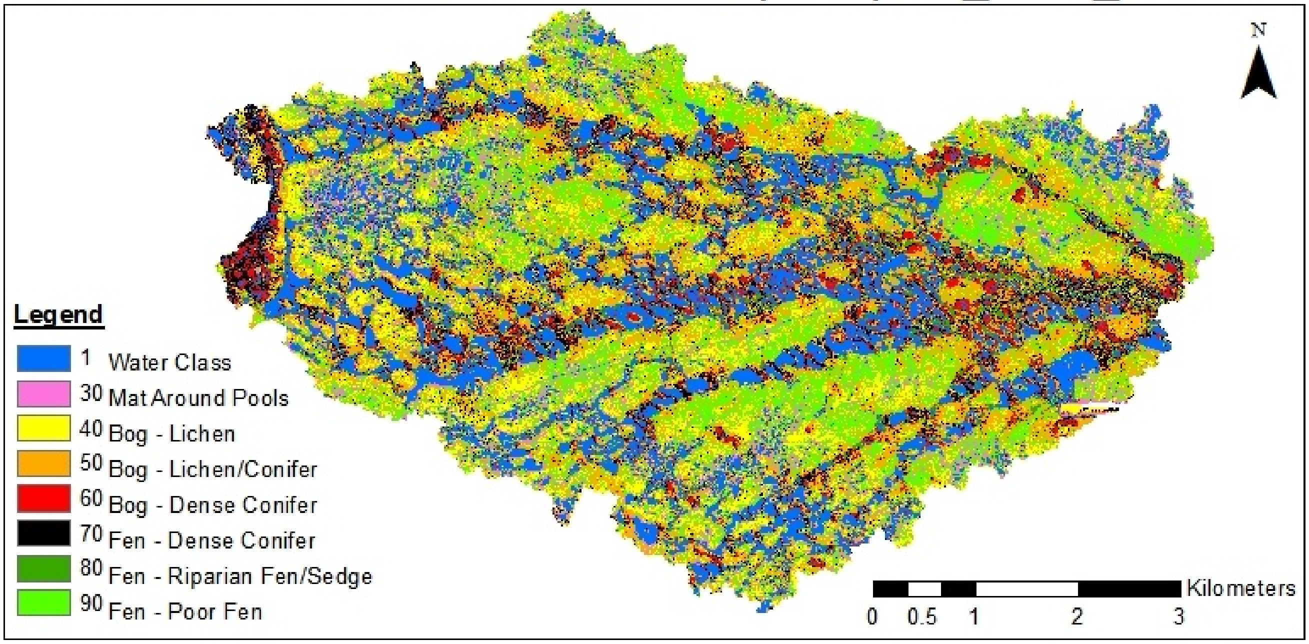
Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	607255	1327111	1,934,366	5.62%
40 - Bog - Lichen	1950421	5562197	7,512,618	21.82%
60 - Bog - Dense Conifer	404610	903802	1,308,412	3.80%
70 - Fen - Dense Conifer	1215147	4118903	5,334,050	15.50%
80 - Riparian Fen / Sedges	365416	863121	1,228,537	3.57%
90 - Fen - Poor Fen	3130946	6921833	10,052,779	29.20%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

South		North	
Bog	59.0%	Bog	64.4%
Fen	20.0%	Fen	16.7%
Water	21.1%	Water	18.9%

APPENDIX D:

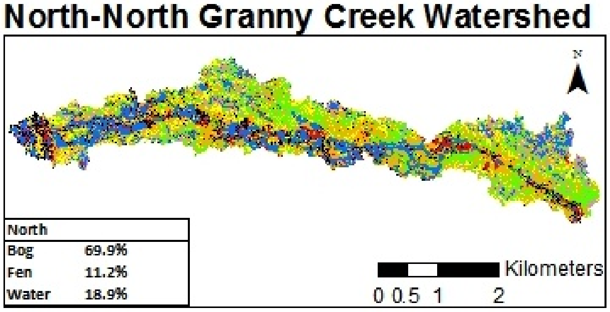
Classification Maps for each Analysis.

SUPERVISED CLASSIFICATION (MLC): IR_RGB_PER70

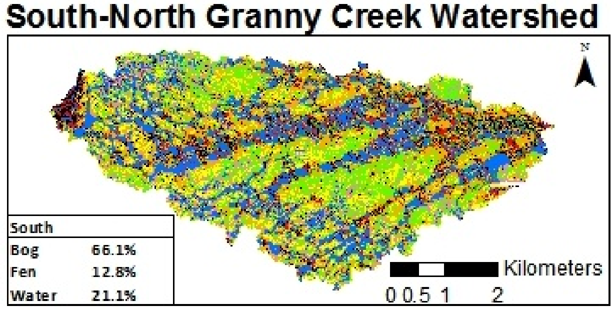


IR_RGB_PER70	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	66.7%
30 - Mat Around Pools	**718**	1	0	0	0	0	17	97.6%
40 - Bog - Lichen	0	**478**	156	6	10	19	61	65.5%
50 - Bog - Lichen / Conifer	0	205	**502**	51	88	175	68	46.1%
60 - Bog - Dense Conifer	0	0	3	**434**	330	12	0	55.7%
70 - Fen - Dense Conifer	0	17	26	242	**301**	68	3	45.8%
80 - Riparian Fen / Sedges	1	2	4	14	20	**470**	3	91.4%
90 - Fen - Poor Fen	31	47	59	3	1	6	**598**	80.3%
Total	95.7%	63.7%	66.9%	57.9%	40.1%	62.7%	79.7%	

