Vernal Pool Mapping in the Williams Lake Watershed, Halifax

supporting small wetland identification in advance of development

Huan Liu, Bachelor of Community Design, School of Planning,
Dalhousie University, Halifax NS. Supervisor: Patricia Manuel. April 12, 2012

Acknowledgement

I am deeply indebted to my supervisor, Dr. Patricia Manuel, whose patient guidance, passion for wetlands, profound knowledge, the timely and brilliant comments made this project and the field trips fascinating and successful. I would also like to thank Raymond Jahncke for his generous and patient support, and enlightenment about GIS mapping and data, and GPS. I am grateful to the generous help and guidance from Dr. John Brazner, whose proficient knowledge of and passionate for wetlands made the field trips worthwhile and enjoyable.

I would like to express my gratitude to the Writing Center at Dalhousie University, especially Paul Hardman, who have helped me to improve my writing throughout the whole project and in the past four years.

Especially, I would like to express my special thanks to all the student colleagues for the stimulating encouragements and brilliant advices that make this project more polished.

Table of Contents

Context and Research Statement

Vernal Pools are isolated temporary ponds that exist intermittently throughout year. Their fishless environment makes them critical habitats for amphibians. There is little awareness of vernal pools in Nova Scotia, their locations and numbers are unknown, and no vernal pool focused study has been conducted. The study area, the Williams Lake Watershed, is zoned for development, and future development may destroy the vernal pools and their adjacent habitats. Vernal pools are particularly vulnerable to development. They are very small and dry intermittently, and therefore can be easily missed in field surveys. They are excluded from wetland protection regulations.

Remote sensing techniques, including aerial photography, satellite photography, and Light Detection and Ranging (LiDAR), are the common methods that previous studies used to map vernal pools. This project tests these approaches by employing them individually in mapping potential vernal pools in the undeveloped area of the central Williams Lake Watershed located in Halifax Regional Municipality, Nova Scotia. This is followed by a pilot field observation to examine the accuracy of the predictions and an evaluation of the methods and data that this project used. The project also discusses to which extent the current policies could be used to protect vernal pools.

Project Goals and Objectives

Goal 1: To map potential vernal pools in the Williams Lake Watershed.

Objective A: Using a variety of remotely sensed imagery including aerial photos and satellite images, as well as delineation of Digital Elevation Data that converted from LiDAR, to locate the potential and actual vernal pools on the undeveloped landscape of the central Williams Lake Watershed.

Objective B: To compare field observations of potential vernal pool sites with the mapped locations.

Goal 2: To explore tools for predicting presences of potential vernal pools.

Objective C: To evaluate the effectiveness and efficiency of the tools used to map the vernal pools, and explore possible reasons for their varying effectiveness and accuracy.

I. Literature Review

Vernal pools, also known as temporary pools, may be present in any landscape (Colburn, 2004). They are small (mostly < 1 ha), shallow (mostly < 1 m), fishless water bodies within or adjacent to woodlands and lack a continuous inflow and outflow of water connections to permanent water bodies (Colburn, 2004). They dry out seasonally or at least every few years and usually exist for at least two continuous months in spring time (Colburn, 2004). Their unique intermittent hydrologic pattern makes them ideal habitat for species that are vulnerable to fish. (Colburn, 2004).

People can find vernal pools in various geomorphic settings, such as depressions and flood plain (Rheinhardt & Hollands, 2008), on a wide range of soil and with a variety of geological settings (Colburn, 2004). Their major water sources are precipitation, snowmelt, groundwater, intermittent stream flow, and flood water (Colburn, 2004). They lose water primarily through evapotranspiration (the combination of vernal pool evaporation and plant transpiration) (Leibowit z & Brooks, 2008). The water temperature of vernal pools varies with the season, time of day, their surroundings and depth. Their water chemistry is highly dependent on their water source, geologic setting, and their adjacent territory (Colburn, 2004).

1.1 Functions and Importance

Vernal pools serve hydrological functions such as balancing surface and ground water supply, storm surge mitigation (NSE, 2009), improving water quality (Hunter, 2008; NSE, 2009), and retaining moisture (Bauder, et al., 2009). They also adjust temperature by holding and "redistributing heat" among different spheres at the micro-terrain level, which are critical to their fauna community (Bauder, et Al., 2009). Vernal pools transfer soluble minerals via intermittent ground and surface water connections with other bodies of water (Bauder, et Al., 2009), and their

combination of moisture, temperature, and oxygen levels may be suitable for decomposition of organic matter (Hunter, 2008).

Like other wetlands, some vernal pools are critical habitats for fauna and flora in their ecosystem, and contribute to biodiversity. Amphibians like wood frogs and salamanders are highly dependent on vernal pools for breeding, and so are other fauna like insects and fairy shrimp (Colburn, 2004; NSE, 2010). Animals from surrounding habitats may rely on the pools for water supply and food sources (NSE, 2010; Mitchell et al., 2008). Moreover, vernal pools are highly contributory to biodiversity given their various species of vegetation, which vary among pools and even different times within the same pool. They also support diverse fauna species, especially a remarkable invertebrate richness (Colburn, 2004). Some researches suggest that vernal pools may act as a keystone in an ecosystem, which means they have important roles in an ecosystem and their significance greatly exceeds the apparent count (in respect of numbers) value (Hunter, 2008; Power et al., 1996).

Vernal pools can also provide social values such as educational, aesthetic, recreational, and scientific study opportunities (Hunter, 2008; NSE, 2009). Because they are small enough to access, they can be particularly appealing to children. Given that the knowledge about vernal pools is still very limited (Colburn, 2004; Hunter, 2008), it is possible that the pools may serve a more critical role in an ecosystem.

Some vernal pools are occupied by fauna but vernal pool occupants could change significantly from year to year (Colburn, 2004). However, the forces from outside (e.g. destruction of vernal pools or their surrounding landscape) could drive fauna from biologically active pools to inactive ones as refuges. Therefore, the biologically inactive vernal pools (at least

for large fauna, such as wood frogs and salamanders) are still significant habitat and should be protected.

Lastly, vernal pool protection is important because these pools are regarded as one of the most difficult wetlands creates artificially (e.g. to restore breeding habitats for amphibians), which make the destruction of vernal pools irreversible (National Research Council, 2001). It is particularly challenging in creating an intermittent landscape and its functions under control: many efforts have been made to recreate vernal pools but have failed (Lichko, & Calhoun, 2003) meanwhile vernal pools have been created inadvertently by construction, such as highways.

1.2 Vulnerability of Vernal Pools

1.2.1 Historic Loss and Lack of Awareness

Since European settlement, over one-seventh of the wetlands in Canada have been lost (Mahaney & Klemens, 2008). The loss of vernal pools may be even greater given their small size, intermittent existences, and some pools might have been converted to land development (Mahaney & Klemens, 2008). There is no study predicts vernal pool loss in Canada; however, in the United States, Beardsley et al. (2009) indicated that over 75% of the vernal pools in central California have been either destroyed or isolated by 2000, and there will be an additional 15% decrease by 2050. A lack of awareness of vernal pool values may account for the remarkable historic loss. The awareness of vernal pools was not raised until recent years in North America (Mahaney & Klemens, 2008).

1.2.2 Regulations

Lack of or inadequate utilization of available regulations may also contribute to the vulnerability of vernal pools. In North America, governments are now realizing the functions provided by wetlands. Various wetland protection policies and regulations have been developed,

such as the *Section 404* in *Clean Water Act* (the U.S.) which established a permit system to protect wetland (EPA, 2011). In Canada, wetlands on federal lands are protected under *The Federal Policy on Wetland Conservation*. This policy acknowledges "no net loss of wetland functions", applies to all wetland sizes and covers their adjacent habitats as well. *The Canadian Environmental Assessment Act* involves public participation in federal projects (Mahaney & Klemens, 2008). However, these federal regulations only apply to on federal lands and the projects involving federal money. They do not protect the wetlands on private land from private development or on provincial inventory not including federal financing. Most states and provinces now have wet land protection or conservation policies, but they place constrains on wetland type or size or level of disturbance. Vernal pools are so small that they usually fall outside the minimum size criteria where general permitting is required (e.g. the Nova Scotia Wetland Conservation Act does not protect the wetland smaller than 100 sq m). They may not even be identified in a development process until the final stages of planning processes, particularly when field survey take place in the month when pools dry out; or they are so small they are simply missed, or the pools may not be identified as wetlands, but simply puddles in the landscape (Mahaney & Klemens, 2008).

1.2.3 Vulnerability to Developments

Development at or around vernal pools can destroy or alter a vernal pool ecosystem significantly. According to Windmiller & Calhoun (2008), direct destruction by filling or draining is less common in recent years, but many vernal pools have already been destroyed. In the case of Boston, Massachusetts, vernal pools may have been completely wiped out the landscape in densely populated areas and the town centers of those less populated communities (Windmiller & Calhoun, 2008). Vernal pool species uses upland habitat as well as vernal pool

habitat. The loss of adjacent habitats can reduce the population and richness of vernal pool amphibians, and their presence at other favourable sites; traffic in adjacent territory of vernal pools could kill vernal pool animals when they travelling across the roads, and decrease biodiversity since roads isolate vernal pools from their adjacent habitats (Windmiller & Calhoun, 2008). An increasing number of domesticate animals, like cats, could also increase the mortality of amphibians (Windmiller & Calhoun, 2008).

1.3 Potential Vernal Pool Mapping

The attention on vernal pools and their values has increased in recent years. Accordingly, locating vernal pool is widely recognized as the first step toward conservation (Carpenter et al., 2011; Burne & Lathrop, 2008; Mahaney & Klemens, 2008). Various methods have been used to identify potential vernal pools (PVPs), including field identification, identification using remotely sensed imagery, and statistical modelling.

1.3.1 Field Identification

Field identification can be conducted on its own or to be used to check PVP sites predicted by other methods, like aerial-photo interpretation (Burne & Lathrop, 2008). Field investigation is good at collecting biological and physical data, which are usually required to verify a water body as a vernal pool; it can also correct false PVP predictions from other mapping methods (Burne & Lathrop, 2008). However, field identification is restricted to small areas because it is labour intensive (Burne & Lathrop, 2008), and usually relies on community members and volunteers (Burne & Lathrop, 2008; Oscarson & Calhoun, 2007).

1.3.2 Remote Sensing

Remote sensing imagery, such as aerial photos (Carpenter et al., 2011; Burne & Lathrop, 2008), satellite photos (Anderson & Hardin, 1992), and LiDAR (Light Detection and Ranging)

imagery (Lichvar et al., 2006; O'Hara & Manager, 2002), have also been used to locate potential sites.

Aerial photographic analysis is a direct visual interpretation of aerial photos, and the characteristics of the features on the image, including colour, size, shape, texture, and other cues (Burne& Lathrop, 2008; Lathrop, et al., 2005). This technique has been widely employed in wetland mapping, including National Wetland Inventory (NWI) mapping (Carpenter et al., 2011; Burne& Lathrop, 2008). It is an efficient tool for mapping wetlands in a large study area, and experienced interpreters can reach a commission error (including sites that are not PVPs) as low as 0% (the PVPs here refers to the sites that have hydrologic features of vernal pools but not necessary biological functions) (Carpenter et al., 2011). However, the accuracy of aerial photographic interpretation could vary tremendously due to the factors like image type (black and white, colour), resolution, vegetation cover at time of photography (leaf on or off), scale, and precipitation level (Burne& Lathrop, 2008; Carpenter et al., 2011). Moreover, omission errors (omitting actual sites) are usually unavoidable (Carpenter et al., 2011).

In addition, satellite images have been used for mapping wetlands: image interpretation is similar to that of aerial photos. Satellite images may be used together with soil maps and aerial photos. Field observation confirms the mapping (Anderson & Hardin, 1992).

Recent PVP identification method uses Light Detection Ranging pa analysis. An interpreter maps PVPs using terrain image generated from raw LiDAR data, such as the Digital Elevation Model (DEM) (Maxa & Bolstad, 2009). This technique can support other vernal pool mapping, (such as the wetland mapping project in Chequamegon National Park in the U.S.(Maxa & Bolstad, 2009)), or it alone to map vernal pools (like the vernal pool mapping project in Beale Air Force Base, Yuba, California (Lichvar et al., 2006)). When LiDAR data analysis is used

alone, interpreters usually convert LiDAR to DEM, smooth the original DEM, subtract the smoothed DEM from the original DEM, and the results from the subtractions are regarded as the depressions on the land (Lichvar et al., 2006). In previous vernal pool mapping projects, slope and terrain elevation are usually created (from DEM) to assist other mapping methods (Maxa&Bolstad, 2009).

The remote sensing mapping techniques are both time and cost efficient in locating PVPs in large areas, and can benefit field identification significantly (Burne& Lathrop, 2008). However, the accuracy depends greatly on the factors like image resolution and interpreters' experience (Carpenter, et al., 2011). Possible technical difficulties (e.g. GIS skills), accessibility and quality of data, and unavoidable errors in data could be drawbacks as well.

1.3.3 Statistical Model Prediction

Statistical modelling has been used to predict PVP locations as well. Grant (2005) built a regression model between PVP sites and their environmental context such as land use and slopes, and successfully predicted 62.5% of the verified vernal pools. Cormier (2007) built another similar model to predict vernal pools based on their physical environment, like occurrence of bedrock in the surrounding landscape, and reached an accuracy of 97% in predicting verified vernal pools. However, given the limited knowledge about vernal pools and their relationship with their surrounding environment, these models may not be universally applicable.

All the methods discussed above have their own advantages and disadvantages; no single tool provides both efficiency and accuracy. There are studies about single tool accuracy evaluation on one study area (Carpenter et al., 2011) and studies that evaluate two mapping methods based on the case studies on different land (Burne & Lathrop, 2008), but no

comprehensive evaluation or comparison of the effectiveness of vernal pool mapping approaches in a single study area has been conducted.

1.4 Vernal Pools in Nova Scotia

Nova Scotia is a maritime province of Canada, located in the north-eastern North America. It covers a territory of 53,338 square kilometres (Statistics Canada, 2005) with a population of 943,414 (NSF, 2011). The province is part of "the glaciated northeast" North America (Colburn, 2004). Vernal pools and other wetlands of this region form in the depressions created by geologically glaciation (Colburn, 2004). According to *the Nova Scotia Wetland Conservation Policy* (2011), a vernal pool is identified as an isolated wetland which is usually shallow and smaller than 0.5 ha and disappears in summer time (NSE, September, 2011).

Although the Government of Nova Scotia recognizes vernal pools as critical breeding habitats for amphibians and feeding sources for larger animals (NSE, 2011), the province exclude small wetlands (less than 100 sq m) from regulated protection (NSE 2011), and many vernal pools could be smaller than this size. The *Environment Act* (2(bg)) recognizes vernal pools as "wetland" regardless of pool size, and the *Activities Designation Regulations* (5(1)(na); 2(1)e; 3(1)) make their alteration prohibited without a water approval granted by the Minister (of Environment and Labour) or someone appointed by the Minister. However, Nova Scotia has not made a "no net loss" commitment (NSE, 2009; Mahaney & Klemens, 2008; NSE, 2011), therefore the adjacent territory of vernal pools is not under protection. In the *Nova Scotia Wetland Conservation Policy* (2011), "no loss" is only committed to "Wetlands of Special Significance", and a buffer between wetlands and development is not required (NSE, 2011). Wetlands under 100 square meters are excluded in this policy (NSE, 2011), and most vernal pools could be smaller than this size (Colburn, 2004).

In Nova Scotia, vernal pools are the most poorly understood wetlands. Within the province, there is no study focuses on vernal pool in literature (NSE, 2010). The distribution and number of vernal pools, and their interaction with the surroundings are not known. Without being realized by people, vernal pools in Nova Scotia might be destroyed. A large portion of the province is private land (DNR, 2000), which makes them more vulnerable to development than the ones on public land.

This project investigates mapping vernal pools in a Nova Scotia watershed threatened by development; this watershed landscape is the Williams Lake Watershed near Halifax.

II. Approach

The undeveloped area of the central Williams Lake Watershed is the study area of this potential vernal pool mapping project. Mapping PVPs is the first step toward understanding their contributions to landscape hydrology and also the implications of landscape disturbances for the pool. Any pool larger than 100 sq m can be protected under provincial policy and all pools can be examined for hydrologic importance under the Environment Act water course regulations. They cannot, however, be assessed or protected if their existences are unknown.

In this project, I mapped PVP sites in the study area, and compared the methods and datasets I used in this project. These methods included stereoscopic mapping and on-screen visual interpretation of aerial photos and satellite images, and delineation of PVPs from DEM in ArcGIS. This was followed by an analysis of the features of all the mapping methods and datasets, and a discussion about the useful points to other interpreters. The evaluation and comparison of methods were important since this information could help potential interpreter to choose the most suitable mapping approach and data quality for them.

III. Methods

3.1 Criteria to Define Potential Vernal Pools

The determination of vernal pools could involve a wide range of criteria. Some studies regard occurrence of biological indicators (e.g. fairy shrimps, amphibians) as necessary criteria for vernal pools; some other studies regard any pool exist intermittently but last more than two months in spring time as a vernal pool. Determining biological indicators requires long-term scientific monitoring, which was not possible within the time frame of this project, and it also exceeded my knowledge and skills. Therefore, this project only focused on surficial physical features but not biological conditions. Based on the vernal pool definition given by Colburn (2004) and the physical criteria for vernal pool certification in Massachusetts (MacCallum, 2009), I regarded a water body or depression as a PVP site if there was no apparent inflow or outflow and there was a reasonable water source. Its surface area was usually less than 0.5 ha (5000 sq m) with a depth under 1 m (Colburn, 2004; NSE, 2011, September). These two criteria were difficult to measure and might vary in different conditions; however, I did not regard a water body or a depression, which was obviously larger than 1 ha or deeper than 3 meters as a PVP (Colburn, 2011).

This information was consistent with the observations from the field trip to Herring Cove area on November 20th, 2011. The nine[1] vernal pools and one puddle I visited in late 2011 were generally shallower than 0.5m and their sizes vary from about 10 square metres to several hundred. Furthermore, each vernal pool environment was unique, and the surface area of a pool itself could change tremendously throughout year.

[1] There are ten sites mapped but one of them is a puddle (so far).

3.2 Potential Vernal Pool Site Mapping

I employed a combination of different approaches to map PVPs in order to minimize the possibility of missing possible pools. The common methods that other scholars had used in previous vernal pool mapping projects in North America – direct visual interpretation (aerial photo and satellite image analysis), and digital data interpretation (DEM data analysis) – were the major mapping approaches in this PVP mapping project. I first located and verified several existing vernal pool sites in Herring Cove – about 10 km to the south of the Williams Lake Watershed and sharing a similar geology setting – in field trips. Then I conducted experimental mapping to examine the feasibility of the proposed mapping methods in PVP mapping, and to find the common features that vernal pools share. Locating existing vernal pools and experimental mapping helped to locate PVP sites in the study area more accurately.

I performed aerial-photo and satellite-image analysis and DEM data interpretation independently to locate PVP sites. To eliminate obvious false predictions (e.g. bedrock), I overlapped all PVP predictions in ArcGIS with a base map of the best quality aerial-photo I have, and observed if the predicted site were actually bedrock or other features that are improbable to be a vernal pool. Finally, I combined the results of all mapping to one map show all the PVP sites and their overlaps. I conducted a preliminary verification of the mapping with a site visit in a field trip on March 20, 2012, to examine the accuracy of the predictions, following a qualitative evaluation of the efficiency of all the mapping methods involved. The field trip was late for this project, however, it was necessary since it was important to examine some of the PVPs in the field, and the trip should be as close to spring (around April and may) as possible, when vernal pools reach their maximum surface sizes.

3.2.1 Aerial and Satellite Photographic Analysis

I used aerial and satellite photographic analysis to approach potential vernal pool mapping through direct visual interpretation. In order to conduct an aerial photos and satellite imagery based vernal pool mapping on the undeveloped central Williams Lake Watershed, a set of recent colour leaf-off aerial or satellite photos with a large scale was most desirable. There was no ideal set of images available for the study area; however, each set of the aerial photos and satellite images that I used to locate PVP sites in this project met at least two of the four criteria (Table 1).

After I collected all required photos, I mapped PVPs using direct visual interpretation base on colour, contrast, and shape (Burne & Lathrop, 2008). Then I performed a preliminary observation of the existing vernal pools in the Herring Cove area to find shared features of vernal pools on each set of photos. I developed mapping criteria for each set of images based on the common features I observed, and used these criteria to map PVPs in the Williams Lake Watershed.

I first mapped the vernal pools on each set of imagery independently. During the mapping process, I either traced each PVP sites directly in ArcGIS (for digital maps) or in Google Earth (for Google Earth maps), or I traced their general boundaries on transparencies (for photographs) that overlapped with photographs. Meanwhile, I recorded the details of mapping processes and the confidence of each mapped PVP site. For the sites that I traced in Google Earth, I recorded the sites in ArcGIS after I finished my mapping. In the case that I recorded the sites on transparencies over photographs, I scanned the transparencies together with photographs, inputted the images into ArcGIS, georeferenced the images, and then traced the sites.

After I finished the mapping, I combined the results on the base map of 2009 Color Aerial – which was the best quality dataset I used in this project, and I eliminated the obvious false predictions (such as bedrock, building ruin) from my mapping results.

3.2.2 DEM Data Analysis

I employed DEM data analysis to map PVPs from the approach of digital data interpretation. In this project, I processed most of the interpretation in ArcGIS with ArcHydro Tool, which is a free added-in to ArcGIS. In order to map PVPs, stream data and a Digital Elevation Model (DEM) that was converted from LiDAR data with a fine resolution (1m) were used to calculate and visualize shallow depressions and flow accumulations.

After I collected the data I needed, I calculated flow accumulations and depressions in ArcGIS using a procedure I developed from *Watershed and Stream Network Delineation* by Merwade (2010). I first performed this process in the Herring Cove area, where there were several existing vernal pools, in order to find the best range of flow accumulations that could map some existing vernal pools while keeping the number of PVPs at a reasonable amount. Then I applied this range of flow accumulations on the Williams Lake Watershed to select the depressions with a preferable amount of water. I created hill shade, slope, and water table maps, but I did not find them to be very helpful in filtering PVPs. I also described the GIS processes in the Table 3 so that other researchers can repeat and examine this project.

3.2.3. Preliminary Elimination of False Predictions

After I finished my mapping from aerial photos and satellite images, and delineated PVP sites from DEM, I combined all maps on the best quality aerial photo (2009 Color Aerial Photo). I examined all the predictions on the base map, and eliminated the PVP predictions that I believed to be apparently false (e.g. large wetlands, developed areas, bedrock) on the best quality

aerial-photo I had. I marked the PVPs I eliminated in this stage and excluded them from the final PVP map.

3.2.4 Field Observation

I undertook preliminary field checking of the mapped potential vernal pools in a field trip in March 20, 2012. The synthesis map with all PVP predictions, which I create in previous mapping processes, was the guide to the field trip. I planned to visit a small number of sites that physically accessible, and cover both DEM and different confidence levels from all sets of images. Sites coordinates were inputted into a handheld Global Positioning System (GPS), which was the major navigating tool during the field trip. The actual trip did not follow the original plan, but still checked several PVPs and found some missed PVPs in the woods during the trip.

3.3 Evaluation

I performed qualitative evaluations of all the methods (together with their datasets) that I used in locating PVP sites in this project, including field observation. I evaluated all methods based on the time length of the mapping process, efficiency (number of predictions, sizes, etc.), feasibility (skill requirement, data accessibility and quality, etc.), efficacy (e.g. error, potential omission error, to what extent the accuracy can be improved), and other limitations (e.g. natural settings, etc.).

3.4 Policy Review

I reviewed the current government policies and their effectiveness in vernal pool protection and various regulations, such as the Environment Act and Halifax Regional Municipal Planning Strategy. I also discussed whether or not and to what extent the existing regulations can protect vernal pools, and explored the gaps in regulations with respect to vernal pool protection.

IV. Study Area

The Williams Lake Watershed is located on the southern shore of the Northwest Arm, to the south of Halifax Peninsula, in Halifax Regional Municipality, Nova Scotia [Figure 1**].** It is about 4 kilometres to the south of Halifax Peninsula (DNR, 2004). Within the watershed there are two lakes, Colpitt Lake and Williams Lake, and these two lakes cover an area of about 550 ha (DNR, 2004). The land on the north shore of the Williams Lake is low density residential uses, as well as the land along the Herring Cove Roads (which is on the west of the Williams Lake and Colpitt Lake). Most of the watershed, however, is remain undeveloped. This project studies the central undeveloped watershed between Williams Lake and Colpitt Lake.

The dominant bedrock within the study area are Slate and Granite (Prime, 2001). There are several patches of till on the eastern land, and the rest of this area is limited in surficial material (DNR, 2011). Most soil within the watershed is well-drained brownish stony sandy loam, and the land around Colpitt Lake is mostly exposed bedrock with limited soil cover (MacDougall, et al., 1963).

The study watershed has an undulating topography, slopes from the north-eastern to the south-western (DNR, 2004). The rainwater collected in the southern slopes runs into Colpitt Lake (DNR, 2004). The water in Colpitt Lake, together with the precipitation collected in the northern watershed and at the wetland in the central watershed, runs into Williams Lake, and eventually goes into the Northwest Arm.

Several wetlands within the watershed have been mapped (DNR, 2004); however, just as other watersheds within the province, the vernal pools have never been mapped, and the presence of vernal pools is usually noticed by hikers (NSE, 2011). On the other hand, since most vernal pools are created during glacial activities in northeast North America and are usually related to

woodlots (Colburn, 2004), vernal pools are likely to occur in the forested areas within the study watershed.

This watershed has experienced an increase in development (Mandell, 1994; Google Map 2003; Google Map 2010) [Figure 2], and future development is imminent. Recently, the whole central watershed was sold to Clayton Developments, the Shaw Group, and this implies a future residential development (personal conversation with Dr. Patricia Manuel, January 10, 2012). The destruction of vernal pools and their adjacent territory could result in degraded water quality, extinction of vernal pool species, and more frequent floods in the surrounding lower lands (EPA, 1993).

V. Results and Analysis of Results

This section starts with a brief review of the findings of the PVP mapping in section 4.1, and then more detailed explanation of my results based on the application of the methods and my mapping experience in section 4.2. The mapping datasets and results are synthesized in Table 1, Table 2, and from Figure 9 to Figure 19. The detailed record of each PVP site is available from Table 4 to Table 11.

5.1. Results

5.1.1. Aerial Photos and Satellite Images

The quality of images and features are very different among the sets of aerial photos and satellite images I used to map PVPs, and my mapping process of PVPs is subjective. In order to record my mapping experience and the results more precisely, I gave each PVP prediction a confidence level. The confidence level varies from 1 (least confident) to 4 (almost assured), and it represent the likelihood of the site to be a vernal pool. Most PVPs have a confidence of 1 or 2 while the number of high-confidence PVP sites ranges from 5% to 39% of each dataset, and the average confidence level of the PVP sites of each set of images varies from 1.55 to 2.19 out of 4.

From my primary mapping of aerial photos and satellite images, I delineated 36 to 213 PVP sties from each set of photos. After reviewing these results, I revised the PVP predictions with an addition of up to 58 sites (e.g. 2009 color aerial photos) while eliminating probable mapping errors. Probable errors are sites deemed very unlikely to be a PVP, which number ranges from 1 to 82 sites per set of images. I also eliminated an extra 18 obvious false prediction based on the best quality map I used in this project (the 2009 color aerial photo). The obvious false predictions include the sites that fully overlap with exposed bedrock, building ruins, river system or significant flat bare land that are improbable locations for potential vernal pools. In

addition to this, I eliminated three large wetlands from the PVP mapping results. This increases the precision of my analytical calculation since the high confidence given to these wetlands could boost the average confidence level significantly. In the end, I mapped 760 PVPs in total from the eight sets of aerial photos and satellite images.

The size of PVP predictions varies from 0.27 sq m to 3,719 sq m, and the average PVP size of each set of images ranges from 38.93 sq m (2009 color aerial photo) to 655 (2005 CIR). The minimum size of the PVP with the highest mapping confidence is 4.78 sq m.

5.1.2. DEM

I delineated 574 PVP sites by overlapping the depression, which I generated from 1m DEM in ArcGIS, with the flow accumulation of 1430 sq m to 16001 sq m. The range was determined by experimenting with different flow accumulations in the Herring Cove area and this range was found to be able to map four out of ten existing vernal pools. I did not observe any of the 574 PVPs to be obvious false predictions on the best quality aerial-photo (2009 color aerial photo).

The average size of the PVP prediction is 49 sq m with a minimum size of 1 sq m, a maximum of 1,797 sq m, and a standard deviation of 153. All the depressions within the study area share a similar number of average and minimum size with the PVP predictions, but have a much larger maximum size and standard deviation.

5.1.3. Field trip results

A field trip on March 20 visited some of the PVPs in the western study area [Figure 21] with sites' coordinates and GPS. Before the field trip, I developed a plan to visit a minimum number of sites to examine the accuracy of the sites with different confidence levels from all

datasets. However, due to accessibility, the field trip was only able to visit the sites that are physically accessible.

Among the sites visited in the trip, most of them were wet but not a pool: some of them were part of an intermittent drainage system while some were dry at the surface but had wetland vegetation and uplifted tree roots. There were several sites, however, had standing water and were likely to be vernal pools. There were also several PVPs that did not have any water, and were dry depressions, tree shadow or exposed bedrock.

The day of the field trip was extraordinarily warm for that time of the year. There was no snow accumulation in the field; it was likely melted in the warm weather. Therefore, the pool sizes may be larger than in a usual spring; on the other hand, the sites that were dry during the field trip were not likely to have more water in the coming spring, either.

5.2. Mapping Experience

5.2.1. Mapping Confidence

I created scatter plots between average confidence levels of each set of images and other factors, including image scale (or resolution), color, date, leaf condition, mapping methods. However, I did not find any obvious trend between average confidence level and any other factor. For instance, the aerial-photo dataset with the best resolution (15 cm) has an average confidence of 1.90 while that of the 2.4m resolution Satellite CIR image is 1.75. Instead, I found the number of mapping hours have a positive correlation with several other factors: the more time I spent on mapping one set of images, the higher was my confidence in the PVP predictions for that dataset, and the more revisions I did after review. It seems that the mapping hours also have a strong impact on the other factors, including average confidence.

However, this does not mean image quality has no impact with respect to mapping vernal pools. It is likely that the better image quality allowed me to identify the sites with subtle suspicious features (e.g. non-parallel tree shadow). Meanwhile, these differences are unobservable on poor quality images, and therefore I could only delineate the PVPs that are larger, more distinctive, and where I had higher confidence.

In general, I found the confidence level is useful in recording the likelihood of a site being a PVP, and it is valuable data in evaluating the accuracy of various mapping methods and datasets after the sites are visited in the field. I found the average confidence level of each site, however, did not reflect my mapping confidence of each set of images.

Unlike the subjective PVP mapping from aerial photos and satellite images, the process of created PVPs from DEM is objective, and therefore I did not give confidence level to each of the sites I generated from DEM.

5.2.2. PVP Size

Aerial photos and Satellite images

Most of the average of the PVP sites of each set of images is below 100 sq m, and even the largest PVP prediction is smaller than the "normal" size of vernal pools (5000 sq m) defined by Colburn, 2004. The PVP sizes, however, have a strong dependence on resolutions. The PVPs I mapped from fine resolution images have smaller sizes on average, smaller minimum sizes and smaller standard deviation. In addition, fine resolution images can also map smaller PVP sites with the highest confidence. The maximum PVP size and the PVP sizes of several distinctive and highly-overlapped sites [Figure 8], however, do not show a strong correspondence with image resolution or scale.

Among all the PVP sites, the PVPs I mapped using aerial-photograph have much larger sizes than the digital images with similar resolution and leaf condition (e.g. 2010 Google map; Satellite Bing Map). The larger sizes are likely the result of the different mapping methods. When I mapped aerial photographs, I used stereoscope and traced the pool boundary on transparencies using permanent-ink pen, and the thickness of the pen may make the site larger (I used 0.1 mm pen). After that, when I scanned my mapping results, georeferenced the images and traced the boundary in ArcGIS, the tracing process may have enlarged the sizes again. Similar problems could happen to the PVPs I mapped from Google Map since I needed to georeference and trace them in ArcGIS, but the distortions were not as large as those in mapping from photographs.

What is worth noticing is that the actual pool sizes could be very different from on the images, especially when the trees are leaf on. In the field trip, I found the PVPs I mapped from aerial photos are much smaller than in the field especially the sites within the leaf-on woodlands. This is because it is difficult to map the shallow drainage surrounding the PVPs, and the tree canopy could cover some of the pools on the ground as well.

DEM

Since I created PVPs from 1m resolution DEM in ArcGIS, the minimum unit of the PVPs is 1 sq m, and the shapes of PVPs are squared. The sizes of these PVPs are much smaller than from the aerial photos and satellite images, and the minimum size of the PVP predictions is 1 sq m, which is the smallest size possible. Moreover, the PVP predictions are fragmented into small sizes except for the very few large and obvious depressions. Some of the PVPs from DEM may still overlap with the predictions from photographs or digital images, but the DEM may map one PVP as two depressions.

5.2.3. Mapping Hours

Aerial photos and Satellite images

I found mapping from aerial photos and satellite images to be time consuming in general. Six hours of attentive work was necessary to map one set of images, and this could extend to as long as almost 18 hours of concentrated work when the images had a very fine resolution. My work process usually included a review of the common features of the existing vernal pools in the Herring Cove Area, develop PVP record criteria for each set of images, tracing the PVPs, and revise the PVPs I mapped before while recording the criteria for each site. The mapping hours were highly dependent on the resolution of images. The finer the resolution of the imagery, the more time it took to map and review the PVPs, and the more details I could record for each site. In addition, I found I mapped more sites from fine resolution images but with more omission errors and therefore a longer reviewing time.

Mapping PVPs from aerial-photographs with stereoscope took a longer time since the stereoscope was difficult to use, and this mapping process needed an extra effort in converting the sites from transparencies into ArcGIS. Similarly, mapping from Google Map took an extra converting effort, and therefore longer mapping hours than the other images with similar resolution.

DEM

Delineating PVPs from DEM could be significantly more efficient than mapping from aerial photos and satellite images. It can map even PVP sites as small as 1 sq m within several hours – when an interpreter with proficient GIS knowledge follows a detailed mapping guide, with all data on hand, a pre-determined preferable range of flow accumulations, and a computer

that does not crash. When any of these conditions is not available, the mapping process could take several days or even longer.

Among the whole process of mapping PVPs from DEM, finding the preferable range of flow accumulations and redoing the whole process due to mistakes are the two most time consuming steps. Finding the range of flow accumulations requires extensive experiments. The shape of the channels changes after converting them from raster data to vector data, which is necessary for efficient PVP mapping. In addition, mistakes are likely to happen during mapping, and these usually result in redoing the whole process.

5.2.4. Errors

Aerial photos and Satellite images

Errors are unavoidable and could occur extensively in any set of images. Omission errors can easily occur for an un-experienced interpreter, like me. Moreover, offsets of different images in ArcGIS and the limitation of georeferencing in correcting the offsets caused an additional major source of errors, especially the images which need to be geo-referenced before mapping. Using buildings as landmarks to ensure a better consistency among datasets could be one potential solution; however, it is difficult to keep the whole image consistent with the base map without sacrificing any section of the image. In addition, most high-resolution images only cover a small area to reduce the image size, and there is no convenient anchor point (such as a reliable landmark) within the images.

Interference from tree shadows, trees and bedrock was another significant source of errors during my PVP mapping. The texture and color of the tree shadows on some images (such as Bing map and 2009 color aerial photos) were visually similar with water bodies and wet soil. I could eliminate some of the shadows by observing their directions with the trees in the

surrounding landscape; however, the directions of shadows were different from one section to another on some set of images (e.g. Google map). The trees were trickier than their shadows because they were not always visually distinctive from bare land (the differences are sometime subtly) and it was likely for me to map their shadows as PVPs. Moreover, exposed bedrock could have a similar color to water especially on black and white images.

I found the best way to eliminate omission errors was not to map slowly but to review as many times as possible. Overlapping various PVP predictions from different datasets was a good way to minimize both omission errors (sites not mapped on more than one dataset made me re-evaluate their possibility of being a pool) and commission errors (some sites are not observable on one dataset but could be distinctive on another).

DEM

Among all the 574 sites I delineated from DEM, none of them was fully overlapped with exposed bedrock on the best aerial-photo I used in this project. Since the whole mapping process is objective, there was no omission error which happened during the mapping from visual interpretation. However, there were still errors in the PVP predictions from DEM, and overlapping with flow accumulations and the imperfection of the DEM were the two major reasons.

Originally, the DEM delineated 2199 depressions within the study area, with a total area of 98,498 sq m. This number was obviously too large, and therefore I narrowed down this number to 572 by eliminating the depressions with too much or too little water - overlapping depressions with the flow accumulation range of 1,430 to 16,001 sq m. When I extended the range to 1,430 sq m to 31,598 sq m, one more existing vernal pool could be picked up, but there would be 103 more PVP predictions within the study area and the total PVP sizes will be

doubled. I used the narrow range of flow accumulations to only pick up the sites that are most likely to be a PVP. However, during the elimination process, not only the non-PVPs might be excluded from the final results but also PVPs as well, which was unavoidable in the mapping from DEM.

The resolution and accuracy of DEM can also cause errors. The 1m resolution prevents the DEM from generating flow accumulations or depressions at a finer scale, and the DEM data has an inaccuracy of 15 cm, which could miss the shallow PVPs. Moreover, the DEM cannot generate all the depressions. For instance, there was a large depression next to the site 3 existing vernal pool in Herring Cove, but DEM did not map this area as a depression at all.

5.2.5. Accessibility / Feasibility

Aerial photos and Satellite images

The datasets, tools, and skills I used in this project may not be available or accessible to everyone. Most of the aerial photos within the study area do not have enough resolution and they are leaf-on, which may be because they were originally taken to observe forest coverage condition; the only fine resolution leaf-off image in this project was taken to observe a forest fire, and therefore it only covers a small area (not even Herring Cove). Some satellite images from Google Earth are from leaf-off seasons, but their resolution is not ideal, and the image quality depends highly on weather (e.g. the 2003 Google Earth Satellite Image is partially covered by cloud). In addition, not all datasets are accessible to the public – such as the images I obtained from the GIS center is only available to Dalhousie faculty members and students [Figure 1]. The development of technology, however, can help to overcome these issues since the resolution has increased tremendously in the past decades. Meanwhile the cost has dropped a lot.

The major tools I used to map PVPs from aerial photos and satellite images are a computer with ArcGIS and a pocket stereoscope. The ArcGIS software is on all computers on Dalhousie Campuses but not common software among the public. Other tools, such as tracing paper with paper maps can be the substitution of mapping PVPs; however, these substitutions require print copies of maps and could be more difficult in determining the coordinates of each PVP. A pocket stereoscope is affordable and is available for renting from many universities; mirror stereoscope, which is more precise and easier for mapping, is expensive. It is available for in-library use from the Map Collection at Dalhousie University and may be common in other institutions, but it may not be affordable for individuals.

In order to conduct this project, there are some mandatory skills and physical requirements which include no color blindness and normal eyesight for direct visual interpretation, and basic knowledge of GIS in order to locate and trace the pools in ArcGIS. Experience in aerial-photo interpretation may greatly improve the mapping efficiency and accuracy but it is not necessary for direct visual interpretation.

DEM

The data, tools and skills that were involved in the PVP mapping from DEM are not easily accessible to the public, and the fine data may not be available everywhere throughout the province.

I obtained the 1m resolution DEM data from the GIS Center at Dalhousie University, which originally came from HRM and was not available to the public or other institutions. In addition, the 1m resolution DEM does not cover the whole province but 20 m resolution DEM instead, which is too coarse for PVP mapping. In the future, the 1m or better resolution DEM

may cover the whole province but the data may still not be widely accessible due to security and privacy concerns.