North-North Granny Creek Watershed

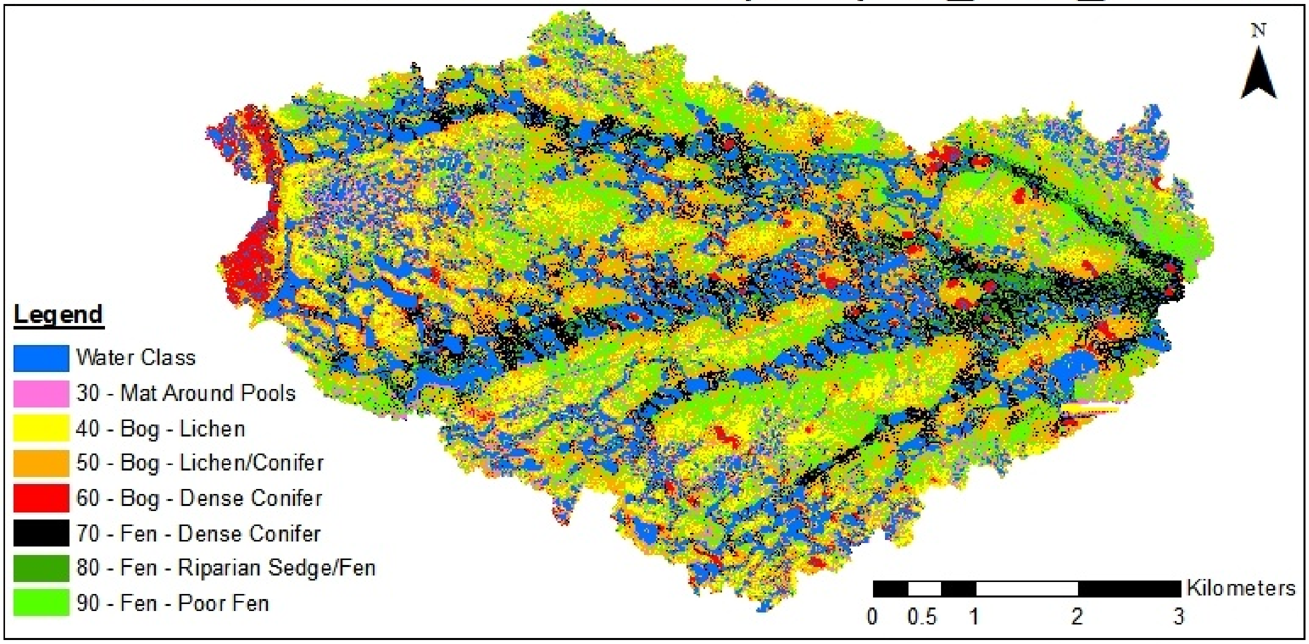


South-North Granny Creek Watershed



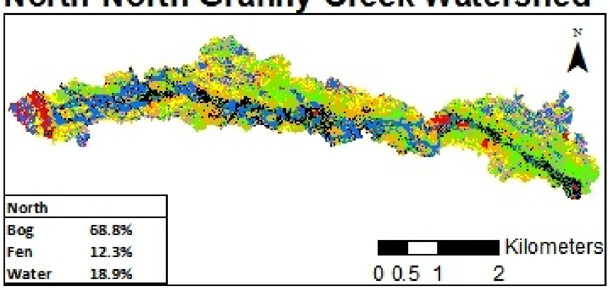
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	601922	1362346	1,964,268	5.71%
40 - Bog - Lichen	1101565	3122834	4,224,399	12.27%
50 - Bog - Lichen / Conifer	2328042	5983009	8,311,051	24.14%
60 - Bog - Dense Conifer	481943	1658156	2,140,099	6.22%
70 - Fen - Dense Conifer	645242	1927377	2,572,619	7.47%
80 - Riparian Fen / Sedges	415437	1278242	1,693,679	4.92%
90 - Fen - Poor Fen	2099656	4365003	6,464,659	18.78%
Total	**9,465,556**	**24,958,052**	**34,423,608**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_PER250

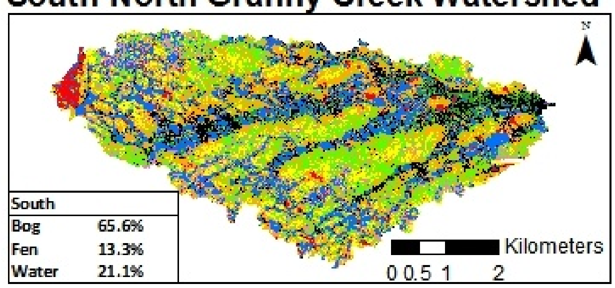


IR_RGB_PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	71.8%
30 - Mat Around Pools	728	2	0	0	1	0	22	96.7%
40 - Bog - Lichen	0	387	194	8	7	0	31	61.7%
50 - Bog - Lichen / Conifer	0	261	500	48	140	0	80	48.6%
60 - Bog - Dense Conifer	0	1	12	468	135	1	0	75.9%
70 - Fen - Dense Conifer	0	38	1	223	458	127	3	53.9%
80 - Riparian Fen / Sedges	1	3	0	3	5	614	0	98.1%
90 - Fen - Poor Fen	21	58	43	0	4	8	614	82.1%
Total	97.1%	51.6%	66.7%	62.4%	61.1%	81.9%	81.9%	

North-North Granny Creek Watershed

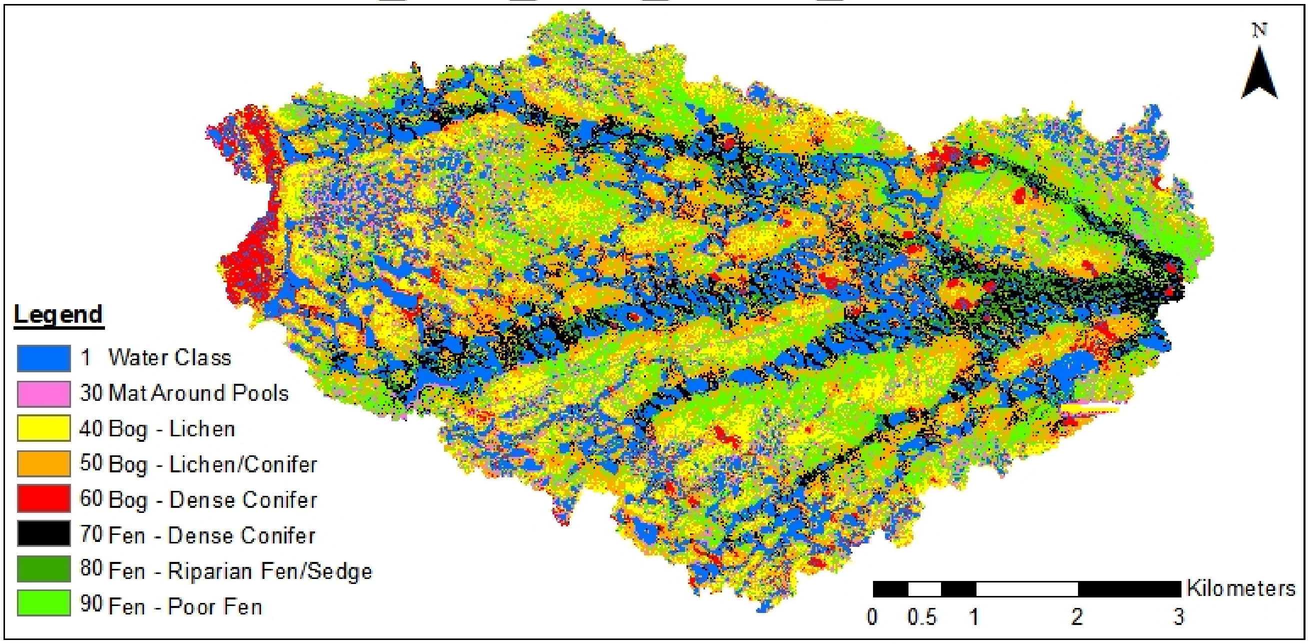


South-North Granny Creek Watershed



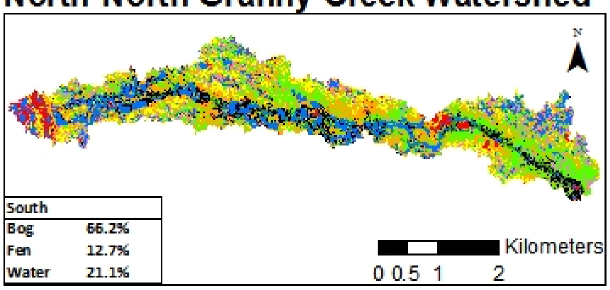
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	601912	1361302	1,963,214	5.70%
40 - Bog - Lichen	945122	2846498	3,791,620	11.01%
50 - Bog - Lichen / Conifer	2374786	6667614	9,042,400	26.27%
60 - Bog - Dense Conifer	347477	1050379	1,397,856	4.06%
70 - Fen - Dense Conifer	815966	2529316	3,345,282	9.72%
80 - Riparian Fen / Sedges	347010	801457	1,148,467	3.34%
90 - Fen - Poor Fen	2241522	4440401	6,681,923	19.41%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_RGB_PER70_PER250

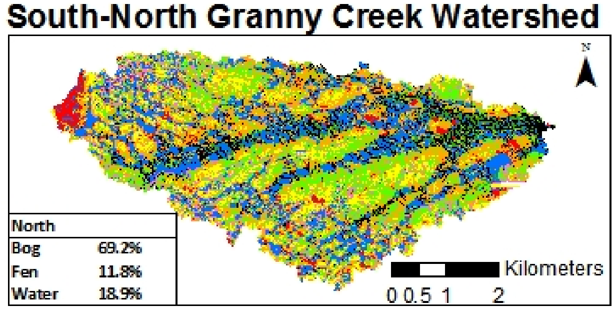


IR_RGB_PER70 _PER250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	73.5%
30 - Mat Around Pools	701	2	0	1	0	0	19	97.0%
40 - Bog - Lichen	0	383	181	9	5	0	30	63.0%
50 - Bog - Lichen / Conifer	0	259	511	45	115	5	74	50.6%
60 - Bog - Dense Conifer	0	1	10	480	73	0	0	85.1%
70 - Fen - Dense Conifer	0	28	3	133	476	124	3	62.1%
80 - Riparian Fen / Sedges	1	4	0	6	7	371	0	95.4%
90 - Fen - Poor Fen	20	62	39	0	5	11	615	81.8%
Total	97.1%	51.8%	68.7%	71.2%	69.9%	72.6%	83.0%	

North-North Granny Creek Watershed

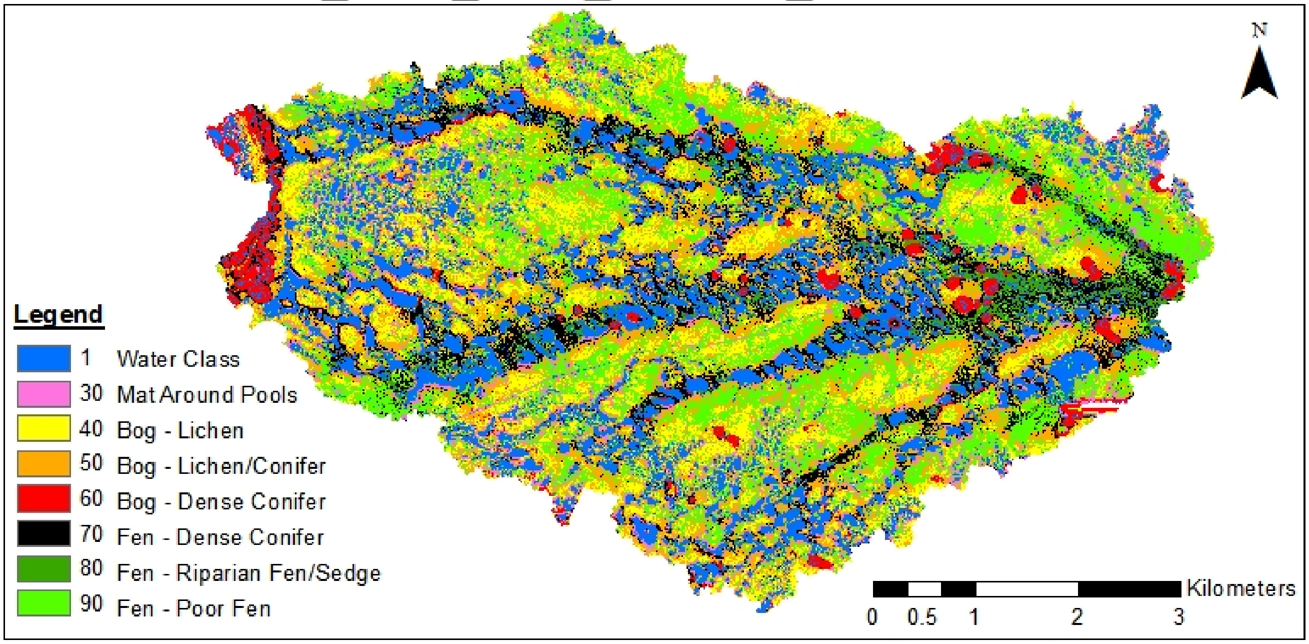


South-North Granny Creek Watershed



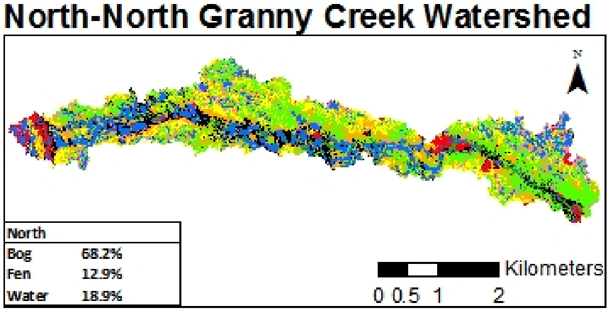
Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	642841	1451231	2,094,072	6.08%
40 - Bog - Lichen	984666	2927047	3,911,713	11.36%
50 - Bog - Lichen / Conifer	2368153	6740527	9,108,680	26.46%
60 - Bog - Dense Conifer	390355	1165839	1,556,194	4.52%
70 - Bog Conifer / Sphagnum	777972	2323753	3,101,725	9.01%
80 - Riparian Fen / Sedges	342242	850181	1,192,423	3.46%
90 - Fen Dense Conifer	2167566	4238389	6,405,955	18.61%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): _ IR_RGB_PER250_SLOPE10m