The major tool I used to map PVPs from DEM is a computer with ArcGIS with ArcHydro added-in. The ArcHydro tool is free, but it cannot run without ArcGIS, which is available from any computer on Dalhousie University campuses but is not common for the public and could be very expensive (if it is not for personal use). In addition, the hardware of the computer needs to be updated enough to run ArcGIS and the high resolution data. These issues can be resolved by using free GIS software (in which case the processes would be different and probably the results as well), and the computer problem will be solved with the updates of computer technology.

Respecting skills, mapping PVPs from DEM not only requires that the interpreter has a certain familiarity with ArcGIS software but also needs a reliable GIS support to solve the problems that may occur during the mapping process. Knowledge about GIS is not a common skill among the public, and it is also difficult to find a GIS specialist for the people who does not work in related disciplines.

5.2.6. Common Features

Aerial photos and Satellite images

From the sites I have mapped from aerial photos and satellite images, I found PVP predictions from each dataset were distinctive from other landscape in color, texture, depression and water occurrence (frozen water or wet soil in some cases); however, I found it is very difficult to sort out high-confidence predictions from low confidence ones simply by applying these features.

I have observed some high-confidence sites share features like obvious depression, significant water occurrence, non-wetland texture and distinction from tree shadow; however, these features do not apply to all the PVP predictions. Especially for the PVP predictions from 2002 Aerial Photos which are photographs taken in summer time when most pools were dry, I could only pick out half of the high-confidence predictions (confidence 3 and 4) by applying very strict criteria. In other datasets, I could pick up most of the high confidence predictions but together with a large number of low confidence ones. In addition, the most high-confidence sites are various in shape, size, and color and these features were not distinctive between high confidence PVPs and low confidence predictions. The field trip observations confirmed these findings since the surrounding, depression, color, and texture of the two potential vernal pools that I observed in the field are completely different on aerial photos and satellite images.

DEM

Since I delineated the PVPs from DEM only based on their depression and the flow accumulations that I calculated in ArcGIS, I did not record the landscape features for each site. When I overlap the predictions with the best quality aerial-photo I have, I did not find any significant features that these predictions share either.

VI. Discussion

This section discusses the overall findings, the useful points (useful to others in mapping VPs) about the mapping experience (skill level, time, efficiency, etc.), and the implications of the work with respect to contribution to the literature. The discussion also considers the relevance of mapping VPs to wetland protection, considering the usefulness of wetland policy for vernal pool management.

6.1. Discussion of Findings

In this project, I found it is very difficult to accurately locate PVP sites by using current remote sensing technology. Both omission and commission errors are unavoidable and could occur extensively in these approaches. However, they can significantly contribute to the field work as a guide to the potential sites. More importantly, these approaches allow researchers to locate PVPs during the seasons that are not suitable for observing vernal pools in the field, or simply on the land that are not easily accessible because of the factors such as distance and steep slopes.

Respecting the mapping experience, I found the datasets and their mapping methods I used in this project have different benefits and drawbacks as well. There is no ideal method or dataset for mapping PVPs; instead, the most suitable mapping dataset and approach varies depends on resources available and needs.

6.1.1. Mapping Methods

Methods

Stereoscopic mapping is unique in generating 3-D view of images, which is helpful in identifying trees and depressions. Using software can create anaglyph images from digital images and provide a 3-D view to the interpreters with anaglyph glasses; however, the

depression is not as obvious as using stereoscope from photographs. It is easier to use a mirror stereoscope than a pocket stereoscope but with the sacrifice of range of vision. In addition, mirror stereoscopes are much more expensive than pocket ones and therefore less affordable. The disadvantage of this approach is that it is difficult to get coordinates of the PVPs. One of the easiest ways to get coordinates is to scan, input, and georeference these images in ArcGIS. However, the site may move or distort during this process.

Direct visual on screen interpretation of digital images are easier to perform than stereoscopic mapping, and the interpreters can easily zoom in or zoom out to a preferable scale. This approach takes a shorter mapping time than stereoscopic mapping if the interpreters choose not to record mapping experience for each PVP site. The disadvantages are that the depressions are not as obvious as in 3-D mapping, and the easy-tracing may cause more mapping sites than stereoscopic mapping and lower confidence level on average.

The strongest benefit of delineating PVPs from a DEM is that it is objective. As long as the interpreters use the same data and follow the same guideline, the results should always be the same. In addition, to a proficient GIS interpreter, the delineation will take only several hours with no obvious false prediction, which could occur in visual interpretation. The drawbacks of this approach are that the accuracy and size of PVPs are highly dependent on data quality and computer condition, and the mistakes that may occur in the process cannot be easily observed.

Feasibility

Among all the mapping methods and the data in this project, I found the mapping from Google Earth or Bing Map in ArcGIS to be the most feasible approach to the majority of the public. It only requires some basic training (e.g. what are the features for a PVP, how to record the PVP, and how to add base map in ArcGIS), and the data are open to the public.

Direct visual on screen mapping of Hurricane Juan Imagery and the stereoscopic mapping from photographs are less accessible. Both the data and the tools are accessible to the public. However, the stereoscopic mapping requires more training on using stereoscopes, inputting, and georeferencing them in ArcGIS; the mapping from Hurricane Juan Imagery requires extra training on georefencing images in ArcGIS as well, because the original images on the provincial website are not georeferenced.

The visual on-screen mapping from 2009 color aerial images, 2009 black and white images, and 2003 color infrared images are not feasible. This is not only because they require training in creating PVP features in ArcGIS, but also that I obtained these data from the GIS center at Dalhousie University. These data are only accessible to Dalhousie faculty members, students, and HRM employees where the data originally came from.

I found the mapping from DEM to be least feasible. Even though a detailed guideline of the whole mapping procedures can make the process more feasible to the people who do not have proficient knowledge in ArcGIS, the interpreters still need to solve other errors or mistakes that may occur during the mapping. Since the knowledge in ArcGIS is not common among the public, the training to complete this mapping could be extensive to a person with no previous experience. In addition, the fine resolution DEM came from the GIS center at Dalhousie University, which is not accessible to the general public. Moreover, fine resolution DEM, such as the 1m DEM I used in this project, does not cover the whole province. In some regions, the DEM resolution is as coarse as 20m, which is not good enough for PVP mapping.

6.1.2. Mapping Data

Resolution / Scale

Interpreters can observe smaller pools on the images with finer resolution at the cost of a significantly longer mapping time. Moreover, the confidence level on average will decrease since the fine resolution will allow the interpreter to see subtle differences and pick up the pools with even just a bit of difference from the surrounding landscape. However, fine resolution images are less accessible than coarse ones, and are more expensive to take as well. In general, fine resolution images are particularly useful to the interpreters who need to delineate even the smallest size of PVPs, have adequate mapping time, and who have accessibility to those images.

It is very difficult to observe small PVPs on the images with a coarse resolution. However, the larger pools (above 100 sq m) without ever green tree cover were still observable on these maps, the mapping process was much shorter than fine resolution ones, and they are usually easier to obtain and less expensive to take a new ones. Therefore, coarse resolution images are most suitable to the interpreters who focus on larger pools, have limited mapping time, or do not have access to finer resolution images.

Aerial Photos and Satellite Images

I found there is no significant difference between digital aerial photos and digital satellite images. However, aerial photos can uniquely generate 3-D vision (from both paper format and digital format), which satellite images cannot. In addition, satellite images are more dependent on weather since it is easier to reschedule a flight but more difficult to reposition a satellite (especially respecting that satellite move along orbits and take times to reposition). Weather interference was obviously reflected on the Google 2003 satellite images because part of the study area was covered by clouds. Therefore, aerial photos and satellite images without weather

interference will perform similarly if the interpreters do not need to map in 3-D view; otherwise, aerial photos are more suitable for 3-D image generation.

Color

I found color images to be ideal for stereoscopic mapping and visual on screen mapping. The color of different objects can give various clues to the interpreter in determining PVPs. However, I found the color itself is not fully reliable since some trees may share similar color with bare land, while tree shadow or bedrock could be sometimes confusing with water color. Black and white images could be difficult to interpret when they are not at a fine resolution, but their anaglyph images are surprisingly clearer than color images. In addition, it is less expensive to take new ones. The major drawback of black and white images is that it is difficult to distinguish trees, their shadows, bedrock, shallow water bodies, and wet soil without color.

The set of color-infrared images I used in this project did not have a fine resolution (it is only 2.4m x 2.4m). I did not find it helpful in delineating small PVPs, and sometimes the features like bare land and concrete may share similar color with water. However, CIR images did highlight the large water bodies, such as river and lakes, from trees. Therefore, CIR images are helpful in mapping water bodies when they have a fine scale.

Season

I found the season of the mapping images are as critical as resolution respecting mapping PVPs, and this is because of leaf-condition and water stands. I found the images from early spring (e.g. 2009 color aerial photos) are most desirable since it is mostly leaf-off (except for ever-green trees) and the melting snow begins to refill vernal pools. Late autumn is fine as well if it is leaf-off and still have some water still remains (or at least wet soil), such as the Hurricane Juan Imagery from 2003.

The aerial photos and satellite image from winter time may be useful. The images are usually leaf-off, but snow may cover both bare land and frozen pools, and make PVPs less distinctive. If there is no significant snow accumulation, however, the frozen water bodies could be a unique and effective feature in determining water bodies.

Any image from summer time may only have limited use respecting mapping PVPs, no matter what resolution they have. For instance, the 2002 aerial photographs have a fairly fine resolution, but tree leaves cover most of the watershed. I mapped the least number of PVPs from this set of images. It is not only because of the different mapping method (stereoscopic mapping), but also because I could barely see the land underneath the canopy.

6.1.3. Comparison with Literature

Errors

The errors occurred in this project are similar to the error described in the literature. The major commission errors I had were wet soil, tree shadow, dry depressions, bedrock, part of a larger water body, or not enough water stands. Similarly, Brooks et al. (1998) found some sites to be "a seep with wet soil" or tree shadow; Carpenter et al. (2011) found some typical commission errors to be "not a basin depression", "low but dry area", part of a wetland connected to permanent water bodies, or a permanent pond; Stone (1992) found many PVPs she checked in the field are too shallow to exist for two continuous months in spring time.

During the field trip, I found some PVPs that I did not observed on images or delineated from DEM. As Stone (1992) reported similar errors, for example, she missed 24 additional sites during her field observation. Calhoun et al. (2003) found 77 extra pools in the field, and found that 75% of them are under evergreen or mixed forest. Since I have not checked all my PVP predictions in the field, I do not know how many pools I missed during mapping and the reasons

why I missed them. However, I found the heavy canopy to be a reasonable explanation since many of the existing vernal pools in Herring Cove are not observable on some images, and they are located in or adjacent to heavily forested land.

Minimum Mapping Size on Aerial photos

The minimum reliable mapping PVP sites in this project range from about 5 sq m (on the 0.15m resolution leaf-off color aerial-photo) to about 190 sq m (on 1:10,000 color aerial photograph). On the heavily vegetated images (2010 Satellite Google Earth Map) or coarse resolution images (2.4m resolution CIR), I did not map any PVP with full confidence. Respecting DEM, I found it is possible to delineate PVPs as small as 1 sq m from DEM, and they were found to have water stands in the field.

These minimum reliable mapping sizes are significantly smaller than in the literature. Brookes et al. (1998) reported a smallest reliable size of 25 sq m on leaf-off 1:12,000 CIR photographs (Carpenter, et al., 2011). Brune (2001) found the minimum reliable identification to be 114 sq m for the pools on the land that evergreen trees are not the dominant vegetation, though it was possible to identify 13 sq m pools occasionally. R.G. Lathrop et al. (2005) identified the minimum detectable size for a PVP to be 20 sq m, and found interpreters could easily omit smaller PVPs. I found the most likely explanations for these differences to be the mapping methods and image quality (color and scale). It is possible that the smallest sites I mapped may not stand long enough to be a vernal pool, or the PVPs in the study areas of the literature are larger than in the Williams Lake Watershed.

6.2 Implications

In literature, there are many studies that evaluate the effectiveness of single or various mapping methods and datasets on different areas; however, no literature compares the mapping

with various methods and dataset on the same land. My project uses and evaluates different mapping approaches and various datasets to delineate PVPs on the same area. This contributes to the understanding of remote sensing in mapping PVPs since there is no similar study in literature. Instead, many studies evaluate the effectiveness of single or various mapping methods and datasets on different areas. Other than this, future researchers can use my evaluation and mapping experience of different methods and data as a guide, and therefore choose the most suitable methods to them without trying various approaches by themselves.

My project can contribute to field work as well. The field trip in late March showed that the PVP predictions are not always PVPs, but most predicted sites were wet soil. Therefore, my mapping results can provide direction to the possible locations of PVP, which is more efficient than directly going into the woods to find PVPs. Moreover, the project explored the possibility and efficacy of mapping PVPs in summer time (when pools dry and disappear) and winter time (when it is too cold to go into the woods), neither time period is suitable for traditional field observation.

The Nova Scotia Department of Environment launched a vernal pool monitoring and mapping project in spring 2011 in order to map the locations of pools and raise awareness of these small wetlands. The mapping results from this project can be a base map for locating PVPs in the Williams Lake area and be part of the provincial vernal pool database once they are monitored and proved to be vernal pools. Moreover, this project has the capacity to raise awareness of vernal pools and their possible locations within the Williams Lake Watershed among the public, potential developers and decision. This is particularly important since the watershed is available for development. There is active development interest in the site. There is also active watershed group promoting responsible land use in the area. This group could engage

in discussion with the current land owner regarding wetland protection (see section 5.4 for further discussion). By recognizing the potential PVP sites before the development, planners can suggest design on land use development with minimum impact on these pools.

Policies

This project explores the approaches to and feasibility of pre-development mapping of small wetlands, which is crucial in protecting those wetlands, their surrounding habitats, dependant fauna and flora and local hydrological functions. The capacity of existing wetland and related policies has limited power, however, in protecting small wetlands, such as vernal pools. Even the protections that are available are highly dependent on whether the wetlands are known or mapped.

The Nova Scotia Environment Act recognizes vernal pools as "wetland"[2] (3(bg)). It gives the Minister of Environment the power to "authorize, restrict or prohibit the alteration of watercourses and wetlands" (105 (3) (a)), and the Governor in Council[3] the power to make regulations "respecting the infilling or alteration of wetlands, swamps, marshes, ravines or gulches"(110 (1) (d)).

In theory, the regulations alone should apply to vernal pools; however, wetland specific policies do not protect vernal pools. For instance, the Nova Scotia Wetland Conservation Policy applies to wetlands larger than 100 sq m. There is an exception for wetlands of special significance[4] but such wetland are typically larger than 100 sq m. Vernal pools are often smaller

[2] In the Environment Act, "wetland" is defined as "*land commonly referred to as a marsh, swamp, fen or bog that either periodically or permanently has a water table at, near or above the land's surface or that is saturated with water, and sustains aquatic processes as indicated by the presence of poorly drained soils, hydrophytic vegetation and biological activities adapted to wet conditions."* (the Environment Act 3(bg)).

[3] Governor in Council refers to "*the Lieutenant Governor acting by and with the advice of the Executive Council of the Province*" (the Interpretation Act 7(1)(q)).

[4]Wetlands of Special Significance refers to "*all salt marshes; wetlands that are within or partially within a designated Ramsar site, Provincial; Wildlife Management Area (Crown and Provincial lands only), Provincial Park, Nature; Reserve, Wilderness Area or lands owned or legally protected by non-government charitable*

than 100 sq m, and most of the PVP in this project are small (less than 100 sq m). The Halifax Regional Municipal Planning Strategy requires an Environmental Impact Assessment under the Environmental Assessment Act for the wetlands larger than 2 hectare (2,000 sq m) but does not protect smaller ones (E-9).

Some vernal pools are larger than 100 sq m, and this is also also true for my study area. These pools should be served by the provincial protection policy. However, such protection requires that the land owners identify the pools to Department of Environment and apply for a permit to alter the wetland, which may or may not be granted (the policy is intended to protect wetlands). However, many pools go unnoticed because they are not included in the provincial wetland database and not under monitoring. Furthermore, developers are potentially unaware of the pools in their property if field work happens during dry seasons. Also, they may not acknowledge that such small pools are wetlands and might not register them with the Department of Environment. Therefore, it is difficult to prove there was a wetland after the land owner drained it. This is particularly a problem to vernal pools, which only exist intermittently.

Hence, by providing possible locations of PVP sites, the government, community members and researchers can use the mapping results from this project as a guide, and conduct follow-up field trips to verify the existence of the PVPs. The possible vernal pools will be under monitoring, and the verified ones can be included in the provincial database. These actions can effectively minimize the alteration of small wetlands by making more wetland alteration under the protection of approval system. On the other hand, the land owners may choose not to alter these periodical pools after realizing they are actually wetlands but not wet soil. This project

---

conservation land trusts; intact or restored wetlands that are project sites under the North American Waterfowl Management Plan and secured for conservation through the NS–EHJV; wetlands known to support at-risk species as designated under the federal Species At Risk Act or the Nova Scotia Endangered Species Act; wetlands in designated protected water areas as described within Section 106 of the Environment Act" (p11-12, Nova Scotia Wetland Conservation Policy)

provides support for developing greater accuracy with pre-development identification of vernal pools.

6.3. Limitations of this Project

This project has many limitations due to the time available for the work, season, and my skill level. The time and short period of this project (January to mid-April) made it difficult for me to include comprehensive field observations. This is because most vernal pools reach their maximum surface area in spring time, which is around May in Halifax. An unseasonably warm spell in March allowed some initial field work, but due to the lack of comprehensive ground-truthing, the accuracy of the mapping methods I used in this project were not completely known. Moreover, the short period of project time makes errors and flaws unavoidably occur in this project.

I began with no experience with interpreting aerial photos, satellite images, or using ArcHydro tool to delineate vernal pools from DEM in ArcGIS before. During the project, my interpretation skills increased, which likely skewed the accuracy of the results, and other factors such as mapping hours and confidence level. I tried to over-come these biases by reviewing my earlier mapping, but it is still possible that my developing skill level distorted the results.

6.4. Suggestions for Future Study

Since this project is exploratory, it reveals many questions and potential project topics. The Department of Environment Nova Scotia had shown great interest in this project and the wetland specialist participated at various stages of the project. The department can take over this project as a pilot study, and conduct PVP mapping on other watersheds within the province. They can also use the mapping results as a direction for field work, check the PVP sites,

monitoring the sites that are more likely to be vernal pools, and include them in the provincial database when there is enough evidence.

The local community groups, such as The Williams Lake Conservation Company, can use the mapping results as directions and visit them in the field. They can also use the evaluation of the project as a guide and employ some of the methods to conduct another PVP mapping with more interpreters in a specific area.

Repeating the mapping processes of this project is another potential topic. Future researchers can repeat this project, or some of the methods, on another land, alternatively, other interpreters can check the validity of this project.

During the field trip, I noticed many PVP sites are part of intermittent drainage systems. Therefore, a study of the hydrological significance of vernal pools or potential vernal pools in micro watersheds would be an interesting project.

Mapping the PVPs from mid-twentieth century imagery (e.g. aerial photos from 1969), and comparing their modern condition would demonstrate how development in the area may have impacted these small wetlands could be another project. This project can also study the fire history within the watershed and how fire might influence the occurrence of the pools. Small wetlands may be quite vulnerable to the hydrologic change that following fires.

A comprehensive policy review could be another potential project. The potential project can study if the existing regulations can protect very small wetlands in Halifax or the Province of Nova Scotia. A parallel study would investigate what are the other provinces in Canada, or how the wetland protection policies and programs in other countries address vernal pools.

VII. Conclusion

The goals of this project are to map potential vernal pools within the Williams Lake Watershed, and to explore the possibility of mapping PVPs in pre-development area with remote sensing techniques. In order to achieve these goals, this project used stereoscopic mapping on one set of photographs, direct on-screen visual interpretation on three sets of aerial.-photos and four sets of satellite images, and delineation from DEM in ArcGIS.

I mapped 760 PVPs in total from aerial-photos and satellite images, and delineated 574 sites from DEM. I gave a confidence level of 1 to 4 to each subjective PVP prediction (the sites I mapped from aerial photos and satellite images) to represent the likelihood of the site to be a vernal pool. The highest average confidence level of PVP predictions is 2.19 from 2009 black and white aerial photos, and the lowest confidence level on average is 1.55 from 2010 Satellite Google Earth Map. The smallest size I mapped with the highest confidence is from 2009 color aerial photos, and the size is 4.78 sq m. The smallest site I mapped from DEM is 1 sq m, which is the smallest size possible for this mapping approach with the 1m resolution DEM data. Most of the PVP predictions are less than 100 sq m. I visited some of the PVPs in late March. I found two sites were likely to be sites, many PVPs to be wet or depressions without adequate water stand, and several obvious false predictions (e.g. bedrock, tree shadow).

From the results, I found fine resolution images can show small pools but need a longer time to map. DEM is efficient but requires proficient knowledge in GIS. Errors are unavoidable, but they can be minimized by reviewing the primary mapping results, improving image and DEM quality, and refining DEM delineating procedures. The leaf condition of images is important in mapping small PVPs but not critical to larger wetlands.

I found Google Earth and Bing Map are most suitable for the public. Their data is accessible on any computer with the Internet, and the mapping only requires basic training. Stereoscopic mapping with photographs are feasible to the public but requires more training in using stereoscopes, and the tools and data are only available for in-library use. Other visual on-screen mappings are still feasible but less suitable for the public because some images may require geo-referencing in ArcGIS, and fine resolution imageries are not always available to the public. Mapping with DEM is efficient and with low error rate, but it is the least feasible method for the general public to perform since the mapping process requires both proficient knowledge in GIS and accessibility to fine resolution DEM data.

Compared with the literature, I found the reasons for my errors are similar with previous studies, but my PVP sizes are much smaller. This may be because I used better resolution data and my study is on a different landscape.

In general, I found remote sensing techniques cannot accurately locate PVPs but can provide great direction for field work. These techniques are also advantages in that interpreters can map PVPs with remote sensing techniques on any land (wherever the data is available) at any time of the year, especially during the seasons that are not suitable for field work (e.g. winter).

Because of the limited time of this project, I cannot review my mapping results for several times, and cannot finish the ground-truthing of the PVP predictions. In addition, I finished this project in the winter semester, which is not an ideal time to visit vernal pools in the field. My lack of mapping experience and limited knowledge in hydrology and geology are the limitations of this project as well. It is likely that these limitations skewed the mapping results while leaving potential project topics. Other interpreters can repeat the methods I used in this

project for validity; community groups and the provincial government can take over the project as a pilot study and apply it to another watershed, or check the PVPs in the field. To hydrologists, they can use the mapping results to study the possible hydrological consequences of altering these water bodies. A comprehensive review of the capacity of current regulations in protecting small wetlands could also be an interesting project.

References

Anderson, V. J., & Hardin, P. J., (1992).Infrared Photo Interpretation of Non-Riparian Wetlands.*Rangelands, 14, pp. 334-337*

Bauder, E.T. &Bohonak, A.J. & Hecht, B. &Simovich, M. A. & Shaw, D. & Jenkins, D. G. & Rains, M., (December, 2009). A Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Vernal Pool Depressional Wetlands in Southern California. San Diego State University, San Diego, CA

Beardsley, K., & Thorne, J. H., & Roth, N. E., &Gao, S., & McCoy, M. C., (2009). Assessing the Influence of Rapid Urban Growth and Regional Policies on Biological Resources.*Landscape and Urban Planning, 93, pp. 172-183*

Brune, M.R., (2001). Massachusetts Aerial Photo Survey of Potential Vernal Pools. Natural Heritage and Endangered Species Program, Westborough. Accessed From Carpenter, L. & Stone, J. & Griffin, C. R. (2011).Accuracy of Aerial Photography for Locating Seasonal (Vernal) Pools in Massachusetts. *Wetlands, 31, 573-581.*

Burne, M. R., & Lathrop Jr. R.G. (2008).Remote and Field Identification of Vernal Pools.In Calhoun, A.J.K., &DeMaynadier, P. G. (Ed.).Science and Conservation of Vernal Pools in Northeastern North America (pp.55-68). Boca Raton: CRC Press

Brooks, R.T., & Stone, J., & Lyons, P. (1998). An Inventory of Seasonal Forest Ponds on the Quabbin Reservoir Watershed, Massachusetts. *Northeastern Naturalist, 5, 219-230.*

Canadian Soil Information Service (CanSIS). (2011). Soil Survey Reports for Nova Scotia. Retrieved November 11, 2011, from http://res.agr.ca/cansis/publications/surveys/ns/index.html

Carpenter, L. & Stone, J. & Griffin, C. R. (2011).Accuracy of Aerial Photography for Locating Seasonal (Vernal) Pools in Massachusetts. Wetlands, 31, 573-581.

Calhoun, A.J.K., & Walls, E.T., & Stockwell, S.S., & McCollough, M., (2003). Evaluating Vernal Pools as a Basis for Conservation Strategies: A Maine Case Studies. *Wetlands 23, 70-81.* Accessed from Carpenter, L. & Stone, J. & Griffin, C. R. (2011).Accuracy of Aerial Photography for Locating Seasonal (Vernal) Pools in Massachusetts. *Wetlands, 31, 573-581.*

Colburn, E. A. (2004). Vernal pools: National History and Conservation. Blacksburg, Va: McDonald & Woodward Pub. Co.

Cormier, T. A. (2007). Statistical and Cartographic Modeling of Vernal Pool Locations: Incorporating the Spatial Component into Ecological Modeling (Master Dissertation). Retrieved from ProQuest Dissertations & Theses.(Publication No.AAT 1449582).

Department of Natural Resources (DNR). (2000). Land Designation and Ownership in Nova Scotia, Scale 1:500,000 (map). Retrieved October 25, 2011, from http://www.gov.ns.ca/natr/meb/download/dp044dds.asp

Department of Natural Resources (DNR).(2004). Natural Resources –Significant Habitats of Nova Scotia. Retrieved October 25, 2011, from http://gis4.natr.gov.ns.ca/website/nssighabnew/viewer.htm

Department of Natural Resources (DNR). (2009). Map of Land Use Constraints in the Halifax-Dartmouth Metropolitan Area, Nova Scotia, scale 1:100,000 (map). Retrieved October 25, 2011, from http://www.gov.ns.ca/natr/meb/download/dp049.asp

Department of Natural Resources (DNR). (2011). Digital Surficial Geological Data of the Halifax Metropolitan and Surrounding Areas, NS, scale. (GIS data). Retrieved November, 15, 2011, from http://www.gov.ns.ca/natr/meb/download/dp447.asp

Environmental Protection Agency (EPA) (US).(2011). Section 404 Permitting. United States Environmental Protection Agency. Retrieved October 25, 2011, from: http://water.epa.gov/lawsregs/guidance/cwa/dredgdis/

Google Earth, (2003). Software. Accessed from: http://www.google.com/earth/index.html

Google Earth, (2010). Software. Accessed from: http://www.google.com/earth/index.html

Grant, E. H. C. (2005). Correlates of Vernal Pool Occurrence in the Massachusetts, USA Landscape. Wetlands, 25, 480-487.

Lathrop, R. G., & Montesano, P., &Tesauro, J., &Zarate., B. (2005). Statewide Mapping and Assessment of Vernal Pools: A New Jersey Case Study. Journal of Environmental Management, 76, 230-238

Lichko, L. E., & Calhoun, A. J. K., (2003). An Evaluation of Vernal Pool Creation Projects in New England: Project Documentation from 1991-2000. *Environmental Management, 32, pp. 141-151*

Lichvar, R. W., & Finnegan, D. C., & Newman, S., & Ochs, W. (2006).Delineating and Evaluating Vegetation Conditions of vernal Pools Using Spaceborne and Airborne Remote Sensing Techniques, Beale Air Force Base, CA. US Army Corps of Engineers. Retrieved October 4, 2011 from http://www.crrel.usace.army.mil/library/technicalnotes/TN06-3.pdf

MacCallum, W. F., (2009). Natural Heritage & Endangered Species Program's Guidelines for the Certification of Vernal Pool Habitat. Accessed from: http://www.mass.gov/dfwele/dfw/nhesp/vernal_pools/pdf/vpcert.pdf

MacDougall, J.I., &Cann, D. B., &Hilchey, J.D. (1963).Soil Survey of Halifax County Nova Scotia (Report No. 13). Retrieved from Agriculture and Agri-Food Canada: http://sis.agr.gc.ca/cansis/publications/ns/ns13b/intro.html#report

Mahaney, W. S., &Klemens, M. W. (2008). Vernal Pool Conservation Policy: The Federal, State, and Local Context. In Calhoun, A.J.K., &DeMaynadier, P. G. (Ed.).Science and Conservation of Vernal Pools in Northeastern North America (pp.11-29). Boca Raton: CRC Press

Mandell, P.R. (1994). The Effects of Land Use Changes on Water Quality of Urban Lakes in the Halifax/Dartmouth Region (Master Dissertation).p170. Retrieved October 26, 2011, from http://lakes.chebucto.org/watersheds/mandell/mandell.html

Maxa, M., &Bolstad, P. (2009).Mapping Northern Wetlands with High Resolution Satellite Images and LiDAR.*Wetlands, 29, pp.248-260*

Mitchell, J. C., & Paton, P. W. C., &Raithel, C. J., (2008).The Importance of Vernal Pools to Reptiles, Birds, and Mammals.In Calhoun, A.J.K., &DeMaynadier, P. G. (Ed.).Science and Conservation of Vernal Pools in Northeastern North America (pp.169-190). Boca Raton: CRC Press

National Research Council, (2001). Compensating for Wetland Losses Under the Clean Water Act. Washington DC: the National Academy Press.

NSE (Nova Scotia Environment). (July 16, 2009) Nova Scotia Wetland Conservation Policy (Draft for Consultation). Retrieved from http://www.gov.ns.ca/nse/wetland/

docs/Nova.Scotia.Wetland.Conservation.Policy.pdf

NSE (Nova Scotia Environment). (July 8, 2011) Vernal Pool Mapping and Monitoring Project. Retrieved October 5, 2011 from http://www.gov.ns.ca/nse/wetland/vernal.pool.mapping.project.asp

NSE, (Nova Scotia Environment). (September, 2011). Nova Scotia Wetland Conservation Policy. Retrieved October 24, 2011 from http://www.gov.ns.ca/nse/wetland/docs/ Nova.Scotia.Wetland.Conservation.Policy.pdf

NSF (Nova Scotia Finance).(2011). Statistics at a Glance. Retrieved October 25, 2011, from http://www.gov.ns.ca/finance/statistics/default.asp

O'Hara, C. G. & Manager, C. (2002)., Remote Sensing and Geospatial Application for Wetland Mapping, Assessment, and Mitigation. Retrieved from International Society for Photogrammetry and Remote Sensing: http://www.isprs.org/proceedings/XXXIV/part1/paper/00079.pdf

Oscarson, D. B., & Calhoun, A. J. K., (2007). Developing Vernal Pool Conservation Plans at the Local Level Using Citizen-Scientists.*Wetlands, 27, 80-95*

Power, M.E., &Tilman, D., & Estes, J.A., & Menge, B. A., & Bond, W. J., & Mills, L. S., & Daily, G., &Castilla, J.C., &Lubchenco, J., & Paine, R.T., (1996). Challenges in the Quest for Keystones.*Bioscience 46, 609-620*.

Prime, G., (2001). Map of Bedrock Aggregate Potential in the Halifax-Dartmouth Metropolitan Area, Nova Scotia. Nova Scotia Department of Natural Resources, Minerals and Energy Branch. Open File Map ME 2001-1

Statistics Canada.(2005). Land and Freshwater area, by Province and Territory. Retrieved October 25, 2011, from http://www40.statcan.ca/l01/cst01/phys01-eng.htm

Stone, J.S., (1992). Vernal Pools in Massachusetts: Aerial Photographic Identification, Biological and Physiographic Characteristics, and State Certification. MS Thesis. University of Massachusetts Amherst, Amherst. Accessed from Carpenter, L. & Stone, J. & Griffin, C. R. (2011).Accuracy of Aerial Photography for Locating Seasonal (Vernal) Pools in Massachusetts. Wetlands, 31, 573-581.

Windmiller, B., & Calhoun, A. J. K. (2008).Conserving Vernal Pool Wildlife in Urbanizing Landscapes.In Calhoun, A.J.K., &DeMaynadier, P. G. (Ed.).Science and Conservation of Vernal Pools in Northeastern North America (pp.233-251). Boca Raton: CRC Press

Appendix A: Glossary

DEM – Digital Elevation Model

GIS – Geographic Information System

LiDAR – Light Detection and Ranging

PVP – Potential Vernal Pool

VP – Vernal Pool

Appendix B: General Description of Generating PVP Sits from DEM using ArcGIS and ArcHydro

Requirement:

- ArcGIS (ArcInfo Version)
- ArcHydro
- DEM
- Stream Data

General Procedures:

1. ArcHydro -> Terrain Processing -> DEM Manipulation -> **Reconditioning (reduce Sharp Drop/Raise to 10) (layer 1)**
2. ArcHydro -> Terrain Processing -> Data Manimupation -> **Fill Sinks (layer 2)**
3. ArcHydro -> Terrain Processing -> Flow Direction
4. ArcHydro -> Terrain Processing -> Flow Accumulation
5. ArcHydro -> Terrain Processing -> Stream Definition

   (in this step, you can change the catchment area of the flow accumulation channels)

   Find a range, an upper limit (the channel with more water flow) (**layer 3**), and an lower limit (the channel with least water flow) (**layer 4**).

(step 1 - 5 are from Watershed and Stream Network Delineation by Merwade (2010), which can be accessed from http://web.ics.purdue.edu/~vmerwade/education/terrain_processing.pdf)

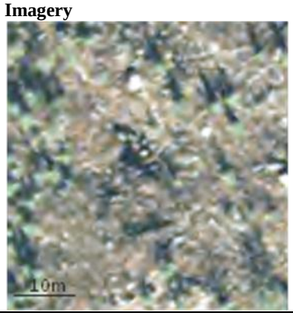
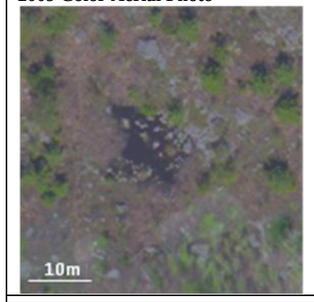
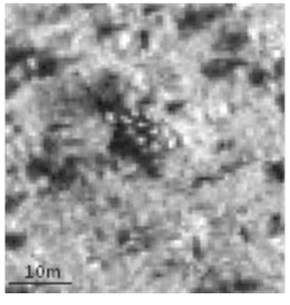
6. Minus **Layer 2** from **Layer 1** (get **layer 3, the depressions**)
7. Convert Layer 3 (raster) into Vector data (there may be several ways to do this. What I did is:
   1) spatial analysis-> extract by attribute;

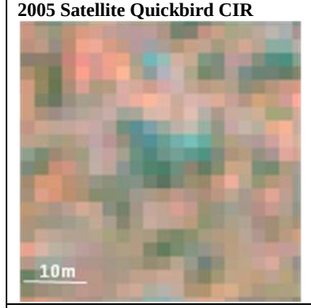
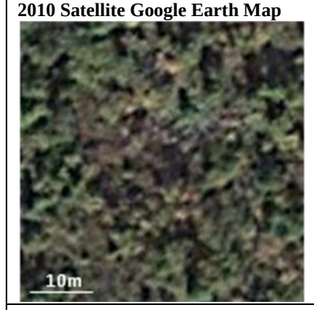
2) “multiply” tool: mutiply the layer by 1000;
3) “Int” tool (transfer data into integrals in order to perform conversion to vector data);
4) convert raster to polygon (uncheck “simplify”);
5) divide 1000 (get a depression unit of m) or divide by 10 (get a depression unit of cm)

8. Convert Flow Accumulations (**layer 3 and layer 4**) from raster to vector
9. Select By Locations

Appendix C: Tables

Table 1: Summary of Aerial-Photos, Satellite-Images, and the PVPs I Mapped from These Data

Data	# of PVPs delineated in the first mapping	revised mapping (1)		Mapped PVPs	# of PVPs within the study area	obvious false predictions (very certain)	obvious wetlands (non VP wetland)	final mapped PVPs	average Confidence (of Final Mapped PVPs) (1-4)	confidence score distribution	average area as mapped (delineated) (sq m)	mapping time (hour) (excluding distracted hours)	image date	scale / resolution	leaf condition	color / B&W	mapping methods	source
		Add (+)	Errors (-)															
Aerial																		
2002 Aerial Photograph (digital image unavailable)	36	2	1	37	30	2 (bedrock)	0	28	2.1786	1: 17 (61%) 2: 4 (14%) 3: 4 (14%) 4: 3 (11%)	Avg: 208.35 Std: 209.42 Min: 41.99 Max: 1037.14 Min Confident 4: 190.49	11 + (review EVP, map, scan, georef, trace, review)	2002 July-26	1:10,000	Leaf on	Color	Stereoscope	Nova Scotia Natural Resources Library
2003 Aerial Hurricane Juan Imagery 	168	2	36	134	134	3 (bedrock)	0	131	1.7099	1: 64 (49%) 2: 45 (34%) 3: 17 (13%) 4: 4 (3%)	Avg: 70.73 Std: 70.45 Min: 14.69 Max: 551.97 Min Confident 4: 71.58	About 10 + (similar with Bing) (Review, map, review)	2003 October - November	0.5m x 0.5m	Partially leaf on	Color	Direct visual interpretation of digital image	Hurricane Juan Imagery – Nova Scotia Natural Resources Website
2009 Color Aerial Photo 	213	58	82	189	189	2 (bedrock)	0	187	1.8984	1; 70 (37%) 2: 72 (39%) 3: 33 (18%) 4: 12 (6%)	Avg: 38.93 Std: 10.57 Min: 0.27 Max: 1168.19 Min Confident 4: 4.78	About 15 + (very similar with 2009 bw) (map, review)	2009 May 14-21	0.15m x 0.15m	Partially leaf on	Color	Direct visual interpretation of digital image	GIS Center, Dalhousie University
2009 Black and White Aerial Photo 	115	55	24	146	146	5 (bedrock); 1 (part of river); 1 (building ruin)	1	138	2.1870	1: 32 (23%) 2: 52 (38%) 3: 44 (32%) 4: 10 (7%)	Avg: 137.47 Std: 150.04 Min: 13.65 Max: 885.23 Min confident 4: 105.48	17.75 + (review EVP, map, review)	2009 April	0.6m x 0.6m	Partially leaf on	Black and White	Direct visual interpretation of digital image	GIS Center, Dalhousie University

Satellite																		
2005 Satellite Quickbird CIR 	57	6	3	60	42	1 (bare land)	3	38	1.6646	1: 17 (45%) 2: 19 (50%) 3: 2 (5%) 4: 0 (0%)	Avg: 655.63 Std: 691.58 Min: 39.48 Max: 3719.50 Min Confident 4: -	6 + (review EVP, map, review)	2005 October-1	2.4m x 2.4m	Partially leaf on	Color (CIR)	Direct visual interpretation of digital image	GIS Center, Dalhousie University
2003 Satellite Google Earth Map 	89	31	11	109	109	1 (bedrock)	0	108	2.0278	1: 32 (30%) 2: 48 (44%) 3: 24 (22%) 4: 4 (4%)	Avg: 71.61 Std: 100.61 Min: 6.74 Max: 890.60 Min Confident: 48.39	14.5 + (review EVP, map, screen shot, georef, trace, review)	2003 May-1	-	Leaf off	Color	Direct visual interpretation of digital image	Google Map
2010 Satellite Google Earth Map 	42	0	3	39	39	1 (bedrock)	0	38	1.5526	1: 19 (50%) 2: 17 (45%) 3: 2 (5%) 4: 0	Avg: 60.15 Std: 78.33 Min: 5.04 Max: 420.23 Min Confident 4: -	6.5 + (review EVP, map, trace, review)	2010 October-13	-	Leaf on	Color	Direct visual interpretation of digital image	Google Map
Satellite Bing Map 	132	0	36	96	96	1 (bedrock)	3	92	2.0543	1: 36 (39%) 2: 27 (29%) 3: 17 (18%) 4: 12 (13%)	Avg: 87.99 Std: 165.37 Min: 0.36 Max:1176.80 Min Confident: 5.01	10.25 + (review EVP, map, review)	-	-	Leaf on	Color	Direct visual interpretation of digital image	Bing Map

(1) The revisions I made during my review of my initial mapping results.