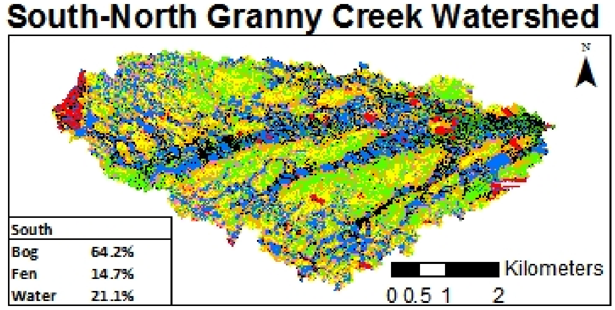


IR_RGB_PER250_ SLOPE10M	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Bog Conifer / Sphagnum	80 - Riparian Fen / Sedges	90 - Fen Dense Conifer	70.2%
30 - Mat Around Pools	718	0	0	2	0	0	3	99.3%
40 - Bog - Lichen	0	441	429	8	6	0	36	47.9%
50 - Bog - Lichen / Conifer	1	58	259	30	168	2	44	46.1%
60 - Bog - Dense Conifer	0	0	4	458	90	0	0	83.0%
70 - Fen - Dense Conifer	1	115	7	170	404	55	2	53.6%
80 - Riparian Fen / Sedges	1	7	0	6	5	443	0	95.9%
90 - Fen - Poor Fen	1	118	45	0	8	11	656	78.2%
	99.4%	59.7%	34.8%	68.0%	59.3%	86.7%	88.5%	

North-North Granny Creek Watershed

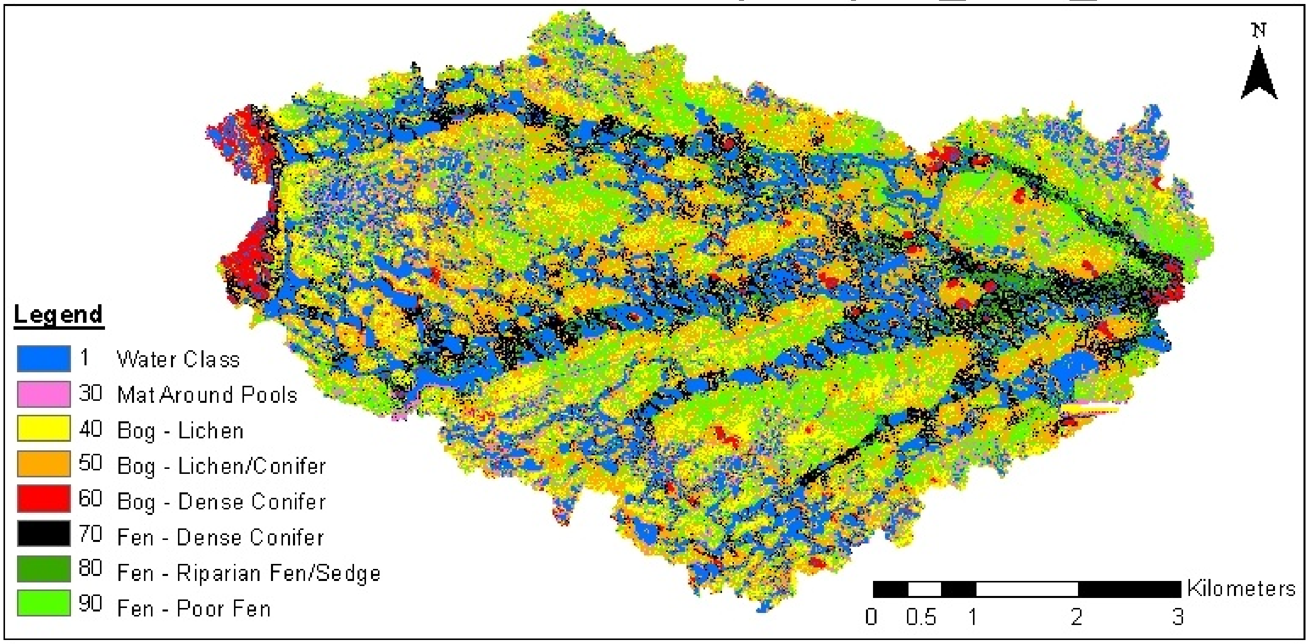


South-North Granny Creek Watershed



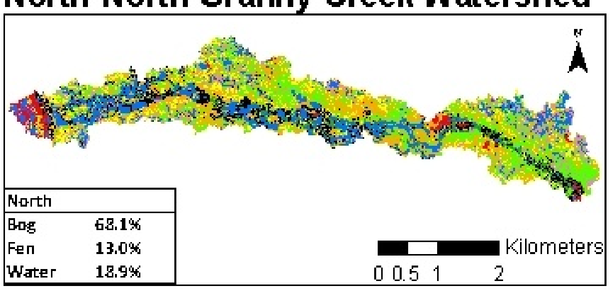
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.50%
30 - Mat Around Pools	513772	1345188	1,858,960	5.40%
40 - Bog - Lichen	1306045	3510998	4,817,043	14.00%
50 - Bog - Lichen / Conifer	1820726	5839120	7,659,846	22.26%
60 - Bog - Dense Conifer	381903	770525	1,152,428	3.35%
70 - Fen - Dense Conifer	813820	2745049	3,558,869	10.34%
80 - Riparian Fen / Sedges	407544	932326	1,339,870	3.89%
90 - Fen - Poor Fen	2428139	4544372	6,972,511	20.26%
Total	**9,463,698**	**24,948,663**	**34,412,361**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_DME250

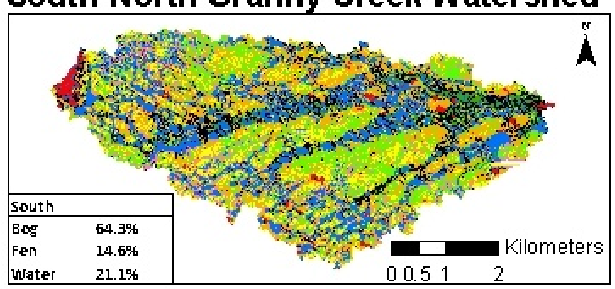


IR_RGB_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.3%
30 - Mat Around Pools	**727**	2	0	0	1	0	21	96.8%
40 - Bog - Lichen	0	**491**	153	9	13	1	50	68.5%
50 - Bog - Lichen / Conifer	0	172	**544**	49	147	0	73	55.2%
60 - Bog - Dense Conifer	0	0	7	**446**	44	0	0	89.7%
70 - Fen - Dense Conifer	0	26	2	243	**534**	136	3	56.6%
80 - Riparian Fen / Sedges	0	2	0	3	7	**606**	0	98.1%
90 - Fen - Poor Fen	23	57	44	0	4	7	**603**	81.7%
Total	96.9%	65.5%	72.5%	59.5%	71.2%	80.8%	80.4%	