Table 2: Summary of DEM, and the Mapping Results

Table 2.1. Digital Elevation Model Predicted Potential Vernal Pools within Herring Cove

site	size (sq m)	area that overlapped with depression (sq m)	mean depth (m)	max depth (m)	touch with flow accumulation of 1430 (0.705m buffer)[5]	touch with flow accumulation of 16000 (no buffer)
1	109.4167	27.2577	0.987156	7	y	n
2	65.42213	64.8396	27.49375	42	y	n
3	12.77072	0	0	0	n	n
4	26.36781	0	0	0	n	n
5	5.832667	0	0	0	n	n
6	79.07665	0	0	0	n	n
7	295.7108	295.6882	65.10101	85	y	n
8	27.58536	2.193001	0.060714	0	n	n
9	303.4065	295.8886	40.84136	66	y	y
10	396.4539	396.4539	71.24332	80	y	n

Table 2.2. PVPs (and their sizes) Delineated from DEM, and Comparison with Depression before being Filtered by Flow Accumulations

	depressions (in total)	**depressions (1,430 to 31,599, wider range)**	**% with total depression**	**depressions (1,430 to 16,001, narrower range)**	**% with total depression**
Count:	2199	677	31%	574	26%
Minimum:	1	1	100%	1	100%
Maximum:	4859	4859	100%	1797	37%
Sum:	98498	50950	52%	27881	28%
Mean:	45	75	168%	49	108%
Standard Deviation:	258	337	130%	153	59%

[5] The buffer is added because after the raster data was converted to vector data, the shape changed, and the sites that used to touch with this channel before does not touch with this channel anymore. Therefore, I added a buffer.

Table 3 Evaluation of Methods and Data

Data	Date	Scale / Resolution	Leaf condition	Color / B&W	Mapping Methods	# of PVPs (final)	Confidence	PVP Size (average)[(1)]	Obvious Error Rate	Data accessibility	Tool Accessibility	Skill Requirement	Mapping Hours	Cost / required tools
Aerial														
2002 Aerial Photograph	2002 July-26	1:10,000	Leaf on	Color	Stereoscope	28	2.1786	Large (200 - 300 sq m)	2 (bedrock)	Accessible to everyone (Nova Scotia Natural Resources Library)	Accessible to everyone (there is a pocket stereoscope in the library available for renting)	Low (need to learn how to use stereoscope; pervious mapping experience is an asset but not necessary)	Long (10-15 hr)	Pen Transparencies Stereoscope (can rent for free) Aerial Photos (for purchase, can be used for free for in-library use) Locations and boundaries of existing vernal pools useful but not necessary
2003 Aerial Hurricane Juan Imagery	2003 October - November	0.5m x 0.5m	Partially leaf on	Color	Direct visual interpretation of digital image	131	1.7099	Small (50 - 100 sq m)	3 (bedrock)	Accessible to everyone (Hurricane Juan Imagery – Nova Scotia Natural Resources Website)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas.	Low (very basic knowledge about ArcGIS; there are tutorials available online; previous experience in visual interpretation is an asset but not necessary.)	Long (10-15 hr)	Digital Aerial Hurricane Juan Imagery (free) GIS software (ArcGIS, or other substitutions) Pen, transparencies, paper map with coordinates, ruler (if choose to map PVPs on print copy) (cost varies) * Locations and boundaries of existing vernal pools
2009 Color Aerial Photo	2009 May 14-21	0.15m x 0.15m	Partially leaf on	Color	Direct visual interpretation of digital image	187	1.8984	Very Small (< 50 sq m)	2 (bedrock)	Accessible to Dalhousie Faculties and students, and HRM employees (GIS Center, Dalhousie University)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas.	Low (very basic knowledge about ArcGIS; there are tutorials available online; previous experience in visual interpretation is an asset but not necessary.)	Very Long (>15 hr)	Digital Aerial Hurricane Juan Imagery (free) GIS software (ArcGIS, or other substitutions) Pen, transparencies, paper map with coordinates, ruler (if choose to map PVPs on print copy) (cost varies) * Locations and boundaries of existing vernal pools
2009 Black and White Aerial Photo	2009 April	0.6m x 0.6m	Partially leaf on	Black and White	Direct visual interpretation of digital image	138	2.1870	Medium (100 – 200 sq m)	5 (bedrock); 1 (part of river); 1 (building ruin)	Accessible to Dalhousie Faculties and students, and HRM employees (GIS Center, Dalhousie University)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas.	Low (very basic knowledge about ArcGIS; there are tutorials available online; previous experience in visual interpretation is an asset but not necessary.)	Very Long (>15 hr)	Digital Aerial Hurricane Juan Imagery (free) GIS software (ArcGIS, or other substitutions) Pen, transparencies, paper map with coordinates, ruler (if choose to map PVPs on print copy) (cost varies) * Locations and boundaries of existing vernal pools
Satellite														
2005 Satellite Quickbird CIR	2005 October-1	2.4m x 2.4m	Partially leaf on	Color (CIR)	Direct visual interpretation of digital image	38	1.6646	Very Large (> 300 sq m)	1 (bare land)	Accessible to Dalhousie Faculties and students, and HRM employees (GIS Center, Dalhousie University)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas.	Low (very basic knowledge about ArcGIS; there are tutorials available online; previous experience in visual interpretation is an asset but not necessary.)	Short (5-10 hr)	Digital Aerial Hurricane Juan Imagery (free) GIS software (ArcGIS, or other substitutions) Pen, transparencies, paper map with coordinates, ruler (if choose to map PVPs on print copy) (cost varies) * Locations and boundaries of existing vernal pools
2003 Satellite Google Earth Map	2003 May-1	-	Leaf off	Color	Direct visual interpretation of digital image	108	2.0278	Small (50 - 100 sq m)	1 (bedrock)	Accessible to everyone (Google Earth)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may	Low (very basic knowledge about ArcGIS; very basic knowledge about Google earth; corresponding tutorials available online; previous	Long (10 - 15 hr)	Google Earth GIS software (ArcGIS, or other substitutions) * Locations and boundaries

											not calculate areas. Free Google Earth software.	experience in visual interpretation is an asset but not necessary)		of existing vernal pools
2010 Satellite Google Earth Map	2010 October-13	-	Leaf on	Color	Direct visual interpretation of digital image	38	1.5526	Small (50 - 100 sq m)	1 (bedrock)	Accessible to everyone (Google Earth)	Free GIS software includes the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas. Free Google Earth software.	Low (very basic knowledge about ArcGIS; very basic knowledge about Google earth; corresponding tutorials available online; previous experience in visual interpretation is an asset but not necessary)	Short (5 – 10 hr)	Google Earth GIS software (ArcGIS, or other substitutions) * Locations and boundaries of existing vernal pools
Satellite Bing Map	-	-	Leaf on	Color	Direct visual interpretation of digital image	92	2.0543	Small (50 - 100 sq m)	1 (bedrock)	Accessible to everyone (Bing Map)	Free GIS software includes adding Bing Map as a base map and the function of tracing the PVP locations and shape, but cannot generate coordinates and may not calculate areas.	Low (very basic knowledge about ArcGIS; there are tutorials available online; previous experience in visual interpretation is an asset but not necessary.)	Long (10 – 15 hr)	GIS software (ArcGIS, or other substitutions) * Locations and boundaries of existing vernal pools
DEM														
1m resolution DEM						574	Not Applicable	Very Small	None	Accessible to Dalhousie Faculties and students, and HRM employees (GIS Center, Dalhousie University)	Need full version of ArcGIS, and ArcHydro add-on (free). Not accessible to most people since it is not common software for individual uses. Accessible to Dalhousie students and faculties, and the people who works in a relative field.	High (proficient knowledge about ArcGIS is necessary; need technical supports from GIS specialists)	Very short to very long (varies based on skills and data availability)	GIS software (ArcGIS, or other substitutions) 1m DEM data Locations and boundaries of existing vernal pools

(1) The descriptions here represent the comparative larger / smaller, etc.

Table 4: Records of 2002 Aerial Photograph

Id	% Adjacent to Trees	% Adjacent to Grass/shrub/land	Brownish Boundary	Wetland Texture	Depression	Water	Distinguishable from Surroundings	Color	Shape	Area (sq m)	Confidence	Others
1												out of boundary
2												out of boundary
3												out of boundary
4												out of boundary
5	70-80%	20-30%	Y	not sure	not sure	might be subtle	moderate	dark, blackish	round	65.10208	1	3 small ones. These spots might be shadows. They are picked up since they have brownish exposed soil (while surroundings are densely covered by trees)
5	70-80%	20-30%	Y	not sure	not sure	might be subtle	moderate	dark, blackish	round	49.45217	1	3 small ones. These spots might be shadows. They are picked up since they have brownish exposed soil (while surroundings are densely covered by trees)
5	70-80%	20-30%	Y	not sure	not sure	might be subtle	moderate	dark, blackish	round	41.99055	1	3 small ones. These spots might be shadows. They are picked up since they have brownish exposed soil (while surroundings are densely covered by trees)
6	30%	70%	N	N	N	might be	subtle	Black & blue	Oval / round	104.9794	1	its color is similar to tree shadow but not exactly the same; chosen for its difference from tree shadows; however, it is adjacent to exposed bedrock (so it might be shadow)
7	50%	50%	Y	N	N	little	subtle	moderate dark blue	linear narrow oval	86.2508	1	might be tree shadow on bedrock
8												out of boundary
9												out of boundary
10	N	0% (central of bedrock)	Y	N	N	Y	Y (subtle, since it is small)	moderate dark blue	oval	129.7363	1	it seems located in on central bedrock but there is no tree adjacent to it.
11	N	50% to bedrock; 50% to grass	Y	Y (subtle)	N	might be (N)	Y (subtle)	dark-brownish with several small dots of dark blue	irregular	255.4021	1	could be wet soil. Kind of like wetland. May be a dried water body
12	40-50%	50-60%	Y	Y	Y (subtle)	Y	Y	moderate dark blue with light to dark brownish boundary	oval	190.4945	4	might be a wetland but vernal pool.
13	30-40%	60-70% (to bedrock)	Y (bedrock)	N	N	Y	Y (subtle)	moderate dark	oval / round	100.0603	1	may be tree shadow but the direction is not very correct
14												deleted during eliminating false predictions - bedrock
15												deleted during eliminating false predictions - bedrock
16												deleted due to being a large wet land
17	0%	100%	Y (bedrock)	N	N	Y (little)	not significant (subtle)	dark blue surrounded by light brown	oval	63.24614	1	it is a black spot that seems like tree shadow (but it seems there is no tree to provide this shadow)
18	35%	65%	Y	subtle	N	N	wet sandy like, a little bit different from surroundings	sandy brown / yellow	irregular, round to square	273.5578	1	seems like wet soil or wet sand
19	100%	0%	N (or very subtle)	Y	N	N	seems like wetland-ish, seems different from empty glade	brownish green	irregular round	149.6101	1	may be just a glade (though the brownish tint seems very suspicious)
20	100%	0%	Y (the PVP itself is brown)	Y	subtle	N	Y	coarse brownish	irregular	469.6508	3	very likely to be wetland. Might not be a PVP though.
21	about 90%	10%	N	Y	subtle	N	Y, but not significant	green (brownish / grayish green)	oval / linear	1037.136	3	might be wetland, or wet soil along the brook. Might not be a PVP though
22	90%+	<10%	N	Y	Y (subtle)	N	Y	grayish blue/green, kind of brownish as well	irregular, oval like	510.9567	4	must be a wetland but might not be a PVP
23	50%	50%	Y	N	Y (subtle)	Y	Y	moderate dark blue (with grey0ish brown boundary)	irregular	166.5214	3	very likely to be a water body
24	40%	60%	N	N	N	Y	very subtle	moderate dark blue	oval	43.33614	1	it look like a tree shadow; but it is close to water body / wetland and has no significant tree to

												provide shadow
25	20%	80% to grassland	N	N	N	cannot tell	subtle	moderate dark blue with traces of green	round	126.4468	1	it is adjacent to a tree but the tree cannot explain the shape
26	not immediate	Grassland	N	N	N	cannot tell	Y (the direction of the shadow cannot be explained)	moderate dark blue; traces of green	oval	209.9255	3	there is a tree next to it, but it seems the shadow is short. In addition, the color of this site is very different from surroundings (it has a tint of blue). In addition, it is located in a glade, which could be a depression. Its confidence if between 2-3, but I gave it a 3 due to its distinctive color with surrounding tree shadows.
27	N	grassland (with brown buffer)	N	N	cannot tell	cannot tell	subtle	moderate dark blue	round	170.0479	2	it is overlapped with tree shadow but its color is subtle different from shadow black.
28	20%	80% grassland	Y	N	cannot tell	cannot tell	subtle	moderate dark blue	round	319.516	1	it may just be a tree shadow, but it is adjacent to a brownish patch
29	15%	85%	N	N	N	cannot tell	Y	moderate dark blue; traces of green	irregular (crescent)	64.07817	2	the shape; location, and lack of shadowing trees (but have forest within a certain distance) make this area suspicious
30												out of boundary
31	70%	30% bare land	subtle	N	Y (subtle)	cannot tell	subtle	moderate dark blue with traces of green (and blackish water body as well)	oval	131.867	1	it is likely to be tree shadow but it also has subtle sign of depression
32	20%	80% grassland	N	N	N	cannot tell	subtle	blackish and blue	oval	54.0594	1	it is likely to be tree shadow but it is too long
33	50%	50% bare land	Y	N	N	cannot tell	subtle	moderate dark blue with a small dot of white/light green	oval	366.8997	1	adjacent to a tree therefore likely to be a tree shadow; however, as a shadow, it is too long
34	50%	50% grassland	N	N	subtle	cannot tell	subtle	moderate dark blue with traces of green in the middle	oval	471.5945	1	likely to be tree shadow but the direction and size is suspicious
35												out of boundary
36	20%	80% grassland	N	N	N	cannot tell	subtle	pale blue; green; moderate dark blue	triangle	243.808	1	it could be a partially dried pool
37	50%	30% grassland 20% exposed bedrock	N	N	N	cannot tell	subtle	moderate dark blue	oval	93.26855	2	it looks like a tree shadow but the direction is very wrong
38	N	100% exposed bedrock	bedrock	N	N	Y	Y	moderate dark blue	round	53.18241	2	it is a small dot in the middle of exposed bedrock with no tree around (but the tree color could be so light that does not reflect on the photo) or it could just be a deep color exposed bedrock; or it could be aerial photo problem

Table 5: Records of 2003 Aerial Hurricane Juan Imagery

Id	color	shape	surroundings	brownish boundary	wetland texture	depression	Shadow (possible)	wet soil (possible)	Area (sq m)	confidence	others
1	dark blue; purple; brown	irregular	bare land	N	N	Y (subtle)	N	Y	159.2289	2	very close to developed area
2	purple	oval	bare land	N	N	N	N	maybe	17.12092	1	could be bedrock
3	dark blue; purple; patches of green	long linear	bare land	N	N	N	maybe	Y	107.134	1	the shadow in this area seems to be very long; therefore could be a shadow; however, the sharp shape in the north-west makes this site suspicious
4	dark blue; tint of purple	round	bare land	Y (subtle)	N	Y (subtle)	N	maybe	15.87894	1	the tint of purple color makes this site suspicious; however, it still could be just a patch of wet soil
5	dark blue; tint of purple (at the boundary)	long oval	trees	N	N	N	maybe	maybe	23.741	1	it is likely to be a tree shadow (on the right direction and with a reasonable length); but the blur purple boundary makes this site suspicious
6	dark blue; traces of white	oval	90% bare land; 10% trees	N	N	N	maybe	maybe	56.82054	2	it Is likely a tree shadow; however, the shape is too wide for the tree on the south-east. The tint of purple color makes this site suspicious as well
7	dark blue; brown; traces of white; tint of purple	square	bare land	N	N	Y (subtle)	N	maybe	57.6229	3	not a shadow, deep color and slight depression make this site suspicious
8	dark blue (at the top); brown (underneath); tint of deep red	square	70% trees; 30% bare land	N	Y	Y (subtle)	Y (on the top)	Y	255.9743	3	the reddish color underneath and the coarse wetland texture make this site suspicious
9	dark blue; tint of purple; brown	round	trees	Y	N	Y (subtle)	N	maybe	27.93819	2	it does not looks like a shadow and the deep color make this site suspicious; however, given the blur surrounding, it is difficult to tell if that is a PVP or is just a distorted tree
10	dark brown; dark blue; traces of light brown	round	bare land	N	N	Y	N	N	27.13278	1	it has obvious depression but there is no water remain
11	dark blue; patches of brown and white	triangle	bare land	N	N	Y	N	maybe	41.37033	1	it has obvious depression; the pale blue color could be water but may also be shadow or just wet soil
12	dark brown; traces of white; dark blue	oval	60% trees; 40% bare land	N	Y	Y	N	Y	75.29248	3	obvious depression; the patch of dark color in the middle could be water remain; however, the image is too blur to be sure about the depression
13											deleted during review
14	dark blue; tint of purple; traces of white	round	bare land	Y (subtle)	Y (subtle)	Y (subtle)	N	Y	24.91029	2	does not looks like a shadow (as a whole site); suspicious wetland-texture and depression; the blue color seems to be water remain but may also be a small shadow from the tree on its south-west
15	pale grey dark blue; tint of purple; traces of brown	square	60% trees; 40% bare land	N	N	Y	N	Y	25.26596	2	the depression is visually obvious; the blue color in the middle could be water remain; however, the image resolution is too blur to be sure about the depression or the water remain
16											deleted during review
17	brown; dark blue; traces of green	irregular	50% bedrock; 50% bare land	N	N	Y	Y (on the north-east)	maybe	109.003	2	the location of the site (partially surrounded by bedrock) is suspicious; the dark blue color could be shadow or water
18	dark blue; tint of purple; traces of white and green	round	70% trees; 30% bare land	Y (subtle)	N	Y (subtle)	maybe	maybe	35.0092	2	the tint of purple and green make this site suspicious; the dark blue color is likely to be water but could also be the shadow of the trees from the south-east
19	dark blue; tint of purple; tint of white	irregular	50% bare land; 50% trees	N	N	N	Y	maybe	163.4492	1	this site contains shadow but not the whole site can be explained by shadow; the
20	dark blue; traces of white; tint of purple	irregular	70% trees; 30% bare land	N	N	N	N	maybe	53.21411	1	the white color is suspicious (because it is distinctive from the shadow), but could be wet soil or image color distortion
21	brown; patches of dark blue; traces of white	oval	trees	N	N	Y	Y (but distinctive)	N	31.24169	2	it is not a tree shadow (the brown part), and is distinctive from tree shadow; the brown color could be bare land as well
22	pale white; dark blue; tint of green and purple	round	trees	N	N	Y	Y (contains shadow but distinctive)	N	29.6586	1	not sure what this patch is (especially the white color); not a tree shadow, the blue color in the middle could be water remain
23	dark blue; tint of brown and purple	round	trees	N	N	N	maybe	maybe	45.31699	1	likely a tree shadow, there is a slightly darker color in the center but is too blur too be sure if it is a water body
24	dark blue; traces of brown	oval	trees	N	N	Y	Y (part of)	Y	27.6044	1	possibly wet soil and partially covered by tree shadow; however, there is no sign of water remain
25	brown; dark blue (shadow)	long oval	trees	N	N	Y	Y (part of)	N	19.15697	1	not a shadow but seems too dry to be a pool
26	brown; dark blue (central); white (in the middle)	oval	bare land / grassland	Y	N	Y (subtle)	N	maybe	43.34082	2	the brownish boundary makes this site suspicious; the blue color in the middle could be water, however, may be shadow if the green-ish color on the south is a tree
27	deep brown; traces of dark blue	round	50% trees; 50% bare land	Y	Y	Y	N	Y	80.77274	3	very likely a wet land; but not sure if it can dry periodically
28											deleted during review
29	dark blue (in the middle); tint of pale white and purple	oval	80% trees; 20% bedrock	N	N	N	N	maybe	25.44209	2	the purple color does not like a tree shadow, though it still could be a shadow from the trees on the south-east (the purple color could be color distortion)
30	dark blue; tint of purple	irregular	bare land	N	N	Y (subtle)	N	maybe	14.69138	2	there is no tree to make this site a shadow; however, the shape is too narrow, and this site could be the shadow of bedrock

31	dark blue; traces of brown and purple	oval	trees	Y	N	N	N	maybe	28.43282	1	this site is mapped due to the purple like color; the blue color could be shadow
32	dark blue; traces of green; tint of purple	round	60% trees; 40% bare land	N	N	N	Y	maybe	36.36999	1	more likely a tree shadow, wet soil, or part of a large wetland
33											deleted during review
34	brown; dark blue	oval	trees	Y	N	Y	N	maybe	18.34999	1	it has depression (seem to be); the blue color on the west section could be water; however, it is too close to trees and therefore could be shadow
35											deleted during review
36	brown	long oval	trees	N	N	Y	N	maybe	71.64367	1	it has depression but no sign of water remain
37											deleted during review
38	brown; dark blue; pale dark blue	irregular	trees	Y	N	Y (subtle)	N	maybe	28.14489	1	the whole site is more like bare land with shadow; what suspicious is the pale blue color in the middle, which may be water
39	brown; pale blue; tint of green	oval	trees	N	maybe	Y	N	maybe	124.0692	2	suspicious because of depression and the blue color (which could be water); likely to be wet soil
40											deleted during review
41	dark blue; patches of green and white	oval	trees	N	Y	Y	maybe	Y	44.92788	1	though it has coarse wetland texture and seems a little bit too large to be a shadow, it is on the right spot of being a shadow (from the tree on the south east), or it is likely to be wet soil
42	dark brown; traces of white	oval	60% trees; 40% bare land	N	Y (subtle)	Y	N	Y	164.0871	2	this site is not a shadow; it has depression but lack significant sign of water remain
43											deleted during review
44											deleted during review
45											deleted during review
46	dark blue; traces of brown; tint of purple	oval	bare land	N	N	N	N	maybe	36.56569	1	from the surroundings, this site is more likely to be a tree shadow; however, I cannot find a there that could reasonable create the whole site as a shadow (probably it is because the tree color is similar to the ground or image color distortion)
47	dark blue; patches of brown and green; tint of purple	irregular	70% trees; 30% bare land	N	Y	Y	Y (part of)	maybe	69.60144	2	the shadow on this landscape seems surprisingly long, and therefore this site still could be a shadow; what makes this site special is the pale-grey and brown patches in the dark blue color, which makes this site possibly a wetland or a partially dried pool
48											deleted during review
49	dark blue; tint of purple	long linear	50% trees; 50% bare land	Y	N	N	maybe	maybe	38.02643	1	very likely a tree shadow; mapped because of the possible "brownish boundary" and the purple color (which may make this site a water body)
50	dark blue; patches of brown	long oval	70% bare land; 30% trees	N	Y (subtle)	Y (subtle)	Y	maybe	117.8479	1	likely a tree shadow from the tree on the south. However, it is suspicious because it links with a black line (which could be trail or gully or river)
51	dark blue; tint of purple and brown	oval	70% bare land; 30% trees	N	N	Y	N	Y	34.83793	2	it does not looks like a tree shadow, and has slight depression; however, this site seems kind of common in the surrounding landscape
52	brown; traces of dark blue and green	oval	bare land	N	N	Y	N	N	43.8184	1	it seems to be a depression but there is no sign of water remain, possibly a shadow, and the depression itself could be the result of image distortion
53											deleted during review
54	dark blue; brown; tint of purple	triangle	bare land	N	N	Y	N	Y	37.90912	2	it is not likely a shadow, the deep color makes this site suspicious; however, the boundary is too straight and looks non-natural
55											deleted during review
56	dark brown; a patch of dark blue	oval	trees	N	N	Y (subtle)	N	N	33.34598	1	too alike bare land
57	dark brown; patches of dark blue; tint of purple	oval	trees	N	Y	Y	N	Y	70.17029	1	it looks like wet soil, and has a depression; however, it could be color distortion as well
58	dark blue; traces of brown; tint of purple	round	50% trees; 50% bare land	Y	N	N	N	Y	31.68079	1	more likely wet soil; it is suspicious because it does not seems like a tree shadow
59											deleted during review
60	dark blue; traces of brown; tint of purple	round	60% bare land; 40% bedrock	Y	Y	Y	N	Y	89.1014	3	it is not a tree shadow; coarse wetland texture; slight depression; has deep water color in the middle; very likely a pool
61	dark blue; tint of purple	irregular	bare land	N	N	Y (subtle)	N	Y	30.24077	1	it does not seems like a tree shadow (cannot find the tree that could provide the shadow); however, it is too small, and the depression is not clear either
62	dark blue; traces of brown	irregular	70% trees; 30% bare land	N	N	Y	N	Y	63.92223	2	likely wet soil or a puddle; it is unclear if this is a tree shadow because the boundary on the north-west is too straight
63											deleted during review

64											deleted during review
65	dark blue; traces of green; tint of purple	oval	bare land	Y (subtle)	N	Y	N	Y	24.17001	2	likely wet soil or a puddle; it is very close to the lake and a river therefore could be part of the dried lake (or gully)
66											deleted during review
67											deleted during eliminating false predictions - bedrock
68	dark blue; patches of purple and green	irregular	70% trees; 30% bare land	N	Y (subtle)	N	Y	maybe	82.36905	1	very likely tree shadow; however, the color of this site seems to be much deeper than the surrounding landscape and therefore could be a puddle
69											deleted during review
70	dark blue; patches of light brown; tint of purple	crescent	bare land	N	Y (subtle)	Y	N	maybe	72.75731	3	it is not a tree shadow; water like color; patches of brown color could be dried pool; however, the image is too blur to ensure this is a pool
71	brown; dark blue; patches of white	roound	bare land	N	Y (subtle)	Y	N	Y	69.85087	2	this site seems to be on the top of an exposed bedrock; there is depression and undulating coarse texture, which may be a pool; however, there is no significant water remain, and the image is too blur to make sure that the brown color is not a pile of trees
72	dark blue; a patch of white	irregular	bare land	N	N	Y (subtle)	N	Y	31.85832	2	I cannot find a clear tree that could make this site a shadow, and the brownish color at the border makes this site particularly suspicious; however, there are some greenish brown patches on the south, which could be trees (due to image quality)
73	dark blue; tint of purple	long linear	90% bare land; 10% trees	N	N	N	Y	Y	26.08263	1	likely a tree shadow or wet soil; this site is mapped due to its strange shape
74											deleted during review
75	dark blue	irregular	bare land	Y	N	N	maybe	N	113.088	1	seems very likely to be a pool at the first glance (because of the slight depression); however, it is more likely to be a tree shadow
76	dark brown; dark blue	round	60% bare land; 40% bedrock			Y	N	Y	83.23088	3	not likely a shadow; obvious depression, seems to be wet soil; may be a pool
77											deleted during review
78	dark blue; traces of green	round	trees	N	N	Y	Y	N	233.5797	1	very likely to be tree shadow; it is mapped because it is too large (however, it still could be a shadow, like the shadow on the west)
79	dark blue; traces of brown and green	long oval	70% bare land; 30% trees	N	N	N	Y	Y	210.558	2	it is likely to be a tree shadow; however, I mapped this site because it seems too long, and could possibly be wet soil
80											deleted during review
81	dark blue; light brown; traces of green	round	70% trees; 30% bare land	Y (subtle)	N	Y	N	maybe	47.00633	1	it seems to be a depression; however, the dark blue patch are likely tree shadows but not water
82	dark blue; traces of green and light brown	triangle	bare land	Y (subtle)	N	Y (subtle)	maybe	maybe	33.05434	3	this site seems to be a pool at the first glace; however, it is adjacent to trees and therefore could be shadow; other than this, it is located in a bare land, has slight depression, and its surrounding landscape is deep color soil (which could be dried pool), and these make this site suspicious
83	green; patches of light brown	oval	70% bare land; 30% trees	N	N	Y (subtle)	Y	maybe	34.8591	1	very likely to be tree shadow; however, the dark green color is suspicious (it is kind of aqua color like)
84	brown; ting of green; dark blue (shadow)	irregular	trees	N	Y	Y	Y (part of)	maybe	103.3766	2	the tree shadow only covers part of the site; the brownish color seems suspicious; likely a patch of wet soil
85	brown; dark blue	oval	60% bare land; 40% trees	Y	N	N	maybe	maybe	80.14439	2	it is suspicious since it seems there is a gully/stream link with this site (or pass by); however, on the south of the site, it seems there is a tree (which could make this site a tree shadow)
86	dark blue; patches of purple-ish brown	oval	80% bare land; 20% trees	N	N	Y (subtle)	Y (part of)	maybe	61.10069	2	this site may contain tree shadow; however, the shape and the size of the dark blue color is suspicious, as well as that there are possible in/outlet on the north
87	dark blue; patches of pale grey and green	irregular	50% trees; 50% bare land	N	N	Y (subtle)	Y (part of)	maybe	66.79938	1	it is covered by tree shadow; however, I am not sure what the white color is (could be bedrock?); also, it seems there is a linear patch with deeper dark blue color on the site, which could be water remain
88	dark blue; patches of white	round	60% bare land; 40% trees	N	N	N	Y	N	21.58232	1	it is very likely a tree shadow; I mapped this site because I do not know what those which patches are, and the very round shape is suspicious
89											deleted during review
90	cyan-blue; brown; tint of green and red	round	60% bare land; 40% trees	N	N	N	maybe	N	41.92184	2	I mapped this site because it has a distinctive cyan color, which might be water; however, it is also likely a tree shadow (since it is on the right direction of being a tree shadow), and the cyan color could be something else, like bedrock.
91											deleted during review
92	brown; a patch of dark blue	irregular	60% trees; 40% bare land	Y	N	N	Y (part of)	N	47.2648	1	it seems to be a normal bare land; it is suspicious because of the dark blue patch in the middle (which could be water)
93	dark blue; tint of cyan	triangle	bare land	N	N	Y	N	N	44.02796	3	it is not a tree shadow; the shape and size of this patch does not like a shadow of rock/cliff either
94	dark blue; tint of brown	round	70% bare land; 30% trees	Y	N	Y	maybe	maybe	79.10844	2	this site could be tree shadow (because there are trees on the south-east); however, the obviously darker color on the southern part of this site is suspicious, as well as the white color

95	dark blue; traces of brown	round	bare land	Y (subtle)	N	Y (subtle)	N	maybe	285.3241	4	this must be a pool (there is no way the tree on the south-east can generate such a large shadow)
96											deleted during review
97	brown; dark blue	oval	70% bare land; 30% trees	N	N	Y	Y (part of)	N	34.25568	1	it is not a shadow (though contains shadow), however its patch color is too common in the surrounding landscape
98	brown; patches of white	triangle	bare land	N	N	Y	Y (part of)	N	30.85433	1	I can see slight depression but no water remain
99	dark blue; cyan	oval	oval	Y	N	Y (subtle)	maybe	maybe	16.59823	1	I mapped this site because of its distinctive cyan color, which could be water; other than this, however, this site is very common in the surrounding landscape
100											deleted during review
101	dark blue; brown (in the center)	round	80% trees; 20% bare land	Y	N	Y (subtle)	maybe	maybe	18.00334	2	it is not on the right direction of the major tree shadow, and the brownish color makes it suspicious; however, it still could be the shadow of the green patch on the south-east
102	dark blue	round	bare land	Y	N	Y (subtle)	maybe	N	18.14582	2	there is a green patch on the south-east and therefore this tie could be a shadow; however, the brownish boundary is suspicious and there is subtle different between the patch color and the shadow color around
103	brown; dark blue; patches of white	oval	60% bare land; 40% rock	Y (subtle)	Y	Y	N	maybe	38.65021	2	the depression is obvious and this site is not a shadow; however, this site is more likely to be wet soil and there is no significant water remain either
104	dark blue; patches of white; tint of purple	irregular	80% bare land; 20% trees	N	N	Y (subtle)	Y	maybe	65.00105	1	as a shadow, it is a little bit too long and irregular; however, it is still possible to be a tree shadow; the white color at the boundary makes this site a little bit suspicious
105	dark blue; cyan-white	oval	bare land	N	N	maybe	N	N	18.37258	3	this is impossible to be a tree shadow; It may be a person but the spot is too large (over 2 sq m); not sure what this is.
106											deleted during review
107	dark blue; tint of purple; patches of white	round	80% bare land; 20% trees	N	Y	Y (subtle)	N	maybe	17.81938	2	not very likely to be wetland or tree shadow; possibly a small water body; however, it is too blur to be sure
108											deleted during eliminating false predictions - bedrock
109	dark blue; tint of purple; a patch of white	oval	trees	N	N	Y (subtle)	maybe	maybe	47.84199	2	it seems very alike a pool at the first glace; the purple color seems like bare land; could be wet soil or a tree shadow
110	pale grey; a patch of white	irregular	bare land	N	N	Y (subtle)	maybe	maybe	32.11311	1	it is very likely a shadow from the cliff/uplift land; however, the pale grey color makes this site suspicious
111	dark blue; tint of cyan	oval	60% bare land; 40% trees	N	N	Y (subtle)	Y	maybe	48.0011	1	very likely to be a shadow; but the cyan color makes this site suspicious
112	dark blue	linear	60% bare land; 40% trees	N	N	N	Y	maybe	23.62243	1	likely to be the tree shadow from the tree on the south-west
113	dark blue; traces of white	oval	bare land	N	N	N	N	maybe	52.98413	1	not likely a tree shadow, however, it could be part of the big wetland (on the west of the site)
114											deleted during review
115	dark blue; tint of brown; a patch of white	oval	bare land	N	N	Y (subtle)	N	maybe	54.47237	3	the size is large, it is not a tree shadow, and is located in bare land (less distractions from trees, and gradient emerge into the surrounding land; it is likely to be a pool or at least wet soil
116	dark blue; tint of brown	oval	70% bare land; 30% trees	N	N	Y (subtle)	N	maybe	84.39357	2	it is likely a patch of wet soil or a shallow puddle; it is not likely to be a shadow (because no tree); however, it does not seems to be very deep and the size could be smaller (since part of the site could be shadow, though not the whole site)
117	dark blue; traces of brown; tint of dar red	irregular	bare land	N	N	Y	N	N	71.57996	4	the red color at the boundary makes this site extremely suspicious, as well as the white tint in the middle of the site
118	dark blue; tint of red and brown	oval	70% trees; 30% bare land	Y	N	Y	N	maybe	106.0305	4	it is almost sure that this is a pool (because it shows water remains and partially dried part); the redish color and the brownish boundary make this site suspicious; this is not a tree shadow for sure
119	dark blue; tint of purple	oval	70% trees; 30% bare land	N	N	N	Y	maybe	67.90656	1	very likely to be tree shadow; however, the color is slightly different from the tree shadows around so still may be a pool
120	dark blue	irregular	trees	N	N	N	Y	maybe	188.5858	1	very likely to be shadow; however, the color is slightly different from surrounding's (probably is because this site is larger)
121	dark blue; tint of purple	round	50% bare land; 50% trees	N	N	N	Y	maybe	52.17807	1	very likely to be a tree shadow; however, the tint of purple color is suspicious (which is different from surrounding landscape)
122	dark blue; tint of purple	linear	80% trees; 20% bare land	N	N	N	Y	maybe	64.09643	1	very likely to be a tree shadow; however, the tint of purple color is suspicious (which is different from surrounding landscape)
123	dark blue; tint of brown; tint of purple	round	60% trees; 40% bare land	Y	N	Y	N	Y	127.7066	4	very likely to be wet land or wet soil, probably have water remain; the tint of purple color is suspicious; the brownish color seems to be dried pool
124	deep brown; patches of dark blue	round oval	70% trees; 30% bare land	Y (subtle)	Y (subtle)	Y	N	maybe	365.762	2	it is an obvious depression (at least visually); it is not tree shadow, and the dark color on the south could be water remain; however, this site still seems to dry to be a pool
125	dark blue; traces of brown	irregular	bare land	N	Y	Y (subtle)	N	maybe	103.8805	3	it is not a shadow, and seems to have water remains with a wetland texture; however, there may not be enough water stands to make this site a pool (because part of the site seems to be dry)

126	dark blue; tint of purple	oval	80% bare land; 20% trees	N	N	N	N	maybe	45.89035	2	the tint of purple color is suspicious; it is not likely a shadow but has a deep color, and this is suspicious as well; however, the deep color could also be other things such as wet soil.
127	dark blue; tint of brown and green	long square	bare land	N	N	N	Y	N	125.4228	1	very likely tree shadow; however, the square shape is suspicious
128	dark blue; traces of white and green	round	bare land	Y	N	Y (subtle)	maybe	maybe	45.30673	1	it seems to have a little bit depression, but this site is more likely to be a tree shadow
129	pale dark blue; traces of green	round	50% trees; 50% bare land	Y (subtle)	N	N	maybe	maybe	29.19408	2	it looks like wet soil, but it is on the right direction with a right size of being a tree shadow; the pale grey color is suspicious
130	dark blue; tint of purple	oval	bare land	N	N	Y	N	Y	66.00457	3	it is very likely to be at least wet soil. If the dark linear color on the north-east is wet soil, the this site is more likely to be wet soil or a pool
131											deleted during review
132											deleted during review
133	dark blue; tint of purple	linear	60% trees; 40% bare land	N	N	N	maybe	Y	52.30676	1	it look like a tree shadow but is on the wrong direction; however, it does not looks like a standard pool either; this site is just slightly suspicious
134	dark blue; patch of brown	irregular	50% bare land; 50% trees	N	N	maybe	Y	maybe	77.4316	1	the brownish patch in the middle is suspicious; however, this site is likely to be a tree shadow (regarding size and direction), and brown color could be a brownish tree
135	dark blue, traces of brown; tint of purple and green	irregular	80% bare land; 20% trees	N	N	maybe	Y	maybe	69.05255	1	it looks like a tree shadow the tint of purple color is suspicious
136	dark blue	round	60% trees; 40% bare land	Y	N	maybe	maybe	N	45.20615	2	it seems to be a tree shadow; however, the brownish boundary and the slight depression make this site very suspicious
137											deleted during review
138	pale dark blue; traces of green and brown	oval	trees	Y	N	Y (subtle)	N	maybe	64.18939	2	the trees that can provide the shadow is not very obvious, this site could be but not likely a tree shadow; the slight depression makes this site more suspicious
139	brown; dark blue	round	50% trees; 50% bare land	N	N	Y	N	maybe	47.8743	1	it is not a tree shadow; however, it share a very similar pattern with surrounding landscape
140											deleted during review
141	brown	oval	trees	N	N	Y	N	N	53.16021	1	it seems to be a depression, but no water remain is observed
142	dark blue; tint of purple and green	oval	50% bare land; 40% bedrock; 10% trees	N	N	N	N	maybe	94.5591	2	it is not likely a shadow; it seems to be adjacent to bedrock (could have groundwater as water source); the site
143											deleted during review
144	brown; traces of dark blue	round	50% bare land; 50% trees	N	N	Y	N	maybe	178.2337	2	there is depression but no significant water remain is observed; however, this site has a confidence of two because there seems to be a gully on the south-west of the site
145	dark blue; tint of cyan	oval	trees	Y	N	N	maybe	N	86.71028	2	it seems to be a tree shadow at the first glance; but the cyan color and the brownish boundary seem to be very suspicious
146	deep brown; brown; patches of dark blue	two round	bare land	N	N	Y	N	maybe	112.4239	3	the depression and the deep brown color make this site suspicious
147	dark blue; traces of pink	oval	80% bare land; 20% bedrock	N	N	N	N	maybe	50.99156	3	the pink color in the middle is suspicious, and this site does not seems to be a shadow; however, it does not have significant depression and the pink color patch could be something else
148	dark blue; traces of red; tint of purple	irregular	bare land	N	Y	N	N	maybe	50.69288	2	it is not likely a tree shadow and has deep color; however, it lacks depression and it could be just a patch of wet soil but not a pool
149	dark blue; tint of brown	triangle	trees	Y	N	N	Y	maybe	104.6617	1	it is very likely to be a tree shadow; the reason why I mapped this site is because its triangle shape, which seems to be too narrow on the side which is adjacent to the trees on the south-east
150	dark blue; a patch of white	round	60% trees; 40% bare land	N	N	N	Y	N	28.88509	1	it is likely a tree shadow because of the similar feature it shares with the tree shadow in the surrounding landscape; however, I cannot clearly identify the tree that provides this shadow, therefore I mapped this site
151											deleted during eliminating false predictions - bedrock
152	dark blue; a patch of reddish brown in the middle	oval	bare land	N	N	N	maybe	maybe	34.19116	2	it is likely to be a tree shadow at the first glace, however, the direction of the shadow is not completely consistent with the shadow in the surrounding landscape
153	dark blue; patches of white and green	irregular	bare land	N	N	Y (subtle)	N	N	88.10033	2	it is not likely to be a shadow; however, the site seems too flat (lack of depression) to be a pool, and the sharp boundary make this site not likely a wet land or wet soil either
154	brown; a patch of dark blue in the middle; tint of purple	oval	trees	Y	N	Y (subtle)	N	maybe	16.14075	2	the dark soil color makes this site a possible pool; however, the dark blue color is too small to be sure that it is a water body
155	dark blue; patches of brown color	irregular	80% trees; 20% bare land	N	Y (subtle)	N	Y	maybe	551.9727	2	there are tree shadows on this land; what underneath the tree shadow is dark brown color, and could possibly be wet soil or even a pool; however, the image is too blur to be sure about if it is a pool underneath or not
156	dark blue; dark brown; a patch	oval	trees	Y	N	Y (subtle)	N	maybe	100.0571	1	it does not like a tree shadow and seems to have slight depression; however, it could also be a tree

	of pale white color in the middle										(and the "depression" is the result of image distortion, which has happened before as well - a tree looks like a depression)
157	dark brown; traces of green	oval	80% bare land; 20% trees	N	N	Y (subtle)	Y	maybe	57.83801	1	this site is covered by tree shadow; the brownish color underneath could be the
158	dark blue; patches of pale blue	irregular	70% bare land; 30% trees	N	N	N	maybe	Y	61.56115	1	this site does not seems to be a whole shadow; however, it lacks depression and is likely to be wet soil but not a pool
159	dark blue; tint of purple	linear	70% trees; 30% bare land	Y	N	Y (subtle)	maybe	Y	32.6575	1	it seems the deep color is very alike water bodies, however, that may be the result of image distortion because this feature is fairly common on the landscape on the west of the site
160	dark blue; tint of brown	round	60% bare land; 40% trees	N	N	N	Y	maybe	25.9077	1	it looks like a tree shadow but a little bit too short compared with the shadows around
161	dark blue; tint of cyan	linear	trees	Y	N	N	Y	N	42.72798	1	likely a tree shadow; but the bended shape and the cyan color make this site suspicious
162											deleted during review
163	dark blue; tint of reddish brown; a patch of white in the middle	round	80% bare land; 20% trees	N	N	Y (subtle)	maybe	maybe	26.13601	1	the shape is a little bit weird as the tree shadow of the tree on the south (since what adjacent to the tree seems too narrow)
164	dark blue; two patches of white color	oval	60% trees; 40% bare land	N	N	N	Y	maybe	71.47777	1	part of the site is likely a tree shadow, and the two patches of white color could be trees; however, the purple color is suspicious and could be wetland
165											deleted during review
166											deleted during review
167											deleted during review
168	dark blue; tint of purple	oval	70% bare land; 30% bedrock	Y	N	Y (subtle)	N	Y	15.34385	3	there are tree shadows around but this site is not (because there is no tree); the purple-ish color is suspicious as well
169	dark blue; tint of brown; patches of green	oval	40% bare land; 30% bedrock; 20% trail; 10% tree	Y (subtle)	Y	Y (subtle)	N	Y	73.68504	3	it seem sot be wetland like land (because the blue color could be water); however, it could be the shadow from the bedrock
170	dark blue; tint of purple; patches of brown and white	irregular	bare land	N	maybe	Y (subtle)	N	Y	190.9695	3	there is no tree around therefore this site is likely wet soil or a pool

Table 6: Records of 2009 Color Aerial Photo

Id	color	shape	area (m^2)	surrounding	crack	buffer	depression	confidence	brief description	why I map this site	why this site may not be a potential vernal pool
1	dark blue	long oval	1.4585529	bare land	N	Y	N	1	wet soil; tree shadow	deep color located in a brownish patch; not likely a tree shadow	there might be a tree on the southwest but too blur to tell; lack of depression
2	dark grey; patches of green	crescent	46.026976	70% trees; 30% bare land	N	Y	Y (subtle)	4	wetland	deep color; wetland texture; small green patches (wetland like)	grayish color (more likely to be a wetland but not a pool)
3	grey	irregular	29.014594	trees	N	N	Y (subtle)	4	wetland	wetland texture	too grayish color (more likely to be wetland but not a pool)
4	dark	irregular	1.2655118	50% trees; 30% bedrock; 20% bare soil	N	N	Y (subtle)	1	shadow	deep color; depression	could be shadow; not sure what's on the south-west (could be tree)
5	brown; patches of dark blue	round	24.105781	50% bedrock; 50% grassland	N	N	Y	3	partially dried puddle; grassland	surrounded by exposed bedrock; depression; distinctive brownish color	not much water remain
6	dark brown; traces of white	irregular	310.75425	trees	N	N	Y (subtle)	2	wet soil; wet land	distinctive deeper color than surroundings; not tree shadow; depression	no significant sign of water remain
7	dark blue	linear	2.0332356	80% bare land; 20% trees	N	Y	N	2	part of gully; shadow	seems to be part of a gully;	too narrow; could be shadow (don't know what is the green color on the south side)
8											deleted during review
9	pale grey; tint of brown	oval	15.77376	60% trees; 40% bare land	N	N	Y (subtle)	2	slight depression	depression; deeper color than surrounding; finer texture; possible outlet/inlet	no significant water remain
10	blue grey	oval	12.246364	60% trees; 40% bare land	N	Y	Y	4	wetland	color; not a shadow (for sure); not like a bedrock (too dark)	seems like a wetland but not a pool
11	dark; tint of purple; traces of brown and grey	round	43.363208	70% bare land; 30% trees	N	N	N	2	wet soil	seems to link with a gully	could be a tree shadow, or wet soil
12	dark	linear	0.541233	bare land	N	N	N	1	part of gully	not a shadow; not a bedrock	seems to be gully;
13	dark blue	oval	0.8135812	bare land	N	Y	Y	1	part of gully; wet soil	not likely a shadow; deep color in the central bare land; brown buffer	no significant depression;
14	dark blue	linear	1.3743291	60% bare land; 40% trees	N	Y	N	1	shadow; wet soil	too large to be a shadow	no depression; no significant sign of water remain
15											deleted during review
16	dark blue; tint of brown	oval	1.175484	bare land	N	N	subtle	2	wet soil; shadow	too large to be a tree shadow; the brownish patch in the middle (like other puddles);	there may be a tree on the southwest (so this site could be a shadow)
17	pale blue	oval	0.5922391	bare land	N	Y	N	1	wet soil	not likely a shadow; deep color in a patch of bare land; brown buffer	no significant depression; no obvious sign of water remain
18											deleted during review
19											deleted during review
20	brownish black	long oval	2.9789371	80% bare land; 20% trees	N	N	Y (subtle)	1	shadow	has depression	very likely to be a tree shadow (has a tree on the south-west)
21	dark blue; trances of brown and green	irregular	16.271844	grassland	N	Y	Y (subtle)	3	wet soil; wetland	impossible to be tree shadow; deeper color than surroundings	too blur to be 100% sure; may not have water remain (being simply a wetland or wet soil)
22											deleted during review
23	deep dark blue; surrounded by brown	oval (in general, together with site 22)	0.2740681	60% trees; 40% bare land	N	Y	N	2	wet soil	not likely to be tree shadow (direction & size); deep color and deep brown surroundings	may be just wet soil
24											deleted during review
25	deep brown	oval	1.5576154	80% bare land; 20% trees	N	N	Y	2	wet soil; tree shadow; part of gully	depression; sign of gully (north-west); deep color	no significant sign of water remain; still could be tree shadow
26											deleted during review
27	pale dark blue; tint of brown	long oval	0.5158749	bare land	N	N	N	1	a black patch	too large to be a shadow; located in bare land	too small; no depression; no sign of water
28	dark blue-ish grey; traces of green and brown	round	20.493207	60% bare land; 40% trees	N	N	N	3	wet land; wet soil	distinctive deep color; wetland coarse texture; not a tree shadow	no significant sign of water remain; more like wet soil
29	dark blue; patches of brown; traces of green	oval	2.8191734	50% trees; 50% bare land	N	N	N	3	a patch of black color; puddle	it is not a shadow; do not like wet soil	the light brown patch in the middle (don't know what it is)
30	deep blue; tint of brown	oval	1.5261164	70% bare land; 30% trees	N	N	N	1	shadow	brownish surrounding (could be a pool)	close to a tree (could be a tree shadow)

31	dark blue	oval	1.0551421	60% trees; 40% bare land	N	N	N	1	shadow	could be a pool between two trees (a small depression)	could just be a tree shadow
32	dark grayish blue; traces of green	round	7.9242788	trees	N	N	Y (subtle)	1	wet soil; tree shadow	immediate to bedrock; immediate to trees; deep color	have trees around so could be wet soil
33	dark blue; traces of brown	square	7.7029991	bare land	N	N	Y (subtle)	2	wet soil; puddle	too large to be a shadow; deep color; large enough to retain water	could be wet soil
34	dark blue; traces of brown	linear	14.329814	80% bare land; 20% trees	N	N	Y (subtle)	2	wet soil	deep color; wetland texture; not like to be tree shadow	may just be wet soil but not a puddle
35	dark blue color; traces of brown	round	2.0522922	bare land	N	N	Y	3	depression with possible in/outlet (gully)	depression; deep color (compare with surroundings); lack of trees (not a shadow); possible in/outlet	may not last long enough to be a vernal pool; could be wet soil
36	dark blue; tint of purple; traces o f white and brown	oval	3.3612876	bare land	N	N	N	2	tree shadow; puddle	deep color; too large as a shadow	not sure about the brownish white dot; could be wet soil
37	dark blue; traces of brown	oval	15.576415	50% exposed bedrock; 40% grass land; 10% trees	N	Y	Y (subtle)	3	wet soil	deep color; felt timbers; adjacent to bedrock; not like shadow	no significant sign of water
38	pale grey blue	irregular	42.219657	50% grass land; 50% exposed bedrock	n	N	Y (subtle)	2	swamp; exposed bedrock	deep color; not a tree shadow for sure; subtle depression	does not look like water remain
39	pale grey; pale blue	oval	81.413382	70% trees; 30% grass	N	Y	Y	2	wet soil	deep color; not the right size and direction if it is a shadow; slight sign of depression	no significant sign of remain of water (so likely to be wet soil)
40	deep dark black; traces of green	irregular	14.949027	60% trees; 40% bare land	N	N	Y (subtle)	2	wet soil	size and color cannot be explained as a shadow; the pale blue could be frozen surface; coarse texture	no significant depression; still could be shadow
41	pale blue	round	6.4553846	60% bare land; 40% trees	N	N	Y	2	depression; wet soil	depression; deep color	adjacent to trees (could be a shadow);no significant sign of water
42	black	oval	0.9037889	grass land; two trees	N	N	N	1	shadow	the edge is too sharp to be a shadow; too deep	next to a tree; no depression; no crack
43	dark brown; tint of blue	round	3.8016187	grass land	N	N	Y	2	depression with a possible outlet	depression in a bare land; possible outlet (gully)	no remain of water; the possible "outlet" may be image di
44											deleted during review
45	dark blue	long oval	3.4550481	70% bare land; 30% trees	N	Y	N	2	deep shadow; wet soil	deep color; too large for a tree shadow	have a tree nearby; no depression; no crack
46	deep blue; tint of brown; traces of green	linear	22.247825	70% trees; 30% bare land	N	N	Y	2	wet soil	deep color; depression; too large as a tree shadow	no sign of crack; no buffer to forest; may be wet soil or part of gully
47	pale brown	round	24.827251	60% grassland; 40% trees	N	N	Y	1	a pile of wood	depression; the timber could provide nutrients if this is a pool	too flat; no sign of water; no buffer
48											deleted during review
49	deep blue	round	0.9296866	80% trees; 20% bare land	N	Y (subtle)	N	1	wet soil / part of gully	deep color; buffer (grayish); gradient color boundary	no depression; too small; no significant sign of water
50	dark blue; patches of green; patches of white	oval	9.1705687	70% bedrock; 30% bare land	N	N	Y (very subtle)	2	wet soil; shadow; puddle	impossible to be tree shadow; could be puddle (close to bedrock)	may be shadow from bedrock
51											deleted during review
52											deleted during review
53											deleted during review
54	dark blue; patches of white; traces of green	round	48.042641	60% trees; 40% bare land	N	N	N	2	wet soil; puddle	white color (frozen surface); deep color (wet soil)	unclear depression; unclear boundary; no obvious sign of water remain
55											deleted during review
56											deleted during review
57											deleted during review
58	pale black; tint of brown; tint of green	round	7.7217095	70% trees; 30% bare land	N	N	N	2	wet soil	not likely a shadow; surrounded by trees; oval shape; the surrounding soil seems wet	no obvious water remain; could just be wet soil
59											deleted during review
60											deleted during review
61											deleted during review
62											deleted during review
63											deleted during review

64	dark grey; tint of blue; patches of green	round	63.425163	80% trees; 20% bedrock	N	N	N	3	wetland	wet land texture; seems to be wetland (grey suggests decomposition)	no sign of water remain; no depression
65	dark blue; pale dark blue; patches of white and green	irregular	41.812067	50% trees; 40% bedrock; 10% bare land	Y	Y	Y	4	puddle; wetland	crack in the ground; deep color; gradient color to surrounding landscape	the photo is too blur to be 100% sure
66											deleted during review
67											deleted during review
68	dark blue; deep brown	irregular	8.4791623	60% bare land ;40% trees	N	N	N	1	wet soil; shadow	may seems too long to be a shadow	no sign of depression; not looks like a water body
69											deleted during review
70	brown; dark blue	irregular	68.546346	90% trees; 10% bedrock	N	N	Y	2	wet soil; wet land	wet soil / wet land color; close to exposed bedrock	no sign of water remain
71											deleted during review
72	pale grey-cyan; dark blue; traces of green	round	36.623601	70% trees; 30% bare land	N	N	Y (subtle)	2	wet land; wet soil	grayish color; suspicious cyan, pale color	no sign of water remain; likely wetland or wet soil
73	dark blue; a patch of white color	oval	8.5223917	trees	N	N	Y (subtle)	3	wet land; puddle	the only deep dark patch in the surrounding; not likely a shadow	not significant depression; it seems there is an outlet/inlet on the north-east
74	pale dark grey; patches of green; patches of brown	irregular	193.72439	60% trees; 40% bare land	N	N	Y (very subtle)	3	wet land	wet land coarse texture; distinctive texture from surroundings	may just be wet soil; may not have enough water remain
75											deleted during review
76											deleted during review
77	dark blue	linear	19.680304	bare land	N	Y	N	1	shadow; bedrock	not likely a tree shadow; deep color	too sharp boundary; not likely a pool; could be a shadow of bedrock
78	dark blue	linear	3.3499918	80% bare land; 20% trees	N	Y	N	1	shadow; bedrock	not likely a tree shadow; deep color	too sharp boundary; not likely a pool; could be a shadow of bedrock
79	dark blue; traces of brown	irregular	67.340638	trees	N	N	N	1	deep color soil	deep color soil	seems too "dry"; no obvious water remain
80											deleted during review
81											deleted during review
82											deleted during review
83	dark blue; a patch of white	oval	6.6752707	60% bedrock; 40% bare land	N	N	Y	2	shadow; puddle	not on the exact direction of tree shadow; the white color could be frozen surface	could be the shadow of rock or trees; no significant depression or water remain
84											deleted during review
85	dark blue	irregular	100.889	70% rock; 30% trees	N	Y	N	2	wet soil	deeper color than surroundings; not shadow	could just be deep color soil; or wet soil
86											deleted during review
87	dark brown; traces of green	oval	47.002384	60% bedrock; 40% trees	N	N	Y (very subtle)	1	wet soil	deep color; not a shadow	lack of water remain; even could be exposed bedrock (covered with thin surficial material)
88	dark blue; tint of brown; traces of green	irregular	35.592399	80% rock; 20% bare land	N	Y	N	2	wet land?	not shadow; wet land texture	located in a patch of stony land; no depression; no significant sign of water
89	pale dark grey; traces of white and green	irregular	20.267833	bare land	N	Y	Y (very subtle)	2	wetland; bedrock	not a tree shadow; wetland texture	could be exposed bedrock (regarding color); no obvious sign of water remain
90											deleted during review
91	dark blue; traces of pale grey	irregular	9.1718578	90% bare land; 10% trees	N	N	N	2	shadow; puddle	suspicious shape; deep color	linked with tree shadow
92	dark blue; white; traces of green	irregular	7.7818847	60% bare land; 40% trees	N	N	N	1	shadow; wet soil	have white patch (could be frozen surface); not consistent to the surrounding trees (as a shadow)	too close to trees (so could be shadow); no depression
93											deleted during review
94											deleted during review
95											deleted during review
96	dark blue; white	oval	6.1244577	70% bare land; 30% trees	N	Y	N	1	shadow	has white color (could be frozen water)	very likely to be a tree shadow (the right direction and size)
97	dark blue; traces of green	irregular	26.171568	bare land	N	N	N	2	wet land; wet soil	coarse wet land texture; distinctive color in the landscape; not tree shadow	lack of significant water remain; the patch is too blur to tell if it is a wetland or a pool

98	pale dark blue; traces of brown	irregular	11.428045	bare land	N	N	N	1	wet land; wet soil	distinctive color in the landscape; not tree shadow	lack of significant water remain; the patch is too blur to tell if it is a wetland or a pool
99											deleted during review
100											deleted during review
101	pale dark blue with tint of purple	irregular	1.5830808	70% bedrock; 20% trees; 10% bare land	Y (very subtle)	Y (subtle)	N	2	exposed bedrock: shadow	too long to be the shadow pf the tree on the south-west; buffer	no depression, too flat
102	pale dark blue	oval	12.365351	70% bare land; 30% trees	N	Y	Y (very subtle)	1	shadow; depression	larger and deeper than a normal tree shadow	too flat; too close to trees; could link with the river
103											deleted during review
104											deleted during review
105											deleted during review
106											deleted during review
107	dark blue; a patch of ice-blue-tint white	oval	2.4883268	60% bare land; 40% trees	Y	Y	Y	3	puddle	white color could be frozen surface; not likely a shadow; brownish boundary could be dried pool	not sure what is the light green color on the south-west (could be tree or something else)
108	dark blue	oval	1.2096424	80% bare land; 20% trees	N	Y	N	1	shadow	a dark color patch located in the middle of a brown land; not on the direction of a tree shadow	no depression; to close to trees (still could be a shadow)
109	light green; pale white	round	8.0911395	60% bare land; 40% trees	N	N	N	1	tree; frozen water; exposed bedrock	color seems to be frozen water	seems similar with exposed bedrock
110	light green; pale white; dark blue	irregular	36.925742	70% trees; 30% bare land	N	Y	N	1	frozen water; exposed bedrock	color seems to be frozen water	seems similar with exposed bedrock
111	dark blue; tint of brown; patches of green	irregular	25.507343	trees	N	Y	Y (subtle)	3	wetland	brownish tree color; not likely a shadow; seems to have water remain	not sure if there is any water remain
112											deleted during review
113											deleted during review
114	pale dark blue; traces of blue and white	triangle	19.530665	bare land	N	N	Y (very subtle)	1	wet soil; deep color soil	cannot be explained by trees	not seems to have water remain; lack depression
115	pale dark blue; pale brown	oval	15.70447	80% bare land; 20% trees	N	Y (very subtle)	N	1	wet soil	it does not have many trees around; deep color in a brown color land	the water remain is not very significant; still could be tree shadow
116	dark blue; dark brown; a patch of white; green	oval	13.329015	70% bare land; 30% trees	N	N	Y	1	depression	wet soil color; frozen surface (the white patch)	no sign of water remain; the dark blue color could be shadow
117	pale brown; patches of dark blue; patches of green	oval	5.0810129	90% trees; 10% rock	N	N	Y (subtle)	2	wet soil	deep color; surrounded by bedrock and trees; close to a stream (on the north)	could be tree shadow (but difficult to tell on aerial photos); could be wet soil
118	pale dark blue; tint of brown	oval	2.9407366	60% bare land; 20% trees; 20% exposed bedrock	N	Y	Y	2	wet soil?	obvious deeper color; looks like water; not a shadow	no significant depression; weird location (between bedrock)
119											deleted during review
120	dark blue; tint of brown and white	irregular	103.12695	70% bare land; 30% trees	N	N	N	1	shadow	it looks very similar with the river on the northwest	common pattern in the surrounding landscape
121	pale dark blue; patches of brown and pale white	triangle to oval	16.202668	bare land	N	N	N	1	shadow	there is no tree to provide such a shadow; close to river	no depression; too alike a shadow
122	dark blue	oval	17.211323	70% trees; 30% bare land	N	N	N	2	puddle	too large to be a shadow; deep color	the texture is too smooth; lack of gradient at boundary (as dried pool)
123	dark blue; tint of brown; traces of green	irregular	140.00682	70% trees; 30% bedrock	N	N	Y (subtle)	3	wetland	coarse wetland texture; deep color; not likely all shadow	could just be wet soil or wet land; may not be a pool
124											deleted during review
125	dark blue; tint of green; traces of brown	irregular	282.09018	bare land	N	N	Y	4	puddle	must be a puddle (depression; color; location, etc)	may be linked with the lake; may not be a vernal pool
126	dark deep blue	linear	5.8948429	50% trail; 50% trees	N	N	N	2	shadow; puddle	distinctively darker color than surroundings; adjacent to trail; not exposed bedrock	could be a tree shadow (since immediate to trees)
127											deleted during review
128	dark blue	oval	8.2472158	80% trees; 20% bare land	N	N	N	2	shadow; puddle	too large to be tree shadow; adjacent to brownish land (may be dried puddle)	immediate to trees (still could be a shadow)
129	dark blue; white	round	11.372743	60% bare land; 40% trees	N	Y	Y	2	frozen puddle; stones; shadow	white color could be frozen water; the black color surrounds the tree (not like a tree shadow)	could be stony land (there are stones adjacent); could be tree shadow

130	white; pale grey	irregular	63.75475	80% bare land; 20% trees	N	N	N	2	snow accumulation; frozen water	snow accumulation (suggests water); light grayish color	what under the snow could be stones; not necessary a puddle (could be just snow)
131	dark blue; green (in the middle); a tint of purple	oval	7.536147	70% bare land; 30% trees	N	Y	N	1	tree shadow; wet soil	the dark color surrounds the tree (which is not likely the shadow of the tree); distinctive color	could be the shadow from the tree on the south; the site is covered by a tree; lack of depression
132											deleted during review
133											deleted during review
134	dark blue; tint of green	oval	9.1177058	80% bare land; 20% bedrock	N	N	Y (subtle)	3	puddle; shadow (from rock/cliff)	not likely a tree shadow (no tree); deep color; oval shape; wet soil color on the southwest	depression is not obvious enough; probably the shadow of the stone on the south
135	dark blue	oval	11.888133	80% tones; 20% trees	N	N	N	2	shadow (from stone/cliff); puddle	not a tree shadow; deep color	could be a shadow from stone; too close to the lake; the texture is too smooth
136	dark blue; traces of green	oval	30.533422	trees	N	N	Y (subtle)	1	shadow	cannot find enough trees to create such a deep and large shadow	too blur to tell if there is any other trees that are not observed (to be obvious) on this photo
137	deep dark blue; green trees; patches of white color	irregular	118.38015	bare land	N	N	Y (subtle)	3	wetland	distinctively darker color; not likely tree shadow (wrong direction);	if it is a wetland or a pool, don't know why there are so many trees
138	dark blue; patches of brown	irregular	30.345544	80% trees; 20% grassland	N	N	N	1	shadow; wet land	too large to be a normal shadow; deep color	still could be a shadow (immediate to trees); could be part of a wetland
139											deleted during review
140	dark blue; patches of white	oval	4.2959057	60% bare land; 20% trees; 20% trail	N	N	N	1	shadow	patches of white color; deep color	it is in the middle of a trail (therefore not likely a pool); and could be a tree shadow
141											deleted during review
142											deleted during review
143											deleted during review
144	dark blue;	oval	5.1104302	bedrock	N	N	N	1	shadow	the shadow surrounds the tree (which is weird)	no depression; could be the shadow from the tree on the south-east
145	dark blue; patches of pale grey; traces of green	irregular	232.21422	70% bare land; 30% bedrock	N	N	Y	4	must be a pool	obvious depression; obviously not a shadow; distinctive large area of water color	may link with lake/wetland; may have outlet/inlet; may not dry during summer time
146	dark blue; traces of white and green	irregular	28.54252	50% bare land; 40% bedrock; 10% trees	N	N	N	3	puddle; wet soil	patches of white (suggests frozen water); not likely a shadow	no depression; too close to the tree on the south
147	pale dark blue; tint of green	oval	11.268998	90% bedrock; 10% tree	N	N	N	2	shadow; puddle	significantly too large as a tree shadow	no depression; could be a shadow of bedrock; texture is too smooth
148	dark blue (middle); pale brown (surrounding)	crescent	26.310037	bare land	N	Y	Y (very subtle)	3	wet soil; part of gully; part of wetland	not a shadow; the "bridge" may prove the water remain	may be part of a large wetland
149											deleted during review
150	dark blue; pale green; traces of brown	round	36.896714	grassland	N	N	N	3	wet land	wetland texture; not shadow; may link with the large wetland on the south-west	may be part of a large wetland
151											deleted during review
152											deleted during review
153											deleted during review
154	brown; pale grey; a patch of white	irregular	97.243386	trees	N	N	Y	3	wet soil; wetland	the white patch (likely snow accumulation); deep color	may link with a large wetland; lack of water remain; the white color could be tent
155											deleted during review
156	dark blue; light green	round	2.7377216	trees	N	Y	Y (subtle)	1	small puddle; shadow	distinctive light green color; buffer dark blue in the middle of a light color patch	far too small (dark patch < 1 sq m)
157	pale dark blue; pale grey	oval	22.4944	trees	N	N	N	1	wet soil	grayish color; not likely a shadow; coarse texture (than surrounding landscape)	no sign of water remain; no depression
158	dark blue; brown; pale white	irregular	76.465289	60% trees; 40% bare land	N	N	Y	2	tree shadow; wet soil	depression; deep color	no significant water remain; likely to be tree shadow or just wet soil
159	dark blue; dark brown; traces of green and pale white	oval	42.375396	60% trees; 40% bedrock	N	N	Y (subtle)	3	part of wetland; wetland	the white color suggest water remain; the site is surrounded by bedrock and trees; deep central	there's a large wetland immediate to it; could be wet land or wet soil
160	dark blue; white	oval	2.3683112	bare land	N	Y	N	1	shadow	the white patch could be frozen water	there is a tree on the south-west that make this site possibly a shadow
161											deleted during review

162											deleted during review
163											deleted during review
164											deleted during review
165											deleted during review
166	dark blue; patches of white	round	10.498277	70% bare land; 30% trees	N	N	Y (subtle)	3	part of wetland; puddle	not likely a shadow; white color suggest frozen water; it seems there is an in/out let	may be part of a large wetland
167	dark blue; pale light green and pale brown	irregualr	50.947308	trees	N	N	Y (subtle)	2	wet soil	the tree color here is different; deeper color; surrounded by trees	no significant water remain
168	dark blue	long oval	4.6336205	bare land	N	N	N	2	part of gully	deep color; not a shadow; lined to a possible gully	may be part of a gully (and therefore may have permanent in/outlet)
169	dark blue	irregular	38.115804	90% bare land; 10% trees	Y	Y	Y	4	wet alnd	obvious a wetland; water remain; crack pattern	may not disappear in summer time; may be part of a large wetland
170	dark blue; light green; pale white	oval	3.5923252	70% bare land; 30% trees	N	N	N	1	shadow	patches of white color (water remain)	likely a shadow (too close to the tree on the south)
171	dark blue; traces of brown and green	irregular	149.77027	90% grass land; 10% trees	N	N	Y (subtle)	3	wet land	very obvious it is a wetland	may not dry in summer time; may have permanent in/out let
172	dark blue	long oval	37.936661	90% grass land; 10% trees	N	N	N	3	part of wetland	not a shadow	may be linked with other large wetland; may not dry during summer time
173	dark blue; traces of brown	irregualr	318.076	bare land/grass land	N	N	Y (very subtle)	4	pool	obvious a pool	may have inlet/outlet
174											deleted during review
175	dark blue; brownish	irregular	45.434331	80% bare land; 20% trees	N	Y (subtle0	N	1	wet soil	part of the dark color cannot be fully explained by tree shadows	very similar texture and color as the tree shadows around
176											deleted during review
177											deleted during review
178											deleted during review
179	dark blue; traces of pale white	irregular	44.963043	70% trees; 30% bare land	N	N	N	1	shadow	there is space between the "shadow" and the tree	the color and texture are too alike the tree shadows around
180	dark blue; traces of pale white	irregular	66.623851	60% bare land; 40% trees	N	N	N (cannot tell)	1	shadow	there is space between the "shadow" and the tree	the color and texture are too alike the tree shadows around
181	dark blue; traces of brown and green	irregular	54.915988	70% bare land; 30% trees	N	N	N	2	wet soil	brownish boundary	more like a tree shadow (or it is very difficult to distinguish this patch with other tree shadows)
182											deleted during review
183											deleted during review
184	dark blue; pale white; traces of brown	oval	271.02469	80% trees; 20% grass land	N	Y	N	3	shadow; wet land	distinctive color from surroundings; white color may be frozen water; brownish buffer	the white could be trees (then the whole site would be just shadows)
185											deleted during review
186	pale brown; dark blue	oval	5.8660791	bare land	N	N	Y (very sublet)	1	bare land	slight depression; a line of dark blue	too small; the depression is not very clear either
187											deleted during review
188											deleted during review
189											deleted during review
190	dark blue; patches of pale grey and brownish green	irregular	143.12446	70% bare land; 20% bedrock; 10% trees	N	N	Y	4	a pool	water color; stones; not a shadow; obviously a pool	may have inlet/outlet
191											deleted during review
192											deleted during review
193											deleted during review
194	white; pale dark blue	irregular	9.5008802	80% bare land; 20% trees	N	N	Y	2	puddle; shadow	white color (could be ice); the	snow does not necessary mean water remains; seems to shallow
195	pale dark blue	irregular	12.888664	70% bare land; 30% trees	N	N	Y	2	shadow; wet soil	the grayish color is subtle different from the surroundings; subtle depression	too likely to be a tree shadow; no water remain
196											deleted during review

197	dark blue; brown; tint of purple	round	21.396203	70% bare land; 30% trees	N	N	N	1	shadow	a little bit too long to be a shadow; has a tint of purple (slightly different from surroundings)	adjacent to trees (could be shadow)
198											deleted during review
199	dark blue; white	round	4.7801659	50% trees; 50% bedrock	N	Y (subtle)	Y	4	puddle; bedrock	impossible to be a shadow; deep color; possible in/outlet; surrounded by bedrock	too small (may not last long enough)
200	dark blue; white	irregular	1.1661241	trees	N	Y	Y (subtle)	1	shadow; part of wetland	deep color; distinctive in the surrounding landscape; white color (could be ice)	far too small (may not last long enough); could be shadow or part of a large wetland
201	dark blue; tint of bronw; traces of green	oval	41.162084	70% trees; 30% bedrock	N	N	Y (subtle)	2	wet soil; wet land	wetland texture; not a shadow	the site seems too solid to be a pool; could be part of a large wetland
202	dark blue	oval	22.415772	50% bedrock; 40% trees; 10% bare land	N	N	N	3	bedrock; pool	not a shadow; significantly deeper color; adjacent to bedrock	not sure if it is on top of the rock or at the bottom; could be dark color rock; texture too smooth
203	dark blue	crescent	1.496364	bare land	N	Y	N	1	shadow; wet soil	its color is significantly deeper than surroundings; boundary is too clear as a shadow	too small (only about 1 sq m); adjacent to trees (could be shadow)
204	dark blue; white	long oval	8.7368387	40% trees; 30% bedrock; 30% bre land	N	N	Y	3	puddle; bedrock; shadow	too unlike a shadow (both shape and deep color); white color (could be ice)	the boundary is too straight; could be bedrock of shadow of a cliff
205	dark blue; traces of white and green	long oval	143.09888	60% trees; 40% bare land	N	N	Y (very subtle)	2	wet soil; dark color soil	not a shadow; dark color	no sign of water remain; could just be a pile of decompositions
206	dark blue; traces of white and green	oval	15.582846	60% trees; 40% rock	N	N	Y	1	shadow	dark color; surrounded by trees and rocks	could be tree shadow (immediate to trees)
207											deleted during review
208											deleted during review
209											deleted during review
210	pale dark blue	oval	3.5243256	50% trees; 50% bare land	N	Y	Y	2	water remains in a depression next to exposed bedrock	deep color; immediate to exposed bedrock; sign of depression	on the direction of tree shadow; lack of crack feature
211	dark brown; patches of green	oval	28.386215	bare land	N	N	Y	3	dried depression	obvious depression; a flow in the middle (if that is a flow)	the flow in the middle could be tree shadow; no water remain
212	pale white; pale blue	irregular	7.4098474	70% bare land; 30% trees	N	Y (subtle)	Y (subtle)	1	frozen surface; bedrock	it has depression; the pale white color may be frozen surface	seems like exposed bedrock
213	white; green	irregular	14.338367	70% bedrock; 30% trees	N	N	Y	1	frozen surface; exposed bedrock	depression; white color (more white than surrounding landscape) could be ice	color is still similar to bedrock
214	deep blue	linear oval	1.5841319	70% trees; 30% grass	N	N	N	1	part of a gully	deep color; has deep color surroundings (could be dried wetland/pool)	no sign of depression; no crack; no buffer
215	dark brown; deep blue; traces of green	oval	10.642694	trees	Y	Y	Y	3	wet depression in woodland	depression; brown color (implies wet soil); deep color (implies water)	no significant sign of water (the pool could be partially dried)
216	deep blue; traces of brown; traces of green	oval	15.721492	trees	N	Y (subtle)	Y	2	wet soil	depression; color; coarse texture	no crack on the ground; no significant remain of water
217	brownish dark blue	oval	2.7036548	grass	N	Y	Y (subtle)	1	exposed bedrock; wet soil	color; shape; locate in a brown patch	no crack; too subtle depression; likely to be exposed bedrock; pale color
218	pale dark blue; traces of brown; traces of green	oval	5.4332083	wetland/wet soil; grassland	N	Y	N	2	wetland; exposed bedrock	wetland texture (coarse texture) of surroundings; color; shape	too close to residential area; no significant sign of water
219	pale dark blue	oval	17.268546	60% grass; 40% trees	N	Y	N	1	exposed bedrock; wet soil	shape; deep brownish color	too flat; no significant sign of water
220	pale dark blue	long oval	2.9433382	70% bedrock; 30% trees	N	Y	Y	2	bedrock depression	it is adjacent to bedrock (water source); sign of depression	not sure if this is a shadow or water remain
221	brownish pale deep blue	irregular	33.151754	exposed bedrock; with several trees	N	N	Y	2	wet soil	deep color; enclosed in exposed bedrock; not likely to be tree shadow	no significant sign of water remain; no depression on the earth; wet soil coarse texture
222	dark blue; tint of brown	round	6.8492862	grassland	N	Y	Y (subtle)	2	tree shadow; wet soil	deep color; location in the middle of a brownish patch; buffer; distance to trees	cannot tell if there is any water remain or just wet soil
223	brown; a patch blue	oval	4.5070815	exposed bedrock	N	N	Y	1	a depression surrounded by rocks	surrounding rocks help accumulating water; dark blue patch could be water	no significant sign of water remain; no crack on the ground
224	dark blue (in the middle); brown	oval	6.8677599	60% trees; 40% trail	N	Y	Y (subtle)	2	wet soil	color; lack of trees (to provide shadow)	there could be a tree to make this site a shadow (since not all trees are obvious on photos)
225	pale dark blue; patches of green	oval	35.344998	60% trees; 40% bare land	N	N	Y (subtle)	1	wet soil; tree shadow	deep color; too large as a tree shadow	no significant sign of water remain; no significant sign of depression
226	pale blue; brown	oval	14.010833	70% bedrock; 30% bare land	N	Y	Y	3	wetland	not a shadow; wetland texture; brown buffer; immediate to bedrock	no significant sign of water; could be wet soil or wetland
227	dark	round	1.8457135	50% bare land; 30% exposed bedrock; 20%	N	N	N	1	a patch of black color	too deep to be tree shadow	no depression; too sharp boundary; too smooth color

				trees							
228	deep dark blue; a patch of brown	irregular	3.1318397	bare land	N	Y	Y	3	wet soil; tree shadow; puddle	gradient brown surroundings; not likely to be a shadow	could be wet soil
229	dark blue; traces of green; tint of purple	irregular	30.24332	70% trees; 30% bedrock	N	N	Y	1	deep color soil; bedrock	deep color (significantly darker than surroundings); immediate to bedrock	no sign of water; may be dark color exposed bedrock
230	pale dark blue; tint of brown (a patch of dark blue in the middle)	oval	6.6291973	70% bare land; 30% trees	N	N	N	1	wet soil	too large to be a tree shadow; brownish color	could be wet soil
231	dark blue	oval	2.6139749	trees	N	Y	N	2	wet soil; shadow	seems to link with site 6 (via a gully); could be	could be tree shadow (there are trees on the south-west)
232											deleted during eliminating false predictions - bedrock
233	pale dark blue; tint of green	oval	9.3704139	70% trees; 30% bedrock	N	N	Y	1	wet soil	deep color; immediate to exposed bedrock	no significant sign of water; could just be wet soil
234	dark blue; tint of brown	oval	2.4040319	90% bare land; 10% tree	N	Y	Y (very subtle)	2	wet soil; shadow	too large to be a shadow (especially when there is a buffer btw the site and the tree)	no significant sign of water; no significant depression
235	pale brown	oval	1.830494	80% bare land; 20% exposed bedrock	N	N	Y (very subtle)	2	dried puddle; wet soil	clear oval shape; almost impossible to be a shadow	no water remains
236	dark blue; brown; patches of white	square	2.3415575	60% bare land; 40% trees	N	Y	Y (subtle)	2	puddle; wet soil; wet land	deep color (water remain); white color (frozen surface)	no significant depression
237	dark blue; brown	oval	9.6465588	60% bare land; 40% trees	N	Y	Y	3	wet soil; puddle	not likely to be a shadow (too big); deep color; depression	adjacent to trees (and their shadows); no crack in the land (to be a water body)
238	white; light green; grey (stone); patches of brown	irregular	66.060315	60% trees; 40% bare land	N	Y	N	3	frozen water	frozen water, means water; greenish colors suggests vegetation	not sure if this is a pool or just frozen ice from snow accumulation
239	light green; pale white	irregular	42.166613	60% bare land; 40% trees	N	N	N	1	frozen water; exposed bedrock	color seems to be frozen water	seems similar with exposed bedrock
240	dark blue; a white patch; patches of green	oval	6.3118773	50% bare land; 30% bedrock; 20% trees	N	N	N	1	wet soil; shadow	cannot find the tree to make this site a shadow	no depression; not obvious water remain; too smooth texture
241	dark blue; tint of brown	irregular	16.436451	trees	N	Y	Y	3	wet land	coarse wetland texture; not likely all shadow; color	no sure if this is a pool; could be wet soil
242	dark blue; patches of green	oval	4.6693433	70% trees; 30% bare land	N	Y	Y	2	wet soil	too large to be a shadow; slight depression	still possible to be a shadow (since it is adjacent to trees)
243	white	crescent	2.6692785	60% bare land; 40% trees	N	N	N	1	snow accumulation	the only snow accumulation in the surrounding landscape	could be other things; most snow has melted, and this patch seems very weird
244	brown; patches of dark blue	irregular	215.75511	70% bare land; 30% trees	N	N	N	2	wet land	distinctive color and texture	have inflow/outflow; could just be wetland but not a vernal pool
245	dark blue; patches of pale white; tint of purple	irregular	11.446968	90% trees; 10% rock	N	N	Y (subtle)	2	wet soil; puddle	not likely to be a shadow; tint of purple color	no obvious water remain; could just be wet soil or part of gully
246	dark blue; traces of green and brown	irregular	27.146822	80% trees; 20% bare land	N	Y (very subtle)	N	2	wet soil; tree shadow	location (surrounded by trees); deep color	still could be tree shadow
247	pale dark blue; white; tint of brown	irregular	48.189364	80% bare land; 20% trees	N	Y	Y (subtle)	2	frozen water	the sites color is deeper an more blur than surrounding landscape (like frozen water); not a shadow	not sure if "blur" means frozen water; could just be image problem
248	dark blue; traces of green	oval	2.0321717	80% bare land; 20% trees	N	Y	Y	1	puddle; shadow; wet soil	suspicious shape as a shadow; brownish surroundings	could be a tree shadow (close to trees); no significant water remain
249	dark blue; white with a tint of green	oval	3.0897825	70% bare land; 30% trees	N	Y	N	1	wet soil	white patch seems to be frozen surface	could be tree shadow
250											deleted during eliminating false predictions - bedrock
251	deep brown	irregular	12.568467	40% bedrock; 30% trees; 30% bare land	N	Y	Y	2	dried pool; depression	the obvious depression both in the middle and the site as a general; not a shadow; close to bedrock	no significant remain of water; may not have water accumulation
252											deleted during review
253	dark blue; traces of green	irregular	78.745849	70% trees; 30% bare land	N	N	Y (very subtle)	1	wet land; wet soil	deeper color than surrounding landscape; wetland texture; not tree shadow	no significant water remain; may be part of a larger wetland
254	dark blue; tint of purple; patches of white	irregular	13.555648	bare land	N	Y (subtle)	Y (subtle)	2	gully	it does not look like tree shadow; light brownish color may be dried pool; seems part of gully	too narrow to be a puddle; could be shadow
255	pale dark blue; pale while; patches of white	irregular	19.879597	exposed bedrock	N	Y (subtle)	Y (subtle)	2	part of gully	deep color; not likely a shadow; brownish buffer seems to be dried pool	too narrow; could just be a gully
256	dark brown; patches of green and dark blue	irregular	12.761677	70% trees; 30% cliff	N	N	Y	2	part of gully	from surrounding landscape, this site seems to be part of gully (but have deep color)	it may have permanent inlet/outlet; may not maintain water long enough; may be wet soil
257	dark blue; traces of white and green	irregular	19.570467	70% rock; 30% trees	N	N	Y (very subtle)	2	part of lake; shadow	too deep and large to be a shadow (and no traces of rock underneath)	may be linked with the lake; could be flat rock with shadow on it