North-North Granny Creek Watershed

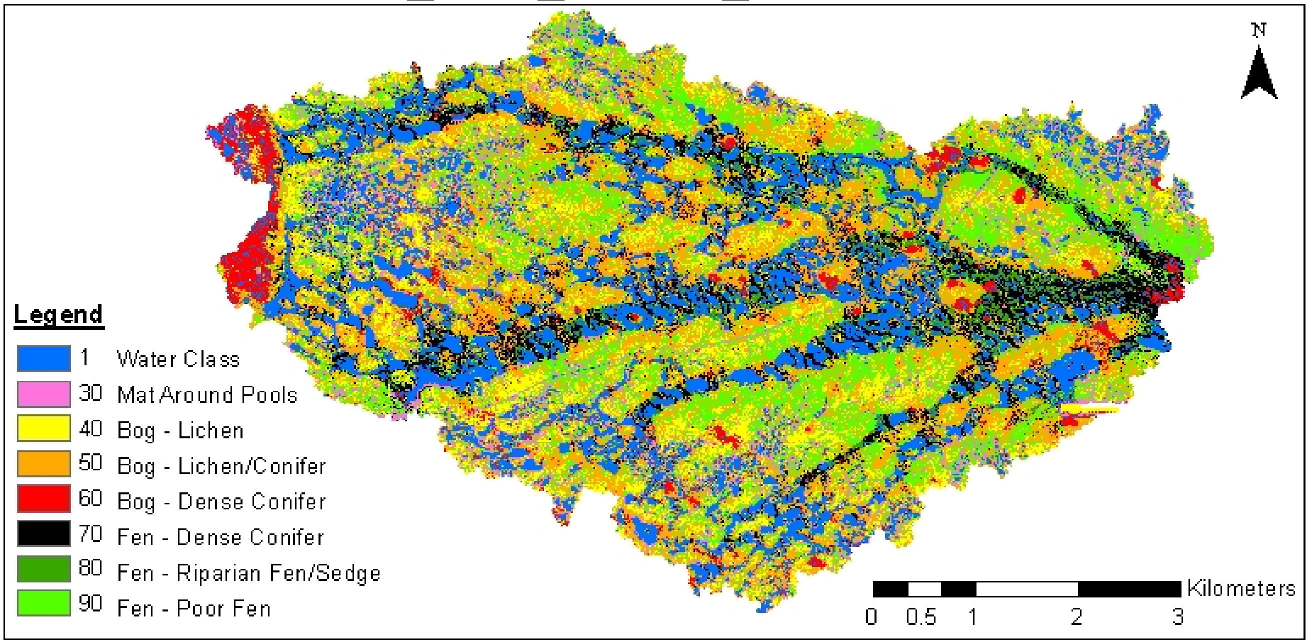


South-North Granny Creek Watershed



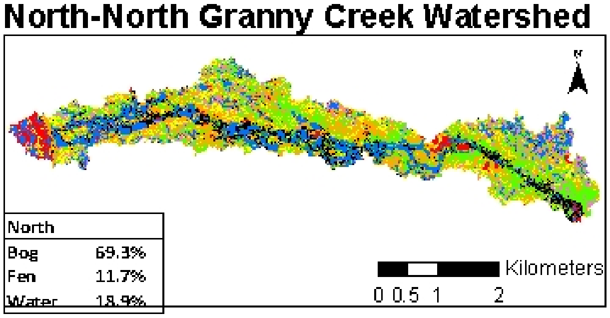
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	640173	1440231	2,080,404	6.04%
40 - Bog - Lichen	1067613	3085040	4,152,653	12.06%
50 - Bog - Lichen / Conifer	2302153	6788090	9,090,243	26.41%
60 - Bog - Dense Conifer	422589	1071872	1,494,461	4.34%
70 - Fen - Dense Conifer	796033	2324776	3,120,809	9.07%
80 - Riparian Fen / Sedges	314718	846445	1,161,163	3.37%
90 - Fen - Poor Fen	2130516	4140513	6,271,029	18.22%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_DME70_DME250

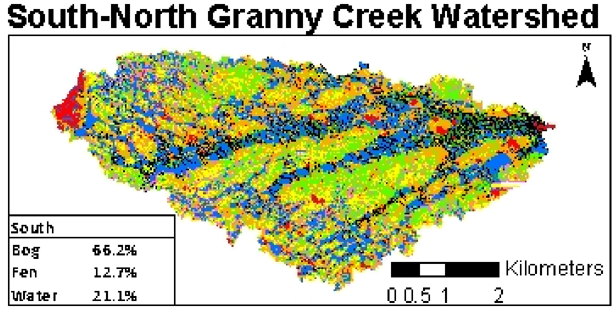


IR_RGB_DME70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.2%
30 - Mat Around Pools	**701**	1	0	1	0	2	15	97.4%
40 - Bog - Lichen	0	**475**	135	7	12	1	45	70.4%
50 - Bog - Lichen / Conifer	0	186	**556**	52	129	0	73	55.8%
60 - Bog - Dense Conifer	0	2	7	**482**	71	7	1	84.6%
70 - Fen - Dense Conifer	0	19	9	127	**455**	146	2	60.0%
80 - Riparian Fen / Sedges	1	3	0	5	9	**345**	0	95.0%
90 - Fen - Poor Fen	20	53	37	0	5	10	**605**	82.9%
Total	97.1%	64.3%	74.7%	71.5%	66.8%	67.5%	81.6%	