258	dark blue; brown	irregular	10.122867	60% wetland/bare land; 40% bedrock	N	N	N	4	part of a large wetland	it may only link with the large wetland intermittently; obvious water remain and wetland texture	could be part of the large wetland; may not dry in summer time or may not retain water long enough
259											deleted during review
260	dark blue	oval	1.0295299	bare land	N	Y	N	1	shadow; puddle	brownish buffer; not adjacent to trees; deep color	too small; no depression
261	dark brown; traces of green and dark blue	irregular	33.674128	bare land	N	N	Y	2	part of wetland; depression	depression; dark blue color	no water remain; could be wetland or wet soil but not a pool
262	dark blue; dark brown	irregular	25.292217	trees	N	n	N	3	wetland	wetland texture; seems to have water remain	could be part of a larger wetland; could just be wetland
263	dark blue; pale white; pale brown	square	23.408271	50% bedrock; 30% bare land; 20% trees	N	N	N	2	shadow; wet soil	the gradient of dark blue does not seems like a shadow	immediate to a tree
264	dark blue; patches of green and white	oval	1168.1905	70% bare land; 30% trees	N	N	Y	4	wet land	wet land; not too massive so it may dry in summer time	it is a wet land, may not dry, and may have inlet/outlet
265	pale grey; pale dark blue	oval	41.261891	80% trees; 20% bedrock	N	Y (subtle)	N	1	puddle; wetland; dark color soil	its texture and color are distinctive from surrounding landscape; could be puddle on the hill top	no significant sign of water remain
266	dark blue; white	round	5.3882627	trees	N	N	Y (subtle)	1	puddle; shadow; wetland	white color (frozen water); deeper color than surroundings	may be tree shadow or part of a wetland
267	light green	round	7.0290439	60% trees; 40% bare land	n	n	Y (subtle)	2	pool; tree	the light green color is very distinctive in this landscape; adjacent to "wet soil" on the north	may be a tree with light color
268	dark blue	oval	8.0715639	bedrock	N	N	N	1	bedrock	not likely a shadow wrong direction, wrong shape); isolated	could be dark color bedrock or soil
269	dark blue; patches of green	oval	30.278571	bedrock	N	N	N	1	wet soil	not likely a shadow; could be a puddle on the bedrock	not sure if the site can retain water; may be wet soil
270	pale dark blue; tint of grey	irregular	19.518037	50% trees; 50% bare land	N	N	Y	2	wet land	its grayish color is slightly different from surroundings; not a shadow	may be part of a large wetland; the color difference may be image problem
271	light green; pale dark blue	oval	269.4609	80% bare land; 20% trees	N	N	N	2	wet land	the vegetation color is very different from surrounding; wetland texture	no significant sign of water remain; could be a wetland but may not dry periodically

Table 7: Records of 2009 Black and White Aerial Photo

Id	color	buffer	(% of) flat surrounding	(% of) moderate surrounding	(% of) undulating surrounding	shape	area (m^2)	boundary	depression	confidence	others
1	medium grey	N	50	50	0	irregular	86.2661	moderate	Y	3	could be wet soil
2	medium grey	N	50	50	0	irregular	109.3172	medium soft	Y (subtle)	1	it has depression but more likely to be wet soil
3	light grey	N	100	0	0	oval	13.64975	medium to sharp	Y (very subtle)	1	may be tree shadow
4	dark grey	N	80	20	0	round	21.17607	medium to sharp	Y (very subtle)	2	too flat; too small; may be part of gullies (seems to have outlet)
5	medium grey	Y	20	80	0	irregular	134.5459	sharp	Y	4	clear depression; clear water remain in the middle of a depression
6	medium to dark grey	N	80	20	0	irregular	33.9165	medium softness	Y (subtle)	2	ma be linked with site 5
7	medium to dark grey	Y	80	20	0	oval	123.4345	medium softness	Y (subtle)	2	could be wet soil or tree shadow
8	medium to dark grey	N	0	100	0	irregular	38.42372	medium softness	Y (very subtle)	1	looks like glade with shadow; but has slight depression
9											deleted during review
10	deep dark	Y (could be dried pool)	40	20	40	irregular	27.55748	medium softness	Y	3	not likely to be shadow; the grayish buffer could be dried pool bed
11	medium grey	Y (could be dried bed)	30	0	70	irregular	107.8844	medium softness	Y	1	the steepness of the surrounding landscape is difficult to determine
12	medium to deep grey	N	0	100	0	oval	110.5777	sharp	Y (subtle)	1	the boundary seems to be too sharp
13	light grey	N	100	0	0	crescent	207.6178	medium softness	Y	3	there is no tree around therefore not likely to be tree shadow; could link with site 14
14	medium grey	N	70	0	30	round	84.98147	medium softness	Y	3	no tree, no valley; likely to be a pool link with site 13; however, not sure what is on the south
15	medium to deep grey	Y	80	20	0	oval	123.4287	medium to sharp	Y (subtle)	2	it seems to be in the middle of a depression; not likely to be tree shadow
16	light to medium grey	N	100	0	0	oval	205.7609	soft	Y (subtle)	1	wetland texture, therefore could be wet soil
17	medium to deep grey	N	100	0	0	irregular	97.22788	medium softness	N	1	this is likely to link with site 18; likely to be tree shadow
18	grey	N	100	0	0	oval	69.23702	medium softness	N	1	very likely to be tree shadow (but not very sure because the trees are too blur)
19	medium to dark grey	Y	100	0	0	oval	543.2379	medium to sharp	Y (very subtle)	1	can see a little bit depression; likely to be tree shadow but cannot clearly identify the trees
20	deep dark	N	100	0	0	round	182.6581	sharp	N	1	the boundary is too sharp to be a pool; but cannot explain what this patch of black color is
21	medium to deep dark	N	0	100	0	oval	38.127	medium to sharp	Y (subtle)	1	what on the west could be trees (and therefore this site could be shadow)
22	medium grey	N	100	0	0	oval	31.39756	soft to medium	Y (subtle)	1	looks like tree shadow; but cannot find tree and the medium grey patch on the west seems like wetland texture
23											deleted during review
24	medium to deep color	N	100	0	0	oval	77.51465	medium softness	N	1	it does not seems like a pool but cannot find other explanation
25	light to medium grey	N	100	0	0	oval	41.39082	soft	N	2	it seems like wet soil or pool since it is in the middle of a flat land
26											deleted during review
27											deleted during review
28	deep dark	N	100	0	0	oval	216.3945	medium to sharp	Y (very subtle)	1	too large to be tree shadow; however, do not looks like a pool either
29	light to moderate grey	N	100	0	0	irregular	43.50628	blur	Y (subtle)	1	could be a cluster of trees and their shadows
30	light to medium grey	N	100	0	0	oval	311.6602	soft	Y (subtle)	2	there is no tree around; seems like a depression
31	moderate to deep grey	N	100	0	0	round	471.1296	soft	Y	3	it cannot be tree shadow; wetland texture therefore could be wetland
32	light to medium grey	N	100	0	0	oval	222.4094	medium to sharp	Y	3	it seems to have frozen water surface; the coarse texture makes this site like water bodies
33	medium grey	Y	100	0	0	long oval	65.52805	soft	Y	3	not looks like tree shadow; soft boundary looks like dried pool
34	deep grey	N	80	20	0	long oval	96.99088	sharp	Y (very subtle)	1	it could be tree shadow (just like what are on the south); however, it seems too long to be a tree shadow
25											deleted during review
36	medium grey	N	100	0	0	crescent	27.28892	sharp (in the middle); soft (general outside	Y	3	the middle crescent shape looks like a pool; the medium grey round patch seems like wet soil (e.g. dreid pool)

								round boundary)			
38	medium grey	N	100	0	0	linear	69.22619	medium to sharp	N	1	it could be tree shadow (since some trees are not very obvious on this image0
39	white	N	50	0	50	round	59.21714	medium to sharp	N	2	it looks like frozen water bodies (and it is different from the surrounding landscape)
40	light to medium grey	N	100	0	0	oval	36.28259	medium to sharp (of each small pool); soft (the site in general)	Y	3	there is no tree around; the shapes seems like pools; the whole sites seems to be a partially dried pool
41	pale white	N	0	100	0	crescent	22.0214	medium to sharp	Y (very subtle)	2	it seems like a frozen water body in the forest; has a confidence of 2 because it is different from surrounding landscape but still a little bit common in the whole image
42	medium to deep grey	N	20	80	0	irregular	85.03872	medium to sharp	Y (very subtle)	1	likely to be wet soil; cannot find trees to make this area a shadow; but not like a pool either
43	medium grey	N	0	100	0	irregular	15.90967	medium to sharp	Y	3	does not look like shadow; seems like a crack in the earth (shared feature of many water bodies); but it still could just be undulating landscape
44	light to moderate grey	N	0	100	0	irregular	179.6362	medium to sharp	Y	2	it looks like a glade; but it is still picked up since not all the observed trees can explain the deep shadow on the south part of this site (the "shadow" seems obviously longer than the north part of the site)
45	dark grey	N	20	80	0	oval	114.8024	medium to sharp	Y	2	the dark color is too even to be a shadow (compared with the shadow on the west of this site); however, this image it too blur to be sure this is a pool
46											deleted during review
47	light to medium grey	Y	80	20	0	oval	70.49919	sharp	Y	3	a very obvious depression; the shape looks like a water body as well; but still too blur to be 100% sure
48	medium grey	N	40	30	30	irregular	32.07666	soft to medium	Y (subtle, but too blur to be sure)	3	there is no tree around (seems to be); seems to have a cliff on the southern part); could accumulate water on the south-west corner of the site
49											deleted during review
50											deleted during review
51	light to medium grey	N	100	0	0	long oval	96.0066	sharp (in the middle); soft (outside)	Y	3	the site in the middle is very obvious to be a depression; however, the black color on the south-west seems to be part of this site as well (but with less confidence)
52	deep grey	N	0	100	0	oval	48.19372	medium to sharp	N	2	this site is picked up since there is nothing around that can provide this "shadow"
53	light to medium grey	Y	100	0	0	crescent	251.0576	medium to sharp	Y (subtle)	1	it is very likely to be tree shadow; however, the image it too blur to be sure that what on the west are trees but not cliff
54	light to medium grey	Y	100	0	0	round	16.59109	sharp (in the middle); soft in general	Y	2	it looks like a shadow but the buffer between the dark dot and the surrounding landscape make this site suspicious
55	dark grey	Y	100	0	0	round	32.2041	medium to sharp	Y	2	the depression and the shape make this site suspicious; however, there are two trees on the left, which make this site possibly a shadow
56	light to medium grey	Y	100	0	0	round	20.25933	medium to sharp	Y	2	looks like a wetland in a depressed "glade"; but not sure if the "depression" is an illusion from the surrounding trees
57	light grey; deep grey	N	100	0	0	two squares	59.18239	sharp; soft (the depression on the south-east)	Y	2	the crack shape make this site suspicious
58											deleted during review
59											deleted during review
60											deleted during review
61											deleted during review
62											deleted during review
63											deleted during review
64	medium grey	Y	100	0	0	oval	146.5646	medium to sharp	Y (subtle)	1	this could be a pool if there is tree around
65	deep grey	N	70	30	0	irregular	153.3334	sharp on the south; soft on the north	N	2	likely to be a pool but may connects to the lake
66	light grey	Y	100	0	0	oval	25.38664	medium to sharp	Y	2	it seems like a depression in the middle of a glade; not likely to be tree shadow
67	deep grey	Y	100	0	0	long oval	32.51338	sharp	N	1	nothing can explain such a dark patch with sharp boundary; however, it does not like a pool either
68	medium to deep grey	Y	100	0	0	oval	26.0882	medium soft	Y	2	the shape and color are suspicious; not likely to be a tree shadow
69	light grey	N	100	0	0	round	90.56278	medium soft to sharp	Y	1	very obvious depression, very likely a patch of wet soil but not a pool - seems too dry and too shallow
70											deleted during eliminating - part of river system

71											deleted during eliminating - bedrock
72											deleted during eliminating - bedrock
73	white	Y (subtle)	100	0	0	oval	50.65953	soft	Y (subtle)	1	snow accumulation; too common pattern in the landscape
74	dark grey	N	100	0	0	oval	74.72763	soft	Y (subtle)	3	the deep color could be water, and the gradient buffer could because of wetland texture; possibly site 74 and 75 are the same pool but partially dried
75	same as 74		0	0	0		47.20869			3	deleted during review
76	dark grey	N	90	10	0	oval	44.54153	soft	N	2	could be wet soil or a pool (which is very likely link with the lake)
77	black to dark grey	N	0	100	0	irregular	338.4095	medium to sharp	Y	4	this is a pool; however, may link with the lake
78	medium to dark grey	N	100	0	0	irregular	34.6773	soft to medium	N	1	this site is more likely to be a tree shadow (given the surrounding landscape); however, the texture is a little bit coarser than surrounding shadows and therefore I mapped this site
79											deleted during review
80	light to medium grey	Y (subtle)	0	0	0	oval	35.54148	medium	Y	1	the depression may not be significant enough to be a pool; lack of water remain
81	black to dark grey	Y	90	10	0	oval	39.07449	soft to medium	N	3	the boundary, the deep color, and the wet-like soil in the surroundings make this site suspicious
82	black to dark grey	N	100	0	0	oval	67.77958	soft	Y (subtle)	3	it is very likely a pool due to the slight depression, dark color, wet-like boundary, and the pool on the north could be the same pool with this site (partially dried)
83	medium grey	N	50	50	0	oval	68.86495	soft to medium	Y (subtle)	3	this site is not a shadow; it is suspicious not only for the wetland texture but also the wet land like land on the north, which could be dried pool
84	medium grey	N	100	0	0	irregular	58.97036	soft	Y (subtle)	3	suspicious not only for the texture, blur boundary and the deep color (which could be partially dried water); the site on the south-west is likely be the same pool with this site; this is not a tree shadow
85	same as 84		0	0	0		53.99505			3	deleted during review
86	medium to dark grey	N	50	30	20	irregular	103.5622	soft	Y (subtle)	2	this does not like a shadow; however, not sure if it is just a wet land or could actually remain water
87	dark grey	Y (subtle)	40	60	0	oval	94.69095	soft to medium	Y (subtle)	1	it seems to have a little bit depression and the site seems to have coarse wetland texture as well; however, there are many trees around, and this site could possibly be a tree shadow
88											deleted during eliminating - obvious wetland
89	light grey	N	0	100	0	irregular	122.4214	soft to medium	Y (subtle)	2	it is more like a crack on the ground, and have too little water remain (possibly dried)
90	dark grey	N	0	100	0	long oval	385.2058	soft to medium	Y (subtle)	2	it seems like wetland; the depression and the deep color are suspicious; however, not sure what are the white color in the middle of the site
91	light grey; dark (in the middle)	Y (subtle)	0	60	40	oval	619.6102	soft (outside); soft to medium (inside)	Y	4	it is very likely a wetland with a patch of water remain in the middle
92	medium to dark grey	N	100	0	0	round	83.32376	soft	N	2	the deep color and the blue boundary is suspicious; however, this site could just be a patch of wet soil or a shadow
93	light grey	N	0	0	100	long linear	427.8712	medium	Y	3	very likely a wetland given the texture that the depression; however, it could also be a glade in the ever green forest
94	white; light grey	N	0	100	0	oval	240.0983	medium to sharp	Y	4	it is almost sure that this is a pool (and the texture of the site looks like frozen water); however, it is still possible that this site is exposed bedrock
95	white; light grey; dark grey	N	40	60	0	irregular	354.7976	soft to medium	Y	4	it looks very alike frozen water body; however, it is still possible that this site is wet land or exposed bedrock
96	white; light grey	N	100	0	0	oval	58.3038	soft	Y (subtle)	2	it is a depression and the light grey seems like frozen water; however, the light grey is too smooth and could also be bare land; this site is suspicious but the image is too blur to be sure
97	medium to dark grey	N	50	50	0	oval	311.5277	soft to medium	Y (very subtle)	2	compared with a pool, this site is more like a wetland or wet soil
98	dark grey	Y (very subtle)	70	0	30	irregular	478.6699	medium to sharp	Y	4	this must be a pool
99	medium to dark grey	N	60	40	0	round	84.47027	soft to medium	Y (subtle)	3	very likely to be connected with site 98; likely to be a wet land at least; however, when excluding surroundings, this site itself is not likely to be a pool
100	medium to dark grey	Y	100	0	0	irregular	105.4848	soft	Y	4	it is very likely to be a pool due to depression, irregular pattern in a bare land, distance to trees and rock, and the texture is coarse
101	dark grey to black	N	100	0	0	linear	225.8955	soft to medium	Y (subtle)	1	it is more likely to be a shadow (it seems like a pool though); it is on the right direction of being a shadow of the uplifted hill on the west
102	dark grey to black	N	70	0	30	crescent	288.3152	medium to sharp	Y (subtle)	3	it is not a shadow (at least four the south portion); it is very likely to be a wet land or a pool
103	light grey; black	Y	40	0	60	linear	37.39338	soft	Y (subtle)	2	it looks like a pool and has depression; however, it could also be the shadow from the uplifted hill on the north0west
104	black	Y (subtle)	80	20	0	irregular	107.9734	medium to sharp	N	1	it has deep color (could be water); however, i is very similar to the pattern of the tree shadows in the surrounding landscape

105	medium grey	N	100	0	0	oval	73.8263	medium	N	2	the site is suspicious because of its dark color, coarse texture, and it is not very likely to be a shadow; however the pattern of this site is kind of common in the surrounding area, and therefore this site is more likely to be wet sol or wet land
106											deleted during eliminating - bedrock
107	white; light grey	N	100	0	0	triangle	128.5458	medium	Y	3	it is mapped because of the very significant depression, and the white color (snow accumulation); however, similar with site 106, it is kind of weird for a pool to be completely covered by snow at this time
108	black	N	100	0	0	oval	134.7728	medium	Y	4	very likely a pool (due to depression and color); the white color could be stones
109	light to medium grey	N	100	0	0	oval	147.5792	N	Y (very subtle)	2	this site is very likely to be wet, and is not likely to be a tree shadow; however, the color is not deep enough and are more likely to be wet soil but not a pool
110	white; light grey; medium grey	N	0	100	0	oval	142.2727	soft to medium	Y (subtle)	3	the dark color on the north-east corner seems to be water remain, and therefore this site is suspicious; however, the rest of this site seems to be exposed bedrock (but they could be frozen surface as well)
111	black; light grey	N	100	0	0	round	159.9343	soft	Y	3	the deep color depression in the middle could be water remain and the light grey buffer are likely dried pool; however, the light grey seems to be very shallow and therefore the water may not last long enough
112	medium grey; white	N	100	0	0	oval	30.443	soft to medium	Y (very subtle)	1	this site is not likely a pool; I mapped this site because the snow accumulation in the surrounding area are very flat but this site has a little bit depression
113											deleted during review
114	light to medium grey	N	0	100	0	oval	169.9931	N	Y	1	it is morel likely part of the wetland (to the north-west of the site)
115	light grey; medium grey	N	100	0	0	irregular	122.2482	soft	Y (subtle)	2	the site is not a tree shadow; very likely to be wet soil or wet land; not sure if the white color int he middle of the site is frozen water or not; if it is, then this site could be a pool
116	medium to dark grey	Y	80	0	20	triangle	32.85532	medium	Y	2	it seems to be a pool at the first glace; however, its pattern is very similar to the shadows in the surrounding landscape (and the tree color sometimes is very similar with bare land)
117											deleted during eliminating - building ruin
118	dark grey	N	100	0	0	round	37.23529	soft to medium	N	2	this site seems to be tree shadow but there is no obvious tree on the west (or the tree has similar color with the ground)
119											deleted during review
120											deleted during review
121	white; light grey	N	100	0	0	oval	24.41518	medium	Y (subtle)	2	likely frozen water (the light grey color and the slight depression);however, it could also be bedrock or the water may not last long enough
122	medium to dark grey	Y (subtle)	100	0	0	oval	34.4724	soft	Y (subtle)	2	the dark color in the middle of the site makes this site suspicious, and the light grey buffer outside the site could be dried pool; however, the dark color still could be shadow (and the image is too blur to be sure)
123											deleted during review
124	medium grey	N	0	100	0	irregular	250.5944	medium	Y (subtle)	2	it is likely a wet land or wet soil (given the coarse texture and deep color); however, it may not be a water body or it could have a permanent outflow (the grey line on the west of the site)
125	light grey; medium grey	N	0	100	0	irregular	406.904	medium	Y	3	the darker patches in the middle of the site could be water remain, and the lighter grey around could be dried pool; however, similar with site 124, this site may have permanent in/out flow
126	medium to dark grey	N	50	50	0	round	183.8879	soft to medium	Y	2	this site seems to be suspicious (dark color, depression), but it is very likely a tree shadow (similar with the tree shadow on the north-west of the site)
127	medium to dark grey	N	100	0	0	irregular	55.46243	medium to sharp	N	2	this site does not look like tree shadow; however, it seems to have a very common pattern in the surrounding landscape (like other tree shadow) and therefore may not be a vernal pool
128	dark grey to black	Y	0	100	0	irregular	104.0211	medium to sharp	Y	3	it has a much deeper color than surrounding landscape, and the deep color could be water; the lighter grey color at the boundary makes this site more suspicious
129											deleted during review
130	light to medium grey	N	100	0	0	round	33.76285	soft to medium	Y	2	it does not like a shadow, and the dark color in the middle could be water remain; however, it is too blur to be sure if this is a pool or it is just wet soil
131	light grey	N	100	0	0	oval	77.31167	medium to sharp	Y	2	it is a depression, not a shadow; however, it is too dry and not very likely to be a pool
132											deleted during review
133	light grey	Y (subtle)	40	20	40	triangle	101.2614	soft	Y (subtle)	1	it is likely to be a depression, and possibly the soil is wetter than surrounding; however, it seems to be too dry and the depression seems too shallow for a pool
134											deleted during review
135	dark grey to black	Y (subtle)	30	0	70	square	139.651	sharp	Y (subtle)	3	too long to be a shadow, the white color on the east is suspicious (could be frozen water); however, it is also possible that the tree on the west is extraordinarily tall
136	light grey	Y	100	0	0	round	30.19632	very soft	N	2	its location (the middle of a glade) is very suspicious, as well as the coarse texture and deeper color (than surroundings); however, it is likely just wet soil because it does not have obvious depression
137	medium to dark grey	N	60	40	0	round	36.22924	soft to medium	Y	3	the dark color in the middle is very likely water remain, and the lighter color at the border is likely the dried pool; but the image is too blur to be sure about the pool at this size

138	dark grey to black	N	100	0	0	oval	36.52968	sharp	Y (subtle)	3	it seems to be a tree shadow however it is not parallel with the other shadows around; the deep color could be water remain
139											deleted during review
140	medium to dark grey	Y	100	0	0	irregular	73.53148	medium to sharp	Y	3	its location (the middle of bare land and not far away from forest), depression, irregular shape and dark color make this site suspicious; it is not very likely to be a shadow; however, there may be trees un-observable on this image
141	medium grey	Y	100	0	0	square	68.69753	soft to medium	Y (subtle)	2	it is not likely to be tree shadow (unless there are trees on the south-west with a color that is very similar to the ground)l the deep color suggests possible water remain , and the buffer to the forest makes this site suspicious as well
142	dark grey to black	N	60	40	0	irregular	208.3997	medium	Y (very subtle)	2	it is not a shadow; very likely wet soil, or part of the wetland system on the west
143	dark grey to black	N	60	40	0	irregular	27.18403	soft to medium	N	2	it is not a shadow; very likely wet soil, or part of the wetland system on the west
144	dark grey to black	N	60	40	0	irregular	76.25504	soft to medium	N	2	it is composed to two sites (and these two sites are likely linked together); not likely a shadow, but likely wet soil, or part of the wetland system on the west
145	light to medium grey	N	0	100	0	irregular	128.6349	soft	Y	2	it is not a shadow; very likely wet soil, or part of the wetland system on the west
146	light to medium grey	N	60	40	0	oval	77.46874	medium	Y	3	very likely to be wet soil or wet land (because of the coarse texture); but may be too dry to be a pool
147	dark grey	N	60	40	0	irregular	642.1883	soft to medium	Y	4	it is very likely to be a pool with wetland at the border; not likely a shadow; however, this site may link to a gully (to the south-west direction)
148	light grey; dark grey	N	50	50	0	long linear	756.2768	medium	Y	3	looks like a crack on the ground and links with a gully; however, it seems too dry for a pool and therefore probably not the whole site is a pool; it is also possible that it is a shadow (the west could be a cliff)
149	light grey; dark grey	N	60	40	0	long linear	885.2346	medium	Y	3	it is likely a wetland, could be a pool; it could also be a shadow (if what on the left is a cliff)
150	medium grey	N	100	0	0	irregular	210.8035	soft	Y (subtle)	3	likely a drainage, but the dark color could be water remain, and the dark patch on the east may be a pool; not a shadow
151	dark grey	N	100	0	0	irregular	357.5298	medium	N	2	it seems to be wet soil, the dark color could be water but the shape is strange (and the direction looks like shadow)
152	medium grey	N	100	0	0	irregular	131.2456	medium	Y (subtle)	3	the dark color could be water, and together with the depression make this site suspicious; however, it could also be a wetland instead of a pool; this is not a shadow
153	medium grey	Y	100	0	0	round	83.88681	medium	Y (subtle)	2	it is more like a tree shadow (both direction and shape); I cannot find trees that may provide this shadow
154	medium to dark grey	Y	100	0	0	oval	54.62798	medium	Y	3	the direction is not completely parallel with tree shadows and therefore kind of suspicious, as well as the slight depression
155	light to medium grey	Y	70	30	0	round	63.20146	soft	Y (subtle)	3	the depression is not very significant, however, its blur boundary makes this site possibly a wetland; it may be a pool (though the water seems a little bit too shallow)
156	medium grey	N	50	50	0	oval	82.93469	soft to medium	Y (subtle)	2	it seems like a depression, the deep color could be water remain, and it seems there is no tree around (and therefore less likely to be a tree shadow); however, this site shares similar features with the other dark patches in the surrounding landscape
157	medium grey	N	100	0	0	irregular	39.17721	soft to medium	Y (very subtle)	1	it seems very alike tree shadow however I failed to find trees that may provide the shadow
158	dark grey	N	50	50	0	oval	50.10825	soft to medium	N	2	not likely a tree shadow, but could be the shadow from the dune on the south-west
159	dark grey	Y	0	100	0	irregular	144.5241	medium	Y	3	it is not likely a tree shadow very likely wet soil or wet land; not sure if it has enough water to be a pool
160	medium grey	N	0	100	0	oval	314.6953	soft	Y (very subtle)	3	it is not likely a shadow; if the white patches are stones then this site is likely a pool; however, the image is too blur to tell if the white color are stone or something else
161											deleted during eliminating - bedrock
162	light to medium grey	N	100	0	0	round	39.155	soft	Y	2	it is not a shadow; obvious depression; this site is likely a wet land but it seems there is not enough water to make this site a pool (since the color is not deep enough)
163	medium grey	Y	70	30	0	oval	56.42596	soft to medium	Y (very subtle)	2	this is not likely a tree shadow; its location (in the middle of a glade) is suspicious, as well as its dark color; however, it seems to be a little bit too flat and therefore may not be a pool but wet soil)
164	medium to dark grey	Y	60	40	0	irregular	299.0177	soft to medium	Y	4	not a shadow for sure; very likely a pool or wet land (because there are some dried pools on the south section of the site)
165	medium to dark grey	N	100	0	0	irregular	194.4817	medium	Y	2	very likely a shadow from the hill on the south-west (right direction and size); however, what on the north section makes this site suspicious (because this section does not look like a shadow but wet soil)
166	light to medium grey	N	80	20	0	irregular	356.8814	soft	Y (subtle)	3	very likely wet soil or wet land but not sure if the site can hold water long enough to be a pool; not a shadow
167	dark grey	N	30	70	0	square	117.6854	medium to sharp	Y (subtle)	2	seems to be a shadow at the first glance; however, it does not share the similar shape of a shadow at the other tree shadow around (does not have a sharp ending); however, it still share a similar direction as other shadows
168	medium grey	N	70	30	0	round	30.41608	medium	Y (subtle)	3	the depression and the irregular shape seem to be very suspicious; however, it is still possible to be a tree shadow (since there is a light grey color on the south-west and not sure if it is a tree or not)
169	medium grey	Y	100	0	0	round	15.18073	soft to medium	Y (very subtle)	3	the depression and the buffer make this site very suspicious; however, really not sure what the grey color on the south-west is (it could be a tree, and in which case will make this site a shadow)

Table 8: Record of 2005 Satellite Quickbird CIR

Id	shape	area (m^2)	color	% surrounded by trees	clustered brownish patch	block a trial	confidence	other
1								outside boundary
2								outside boundary
3								outside boundary
4								outside boundary
5								outside boundary
6								outside boundary
7								outside boundary
8								outside boundary
9								false elimination (bare land)
10	Irregular, oval like	400.8799	brownish with patches of red and black	Y	Y	N	1	I mapped this since it seems a little bit like brownish and is a cluster. However, it might just be tree shadows. And the mapped PVP is just a possible area of PVP that may occur
11	linear oval	219.5863	brownish green	mostly, 90%	sort of, mixed with green patches	N	1	might be outcrop, but the greenish color is suspicious especially when it goes with brownish patches
12	oval	146.0592	brownish with black and purple-ish color	Y	Y, mixed with dark red, purple and black patches	N	1	might be wet soil. Picked out because of the brownish patches
11								outside boundary
14	irregular, but round in general	283.9164	blackish plus grey-blue	70%	N, clustered red, black and grey-blush	N, but seems to be an origination of brook	1	likely to be a pond that connect to the lake
15	irregular, oval liner	549.0839	grey greenish	about 30%	N	Y, seems to block a brook	2	the same color with a existing vernal pool, but the location is a little bit weird
16	irregular, crescent	363.9352	grey greenish	almost none	N	Y, seems to block a brook	2	the same color with a existing vernal pool, but the location is a little bit weird
17								outside boundary
18								outside boundary
19	irregular, oval, linear	3719.504	light pale brown	30-40%	Y	N	2	very likely to be a wetland, but might not be a PVP
20								outside boundary
21	irregular	433.8624	light brown patches	Y	Y (light pale brown)	N	1	may be nothing. This is picked up because of the brownish patches, which is quite different from surroundings
22	irregular	1912.422	pale light brown patches	40%	Y	N	1	picked up since the brown color is slightly different from surroundings
23	crescent	763.422	reddish pale brown	Y	Y	might be, unclear	1	it seems to be a depression, but it might be just a glade. It is picked up since the pale brown color is slightly different and it shows a depression.
24	irregular	1245.416	brownish with several pale green patches	40%	Y	N	1	close to the lake, might be a glade
25	crescent	1117.317	brownish red with pale black & green	Y	Y	N	1	it seems like a depression
26	oval	347.5333	pale grey & red	50%	N	N	2	the color is quite different fro surroundings and it does not like tree shadow
27	irregular	766.7965	grey-brownish green	N	Y	N	1	it is close to the lake, seems to have wetland texture, but more likely to be thin-vegetation covered bedrock
28	round in general	237.8358	grey pale blue/green	N	N	N	1	seems like the texture of one existing vernal pool, but not exactly the same
29	crescent in general	418.9892	grey pale blue/green	N	N	N	1	seems like the texture of one existing vernal pool, but not exactly the same
30								deleted during eliminating - obvious wetland
31								deleted during review
32								deleted during eliminating - obvious wetland
33	linear	721.2844	pale brown/yellow, pale green, blue, pale red	70%	Y	Y (seems to block a stream or something)	4	must at least be a wet land, very distinctive from surroundings, have obvious depression

34	oval	299.308	pale purple, pale dark red	70%	N	N	2	looks like a depression, may be a wetland or a glade
35	round	39.48047	pale brown/yellow with pale black	20%	Y	N	3	very different from surroundings, so might be a water body
36	irregular	1019.668	pale brown/blue/red	20%	Y	N	1	might be a wetland, wet soil or nothing. Only very slightly different from surroundings
37								outside boundary
38								deleted during eliminating - obvious wetland
39	irregular, round in general	429.1052	pale purple/grey/red	30%	N	N	1	seems to be a depression but not sure
40	round/oval	789.8234	grey green / blue	70%	N	N	2	its color seems to be similar to an existing vernal pool, no tree cover, seems to have an adjacent exposed bedrock (potential water source)
41								outside boundary
42	irregular	2237.833	pale purple & green & black & red	Y	N	N	2	more likely to be a wetland. Surrounded by trees, no vegetation cover, some exposed bedrock
43								outside boundary
44								outside boundary
45	irregular	889.5697	pale white/green/blue/black	50%	N	Y (seems to be on a brook)	2	more like a wetland, but still could be a PVP
46	irregular	1019.829	pale red / black / purple	Y	N	N	2	it seems to be surrounded by trees.
47	irregular	296.6098	pale red / black	Y	N	N	2	it seems to be surrounded by trees, in addition, its color is more blur, which is more like what have been observed in existing vernal pools
48	irregular	337.438	pale grey / red / blue	Y	N	N	2	might be a wetland or just a glade
49	round/ crescent	146.2187	pale grey / red / green	Y	N	N	2	its color is similar to an existing vernal pool
50	oval	470.9414	pale brown/black	50%	Y	Y (seems to block a stream or something)	2	it seems to be on the route of a brook, it seems like a glade, and its brownish color is different from surroundings
51	round	329.5313	light pale brown	50%	Y	N	2	its brownish color is quite different from surroundings
52	crescent	377.9125	pale red, pale brownish	50%	Y	N	1	might be a wetland or a glace, seems like subtle different from surroundings but unclear
53								deleted during review
54								outside boundary
55								outside boundary
56	oval	373.8764	pale red / green black	Y	N	Y (seems to be on a brook)	3	very likely to be a wetland (given the location and the color and texture)
57		134.0573						deleted during review
58	round oval	827.1803	pale dark red	Y	N	N	2	it seems to be a depression, and wet-land like texture; however, it seems there is not much water remain (cyan color) on this site
59	crescent	139.9943	white / cyan	N	N	N	1	it looks like a pool due to the cyan color; however, it could also be snow, and snow not necessary mean water (given that snow is fairly common in the surrounding landscape); what is special with this site is that it is in the middle of a wetland
60	oval	307.2866	dark pale cyan	Y	n	N	2	it seems to be suspicious because of the water color; it could be part of the wetland system in this region or part of the drainage
61	oval	507.8502	pale light red / pale light cyan	N	N	N	2	its slight depression and light color is suspicious; however, it could also be part of the stream system
62	oval	233.7102	pale dark red	N	N	N	1	it has slight depression; close to the wetland on the northwest; however, it does not seems to have significant water remain
63	round	192.8781	pale cyan	n	N	N	2	it seems to be in the middle of wetland and its color seems to have more water remain (except for the snow accumulations in the surrounding landscape)