North-North Granny Creek Watershed

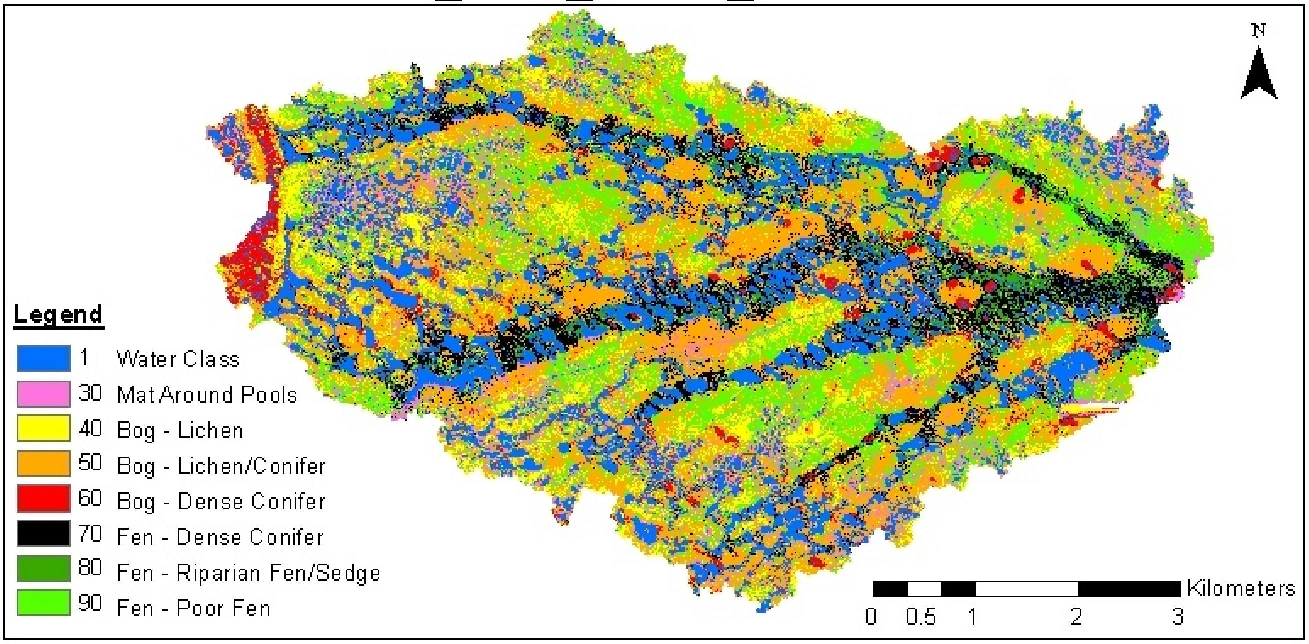


South-North Granny Creek Watershed



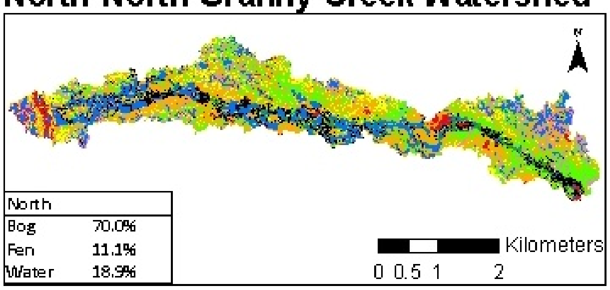
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	640173	1440231	2,080,404	6.04%
40 - Bog - Lichen	1067613	3085040	4,152,653	12.06%
50 - Bog - Lichen / Conifer	2302153	6788090	9,090,243	26.41%
60 - Bog - Dense Conifer	422589	1071872	1,494,461	4.34%
70 - Fen - Dense Conifer	796033	2324776	3,120,809	9.07%
80 - Riparian Fen / Sedges	314718	846445	1,161,163	3.37%
90 - Fen - Poor Fen	2130516	4140513	6,271,029	18.22%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_VDCN_DME250

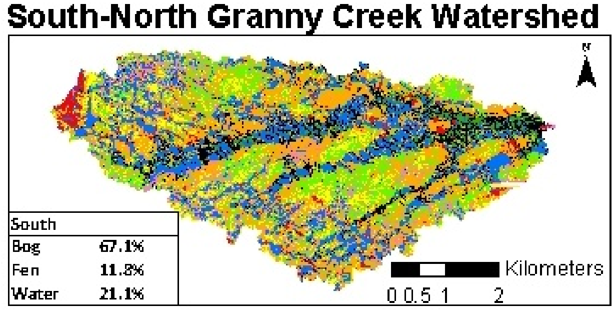


IR_RGB_VDCN _DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	74.8%
30 - Mat Around Pools	**739**	3	1	1	0	0	76	90.1%
40 - Bog - Lichen	0	**350**	29	8	2	0	45	80.6%
50 - Bog - Lichen / Conifer	1	301	**671**	79	68	0	109	54.6%
60 - Bog - Dense Conifer	0	2	18	**471**	56	1	0	85.9%
70 - Fen - Dense Conifer	0	41	19	188	**616**	175	3	59.1%
80 - Riparian Fen / Sedges	0	3	0	3	6	**564**	0	97.9%
90 - Fen - Poor Fen	10	50	12	0	2	10	**517**	86.0%
Total	98.5%	46.7%	89.5%	62.8%	82.1%	75.2%	68.9%	

North-North Granny Creek Watershed

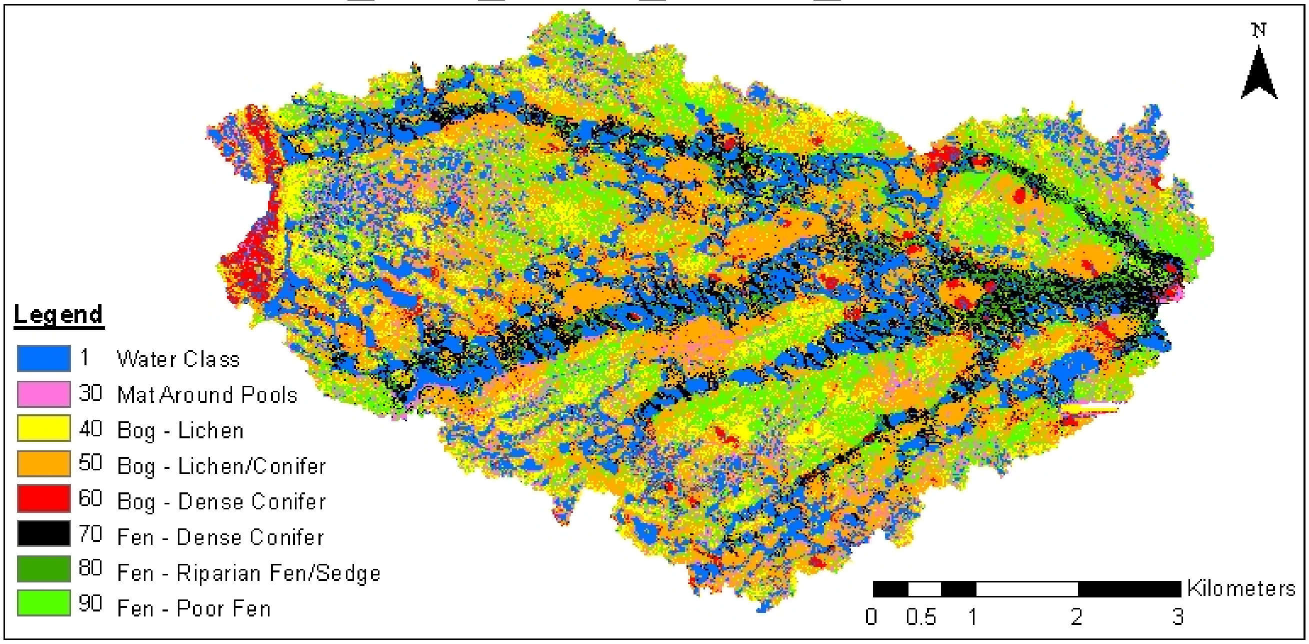


South-North Granny Creek Watershed



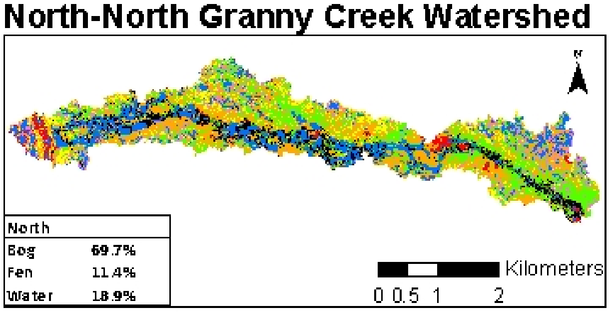
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	657000	1601517	2,258,517	6.56%
40 - Bog - Lichen	913917	2429941	3,343,858	9.72%
50 - Bog - Lichen / Conifer	2638000	7955821	10,593,821	30.78%
60 - Bog - Dense Conifer	302353	994471	1,296,824	3.77%
70 - Fen - Dense Conifer	754453	2273655	3,028,108	8.80%
80 - Riparian Fen / Sedges	293736	677322	971,058	2.82%
90 - Fen - Poor Fen	2110756	3757570	5,868,326	17.05%
Total	**9,461,964**	**24,951,382**	**34,413,346**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_VDCN_PER70_DME250