Table 9: Record of 2003 Satellite Google Earth Map

ID	Color	Brownish boundary	Frozen surface	Surrounding (forest, grassland, bareland)	Shape	Wetland Texture	Confidence	Depression	mapped altitude (ft)	area (m^2)	Others
1	pale dark blue; tint of grey;	Y (same with surroundings)	N	bare land and tree (seems to be)	oval	N	2	N	1105	18.897933	the color is very distinguishable with surroundings
2	pale dark blue; tint of green; tint of brown; a block of brown red	Y (same with surroundings)	N	forest	round	N	2	Y	1098	111.50809	it is overlapped with tree shadows but the shadow should not go that far (and if there is a tree in the middle, it lacks shadow as well)
3	dark blue; traces of green; traces of purple	N	N	60% bare land; 40% forest	oval	N	2	subtle	967	50.335896	it is overlapped with tree shadow but has a subtle depression (visually) and its shape does not consistent with the surrounding trees.
4	dark blue; pale grey blue	N	N	80% forest; 20% bare land	linear	N	2	N	967	8.6229895	the wrong tree shadow direction and shape
5	pale blue-purple; dark blue; traces of brown	N	N	80% forest; 20% bare land	round	N	2	N	700	36.760201	the trees cannot explain this patch of dark color
6	pale blue; white	N	Y	70% trees; 30% bare land	oval	N	3	N	817	51.065818	the frozen surface increases the confidence; however, the image is blur at this site, therefore could still be a tree shadow or probably just color distortion
7											deleted during eliminating - bedrock
8	pale black; pale dark blue; traces of green	N	N	80% bare land; 20% trees	round	N	1	N	817	51.836488	difficult to say if the site is tree and shadow, or is a pool (because the image is blur, and partially blocked by cloud)
9	brown; traces of purple; traces of black	N	N	80% forest; 20% bare land	irregular	Y	2	Y	817	163.97941	it could just be wet soil; the confidence is 2 because its sign of depression
10	dark blue; white; traces of brown	N	Y	80% forest; 20% bare land	irregular	n	2	Y	817	38.481652	it shows sign of depression, frozen surface (sign of water), not likely to be tree shadow
11	pale dark blue; traces of white; traces of green	N	Y	40% forest; 60% bare land	linear	N	2	N	817	15.551383	the direction of tree shadow is incorrect
12	pale grey; traces of dark blue	Y (has a buffer to forest)	Y	bare land	irregular	N	2	N	817	51.321948	this looks like a partially frozen pool; however, it could also be exposed bedrock
13	pale dark blue; tint of white	N (but has a white buffer)	N	20% trees; 80% exposed bedrock	crescent	N	2	N	817	18.377889	this is adjacent to a tree that could make this site a shadow. However, the slightly different color between tree shadow and the pool color give this pool a mapping confidence of 2
14	pale dark blue	N	N	80% bare land; 20% forest	oval	N	2	N	932	6.7369247	this has a confidence of 2 since it does not have a tree to make this pool a possible shadow; in addition, the blur boundary may suggest that this s not an exposed bedrock
15	dark blue; traces of brown	N	N	50% forest; 50% bare land	oval	N	1	Y (subtle)	962	33.153824	it has trees to make this site a shadow; but it is a little bit too big
16	dark blue; a patch of brown	N	N	bare land	irregular	N	2	subtle	962	13.318848	it has trees that could make this site a shadow; however, the shape as well as the brownish dot in the middle of the site make this PVP suspicious
17	dark blue; white; traces of green	N (but has a brown buffer to adjacent forest)	Y	bare land	irregular	N	2	N	982	35.191087	It still have trees around, therefore could possibly be shadow; however, the surrounding trees do not explain the shape and size of the shadow, in addition the white color implies an existence of water
18	dark blue; traces of brown; traces of purple	Y	N	20% forest; 80% bare land	irregular	N	1	subtle	856	41.068926	could be tree shadow; mapped since the size and directions of the shadow cannot be explained by the trees on the image
19	pale black; tint of purple; traces of brown; traces of red	N	N	80% forest; 20% bare land (but very blur, difficult to tell)	round	N	1	subtle	700	7.8877498	it is too blur to tell; it is mapped because it has a subtle depression, and the tree shadow cannot explain the size and shape well
20	pale dark blue; tint of brown	N	N	60% forest; 40% bare land	oval	N	2	N	962	39.842666	lack of reasonable trees to make this site a shadow
21	pale purple-blue; white	N	Y	bare land	irregular	N	2	N	962	32.190389	it could just be accumulation of snow and without a deep-enough depression
22	white; traces of pale purple-blue	N	Y	bare land	oval	N	1	N	962	11.714232	it could be accumulation of snow, but its color seems more concrete than other small patches of snow
23	white	N (has blue boundary)	Y	50% trees; 50% bare land	oval	N	3	N	931	43.280606	its snow color seems concrete therefore suggests an existence of enough water
24	white	N	Y	50% trees; 50% bare land	two small linked oval	N	3	N	931	38.930954	the concrete snow accumulation increase the confidence to 3
25	white	Y	Y	50% forest; 50% bare land (could be dried	round	N	3	N	923	42.513359	the brownish boundary and its location in a large depression make this patch of snow high confidence; however, I si still possible that there is just a pile of snow

				PVP)							
26	aqua; traces of white; traces of blue	N	Y	bare land	round	N	2	N	923	44.680474	not sure what that is, but its color is very distinctive from surrounding landscape
27	white; moderate dark blue with tint of purple	N	Y	50% trees; 50% bare land	oval	N	1	N	904	144.30813	the image has offset in this region; could just be frozen land
28	dark blue	N	N	90% bare land; 10% tree	round	N	4	subtle (on the north-west)	1094	470.87838	it is linked with tree shadow, but it exceed the possible size of shadow far too much, and the direction of the "shadow" is obviously wrong
29	pale dark blue; traces of white	N	Y	60% forest; 40% bare land	round	N	3	Y	775	49.441517	the depression and the pale-ish color make this site very suspicious (the pale color eliminate its possibility of being a shadow).
30	pale dark blue; white (with a tint of red)	N	Y	90% bare land; 10% tree	round	N	2	N	617	25.690675	it is linked with tree shadow, but the direction and the shape cannot be explained by the observed trees;
31	dark blue; tint of brown	N	N	bare land	oval	N	1	N	658	27.222388	the color is distinguishable from tree shadows; it could be exposed bedrock or part of temporary flow
32	dark blue	N	N	bare land	oval	N	1	N	1105	66.60562	its color is different from surrounding tree shadows; it also lacks reasonable trees to provide the right shadow
33	brown; dark blue	N	N	forest	round	N	1	N	776	166.63629	it seems to be on the top of a hill; however, the linear dark blue color suggests a potential water flow; though there is no snow accumulated in this site
34	white; dark blue	N	Y	60% bare land; 40% trees	oval	N	3	Y	834	96.395936	the confidence is between 2 and 3. the boundary of this site is very sharp; its color is similar with tree shadows but there is not tree could explain the shape, size and the location; plus the frozen surface suggest occurrence of water.
35	white; dark blue	N	Y	80% forest; 20% bare land	round	N	3	Y	834	61.810418	it is surrounding by forest; the color is different from tree shadows; the frozen surface suggests water; slightly depression can be observed; could be fed by the high land on the north (about 45 m away)
36	white; purple; traces of dark blue; traces of green	N	Y	60% forest; 40% bare land	irregular	N	3	N	780	161.2074	the high confidence from: purple color, large patch of snow accumulation; the linear blue color within the purple patch (could be water flow); significantly different from trees; flat surface (visual observation)
37	moderate dark blue; traces of white	N	Y (subtle)	60% bare land; 40% forest	round	N	2	N	1179	72.87892	this site is located in a glade and close to a stream; the trees cannot explain if this site is a shadow; however, the lack of depression and the normal color of the rest of the glade prevents this sites from confidence 3
38											
39	deep dark blue	N	N	70% bare land; 30% trees	oval	N	4	N	696	48.389852	it looks like a crack in the earth. Confidence between 3-4. no tree can explain if this is a shadow; shape is suspicious; clear boundary (NOTE: after mapped the site, I compared the site with the aerial photos from other years. This is pretty much a pool; however, on the image, there is offsets, so it may not be completely overlapped with other PVPs mapped from other datasets)
40	dark blue; tint of green	N	N	bare land	oval	N	2	Y	952	153.23414	could just be wet soil. Mapped since there is no tree around; however, the elevation in this area is not very clear, therefore the confidence is between 2 and 3
41	dark blue	N	N	90% bare land; 10% tree	irregular	N	2	N	1023	108.67137	it is almost impossible to be tree shadow (though there are several patches of pale green color, which could be trees) due to its size and shape,
42	moderate dark blue; traces of purple and green	N	N	bare land	irregular	N	2	Y	562	37.110339	the confidence in mapping is based on the depression, traces of white color (which might be snow). It is likely to be a tree shadow though (the size and shape of this patch is similar with the tree shadow on the north)
43	dark blue	N	N	80% bare land; 20% trees	crescent	N	2	Y	517	29.549441	the confidence of 2 comes from the depression (at least looks like a depression); the
44	pale brown; moderate dark blue; tint of purple	N	N	50% forest; 50% bare land	oval	N	2	N	585	64.05291	despite the purple color of the dark color patch on the east, the isolation of the dark color on the east and the pale color that covers the whole area make this site a confidence of 2. however, it could just be bare land.
45	white; moderate dark blue	N	Y	forest	round	N	1	N	828	24.257694	it could just be a temporary puddle
46	white	N	Y	forest	oval	N	2	N	762	30.913596	it is mapped since its shape looks like other mapped high-confidence sites, as well as the snow accumulation; however, there is not further proof that this is a pool or just a patch of snow.
47	pale brown; traces of white; traces of moderate dark blue	N	N	forest	long oval	N	1	N	762	76.384179	could just be exposed bedrock
48	pale dark blue; pale brown	N	N	bare land	oval	N	1	N	816	37.193365	there might be a very subtle depression on the north-east portion of this site, but very subtle. This is mapped in round 1 and when I look at it in round 2, I don't think I might map it now. Instead, I found a site on its north-west direction to be suspicious, and mapped it as site 95
49	moderate dark blue; traces of brown	N	N	bare land	round	N	3	N	705	35.219974	the confidence comes from the lack of surrounding trees 9to give this site dark color), and the subtle light brown boundary make it more suspicious (I did not place "Y" in the brownish boundary section because both light brown and dark brown are brown color).
50	moderate dark blue; traces of brown	Y	Y	70% forest; 30% bare land	irregular	N	3	N	608	38.170711	located in a corner of a glade and has a brownish buffer to the surrounding forest, as well as a patch of white color surface, these make this pool very suspicious; however, it cannot be given a confidence of 4 since there is no concrete proof (given the offset of this set of aerial photo, the pool could also be found in somewhere surround but not the exact mapped site)
51	dark blue; brown; white	Y	Y	70% forest; 30% trail	irregular	N	2	N	697	13.35564	the brownish patch on the east seems to be wet soil; the white patch on the west seems to be snow (so water). They are not mapped independently because they are very close to each other.
52	brown; dark blue; white	N	Y	70% forest; 30% bare land	irregular	N	2	N	620	36.554205	this site include the white patch on the west. The confidence comes from the white patch which could be snow accumulation, as well as the brown glade.

53											deleted during review
54											deleted during review
55	lake blue; pale dark blue; tint of purple	Y (but not exact brown)	N	bare land	oval	N	1	N	819	29.81369	the color is distinctive from surroundings; there is a buffer between the pool and the forest; however, the brighter blue color at the buffer could be exposed bedrock, and this patch could also just be a tree shadow (and the cyan-ish color could come from the bedrock but not water)
56	cyanic blue;	N	N	bare land	oval	N	2	Y (subtle)	819	34.467188	the color is distinctive from surrounding tree shadows; it could be an exposed bedrock, however the subtle depression make this site suspicious (the confidence is more like between 1 and 2)
57	dark blue; a patch of brown in the middle; tint of green	N	N	bare land	irregular	N	1	N	819	29.230817	the confidence of 2 comes from the weird shape: the tree cannot explain the sharp corner on the west (but it seems to be a small tree on the west side of the shadow but kind of dissolved into the bare land brownish color?)
58	dark blue; tint of purple	N	N	70% bare land; 30% trees	irregular	N	1	N	819	28.355013	this site and site 57 are special. One of them is likely to be a pool since their direction of tree shadow is different. Similarly, the shape of this "tree shadow" is very weird and therefore suspicious (because it seems to be a small tree on the south side of the sharp shadow on the east)
59	dark blue; white; patches of brown color	N	Y	bare land	linear (3 linked small pools)	N	3	Y	793	32.071643	these three small linked pools also show a sign of depression
60	same as 59	same as 59	same as 59	same as 59	same as 59	same as 59	3	same as 59	same as 59	14.234902	same as 59
61	dark blue; traces of green; tint of purple	N	N	bare land (tint of green color seems to be low vegetation)	oval	N	3	N	951	38.04758	confidence 3-4. this is not likely to be a tree shadow since there is no vegetation around. It is close to river so may have adequate water sources; however, there seems to be a small stream links this pool to the main stream (therefore this pool could be part of the dried river)
62	dark blue; traces of white	N	N	bare land	oval	N	2	N	951	89.037535	it is linked to the tree shadow on the south. However, it shows a difference in color which makes this site a confidence of 2
63	cyanic dark blue	Y (subtle, but a small buffer to the forest on the north)	n	forest	irregular	N	2	Y	820	101.36481	the color is very different from surroundings; however, the edge seems to be too straight (and therefore suspicious)
64	deep dark blue; tint of purple; traces of white	Y	Y	forest	oval	N	3	Y	692	72.307206	I have a confidence of 4 because I have mapped this pool before; if I didn't know, I probably will map it as 3 to 4 because the depression shows up when I zoom out a little bit. In addition, the brownish border to the forest make this site very suspicious as well.
65	deep green; dark blue; tint of brown	Y	N	bare land (wet soil)	oval to triangle	N	1	Y	674	118.74773	it seems to be in a depression of wet soils; the confidence is as low as 1 because it might have permanent outlet to the lake
66	deep dark blue; tint of purple	N	N	60% forest; 40% bare land	triangle	N	1	N	674	53.527852	it is mapped because the shape of this dark patch is too weird, and this cannot be explained by the surrounding trees; however, I only gave it a confidence of 1 because the edge if too straight (so this could be image quality problem)
67	deep dark blue; tint of purple; traces of green	N	N	bare land	irregular	N	2	N	727	193.46334	the surrounding trees cannot explain the shadow size/shape; the undulating surface makes it more suspicious
68	purple; deep dark blue	N	N	50% forest; 50% bare land	triangle	N	2	Y	774	91.062525	the color (purple, reddish color) and the present of depression make this site special; however, the low confidence is because the triangle shape is too sharp, therefore this site could be a result of image distortion…?
69	dark blue; patches of brown; tint of purple	N	N	70% forest; 30% bare land	square	N	2	N	944	64.238948	the confidence of 2 comes from the difference of color (to tree shadows) and the shape (that cannot be explained by the surrounding trees)
70	white; traces of brown; tint of dark blue	N	Y	50% forest; 50% bare land	oval	N	3	Y	650	111.32492	this site is adjacent to forest; partially covered by tree shadow; very suspicious because the shape of the frozen snow (oval shape); however, cannot be sure if this just snow or actually could become a pool
71	dark blue; purple-red at boundary; white	Y	Y	60% trees; 40% bare land	irregular	N	4	Y	817	332.25224	this must be a pool, at least; it may (or may not) be a vernal pool, and this depends on whether the black lines that linked to this site are permanent flows or just gullies.
72	pale dark blue; traces of green; tint of purple	N	N	50% forest; 50% bare land	irregular	N	1	N	817	173.47291	this seems to be wetland or something similar because of the color and the shape that cannot be explained by surrounding trees; however, this site is too blur to tell if it is really a patch of wet soil or just shadows
73	dark blue; dark red; purple	N	N	80% bare land; 20% trees	oval	N	3	N	985	79.880799	this site is particularly strange because of the small patch of red color in the middle of the pool (distorted); however, the shape and the tint of purple color made this site very suspicious
74	deep dark blue; white	N	Y	bare land	irregular	N	4	Y	1057	890.6022	it must be something; it is too large to be tree shadow, and the deep color seems to be dried pool bed; the only concern is if there is any permanent inlet/outlet
75											out of boundary
76											deleted during review (bedrock)
77	white; light purple; dark blue	N	Y	70% bare land; 30% trees	round	Y	2	Y	863	114.2491	the small patch of frozen surface, purple color, and the irregular shape all bring the confidence level to 2 (but no more, because the image is too blur to tell if there is a pool)
78	cyan; pale grey	N	N	60% bare land; 40% exposed bed rock	round	N	1	N	863	64.713792	this is mapped because the color (the cyan color) is too strange, but probably just a people?
79	dark blue; white; traces of green	N	Y	60% forest; 40% bare land	round	N	3	N	817	62.744562	the confidence of 3 is because there is really no tree can explain this dark color patch and the white color suggest accumulation of water

80	dark blue; tint of black; tint of cyan	Y (deep brown dissolved into light brown bare land)	N	20% trees; 80% bare land	oval	N	1	N	806	56.11439	there is a tree can explain this patch of dark color; however, the cyan color is suspicious
81	pale dark blue; tint of purple; traces of green	Y (deep brown dissolved into light brown)	N	forest (with a buffer of bare land)	oval	N	3	N	806	31.748294	the gradient of brown color surround the site increase the confidence
82	white; traces of dark blue	N	Y	20% trees; 60% bare land	round	N	1	N	817	28.9317	it is mapped due to white snow, which seems to be more concrete than the surrounding snows and it is located in a fairly bare environment
83	white; patches of pale dark blue; traces of green; traces of brown	Y	Y	70% forest; 30% bare land	oval	N	3	N	708	67.886525	the confidence is between 2 and 3. the brownish buffer between the pool and the forest make it likely to be a pool; it is obviously not a shadow; the accumulation of snow implies the existence of water; however, the pale blue color could also be exposed slate
84	deep brown; patches of black	N	N	forest	oval	N	1	N	840	85.221401	it is more likely to be wet soil; its deep brown color is very different from surrounding though
85	white; moderate dark blue; tint of green	N	Y	forest	round	N	3	Y	649	55.554724	the dark blue color in the middle of the white snows make this site possibly a water body with partially melted snows. It is located close to trees so if it is a pool, it will be sufficient in decomposition and have tree shadowing that could supply a favored nutrient and temperature for amphibians (or not?)
86	dark blue; deep brown	Y	N	forest	oval	N	3	Y	811	47.984751	it is a depression with a patch of dark color in the middle (could be water bodies); it is also part of a flow system (can see a gully links this site to a patch of snow on the north-west, site 87)
87	white; traces of pale dark blue	N	Y	80% forest; 20% bare land	round	N	2	N	594	49.723263	it seems to be linked with site 6 via a gully (or a trial?)
88	white; blue with tint of purple	N	Y	70% bare land; 30% forest	oval	N	3	N	713	19.876305	its shape, color, frozen surface, and (probably melted snow) blue color at the boundary make this site suspicious. However, it is not given a 4 confidence because it could also be exposed bedrock with accumulated snow.
89	dark blue; tint of purple	Y	N	bare land	oval	N	2	N	887	11.380292	it is located in the middle of a patch of brown color; it is also in the middle of two mapped sites (40 and 41), therefore it could be a small pool or part of a large pool that links all 40, 41 and 89.
90	dark blue; brown	N	N	bare land	round	N	1	Y	771	59.766373	there is no sign of water; however, when I zoomed out, this is a very obvious depression (and that's why this site is mapped). It could also be image distortion.
91	a small patch of dark blue; light brown	Y	N	bare land	round	N	2	N	771	71.496999	this is mapped since the light brown color is so obvious when I zoomed out. Also, the dark blue color in the middle of the light brown patch makes this site more suspicious.
92	dark blue	N (but surrounded by whit color)	N (probably the white boundary is snow?)	bare land	round	N	3	Y	683	62.975622	the dark color located in a large patch of white color make this site suspicious. It is likely the white color is frozen water or something similar. In addition, the lack of occurrence of trees makes this site even more suspicious. However, it is not granted a 4 confidence due to the low resolution of the image (so I cannot 100% sure if this site is not something else)
93	black; traces of brown	N	N	90% bare land; 10% tree	irregular	N	1	N	687	39.127194	there is a little bit frozen land at the edge, and the shape and the size is slightly suspicious as a shadow; however, it still could be a tree shadow.
94	brown; a small patch o blue in the middle; a small patch of white	N	Y (subtle)	forest	round	N	1	N	762	71.586369	it seems to be a glade with a small patch of blue color in the middle and a patch of snow at the edge. When I zoomed out, this site kind of stands out therefore it is mapped.
95	moderate dark blue; brown; tint of purple	Y	N	bare land	oval	N	2	N	816	83.632627	the brownish buffer and the oval shape of this site make it possibly to be a pool. However, there is a patch of green color on the south so the confidence is limited at 2.
96	pale cyan blue; moderate dark blue	N	N	bare land	round	N	2	N	705	13.346369	the confidence comes from the identifying color, but there is no further proof that this site is a pool
97	moderate dark blue; pale green; white	N	Y	50% forest; 50% bare land	irregular	N	2	N	697	57.105488	this site is close to wet soils or probably wetlands; it is also shows a subtle depression (and therefore it is mapped); however, it could also be exposed bedrock
98	white; traces of dark blue	N	Y	forest	linear	N	2	N	697	85.920163	it does not looks like a wetland or a pool, and it is mapped due to the large area covered by snow, which suggests a potential sites of water accumulations.
99	moderate dark blue	Y	N	forest	oval	N	2	N	697	33.420987	its shape and color, as well as the brownish buffer to the forest, make this site suspicious; it is not mapped a higher confidence since there is another site (51) mapped very close to this site (5m) so they could be the same pool)
100	moderate dark blue; (in a lighter color depression)	N	N	70% forest; 30% bare land	small oval	Y (subtle)	2	Y	613	34.35397	it is located in a depression (from visual observation); however, it could also be exposed bedrock
101	saturated blue color	Y	N	forest	oval	N	1	N	838	22.055309	the color of this site is very special; however, the color does not seems like water
102	pale dark blue	Y	N	90% bare land; 10% tree	linear oval	N	1	N	858	68.091476	thought the color is weird, it still could be a depression since it is located in a patch of light brown; however, it could just be exposed bedrock
103	deep dark blue; traces of pale cyan	N	N	bare land	oval	N	3	Y (very subtle)	793	91.378367	this site is missed at the first round. It is a large patch of dark blue color that cannot be explained by the surrounding trees. In addition, the pattern like "crack" on the ground make this more suspicious

104	white; tint of purple; tint of green	N	Y	80% forest; 20% bare land	oval	N	2	N	803	57.185728	it seems to be forest; however, if it is a tree, then the ice would be frozen on the top of a tree, which is not very likely in this region; however, the photo is too blur to tell if it is a pool or not
105	deep dark green; traces of purple	N	N	60% forest; 40% exposed bedrock; a tree in the middle	crescent	maybe	2	Y (very subtle)	674	115.3183	this site is very strange because there is a tree right in the middle of this site. However, the surrounding trees cannot explain such a deep and even colored patch; the immediate bedrock could also be a source of water (there might be cracks on the bedrock)
106	pale dark blue; deep dark blue	N	N	80% bare land; 20% trees	triangle to oval	N	2	Y	674	27.016378	the triangle size is very strange; other than this, it seems to be a depression, and the dark color may suggest wet soil.
107	dark blue with a tint of purple	Y	N	forest	oval	N	2	Y	806	40.339694	this site is very suspicious (wet-soil like color; buffer to the forest); but the trees are very disturbing, and therefore this site could just be wet soil
108	dark blue; a tint of green	Y	N	forest	round	N	1	N	806	62.630821	the dark blue spot could be remaining water; but the image is a little bit distorted; also, the pool is too small (diameter is about 1.6m) to this scale, and could be a tree shadow
109	brown; a tint of dark blue; a tint of purple	N	N	bare land	round	N	1	Y	944	37.693853	this is a depression, no deep color (which suggests no remaining water); could be wet soil; however, such a depression in the middle of a bare land seems to be very suspicious
110	dark blue	Y	N	80% forest; 20% bare land	oval	N	2	N	696	12.198408	the shadow direction, if this is a shadow, is wrong; the buffer to eh forest enhance the suspiciousness
111	white	N	Y	60% forest; 40% bare land	oval	N	2	Y	817	104.20942	seems to have a little bit depression; it is a very strange place to have snow accumulation especially together with a dark blue boundary and some trees; in addition, this site is not likely to be tree shadow
112	pale green	N	N	forest	round	N	1	Y	817	48.249656	there is nothing looks like a pool but the sign of depression
113	pale dark blue	Y	N	60% bare land; 40% forest	square	N	1	Y	817	34.224268	this is mapped because there is a depression (and a triangle shape depression); and there is a wide buffer to the forest (which make this site looks like locate in a depression)
114	brown; pale dark blue	N	N	70% bare land; 30% forest	oval	N	1	Y	817	44.014599	this site is mapped for its visually obvious depression (but it is very strange why there is no snow accumulation? If it is not a depression then what is it)

Table 10: Records of 2010 Satellite Google Map

ID	color	brownish boundary	surrounding	shape	wetland texture	water remain	confidence	depression	area (m^2)	others
1	black, traces of green and brown	N	forest	oval	N	N	1	N	21.247247	might be tree shadow
2	black; traces of brown	N	forest	oval	N	cannot tell	2	N	51.773788	have a white spot at the middle of the pool, so might be a pool
3	black; traces of brown	N	forest	linear	N	cannot tell	1	N	24.040286	might just be a tree shadow, but it is adjacent to a brook
4	dark blue	Y	barren land	oval	N	Y	2	Y	17.169709	it seems to be located in a barren land, which most vernal pools are likely to happen. However, it still might be tree shadow.
5	dark blue; traces of brown	Y	barren land	oval	N	Y	2	Y	15.51932	could be a partially dried pond. It might be tree shadow, but I failed to find the tree.
6	black; brown	N	forest	oval	Y	N	1	N	208.28086	it is more likely just a glade, but brownish glade
7	black; traces of purple	N	forest	round	N	Y	2	Y	27.952273	the boundary seems darker than the middle, therefore suggests a depression. It seems to have inlet/outlet, but regarding the case of EVP 10, which has sign of outlet as well, this site still might be a PVP.
8	black; traces of green	N	forest	square	N	cannot tell	1	N	35.556951	it seems to be in the middle of a trail, so hard to tell if it is a pool or more likely just a tree shadow.
9	dark blue; traces of purple	Y	80% grassland; 20%forest	long oval	N	Y	3	Y	47.533715	very likely to be a pond; it seems have outlet, but it could also just is tree shadow
10	dark blue; dark green; light brown	N	80% grassland; 20% forest	oval	N	cannot tell	2	Y	18.339602	the boundary is darker than the central, therefore could be a depression. However, it could also just be a tree shadow. The color of this site is slightly different than tree shadows as well, because this site has a trace of light brown and green.
11	dark blu; traces of brown; traces of red	N	forest	round	N	cannot tell	2	N	84.198869	this may just be a tree shadow, but the shadow direction is suspicious
12	dark brown; black; traces of light brown	N	70% forest; 30% grassland	oval	N	Y	2	might be	49.602885	it's not very clear and could be a tree shadow. However, the traces of reddish color make this sight a possible pool
13	black; traces of red	N	forest	oval	N	N	1	N	29.455989	might be a tree shadow
14	dark blue; traces of brown	Y	bare land	square	N	Y	3	Y	26.507605	the shape is weird. However, it seems to be a depression and show signs of cracks in the earth.
15	black; brownish red; traces of green	N	forest	round	N	cannot tell	1	N	420.23017	it looks like something, may be tree shadow
16	blue; traces of green	N	50% grassland; 30% forest; 20% bare land	oval	N	Y	2	N	71.985001	the color make this site special. But it could also be exposed bedrock.
17	dark blue	N	80% bare land; 20% grass land	crescent	N	Y	2	Y	25.951346	the shape is very strange, especially the clear cut of its boundary, which makes it suspicious
18	dark blue; brown; purple	N	forest	irregular	N	N	1	N	57.056951	it might be tree shadow, or it could be dried pond. It seems like wet soil
19	dark blu3	N	80% bare land; 20% forest	round	N	Y	1	N	21.397381	it is very unclear, and there is a tree that could provide tree shadow on this site. However, the shape of the "shadow" is suspicious.
20	black; traces of brown; traces of red	N	70% forest, 30% bare land	irregular	N	N	1	N	115.64453	it is located in a ground of trees, so might be a tree shadow.
21	dark blue; traces of brown	Y	forest	irregular	N	Y	2	cannot tell	7.9009443	it is very small, has a brownish dot in the middle. The pattern of trees and shadow around does not make sense so it is mapped.
22	dark blue; traces of green; traces of brown	N	grassland	linear	N	cannot tell	1	N	119.80395	it might be tree shadow, however its pattern is suspicious
23										wrong, bedrock
24	dark blue; traces of brown	N	70% bare land; 30% forest	round	N	cannot tell	2	N	32.886433	it could be a tree shadow; however, the direction of shadow is suspicious
25										wrong, bedrock
26	dark blue	N	grassland	round	N	cannot tell	2	N	33.962485	it belongs to a tree shadow, but shows a much deeper color and there is no reason could explain that. However, it still could be a tree shadow on a different surface (which makes it seems darker).
27	dark blue; traces of green	Y	70% bare land; 30% forest	crescent	N	cannot tell	2	N	38.147553	it could be a tree, and the grey-blue patch right on its north could be a pool if this site is proved to be a tree.
28	black	N	bare land	round	N	cannot tell	1	N	11.088751	it is part of tree shadow; it is mapped since the shape of the shadow is strange.
29	dark blue; traces of green; traces of brown	N	60% grassland; 40% forest	oval	N	cannot tell	2	Y	125.85601	it is particularly weird since it is likely to be a tree shadow but its border shows signs of depressions. In addition, there is limited tree shadow on the eastern part of the trees.
30										deleted during elimination - bedrock
31	brown; black	Y	forest	round	Y	cannot tell	2	N	232.64228	it may just be a glade

32	brown; black	N	forest	irregular	Y	cannot tell	1	N	62.043125	it may be a dried PVP, but it's too small and unclear. Difficult to tell.
33	dark blue; traces of brown	N	70% forest; 30% grassland	round	N	cannot tell	1	N	47.397079	it is picked out due to the weird shape. But it is very likely to be tree shadow as well.
34	dark blue; traces of green; traces of brown	N	forest	irregular	N	cannot tell	1	N	5.0360302	it is likely to be a tree shadow but is picked since the surrounding trees cannot expain the size and color.
35	black; traces of green	N	50% forest; 50% bare land	irregular	N	cannot tell	1	N	42.861627	very likely to be tree shadow; however the sharp shape of this patch of black color makes this site suspicious
36	dark blue; traces of brown	N	forest	round	N	cannot tell	2	Y	25.920624	it seems to have a depression, though that might just because the trees next to the mapped sites have a lighter color.
37										wrong, shadow
38	dark blue; traces of brown	N	70% bare land; 30% forest	linear	N	N	1	N	6.4169903	could be tree shadow. What made it mapped is because it does not have a tree that could possibly creates the shadow.
39	Black; traces of green	N	forest	oval	N	cannot tell	1	N	27.24456	it is very likely to be a tree shadow but given that it is surrounded by forest, the nice shape of oval make this site suspicious
40	dark blue; traces of green; traces of brown	N	forest	oval	N	cannot tell	2	Y	28.179587	it seems to have a slight depression, and the trees around do not make sense of this small pool. But it still could be tree shadow since tree color could be very light sometimes.
41	dark blue; pale-green; traces of brown	N	forest	round	N	cannot tell	1	N	54.74832	it is picked up since in the middle there is a small black dot, which might suggest a small PVP in the middle of a depression
42	dark blue; traces of green; traces of brown	N	exposed bedrock with little vegetation cover	long linear	N	Y	1	N	14.183695	it could be shadow; it is mapped due to its similarity with site 37

Table 11: Record of Satellite Bing Map

ID	color	shape	area (m^2)	% surrounded by forest	other surroundings	brownish boundary	depression	water remain	crack on earth	timber / bridge	wetland texture	confidence	wetland?	others
1	black	round	11.38746	1	none	N	might be	cannot tell	N	N	N	1	N	might be tree shadow, but the direction seems to be wrong
2	blue	irregular	159.9096	1	none	N	might be	cannot tell	N	N	N	1	N	this might be a glade, but there is too much tree shadow
3	black	oval	20.07679	1	none	N	might be	cannot tell	N	N	N	1	N	might be tree shadow on a glade
4	blue	oval	36.36538	0.8	bared land, 20%	Y	might be	cannot tell	N	N	N	1	N	likely to be tree shadow
5	black	irregular	32.94007	1	none	N	might be	cannot tell	Slightly	N	N	2	N	it seems to link brooks (but unclear), so give a confidence of 40-60%
6	blue; traces of brown	round	20.23829	1	none	Y	N	cannot tell	N	N	N	2	N	it seems to link brooks (but unclear), so give a confidence of 40-60%
7	black; traces of purple and brown	irregular	48.38981	1	none	N	N	cannot tell	N	N	N	1	N	it might just be a tree shadow
8	black	irregular	10.68427	1	none	N	N	cannot tell	N	N	N	1	N	likely to be tree shadow
9														deleted during review
10	black; green	round	23.89992	0.7	grassland	N	N	cannot tell	N	N	Y, because of the green color	2	N	it seems like a tree shadow, but the green patch in the middle is suspicious
11	blue; traces of green	round	40.64748	1		N	N	N	N	N	N	1	N	the wrong direction of tree shadows
12	black; graces of brown	irregular	20.40344	0.7	bare land	Y	N	cannot tell	N	N	N	1	N	likely to be tree shadow
13	blue; traces of green and brown	irregular	15.99767	0.4	grassland, bare land	N	a little bit	might be	N	N	N	2	N	likely to be tree shadow
14	black	oval	8.6967	0.7	bare land	N	N	cannot tell	N	N	N	1	N	might be a tree shadow, but the direction is incorrect
15														deleted during review – omission error
16	black; graces of brown	irregular	78.2895	1	none	N	Y	cannot tell	N	N	Y	3	N	the depression is suspicious
17	black	oval	12.51393	1		Y	N	cannot tell	N	N	N	1	N	might be tree shadow
18	brown	oval	41.10675	1		N	N	N	N	N	N	1	N	
19	blue; traces of brown	irregular	16.49018	0	bare land, grassland	Y	Y	Y	Y	N	N	4	N	very likely to be a pool, water body in glade
20	brown	oval	105.4394	1		N	Y	might be	might be	N	N	2	N	seems to have a crack
21	black; graces of green	irregular	13.06151	0	bare land	Y	Y	might be	might be	N	N	3	N	it is suspicious since it is located at the middle of a bare land
22														deleted during review – tree shadow from the tree on the south-east
23	dark blue; patches of green	irregular	221.9247	0.95	grassland	N	cannot tell	cannot tell	N	N	N	2	N	the tree shadow is weird, and the trees in the middle are not hovered by shadow at all
24	black; tint of purple; traces of green	long oval	60.05243	1		N	Y	very likely	N	Y	N	2	N	it could be tree shadow (because of the direction of the aerial photo)
25	dark blue; traces of green	irregular	48.18994	0.5	bare land, grassland	N	N	cannot tell	N	N	N	1	N	the shape of the dark color seems to be really weird. It seems like tree shadow but they are all linked together
26														deleted during review
27														deleted during review
28	blue; traces of brown and green; tint of purple	oval	98.69303	1		N	Y (subtle)	Y	N	N	N	2	N	likely a shadow; however, unlike the glades on the north, this patch does not appear to be an obvious glade therefore still could be a pool
29	dark blue; cyan-green	irregular	56.63849	1		N	N	N	n	n	n	2	n	the cyan-ish oval on the east is suspicious; the shadow pattern does not consistent with the shadows in the surrounding landscape (on the east or the west)
30	dark blue; tint of purple	round	19.52575	0.9	bare land	N	N	cannot tell	N	N	N	1	N	seems to be tree shadow

31														deleted during review
32	dark blue; tint of purple; traces of green	irregular	30.59633	0.5	grassland	Y	Y	Y	N	N	N	3	N	too large to be a tree shadow; may link with the lake
33														deleted during review
34	green; traces of brown; pale black	oval	43.31537	0.8	possibly grassland	N	N	N	N	N	N	1	N	it is likely tree shadow; however, there still could be a pool underneath the shadow (since it is not like those shadow covered glades which the boundary of the shadow is very obvious)
35	black; tint of purple and green	oval	31.80515	0.7	grassland / wetland	N	Y	Y	N	N	N	2	N	underneath the shadow, the cyan patch may be a pool; the brown patch on the west could be partially dried pool (but could also be trees)
36	blue; traces of green	oval	27.58924	0.5	grassland	N	Y (subtle)	Y	N	N	N	2	N	wrong shadow direction; close to the lake; but still could be the shadow of the tree on the south-east
37														deleted during review
38	brown; traces of blue, green and white	round	18.4239	1		N	N	N	N	N	N	2	N	seems to be on or close to the stream that connects the two water bodies (on the west and on the east); suspicious brownish color (which is distinctive in the surrounding landscape); however, it could just be a tree
39	brown; patches of blue	round	27.89909	1		Y	Y	Y	Y	N	Y (subtle)	3	N	very likely there is a pool; but may link with lake; the brownish color is likely dried pool
40														deleted during review – tree shadow (from south-east to north-west)
41	blue; tint of brown and green	irregular	619.2699	1		Y (subtle)	N	Y	N	N	N	4	N	must be a pool; but may have in/outlet to the lake
42	black; traces of green and grey	linear	47.91986	0.4	bedrock	Y (subtle)	Y	Y	N	N	N	2	N	could be tree shadow (from two trees) but the depression makes this site suspicious
43	green; traces of brown; blue	oval	73.93939	1		N	Y (subtle)	N	N	N	N	1	N	looks like light color trees, but still could be a partially dried pool
44	brown; green; dark blue	irregular	226.7105	1		N	N	Y (maybe)	N	N	Y	3	(maybe)	coarse wetland-like texture; not likely trees; the blue color patches could be water remains; however, too blur to be sure
45														deleted during review – shadow
46	dark blue; traces of green	linear	17.48755	0	grassland	Y (subtle)	N	N	N	N	N	2	N	too blur to be very confident; very likely to be a water body on grassland, but may link with lake and may be too small; cannot find trees to make this site a shadow
47	brown; patches of black; tint of purple	round	64.9781	0.7	rock	Y	Y	Y (maybe)	N	N	Y (subtle)	3	N	water-like color; could be partially dried pool (especially the patches of blue color); but may link with lake
48														deleted during eliminating – obvious wetland
49														deleted during review – tree shadow
50														deleted during review – a tree
51														deleted during review – tree shadow
52	brown; dark blue	oval	0.364466	1		Y	Y	Y (maybe)	N	N	N	2	N	surrounded by trees with possible water remain in the center; however, it is too small and could be a tree (due to image quality and distortion)
53	dark green; pale black; tint of brown	oval	7.501583	1		N	Y	N	N	N	Y (subtle)	2	N	not completely a shadow; the cyan-like green could be a tree or a wetland-texture water body
54	brown; dark blue; traces of green	irregular	14.68563	1		N	Y	N	N	N	Y	2	N	wetland texture but no sign of water
55														deleted during review – too small; likely a shadow from stone
56														deleted during review – tree shadow
57														deleted during review – very likely a tree shadow
58														deleted during review – very likely a tree shadow
59														deleted during review – very likely a tree shadow
60														deleted during eliminating - bedrock
61	dark blue; tint of brown	oval	4.689423	1		Y (subtle)	N	cannot tell	N	N	N	1	N	it looks like a tree shadow; however, it has a tint of purple (which is different from the surrounding tree shadows)
62	dark blue; tint of purple and red	round	68.90091	0.3	bedrock	N	Y	Y	N	N	N	4	N	it is almost sure this is a pool (different color from surrounding tree shadow plus depression and purple color)
63	dark blue; traces of white and green	round	31.91463	0.7	rock	Y	Y	Y	N	N	N	3	N	the round shape depression make this very likely a pool; unless it is the tree shadow from the tall tree on the south-east