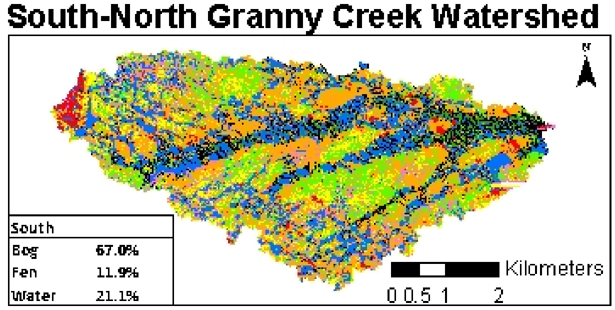


IR_RGB_VDCN_PER70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.2%
30 - Mat Around Pools	739	3	1	3	0	3	85	88.6%
40 - Bog - Lichen	0	341	33	7	1	0	36	81.6%
50 - Bog - Lichen / Conifer	1	328	677	87	76	1	110	52.9%
60 - Bog - Dense Conifer	0	2	17	497	58	1	0	86.4%
70 - Fen - Dense Conifer	0	31	10	143	593	145	1	64.2%
80 - Riparian Fen / Sedges	2	4	0	10	20	585	0	94.2%
90 - Fen - Poor Fen	8	41	12	3	2	15	518	86.5%
Total	98.5%	45.5%	90.3%	66.3%	79.1%	78.0%	69.1%	

North-North Granny Creek Watershed

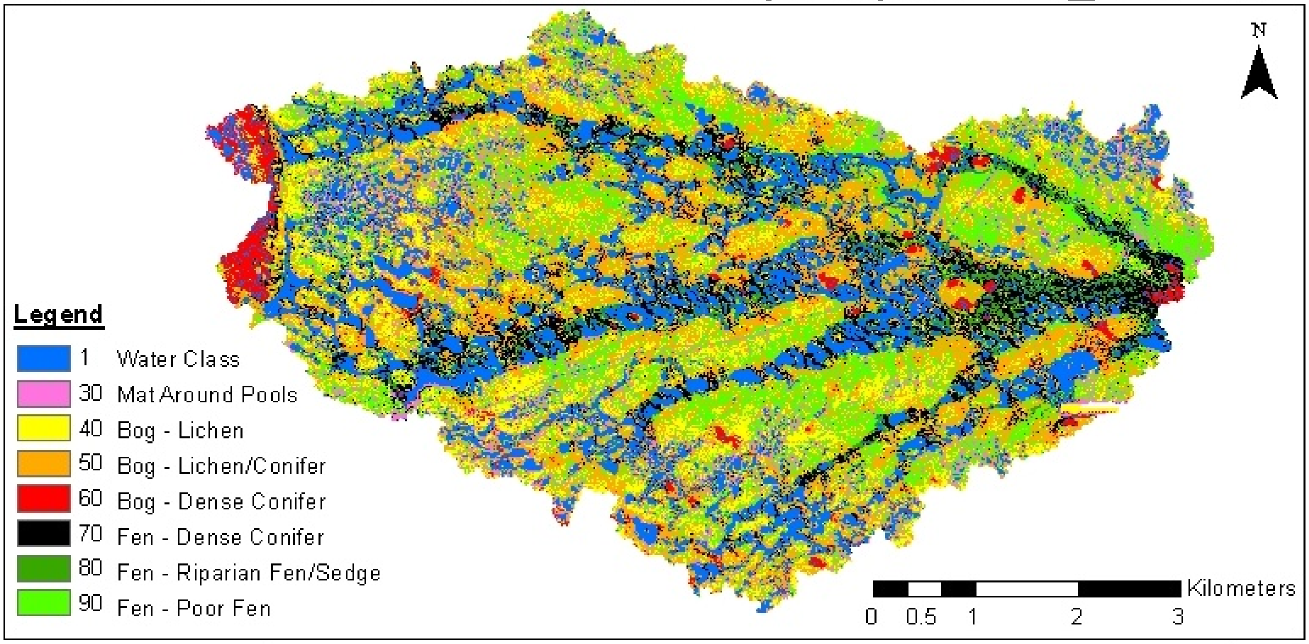


South-North Granny Creek Watershed



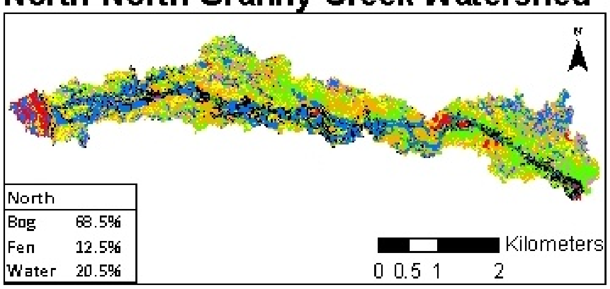
Landscape Type	North	South	Total	% Total Coverage
1 - Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	693720	1691206	2,384,926	6.93%
40 - Bog - Lichen	922147	2401786	3,323,933	9.66%
50 - Bog - Lichen / Conifer	2614398	8068760	10,683,158	31.04%
60 - Bog - Dense Conifer	296831	925246	1,222,077	3.55%
70 - Fen - Dense Conifer	783422	2233375	3,016,797	8.77%
80 - Riparian Fen / Sedges	292057	742284	1,034,341	3.01%
90 - Fen - Poor Fen	2067640	3627640	5,695,280	16.55%
Total	**9,461,964**	**24,951,382**	**34,413,346**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): PER70_DME250

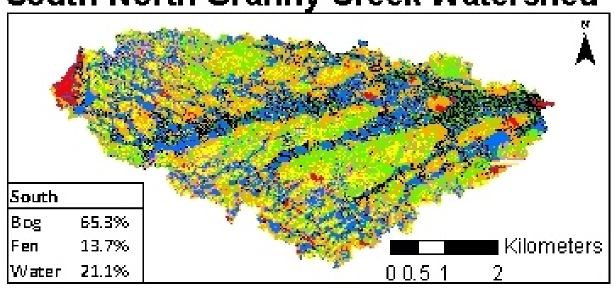


IR_RGB_PER70_DME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.7%
30 - Mat Around Pools	726	1	0	2	0	2	14	97.4%
40 - Bog - Lichen	0	483	147	8	16	1	49	68.6%
50 - Bog - Lichen / Conifer	0	189	556	62	135	1	75	54.6%
60 - Bog - Dense Conifer	0	1	6	496	40	0	0	91.3%
70 - Fen - Dense Conifer	0	17	4	177	544	173	2	59.3%
80 - Riparian Fen / Sedges	1	4	0	5	10	559	0	96.5%
90 - Fen - Poor Fen	23	55	37	0	5	14	610	82.0%
Total	96.8%	64.4%	74.1%	66.1%	72.5%	74.5%	81.3%	