64	dark blue; tint of cyan; patches of brown	irregular	17.95258	1		N	N	N	N	N	N	1	N	likely a tree shadow, but seems to be a little bit too big; the gradient of color (brown, blue and green) makes this site suspicious
65	brown; traces of green and dark blue	long oval	367.7339	0.3	bedrock	N	N	N	N	N	Y	3	Y	wetland, but it still could be a pool (given the size: 500 sq m)
66	brown; dark blue (as shadow)	oval	45.37836	1		N	Y	N	N	N	N	2	N	it is partially covered by tree shadow, there might be some water underneath the shadow; coarse wetland texture; however, no sign of water remain
67														deleted during eliminating – obvious wetland
68	brown; tint of red; patches of dark blue and green	oval	59.97931	1		N	Y	N	N	N	N	3	N	it is more like a coarse-texture glade, not a shadow; it could be wet soil because there is no significant water remain
69	brown; traces of green; dark blue	irregular	170.7722	1		N	Y (very subtle)	Y (maybe)	N	N	Y (subtle)	3	N	wrong direction of the "shadow" on the west (therefore this blue patch could be water); brownish coarse wet land texture makes this site suspicious; however, the brownish color could be trees (which cannot be determined from this image due to image quality)
70														deleted during review – tree shadow (from the shadow on the south-east)
71														deleted during review – bare land and two small patches of tree shadow
72														deleted during review – tree shadow
73	dark blue; traces of green	oval	13.92585	0	grassland	N	N	cannot tell	N	N	N	1	N	it seems to be the shadow of the tree on the south-east; however, the image is too blur to tell if that is a tree or grassland
74														deleted during review
75	dark blue; tint of green and pale grey	long oval	29.14468	0	bare land / rock	Y (subtle)	N	cannot tell	N	N	N	1	N	not very alike a tree shadow (given the size and gradient); however, there is a line of trees on the south-west, which could possibly explain this "shadow"
76	dark blue; tint of purple	long oval	12.74327	0.7	grassland	Y (subtle)	N	cannot tell	N	N	N	1	N	very likely a tree shadow; however, cannot identify the trees (that could possibly provide this shadow) clearly; the purple-ish tint is suspicious as well
77	dark blue; patches of pale brown	oval	13.93095	0.7	possibly grassland	N	Y (subtle)	cannot tell	N	N	N	1	N	it looks like a tree shadow; but it has several patches of white color (these could be stones, which are usually found around puddles
78														deleted during review – tree shadow
79	dark blue; tint of purple; patches of green	crescent	15.69391	0.7	grassland	N	N	N	N	N	N	1	N	likely a tree shadow, but seems too large; the green color on the west could be a tree or dried pool
80	pale dark blue; a patch of white; traces of green	oval	9.144869	1		N	Y (subtle)	Y (maybe)	N	N	N	2	N	it has distinctive purple color (unlike the tree shadows in the surrounding landscape); however, there is no obvious water remain
81														deleted during review - shadow
82	dark blue; a patch of white; traces of brown	oval	8.809041	0.4	grassland	Y (subtle)	Y (very subtle)	Y (maybe)	N	N	N	1	N	it could be a tree shadow; but the patch of light green color make this site suspicious; the pale green on the west side could be wetland
83	dark blue; tint of brown; tint of green	oval	41.00958	0.7	grassland	N	Y (subtle)	Y (maybe)	N	N	N	2	N	this site includes tree shadow; however, the green-dark blue patch on the east is suspicious (not like a normal tree shadow)
84	dark blue; traces of green; tint of purple	oval	202.8506	1		N	Y	Y	N	N	N	3	N	it is very likely a pool; but could have link with the lake; or it could just be a glade that is covered by tree shadow
85														deleted during review – tree shadow
86	dark brown; traces of green; tint of blue	irregular	589.4225	0.8	bare land / grassland	N	Y	Y (very likely)	N	N	Y	4	Y	very likely a wetland; regarding the site, it could disappear sometime during the year
87	brown; tint of blue; traces of green	irregular	362.8225	1		N	Y	Y	N	N	Y	4	Y	very likely a wetland; regarding the site, it could disappear sometime during the year
88	brown; tint of green; dark blue (shadow)	oval	453.4319	1		N	Y (subtle)	Y (maybe)	N	N	Y	4	Y	very likely a wetland; seems a little bit too dry though
89	dark blue; traces of green; tint of purple	irregular	13.87312	0.8	bare land	N	N	N	N	N	N	1	N	very likely a tree shadow; but the boundary seems too straight on the north side and makes this site suspicious
90	dark blue; patches of green	crescent	39.35818	1		N	Y (subtle)	Y (maybe)	N	N	Y (subtle)	2	N	may not be a shadow (not on the right direction and not the right size); the pale and brownish color, and the coarse texture seems suspicious
91	green; deep green; dark blue	round	8.148777	1		N	Y	N	N	N	N	2	N	the deep green color is suspicious; however, this site could be just a tree
92														deleted during review – tree shadow

93	brown; traces of dark blue and green	oval	22.0859	0.8	rock	N	Y	N	N	N	N	1	N	could just be deep color soil or wet soil; however, no sign of water remain
94	dark blue; traces of green	round	46.93108	1		N	N	N	N	N	N	1	N	it is very likely a tree shadow; but kind of suspicious because of the patches of green color within the site
95	dark blue; brown	oval	35.54408	1		N	Y (subtle)	N	N	N	N	1	N	it is likely a shadow; but the patch of brown color in the middle makes this site suspicious
96	dark blue; tint of brown and green	irregular	40.52373	1		N	N	Y (maybe)	N	N	N	2	N	it is very alike a tree shadow; what makes this site suspicious is the possible in/out let and the brownish color on the south
97														deleted during review – tree
98														deleted during review – tree shadow
99	brown; dark blue	irregular	231.4097	1		Y	Y	Y	N	N	Y	4	Y	obviously a wetland; may link with site 88 and site 100; probably can dry periodically
100	brown; patches of green and dark blue	oval	49.12989	1		N	Y (subtle)	N	N	N	Y (subtle)	3	N	seems to link site 88 and site 99; brownish color could be wetland; however, lack of significant water remain
101	dark blue; patches of white and green	irregular	104.9041	0.7	grassland	N	Y	Y	N	N	N	4	N	obviously a pool; may have in/outlet
102	dark blue; tint of green and pale grey	irregular	136.3322	0.7	grassland	N	N	N	N	N	N	1	N	the greenish color makes this site more likely a tree shadow; it is mapped because it may have puddles underneath the shadow (given the surroundings)
103														deleted during review – tree
104														deleted during review – tree shadow
105														deleted during review – tree shadow
106	dark blue (traces of green and white)	irregular	368.1209	1		N	Y	N	N	N	N	1	N	very likely a cluster of tree shadows; however, this site seems a little bit "deep" so it may have water bodies or wet soil at the bottom
107	brown; tint of green; dark blue (shadow)	irregular	205.8936	1		Y (subtle)	Y	Y (maybe)	N	N	Y	4	Y	obviously a wetland
108	dark blue; traces of green	oval	32.786	1		N	Y (very subtle)	Y (maybe)	N	N	N	1	N	very likely a tree shadow (from both direction and size); however, the brownish color on the north-west makes this site a little bit suspicious
109	dark blue; traces of brown	triangle	5.999655	0.2	bare land / wet land	N	N	Y (maybe)	N	N	N	1	N	possibly part of a large wetland; but the site itself seems to be the tree shadow from the tree on the south
110	dark blue	irregular	5.157987	0.7	bare land / wet land	N	N	Y (maybe)	N	N	N	1	N	likely a tree shadow or part of a large wetland; but cannot fully identify the trees that provide the shadow; may link with site 111
111	dark blue	round	1.468123	0.4	bare land / wet land	N	N	Y (maybe)	N	N	N	1	N	likely a tree shadow or part of a large wetland; but cannot fully identify the trees that provide the shadow; may link with site 110
112	dark blue; tint of purple	oval	7.365567	0	bare land / wet land	N	N	Y (maybe)	N	N	N	1	N	possibly part of a large wetland; but the site itself seems to be the tree shadow from the tree on the south
113	dark blue; traces of green	oval	5.990174	0.6	bare land / wet land	Y	Y (very subtle)	Y	N	N	N	3	N	likely a pool as part of a large wetland; the wetland texture on the west make this site suspicious; however, still could be a shadow since there is a tree on the source (which could possibly provide the shadow)
114	green; tint of dark blue; tint of white	irregular	96.00294	0.8	rock / bare land	N	N	Y (maybe)	N	N	Y	3	N	coarse wetland texture but no obvious sign of water; the blue color on the south-west could be water but also could be a tree shadow
115														deleted during review – tree and tree shadow
116														deleted during review – tree shadow
117	pale blue; green	triangle	123.0124	1		N	Y	N	N	N	Y (subtle)	2	N	it has a coarse texture, which looks like a wetland; however, it is so dry and flat, and therefore more likely a bare land (with deep color bedrock underneath) or just deep color soil
118	dark blue; tint of purple	oval	8.217011	0.4	bare land	N	Y (very subtle)	Y (maybe)	N	N	N	1	N	very likely a shadow (on the right direction with reasonable size); however, the purple-ish color and the slight depression makes this site suspicious
119	dark blue; traces of green	oval	9.964158	1		N	Y (subtle)	Y (maybe)	N	N	N	1	N	it is most likely a tree shadow; however, it is mapped because it seems to be on the bottom of the trees (the white color are likely tree bodies), which makes this site suspicious, especially when look at the tree shadow on the east, there are rarely shadow on the east or at the bottom of a tree
120	dark brown; traces of pale grey and green	irregular	182.8061	0.8	bare land	N	Y	N	N	N	Y (subtle)	3	N	more likely is part of a large wetland or bare soil; lack of significant water remain; however, a bare land seems to be suspicious when there are all trees around
121	dark brown; traces of pale grey and green	irregular	1176.802	0.9	bare land	N	Y	N	N	N	Y (subtle)	3	N	more likely is part of a large wetland or bare soil; lack of significant water remain; however, a bare land seems to be suspicious when there are all trees around
122														deleted during review
123														deleted during review

124													deleted during eliminating – obvious wetland
125													error
126	pale black; tint of brown; traces of green	round	19.96924	0.7	grassland	N	N	might be	N	N	N	2	N	it seems have low land around, therefore more likely to be a VP
127	black; traces of green	round	7.646544	0.3	grassland	N	N	might be	N	N	N	2	N	it seems have low land around, therefore more likely to be a VP
128	dark blue; traces of brown	oval	28.61429	0.7	grassland, bare land	N	N	might be	cannot tell	Y	N	2	N	the tree shadow is at the wrong direction
129	dark blue; dark green	round	20.44012	0.5	grassland, bare land	N	N	N	N	N	Y	2	N	the greenish color is suspicious
130	dark blue; traces of green and brown	oval	5.575583	0	grassland	N	N	Y	might be	N	N	3	N	the shape and color looks like a pond, and it is different from the surrounding tree shadow
131	blue; traces of green and brown	linear	55.90387	0	bare land, grassland	N	Y	Y	Y	N	N	4	N	it is definitely a pond, but might have permanent inlet/outlet
132	blue; tint of purple	oval	5.010825	0	grassland	Y (subtle)	Y	Y	Y	N	N	4	N	it is definitely a pond, but might have permanent inlet/outlet

Table 12: Coordinate of PVP predictions from Aerial Photos and Satellite Images
(the Coordinates from DEM are not included in the report due to the large amount of sites. the coordinates are available upon request)

2002 Aerial Photograph		
Id	**X**	**Y**
1		
2		
3		
4		
5	-63.60647469	44.61687337
5	-63.60627381	44.6168285644
5	-63.60610418	44.6167348
6	-63.60741142	44.61456876
7	-63.60670791	44.61360555
8		
9		
10	-63.60404076	44.61247822
11	-63.60035453	44.61347931
12	-63.59946155	44.61667809
13	-63.59488338	44.61949911
14	-	-
15	-	-
16	-	-
17	-63.58646197	44.61889392
18	-63.5855162	44.61944368
19	-63.58476318	44.61882714
20	-63.58705737	44.61803973
21	-63.58854177	44.61787624
22	-63.58910595	44.61704436
23	-63.5880267	44.61687066
24	-63.58809314	44.61647786
25	-63.58854439	44.61524276
26	-63.60819653	44.61358194
27	-63.61298096	44.61524019
28	-63.59423032	44.61015279
29	-63.58766456	44.61205574
30		
31	-63.58311715	44.61751012
32	-63.58296378	44.61525065
33	-63.58478124	44.61252532
34	-63.58344733	44.61339178
35		
36	-63.59105703	44.6182076
37	-63.59129207	44.61672276
38	-63.59452618	44.6165906

2003 Aerial Hurricane Juan		
Id	**X**	**Y**
1	-63.61294996	44.61522389
2	-63.61247492	44.61503185
3	-63.60932225	44.61373509
4	-63.610209	44.61407102
5	-63.61038061	44.61463607
6	-63.60904991	44.61485505
7	-63.60866118	44.61498223
8	-63.60817632	44.61458021
9	-63.61027972	44.61482097
10	-63.60879766	44.61550923
11	-63.60878801	44.61562592
12	-63.60942735	44.61592212
13	-	-
14	-63.60856218	44.61619391
15	-63.6059148	44.61793369
16	-	-
17	-63.60769203	44.61675654
18	-63.60526281	44.61635387
19	-63.60657675	44.61611151
20	-63.6066599	44.61589132
21	3.606057	44.61579757
22	-63.60546779	44.61580929
23	-63.60668021	44.6156187
24	-63.60547866	44.61551868
25	-63.60506016	44.6153728
26	-63.60616019	44.61559636
27	-63.60677763	44.6154116
28	-	-
29	-63.60548428	44.61522503
30	-63.6071402	44.61531202
31	-63.60666873	44.6151059
32	-63.60677556	44.61512294
33	-	-
34	-63.60536362	44.61466208
35	-	-
36	-63.60633599	44.61440441
37	-	-
38	-63.60585376	44.61442235
39	-63.60658442	44.61434514
40	-	-
41	-63.60663528	44.61396466
42	-63.60674867	44.61384999
43	-	-
44	-	-
45	-	-
46	-63.60516334	44.61367124
47	-63.60762451	44.61382332
48	-	-
49	-63.60689413	44.61376779
50	-63.60673993	44.61312189
51	-63.60706373	44.61322152
52	-63.60746861	44.6130061
53	-	-
54	-63.60706897	44.61289009
55	-	-
56	-63.60189916	44.61139278
57	-63.60164678	44.61121324
58	-63.60401294	44.61235132
59	-	-
60	-63.60382364	44.61560505
61	-63.60305753	44.61452312
62	-63.60253072	44.61615448
63	-	-
64	-	-
65	-63.60088868	44.61613621
66	-	-
67	-	-
68	-63.60335983	44.61288429
69	-	-
70	-63.60347206	44.61690394
71	-63.60054247	44.61450599
72	-63.60079638	44.61451469
73	-63.60098383	44.61453548
74	-	-
75	-63.60173597	44.613206
76	-63.601378	44.61463563
77	-	-
78	-63.59668114	44.61146815
79	-63.5962222	44.61173829
80	-	-
81	-63.59537083	44.61217386
82	-63.59536495	44.61226608
83	-63.59543871	44.61251235
84	-63.59502027	44.61312931
85	-63.59784588	44.61335402
86	-63.5960272	44.61368581
87	-63.59813474	44.6134636
88	-63.59755805	44.61451923
89	-	-
90	-63.59907672	44.61518239
91	-	-
92	-63.59522192	44.61447696
93	-63.59510576	44.61535569
94	-63.5981669	44.61566577
95	-63.59939039	44.61666859
96	-	-
97	-63.59607123	44.61813361
98	-63.59533514	44.61817332
99	-63.59598987	44.61864625
100	-	-
101	-63.59368895	44.61891685
102	-63.59464508	44.61873778
103	-63.59311751	44.61826625
104	-63.59078855	44.61830974
105	-63.59070693	44.61782976
106	-	-
107	-63.59133224	44.61761838
108	-	-
109	-63.59334931	44.61717571
110	-63.59320881	44.61779968
111	-63.59443119	44.61693832
112	-63.59435759	44.61636566
113	-63.59096945	44.61565931
114	-	-
115	-63.59309881	44.61529099
116	-63.59386752	44.61489628
117	-63.59024435	44.61435209
118	-63.59303711	44.61419828
119	-63.59032015	44.6132848
120	-63.59176266	44.61243521
121	-63.59117561	44.61105815
122	-63.59101663	44.61112628
123	-63.59451542	44.61161747
124	-63.59496856	44.61186101
125	-63.59465866	44.61088089
126	-63.59375312	44.61117427
127	-63.59332898	44.61032308
128	-63.5922053	44.61045372
129	-63.59366685	44.60983923
130	-63.5907494	44.60958429
131	-	-
132	-	-
133	-63.59100672	44.6100086
134	-63.5885423	44.60881092
135	-63.58900122	44.60891417
136	-63.58618976	44.60933571
137	-	-
138	-63.58966685	44.61078002
139	-63.58602842	44.61045489
140	-	-
141	-63.59005185	44.61159446
142	-63.58626794	44.61144033
143	-	-
144	-63.58908783	44.61253074
145	-63.58557284	44.61311699
146	-63.58895757	44.61426166
147	-63.58976958	44.61682891
148	-63.58927871	44.6171814
149	-63.5863396	44.61799438
150	-63.58738172	44.6177193
151	-	-
152	-63.58645121	44.61840285
153	-63.58544082	44.61942221
154	-63.58497731	44.61995674
155	-63.58535531	44.61792842
156	-63.58527242	44.61832722
157	-63.58573939	44.61748465
158	-63.5847412	44.61643067
159	-63.58420143	44.61394885
160	-63.5858547	44.61271162
161	-63.58510002	44.61195473
162	-	-
163	-63.58463425	44.61088561
164	-63.58364348	44.61061669
165	-	-
166	-	-
167	-	-
168	-63.60983771	44.61495551
169	-63.60991895	44.6150783
170	-63.59060598	44.61806003

2009 Color Aerial Photo		
Id	**X**	**Y**
1	-63.60738346	44.61745212
2	-63.60715735	44.61558308
3	-63.60703132	44.61546892
4	-63.60793075	44.61483443
5	-63.60766593	44.61381855
6	-63.6066768	44.61315849
7	-63.60668285	44.61293903
8		
9	-63.60754212	44.61353272
10	-63.60826325	44.61472494
11	-63.60806411	44.61452631
12	-63.60802814	44.61690937
13	-63.60818251	44.6168164
14	-63.60818036	44.61679992
15		
16	-63.60824902	44.61636948
17	-63.60851053	44.61622165
18		
19		
20	-63.60834976	44.61556644
21	-63.60864123	44.61493974
22		
23	-63.60910921	44.61458282
24		
25	-63.60895203	44.61454346
26		
27	-63.6086618	44.61441387
28	-63.60802774	44.61406559
29	-63.60797257	44.6140529
30	-63.60805061	44.61392024
31	-63.60799662	44.61383611
32	-63.60800177	44.61369581
33	-63.60827771	44.61371205
34	-63.60828439	44.61354139
35	-63.60884501	44.6135153
36	-63.6092417	44.61377499
37	-63.60836862	44.61438199
38	-63.60984847	44.61495643
39	-63.60963275	44.61541068
40	-63.60902262	44.61592179
41	-63.60940485	44.6159154
42	-63.61025221	44.61517909
43	-63.6095733	44.61387362
44		

45	-63.61170956	44.61489294
46	-63.61180402	44.61486899
47	-63.61124192	44.61464945
48		
49	-63.61283719	44.61525215
50	-63.60647817	44.6169849
51		
52		
53		
54	-63.60543251	44.61760742
55		
56		
57		
58	-63.60561617	44.61666065
59		
60		
61		
62		
63		
64	-63.60614646	44.615654
65	-63.60476141	44.61481168
66		
67		
68	-63.6054784	44.61494206
69		
70	-63.60657111	44.61517444
71		
72	-63.60688169	44.61374187
73	-63.60612083	44.61325233
74	-63.605034	44.61297355
75		
76		
77	-63.60304337	44.61159496
78	-63.60307943	44.61151545
79	-63.60443421	44.61259186
80		
81		
82		
83	-63.6044365	44.61394443
84		
85	-63.60389289	44.61441718
86		
87	-63.60381078	44.61426603
88	-63.60307182	44.61471506
89	-63.60271868	44.61424382
90		
91	-63.60361294	44.61662123
92	-63.60408001	44.61680096
93		
94		
95		
96	-63.60331242	44.61740357
97	-63.60475387	44.61721849
98	-63.60487747	44.61723952
99		
100		
101	-63.60061501	44.61641115
102	-63.60089272	44.61586939
103		
104		
105		
106		
107	-63.60204386	44.61223966
108	-63.60548575	44.61529851
109	-63.60548002	44.6165802
110	-63.60570835	44.61641722
111	-63.60549337	44.61628556
112		
113		
114	-63.60454226	44.61681523
115	-63.60241396	44.61201149
116	-63.60201428	44.61254178
117	-63.6048016	44.61395927
118	-63.60822811	44.61576617
119		
120	-63.60063521	44.61550931
121	-63.60205763	44.6144597
122	-63.60202695	44.61373817
123	-63.59975351	44.61517832
124		
125	-63.59948037	44.61666862
126	-63.59566006	44.6123287
127		
128	-63.59559703	44.61298683
129	-63.59612618	44.61320457
130	-63.59637046	44.61344875
131	-63.59603533	44.61363815
132		
133		
134	-63.59525956	44.61844359
135	-63.59589833	44.61894286
136	-63.59330632	44.61393538
137	-63.59402263	44.61326014
138	-63.59429777	44.6101598
139		
140	-63.5948885	44.60961614
141		
142		
143		
144	-63.59158768	44.61772763
145	-63.5908843	44.61827051
146	-63.58962126	44.61739702
147	-63.59058303	44.61706498
148	-63.5890109	44.61656968
149		
150	-63.58988913	44.61362482
151		
152		
153		
154	-63.59092259	44.61191516
155		
156	-63.58945004	44.61113815
157	-63.59042343	44.61144267
158	-63.59028367	44.61130393
159	-63.5907778	44.61042215
160	-63.58637286	44.60820032
161		
162		
163		
164		
165		
166	-63.58680276	44.61036494
167	-63.58713979	44.61126045
168	-63.58661965	44.61161105
169	-63.5867243	44.61274169
170	-63.58800975	44.61534381
171	-63.58616708	44.61562539
172	-63.58636303	44.61576696
173	-63.58679774	44.61585591
174		
175	-63.58669279	44.61671853
176		
177		
178		
179	-63.58630735	44.61725414
180	-63.58616342	44.61736933
181	-63.58762972	44.61725244
182		
183		
184	-63.58604089	44.62010506
185		
186	-63.58642352	44.62037926
187		
188		
189		
190	-63.58547789	44.61940462
191		
192		
193		
194	-63.58406397	44.6178883
195	-63.58478286	44.6159959
196		
197	-63.58319672	44.61305649
198		
199	-63.58452948	44.6124029
200	-63.58446913	44.61248742
201	-63.58445895	44.6128704
202	-63.58466912	44.61220076
203	-63.584369	44.612174
204	-63.58438277	44.61124024
205	-63.58541544	44.61099769
206	-63.58526048	44.61072638
207		
208		
209		
210	-63.61164822	44.61499533
211	-63.60130589	44.61527816
212	-63.59964277	44.61280584
213	-63.59988117	44.61304051
214	-63.61261029	44.61529662
215	-63.61276977	44.615244
216	-63.61193265	44.61469301
217	-63.61169567	44.61464043
218	-63.61106098	44.61521009
219	-63.6112062	44.61474494
220	-63.61019499	44.61507051
221	-63.61006785	44.61499347
222	-63.61024329	44.61492299
223	-63.61071668	44.61440352
224	-63.61017524	44.61533521
225	-63.61014811	44.61457262
226	-63.6090778	44.61485355
227	-63.60902153	44.61576221
228	-63.607509	44.61743317
229	-63.60739451	44.61626684
230	-63.60761056	44.61407026
231	-63.60672319	44.61323356
232	-63.60638481	44.61354768
233	-63.60663579	44.61369852
234	-63.6066379	44.61387711
235	-63.60678541	44.61558344
236	-63.60638297	44.61566736
237	-63.60645137	44.61575045
238	-63.60600469	44.61675965
239	-63.60577282	44.61650733
240	-63.60515566	44.61598482
241	-63.605921	44.61572118
242	-63.60542923	44.61544925
243	-63.60585775	44.61373241
244	-63.60428866	44.61230909
245	-63.60477604	44.61269012
246	-63.60484974	44.61625191
247	-63.60347896	44.61605696
248	-63.60302747	44.61606377
249	-63.60297616	44.6146891
250	-63.59604912	44.61442077
251	-63.59471498	44.61955321
252		
253	-63.59335464	44.61410009
254	-63.59246582	44.61676741
255	-63.59251074	44.61661169
256	-63.59259097	44.6185809
257	-63.59103272	44.61852034
258	-63.59146375	44.61722844
259		
260	-63.59029687	44.61146294
261	-63.59004647	44.61152821
262	-63.59072375	44.61208405
263	-63.58963033	44.61721401
264	-63.58904518	44.61703166
265	-63.58879902	44.61299055
266	-63.58783652	44.61132706
267	-63.58540562	44.61331224
268	-63.58612454	44.61293735
269	-63.58619716	44.61134032
270	-63.58593312	44.60913229
271	-63.58435857	44.61611052

2009 Black and White		
Id	**x**	**y**
1	-63.61290042	44.61547236
2	-63.61263513	44.61536888
3	-63.61284021	44.61504693
4	-63.61293886	44.61520921
5	-63.612232	44.61498033
6	-63.61219816	44.61489767
7	-63.61169383	44.61485131
8	-63.61063666	44.61461799
9		
10	-63.61073998	44.61445049
11	-63.61073514	44.61414368
12	-63.61148448	44.61432962
13	-63.60661157	44.61304457
14	-63.6078039	44.61432578
15	-63.6079377	44.61453564
16	-63.60783362	44.61479822
17	-63.60893639	44.61481736
18	-63.60904405	44.61576474
19	-63.60703175	44.61638973
20	-63.60686158	44.6170961
21	-63.60465474	44.61491515
22	-63.60235279	44.61497951
23		
24	-63.60252836	44.61444517
25	-63.6037279	44.61352466
26		
27		
28	-63.60236568	44.61315227
29	-63.60306658	44.61265852
30	-63.60202591	44.61135488
31	-63.603104	44.61171235
32	-63.60262075	44.61151432
33	-63.60279633	44.61425584
34	-63.6022174	44.61711943
25		
36	-63.60305158	44.61730727
38	-63.60953232	44.61537526
39	-63.60971474	44.61457929
40	-63.60970982	44.61466325
41	-63.60941227	44.61461093
42	-63.61009032	44.61461247
43	-63.60987799	44.61461136
44	-63.61033029	44.61465948

45	-63.61108147	44.61438786
46		
47	-63.61071292	44.61428064
48	-63.61224253	44.61482941
49		
50		
51	-63.61006722	44.61471309
52	-63.60883383	44.61416488
53	-63.61012939	44.61501538
54	-63.60835933	44.6151814
55	-63.60565915	44.61620033
56	-63.60642085	44.61704031
57	-63.60260622	44.6120339
58		
59		
60		
61		
62		
63		
64	-63.60377683	44.61516987
65	-63.60384061	44.61561395
66	-63.60442548	44.6155067
67	-63.60609052	44.61442726
68	-63.60619499	44.6144497
69	-63.59926267	44.61314845
70		
71		
72		
73	-63.59972949	44.61362639
74	-63.60144981	44.6146641
75	-63.60128601	44.61474166
76	-63.59949154	44.61630206
77	-63.59943588	44.61670417
78	-63.59600611	44.61695212
79		
80	-63.59607325	44.61449995
81	-63.59803431	44.61421855
82	-63.59592669	44.61360812
83	-63.59696134	44.61295949
84	-63.59597487	44.61166339
85	-63.59612161	44.61163117
86	-63.59626178	44.61195497
87	-63.59324493	44.61098147
88		
89	-63.5925	44.61673664
90	-63.58932113	44.61779616
91	-63.58898083	44.61707208
92	-63.5892737	44.61421957
93	-63.58679743	44.6084876
94	-63.5880381	44.60816606
95	-63.58690659	44.60935325
96	-63.58622669	44.61116564
97	-63.58699154	44.61508113
98	-63.58679551	44.61589558
99	-63.58687369	44.61613065
100	-63.58643133	44.61636048
101	-63.58629584	44.61589632
102	-63.58616668	44.61563598
103	-63.58661022	44.61562582
104	-63.58579755	44.61576808
105	-63.58567686	44.61685116
106		
107	-63.5863172	44.61861989
108	-63.58544852	44.61946225
109	-63.58683063	44.61927928
110	-63.58631961	44.62041339
111	-63.5834243	44.61646479
112	-63.58464304	44.61141575
113		

114	-63.58383242	44.60912342
115	-63.58535497	44.61108902
116	-63.58514743	44.61217667
117		
118	-63.58373406	44.61491121
119		
120		
121	-63.58527007	44.61483403
122	-63.58505157	44.61571007
123		
124	-63.58689685	44.61803224
125	-63.58662939	44.61784408
126	-63.58502849	44.61788807
127	-63.58535562	44.61773196
128	-63.58624765	44.61735858
129		
130	-63.58678927	44.6167486
131	-63.58802381	44.61399039
132		
133	-63.58631257	44.61180908
134		
135	-63.58766206	44.61167339
136	-63.58862996	44.61115602
137	-63.58861018	44.61020376
138	-63.5853159	44.60958392
139		
140	-63.58960253	44.61230298
141	-63.59018319	44.61320136
142	-63.59058983	44.61517322
143	-63.5908016	44.61511379
144	-63.59103237	44.61495959
145	-63.59070956	44.615567
146	-63.58878987	44.61608865
147	-63.58845527	44.6163039
148	-63.59038638	44.61648062
149	-63.58978723	44.61719141
150	-63.59040257	44.61834816
151	-63.59010674	44.61834828
152	-63.59005722	44.61820198
153	-63.59187193	44.61070026
154	-63.59225362	44.61054186
155	-63.5925669	44.61287736
156	-63.59308254	44.6137414
157	-63.59243601	44.6146186
158	-63.59451552	44.61652646
159	-63.59330258	44.61687712
160	-63.59500555	44.61878495
161		
162	-63.5954151	44.61498792
163	-63.59496327	44.61343937
164	-63.59851228	44.61657602
165	-63.60103409	44.61442054
166	-63.60041803	44.6154718
167	-63.59893704	44.61572594
168	-63.59975556	44.61550165
169	-63.59985128	44.61563823

2005 Satellite Quickbird CIR

Id	X	Y
1		
2		
3		
4		
5		
6		
7		
8		
9	-63.60792496	44.61724123
10	-63.60975358	44.6148412

11	-63.60809766	44.614434
12	-63.60844008	44.6146113
11		
14	-63.60238048	44.61381013
15	-63.60219577	44.61164639
16	-63.6024445	44.6114998
17		
18		
19	-63.60058932	44.61337588
20		
21	-63.59816221	44.61698451
22	-63.597892	44.61585335
23	-63.59779654	44.61449793
24	-63.59974395	44.61194885
25	-63.59566425	44.61091979
26	-63.59747722	44.61202902
27	-63.59561202	44.6187869
28	-63.5933909	44.61807842
29	-63.59360287	44.61826875
30	-63.59335314	44.61591132
31		
32	-63.59455426	44.61294847
33	-63.58835301	44.61792375
34	-63.58897921	44.61706176
35	-63.5883713	44.61644048
36	-63.58951408	44.61785115
37		
38	-63.5911207	44.61487473
39	-63.58769218	44.61549493
40	-63.58825606	44.60800766
41		
42	-63.58462517	44.60764817
43		
44		
45	-63.58685549	44.60897938
46	-63.58743356	44.61218779
47	-63.58776142	44.61317775
48	-63.58435082	44.61580934
49	-63.58463193	44.61633046
50	-63.58695384	44.6180149
51	-63.58609718	44.6190071
52	-63.58555614	44.61927388
53		
54		
55		
56	-63.59932665	44.61667303
57	-63.59872412	44.61660174
58	-63.60773347	44.61409319
59	-63.60623212	44.61367364
60	-63.60387343	44.61203952
61	-63.6051091	44.61257346
62	-63.60546827	44.61311375
63	-63.60608766	44.61583619

2003 Satellite Google Map

ID	X	Y
1	-63.60819476	44.61361274
2	-63.60773778	44.61387782
3	-63.60926892	44.61395954
4	-63.60901079	44.6145494
5	-63.60890939	44.61509194
6	-63.60353446	44.6169479
7		
8	-63.60429666	44.61524755
9	-63.60505704	44.61465652
10	-63.60470509	44.61482783

11	-63.60547853	44.61435844
12	-63.60479759	44.6143782
13	-63.60521797	44.61390519
14	-63.6052476	44.6134781
15	-63.60251287	44.61304116
16	-63.60238134	44.61244182
17	-63.60547529	44.61270321
18	-63.60867749	44.61494147
19	-63.60873969	44.6164369
20	-63.60237747	44.61301849
21	-63.60004233	44.61279019
22	-63.60049491	44.61279526
23	-63.60000054	44.61348087
24	-63.60006831	44.61382446
25	-63.59893952	44.61438138
26	-63.59825655	44.61457782
27	-63.59983618	44.61557793
28	-63.59930402	44.61669959
29	-63.59722232	44.61714783
30	-63.59721324	44.61582401
31	-63.59688018	44.61433754
32	-63.59798966	44.61303417
33	-63.59560815	44.6132417
34	-63.59434303	44.61133808
35	-63.59365481	44.61158985
36	-63.59274403	44.61445366
37	-63.59268164	44.61364912
38		
39	-63.59389284	44.61483124
40	-63.59247696	44.61665269
41	-63.5924426	44.61686529
42	-63.59419616	44.61866631
43	-63.59497714	44.61902522
44	-63.59339588	44.61760361
45	-63.59108223	44.61189199
46	-63.59046905	44.61176543
47	-63.59038281	44.61204526
48	-63.59212847	44.61047442
49	-63.58692649	44.60845178
50	-63.58844459	44.61091266
51	-63.58957292	44.61090811
52	-63.59000654	44.61151563
53		
54		
55	-63.58740189	44.61294866
56	-63.58836212	44.61330968
57	-63.58882	44.61364059
58	-63.58891948	44.6136986
59	-63.58981046	44.61490884
60	-63.58963683	44.61489716
61	-63.59092857	44.61561937
62	-63.58918723	44.61601947
63	-63.58598887	44.62088151
64	-63.58594993	44.62041481
65	-63.58778122	44.61998443
66	-63.58678936	44.62022642
67	-63.58542952	44.61950079
68	-63.58478053	44.61913736
69	-63.58518092	44.61903581
70	-63.58609934	44.61856642
71	-63.58688506	44.61804202
72	-63.58568919	44.61797071
73	-63.58580483	44.61695415
74	-63.58677141	44.61595864
75		
76		

77	-63.58602171	44.61142463
78	-63.58502124	44.61181163
79	-63.58512414	44.6104504
80	-63.60797679	44.61480821
81	-63.60633035	44.61537302
82	-63.60356062	44.61641443
83	-63.59721759	44.61682668
84	-63.59359436	44.61176669
85	-63.59428512	44.61208499
86	-63.592631	44.61237276
87	-63.59323439	44.61254646
88	-63.59328585	44.61693544
89	-63.59244796	44.61677142
90	-63.592119	44.61800733
91	-63.5923653	44.61744792
92	-63.59441649	44.61870222
93	-63.59512238	44.61902329
94	-63.59141664	44.61218715
95	-63.59225429	44.61057998
96	-63.58682522	44.60837942
97	-63.59008394	44.61081802
98	-63.58935034	44.61076139
99	-63.58968367	44.610919
100	-63.59017762	44.61270399
101	-63.59017257	44.61253395
102	-63.59050858	44.61264716
103	-63.58990074	44.61500876
104	-63.5865266	44.62088999
105	-63.58551746	44.62052671
106	-63.58756851	44.61998473
107	-63.58496411	44.61886922
108	-63.58540424	44.61893815
109	-63.58480403	44.6194216
110	-63.58474001	44.61232122
111	-63.58561285	44.61080335
112	-63.58521275	44.61079835
113	-63.58519177	44.61090616
114	-63.58505607	44.61058237

2010 Satellite Google Map		
ID	**X**	**Y**
1	-63.61092021	44.61455556
2	-63.61108475	44.61467624
3	-63.6075528	44.61398943
4	-63.60976652	44.61492896
5	-63.60944104	44.61509975
6	-63.60537483	44.61719469
7	-63.60605829	44.61721915
8	-63.60459403	44.61665597
9	-63.60506337	44.61538281
10	-63.60646377	44.61501786
11	-63.60385968	44.61444154
12	-63.60489408	44.61388797
13	-63.60396681	44.61364311
14	-63.60185242	44.61153881
15	-63.60243531	44.61372292
16	-63.60239774	44.6148263
17	-63.60189561	44.61594556
18	-63.60073669	44.61569656
19	-63.59953084	44.61479589
20	-63.59428604	44.61038335
21	-63.59722399	44.6124138
22	-63.59705201	44.61348877
23		
24	-63.59234327	44.61496602
25		
26	-63.59628072	44.61584581
27	-63.59512226	44.61731392
28	-63.59485519	44.61693621
29	-63.59212744	44.61616676
30	-63.59251212	44.61790188
31	-63.58611765	44.61897073
32	-63.58688658	44.61906921
33	-63.5917955	44.61855848
34	-63.58926409	44.61427535
35	-63.58598112	44.6113811
36	-63.59031568	44.6105485
37		
38	-63.58306274	44.60995284
39	-63.58722687	44.61158143
40	-63.58407708	44.61486565
41	-63.58595325	44.61687636
42	-63.58369138	44.60907579

Bing Map		
ID	**X**	**Y**
1	-63.6124925	44.61491107
2	-63.6129188	44.61524351
3	-63.6116741	44.61480047
4	-63.6116382	44.61470222
5	-63.6116327	44.61456547
6	-63.611585	44.61443756
7	-63.6114273	44.61437876
8	-63.6112966	44.61476073
9		
10	-63.6108963	44.6141726
11	-63.6083648	44.61307383
12	-63.6094855	44.61387782
13	-63.6095008	44.61372757
14	-63.6097439	44.61394498
15		
16	-63.6101676	44.61423311
17	-63.6098919	44.6155604
18	-63.6061862	44.61758664
19	-63.6071222	44.61723336
20	-63.6062814	44.61694599
21	-63.6063901	44.61651084
22		
23	-63.6081396	44.61453287
24	-63.6073259	44.61474231
25	-63.6021824	44.61142556
26		
27		
28	-63.6023889	44.6138119
29	-63.6025447	44.6142914
30	-63.603421	44.61478434
31		
32	-63.6005177	44.61688312
33		
34	-63.6012704	44.61529224
35	-63.6000125	44.61579562
36	-63.5998587	44.61596053
37		
38	-63.5998511	44.61225104
39	-63.5991018	44.61272262
40		
41	-63.5993209	44.61665551
42	-63.5962647	44.6175016
43	-63.5957596	44.61367879
44	-63.5969182	44.61181069
45		
46	-63.5978945	44.61079792
47	-63.5936825	44.60969192
48	-63.5946427	44.61286579
49		
50		
51		
52	-63.5938303	44.61430167
53	-63.5940018	44.61462855
54	-63.5946044	44.61509406
55		
56		
57		
58		
59		
60		
61	-63.5934928	44.61891346
62	-63.5908097	44.61832989
63	-63.592175	44.61850495
64	-63.5914493	44.61775835
65	-63.5916184	44.61705487
66	-63.5912879	44.61686682
67	-63.5933722	44.61587799
68	-63.5932977	44.61390899
69	-63.5930732	44.61381876
70		
71		
72		
73	-63.5909755	44.61184312
74		
75	-63.5892893	44.6133321
76	-63.5913164	44.61304057
77	-63.589032	44.61346243
78		
79	-63.5906019	44.61644629
80	-63.5896921	44.61683493
81		
82	-63.5904897	44.61785795
83	-63.58677	44.62063236
84	-63.5874948	44.62024307
85		
86	-63.5869695	44.61803317
87	-63.5889672	44.61707702
88	-63.5868263	44.61588654
89	-63.5875207	44.61442033
90	-63.588156	44.613405
91	-63.587831	44.61329714
92		
93	-63.5881182	44.61215891
94	-63.588518	44.60839545
95	-63.5881579	44.60873045
96	-63.588046	44.60869265
97		
98		
99	-63.5861496	44.6156175
100	-63.5864003	44.61585127
101	-63.5854608	44.61944493
102	-63.5863468	44.6212714
103		
104		
105		
106	-63.5842842	44.62062169
107	-63.5843004	44.61612091
108	-63.5838349	44.61493154
109	-63.5842116	44.61510958
110	-63.5842009	44.61516928
111	-63.5842386	44.61516735
112	-63.5841563	44.61507657
113	-63.5839406	44.61507354
114	-63.5834977	44.61480609
115		
116		
117	-63.5830426	44.60989045
118	-63.5842972	44.6090071
119	-63.5843967	44.60842441
120	-63.5829322	44.6181357
121	-63.5823984	44.61789253
122		
123		
124	-63.5911712	44.61491543
125		
126	-63.609269	44.61546359
127	-63.6091139	44.61547366
128	-63.6094777	44.61533404
129	-63.6064537	44.61780866
130	-63.6025894	44.61316381
131	-63.6019633	44.61307629
132	-63.6020592	44.61301267