North-North Granny Creek Watershed

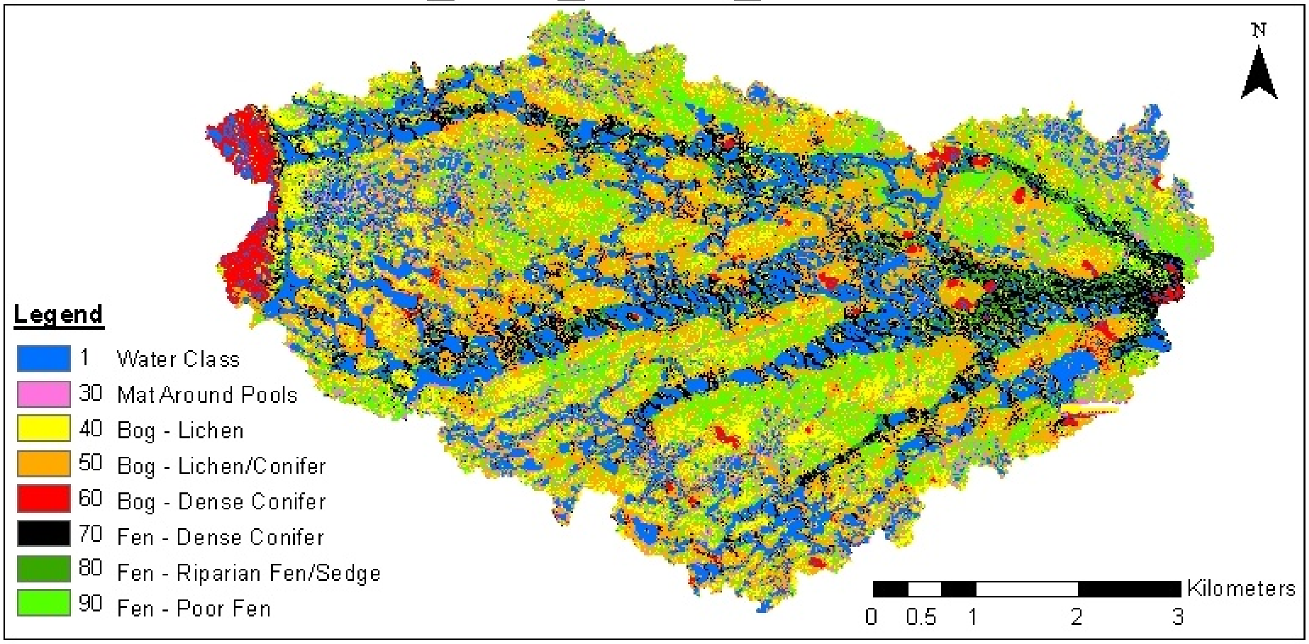


South-North Granny Creek Watershed



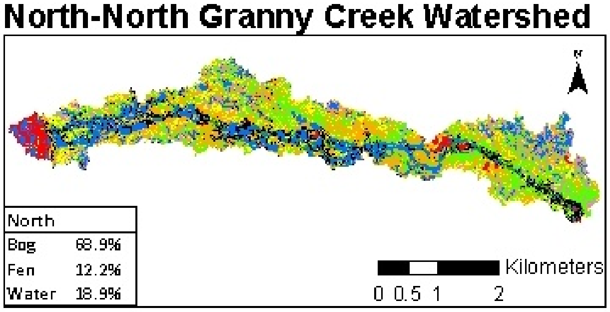
Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	631851	1414108	2,045,959	5.94%
40 - Bog - Lichen	1079659	3113458	4,193,117	12.18%
50 - Bog - Lichen / Conifer	2301723	6789830	9,091,553	26.41%
60 - Bog - Dense Conifer	320371	765550	1,085,921	3.15%
70 - Fen - Dense Conifer	829948	2511572	3,341,520	9.71%
80 - Riparian Fen / Sedges	356341	896514	1,252,855	3.64%
90 - Fen - Poor Fen	2153902	4205935	6,359,837	18.48%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**

SUPERVISED CLASSIFICATION (MLC): IR_RGB_PER70_DiME250

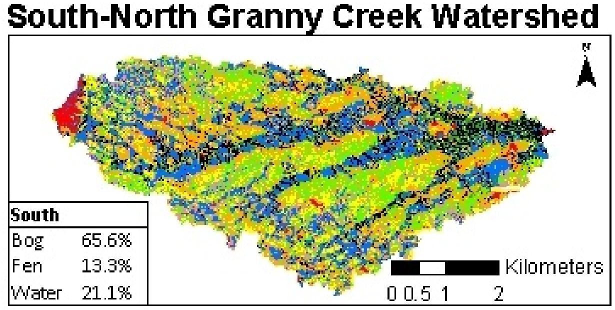


IR_RGB_PER70 _DIME250	30 - Mat Around Pools	40 - Bog - Lichen	50 - Bog - Lichen / Conifer	60 - Bog - Dense Conifer	70 - Fen - Dense Conifer	80 - Riparian Fen / Sedges	90 - Fen - Poor Fen	75.5%
30 - Mat Around Pools	**724**	2	0	0	0	2	19	96.9%
40 - Bog - Lichen	0	**482**	126	8	16	14	49	69.4%
50 - Bog - Lichen / Conifer	0	210	**574**	66	149	1	80	53.1%
60 - Bog - Dense Conifer	0	1	4	**498**	42	0	0	91.4%
70 - Fen - Dense Conifer	0	9	5	172	**529**	170	0	59.8%
80 - Riparian Fen / Sedges	1	1	0	5	11	**555**	0	96.9%
90 - Fen - Poor Fen	25	45	41	1	3	8	**602**	83.0%
	96.5%	64.3%	76.5%	66.4%	70.5%	74.0%	80.3%	

North-North Granny Creek Watershed



South-North Granny Creek Watershed



Landscape Type	North	South	Total	% Total Coverage
1 - Open Water Class	1791749	5261085	7,052,834	20.49%
30 - Mat Around Pools	629479	1380644	2,010,123	5.84%
40 - Bog - Lichen	1055745	2992299	4,048,044	11.76%
50 - Bog - Lichen / Conifer	2343440	7005247	9,348,687	27.16%
60 - Bog - Dense Conifer	359997	718550	1,078,547	3.13%
70 - Fen - Dense Conifer	801397	2417125	3,218,522	9.35%
80 - Riparian Fen / Sedges	355072	911205	1,266,277	3.68%
90 - Fen - Poor Fen	2128665	4271897	6,400,562	18.59%
Total	**9,465,544**	**24,958,052**	**34,423,596**	**100.00%**