Appendix D: Figures

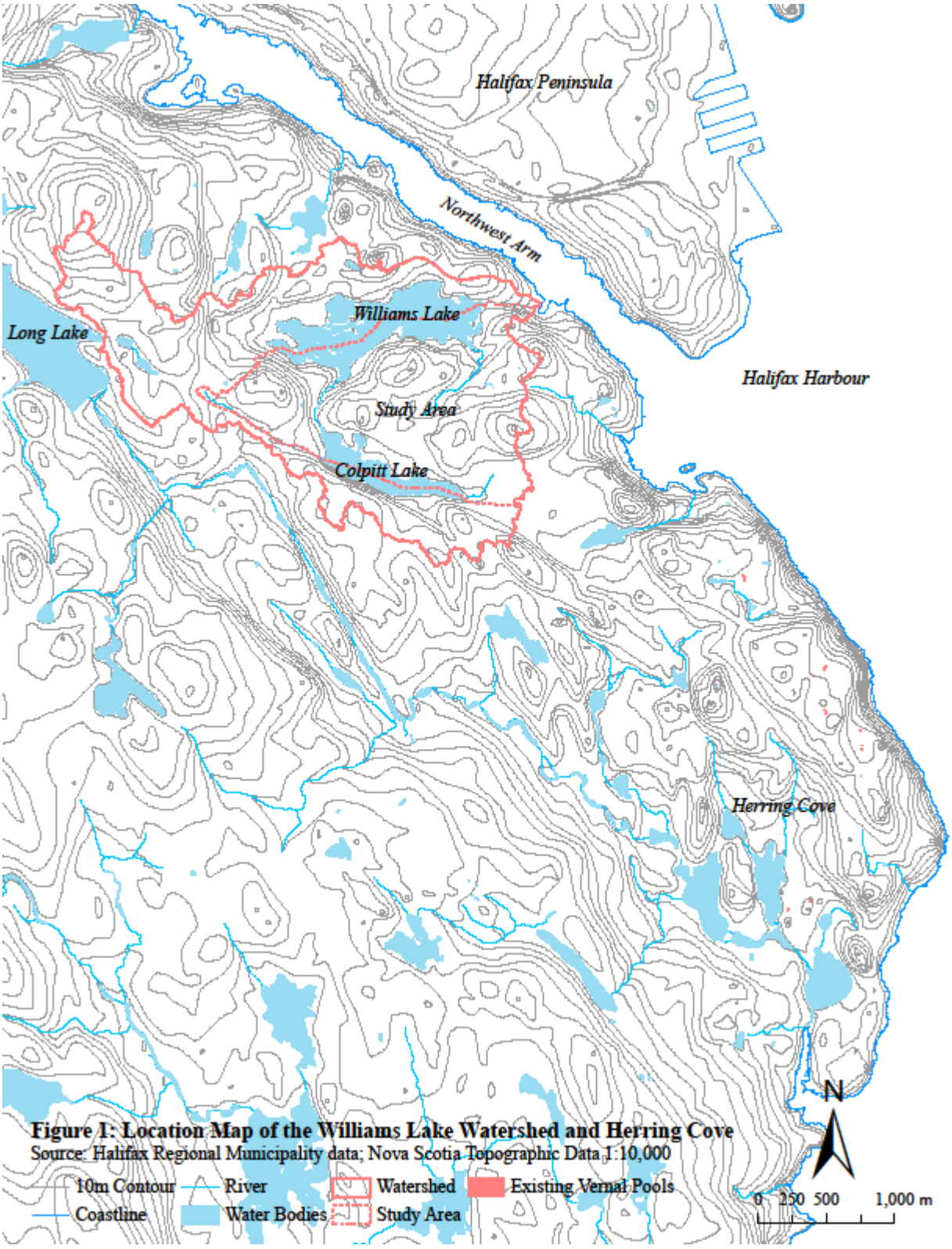
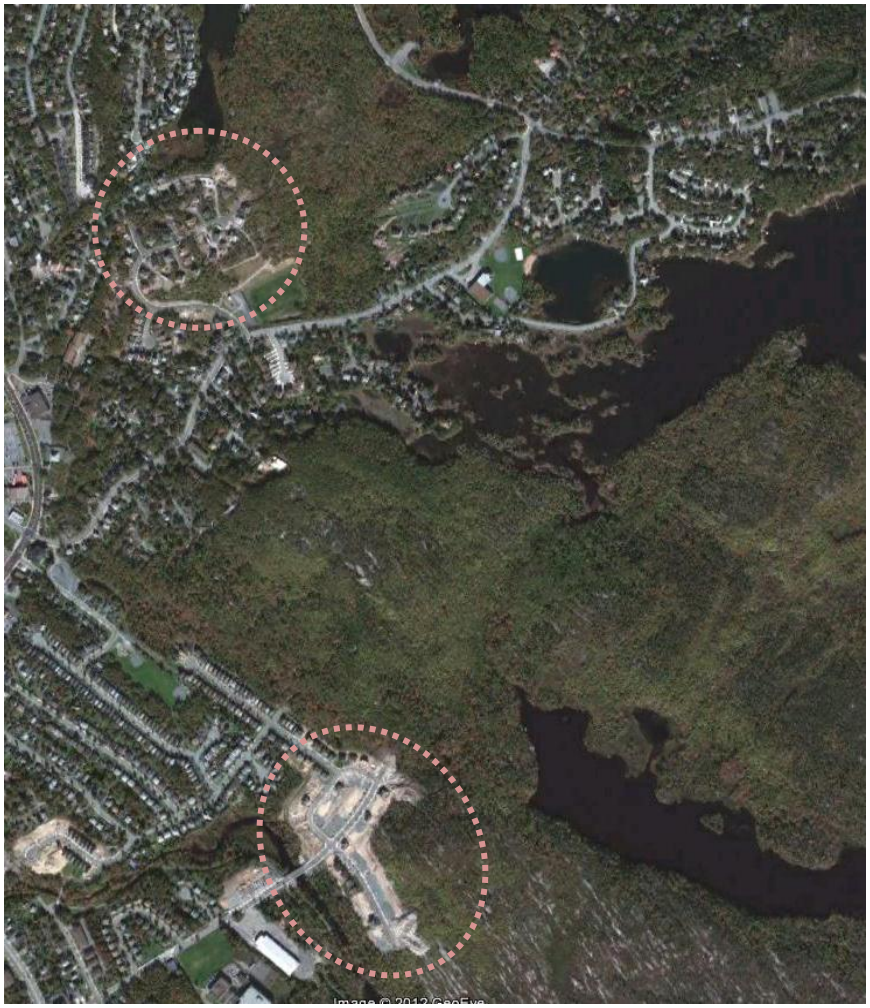


Figure 1: Location Map of the Williams Lake Watershed and Herring Cove
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000

Figure 2: Recent Development in the Williams Lake Watershed

Google Earth Satellite Imagery from 2003



Google Earth Satellite Imagery from 2010

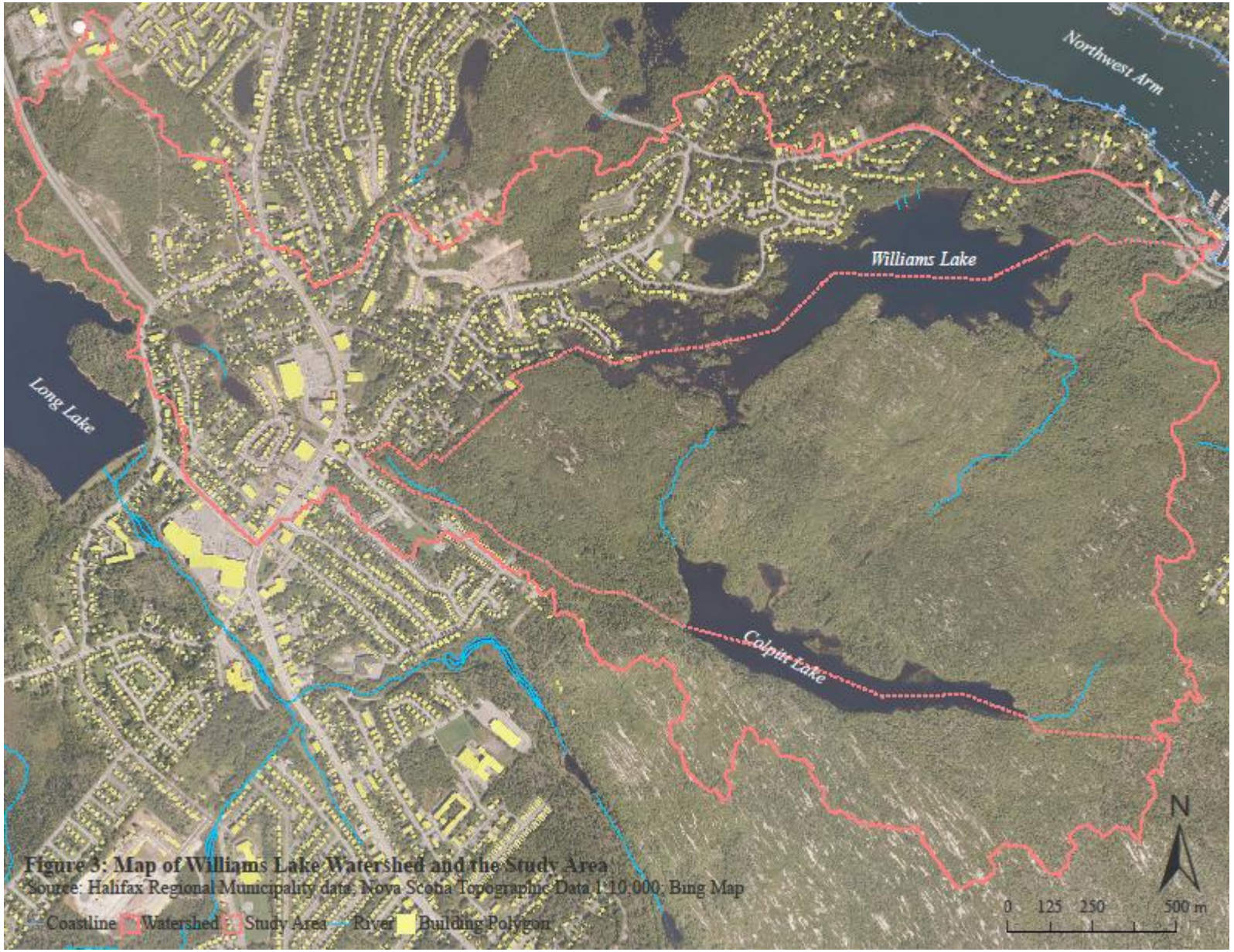


Figure 3: Map of Williams Lake Watershed and the Study Area
Source: Halifax Regional Municipality data, Nova Scotia Topographic Data | 10,000, Bing Map

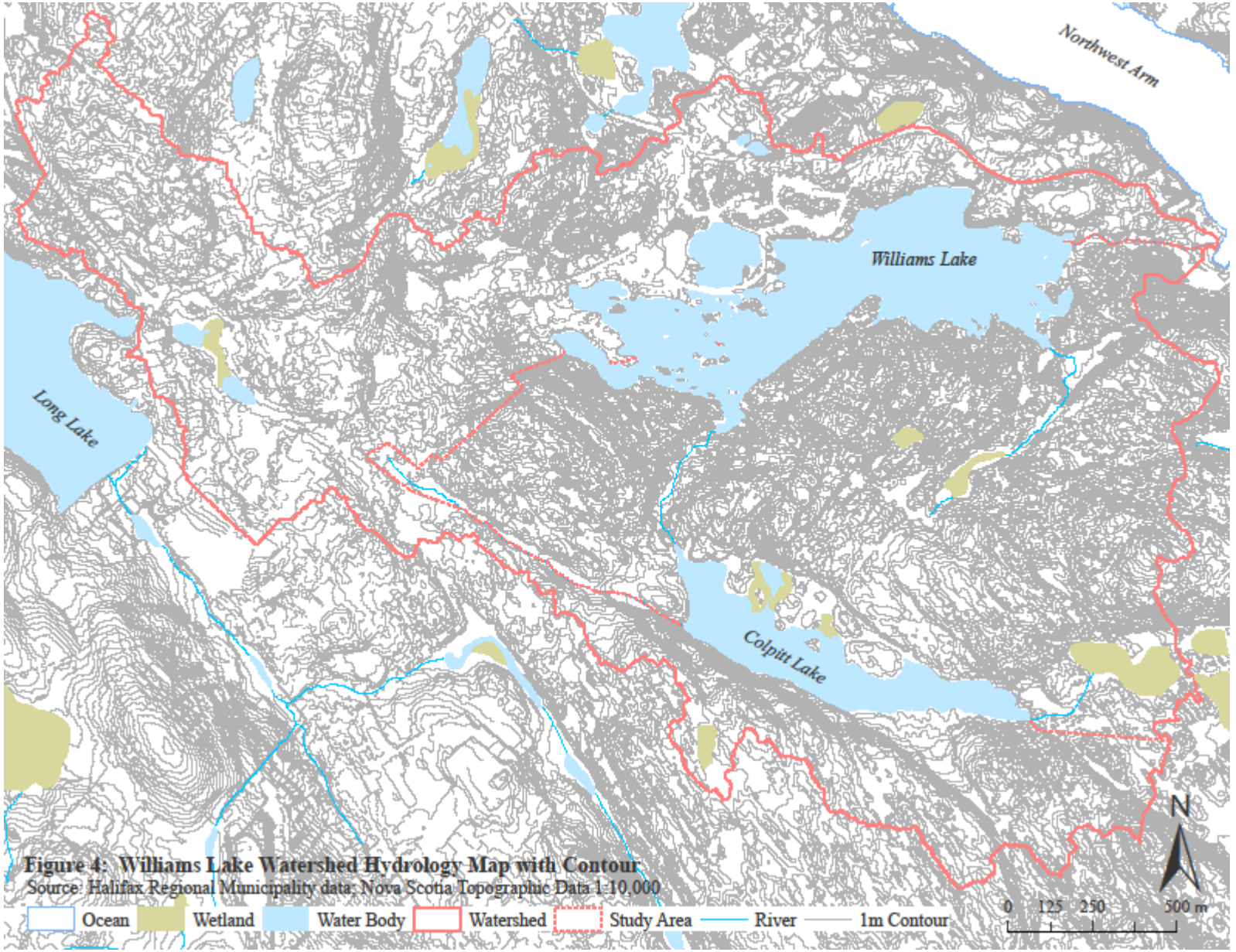


Figure 4: Williams Lake Watershed Hydrology Map with Contour
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000

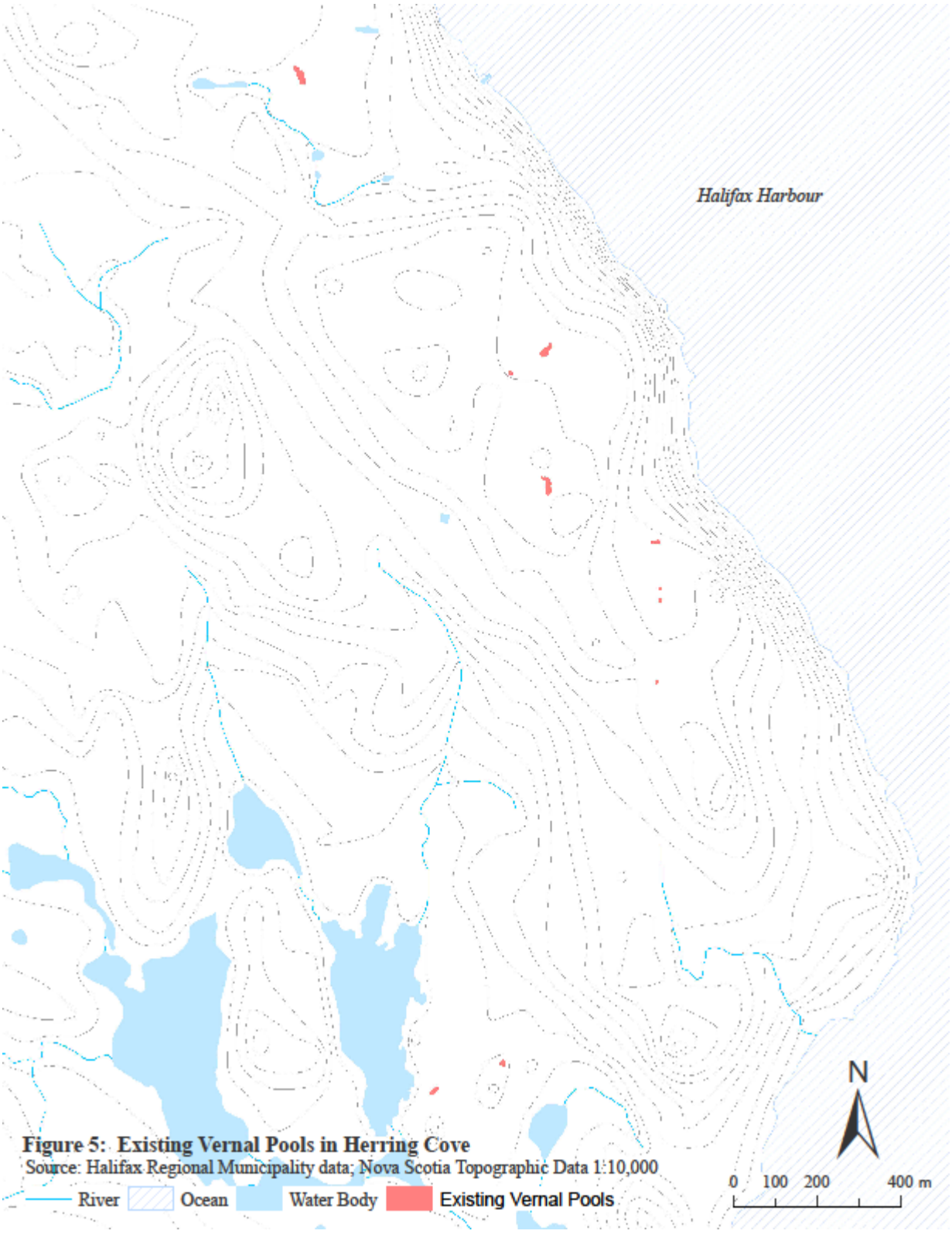
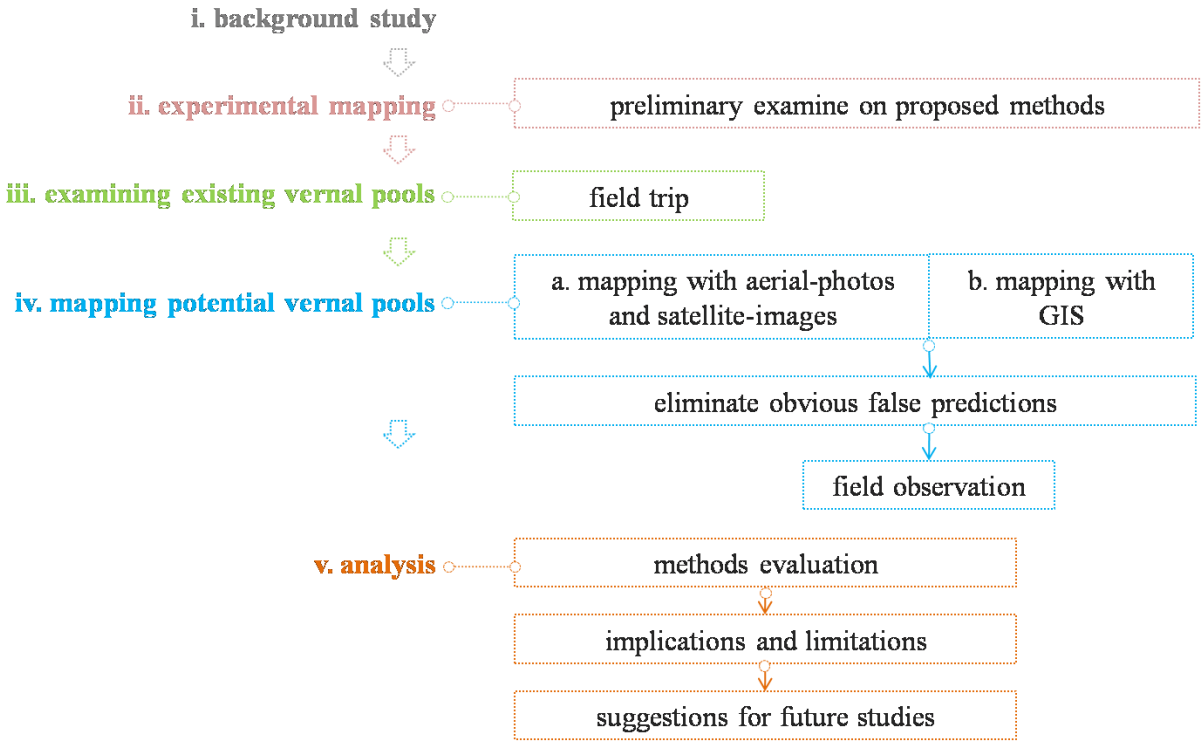


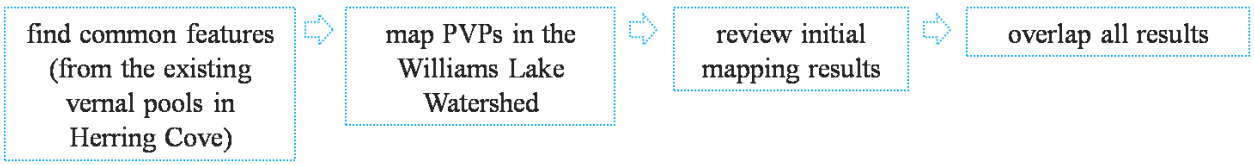
Figure 5: Existing Vernal Pools in Herring Cove
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000

Figure 6: Flow Charts of Work Process

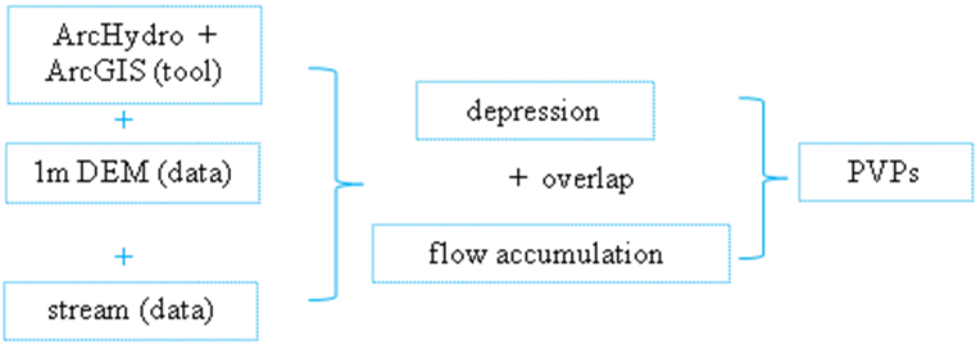
6.1. The Mapping Process of the Project



6.2. The Mapping Process of Visual Interpretation of Aerial Photos and Satellite Images



6.3. The Mapping Process of Delineating PVPs from DEM

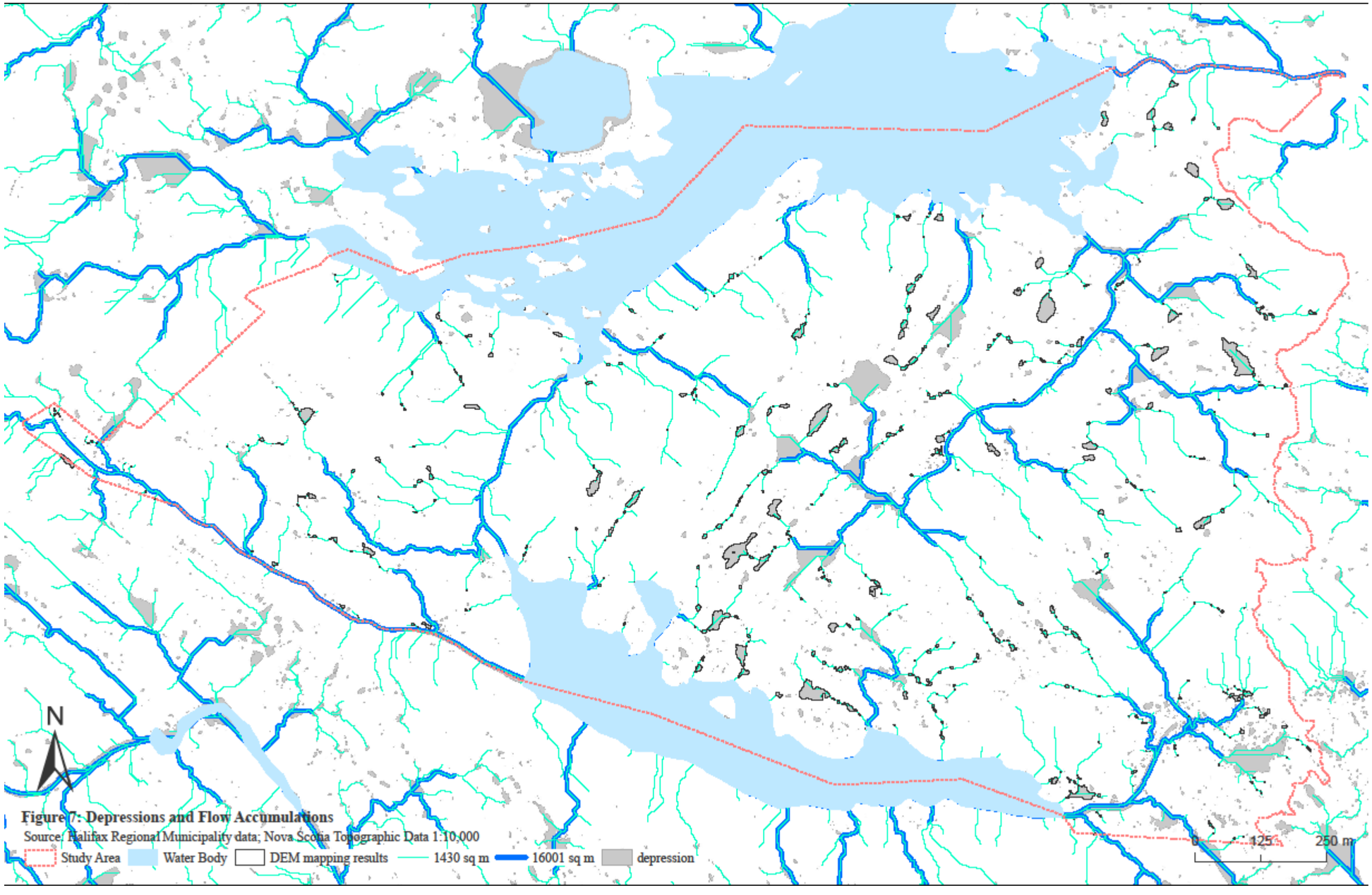


Step 1: find the most appropriate range of flow accumulations

(experiment in Herring Cove)

Step 2: apply the preferable range on the study area

(delineate potential vernal pools)


N
Figure 7: Depressions and Flow Accumulations
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000
Study Area
Water Body
DEM mapping results
1430 sq m
16001 sq m
depression
0
125
250 m

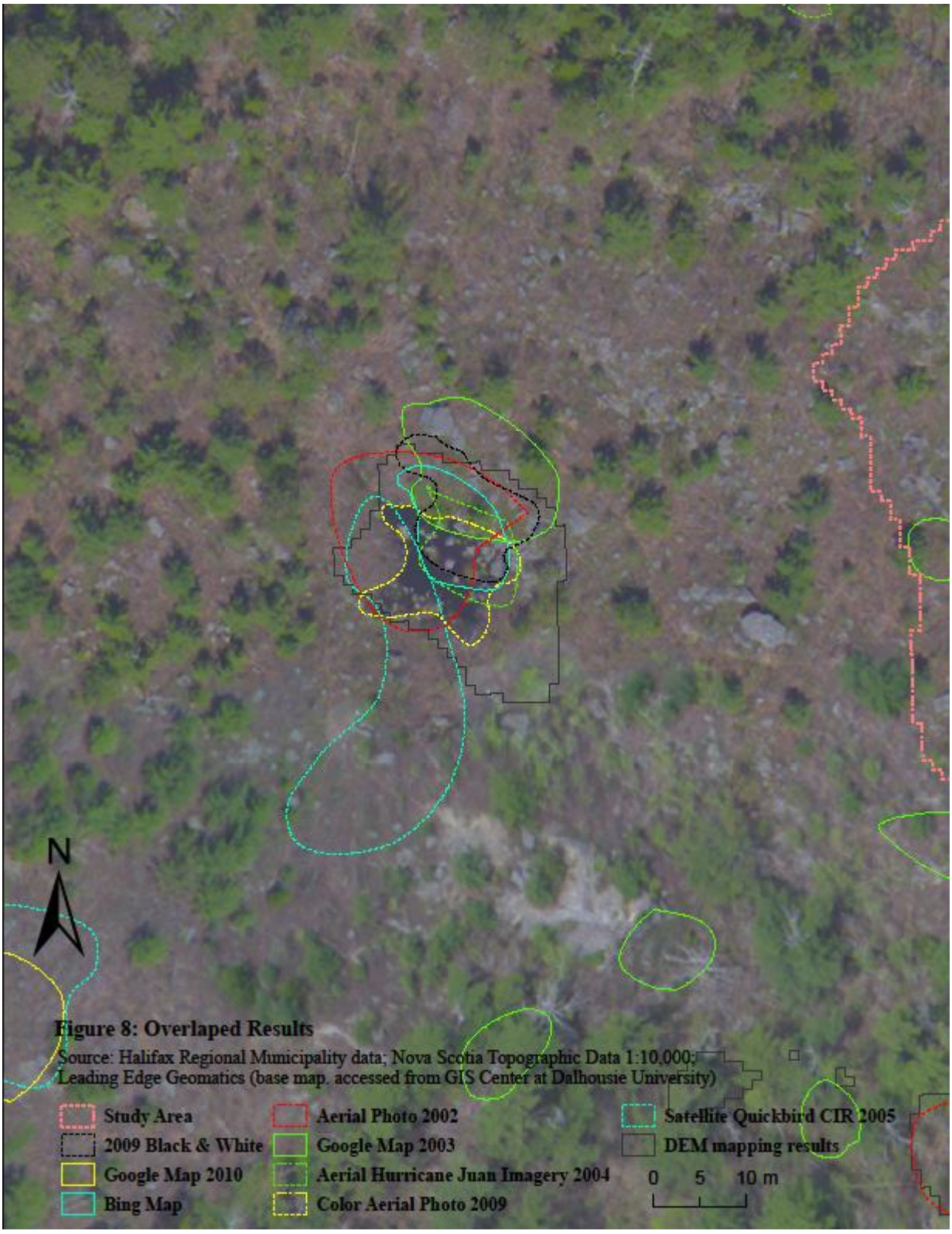


Figure 8: Overlaped Results

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)

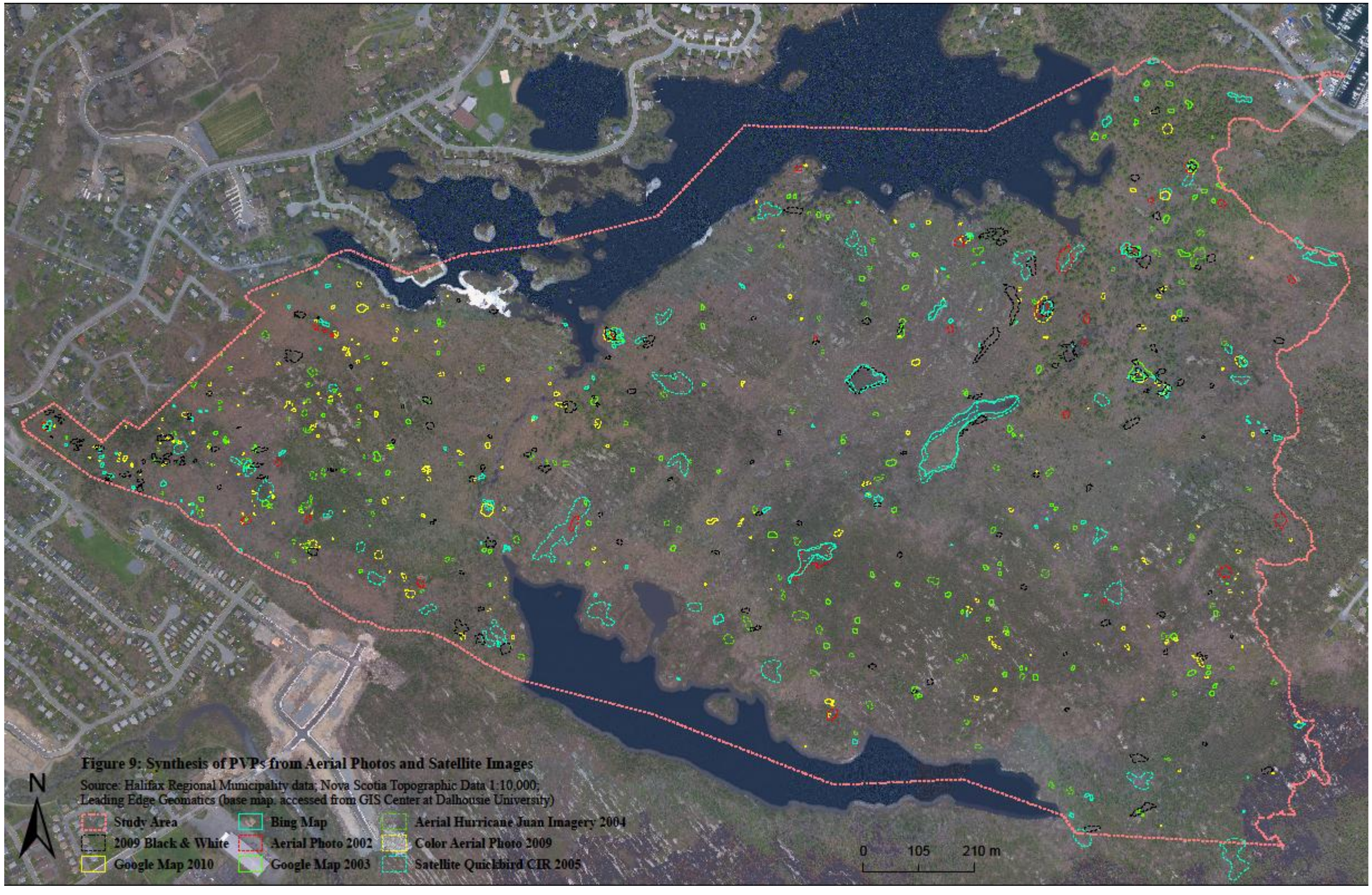
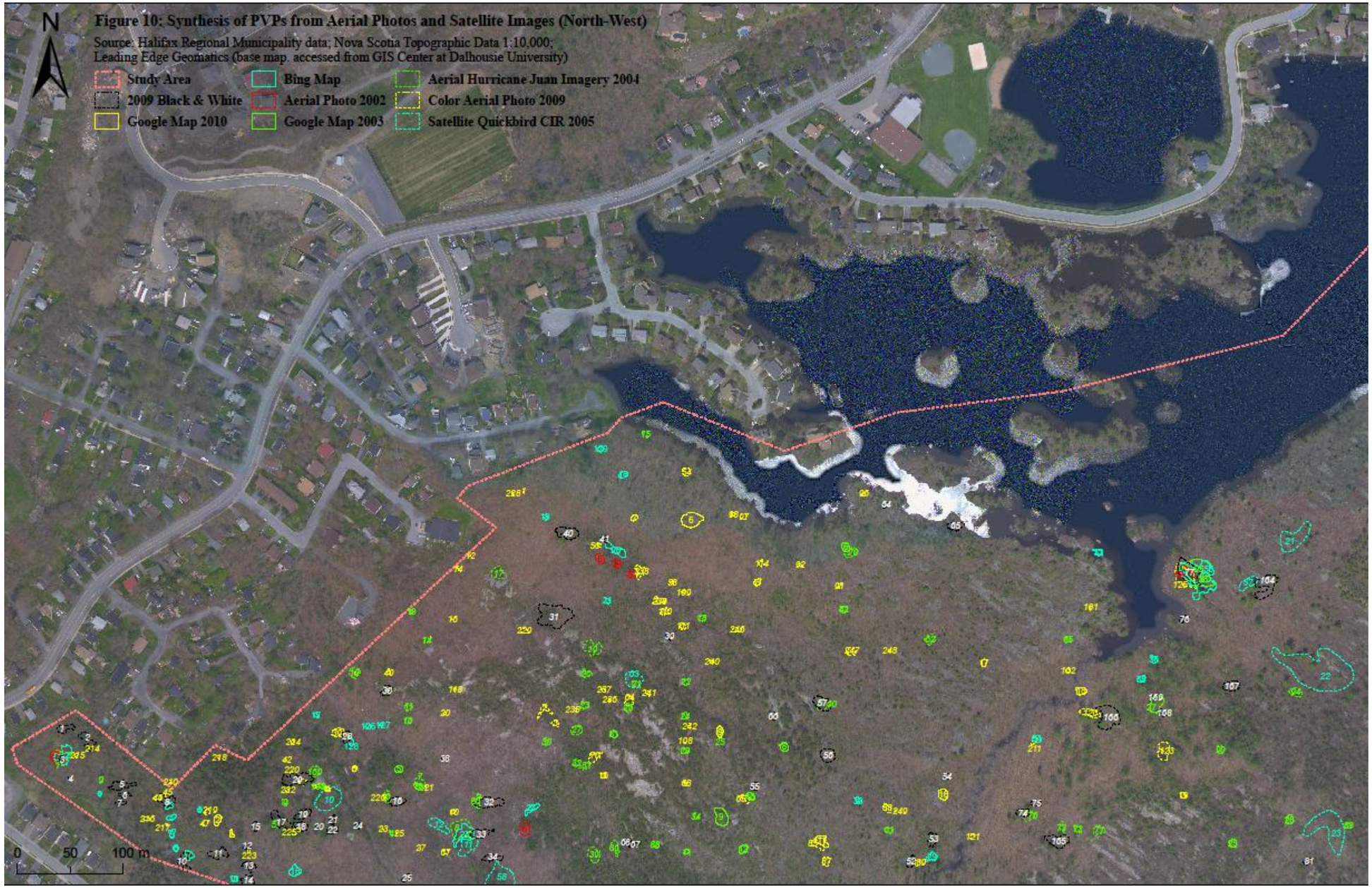


Figure 9: Synthesis of PVPs from Aerial Photos and Satellite Images

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)


N
Figure 10: Synthesis of PVPs from Aerial Photos and Satellite Images (North-West)
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000;
Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)
Study Area
2009 Black & White
Google Map 2010
Bing Map
Aerial Photo 2002
Google Map 2003
Aerial Hurricane Juan Imagery 2004
Color Aerial Photo 2009
Satellite Quickbird CIR 2005
0
50
100 m

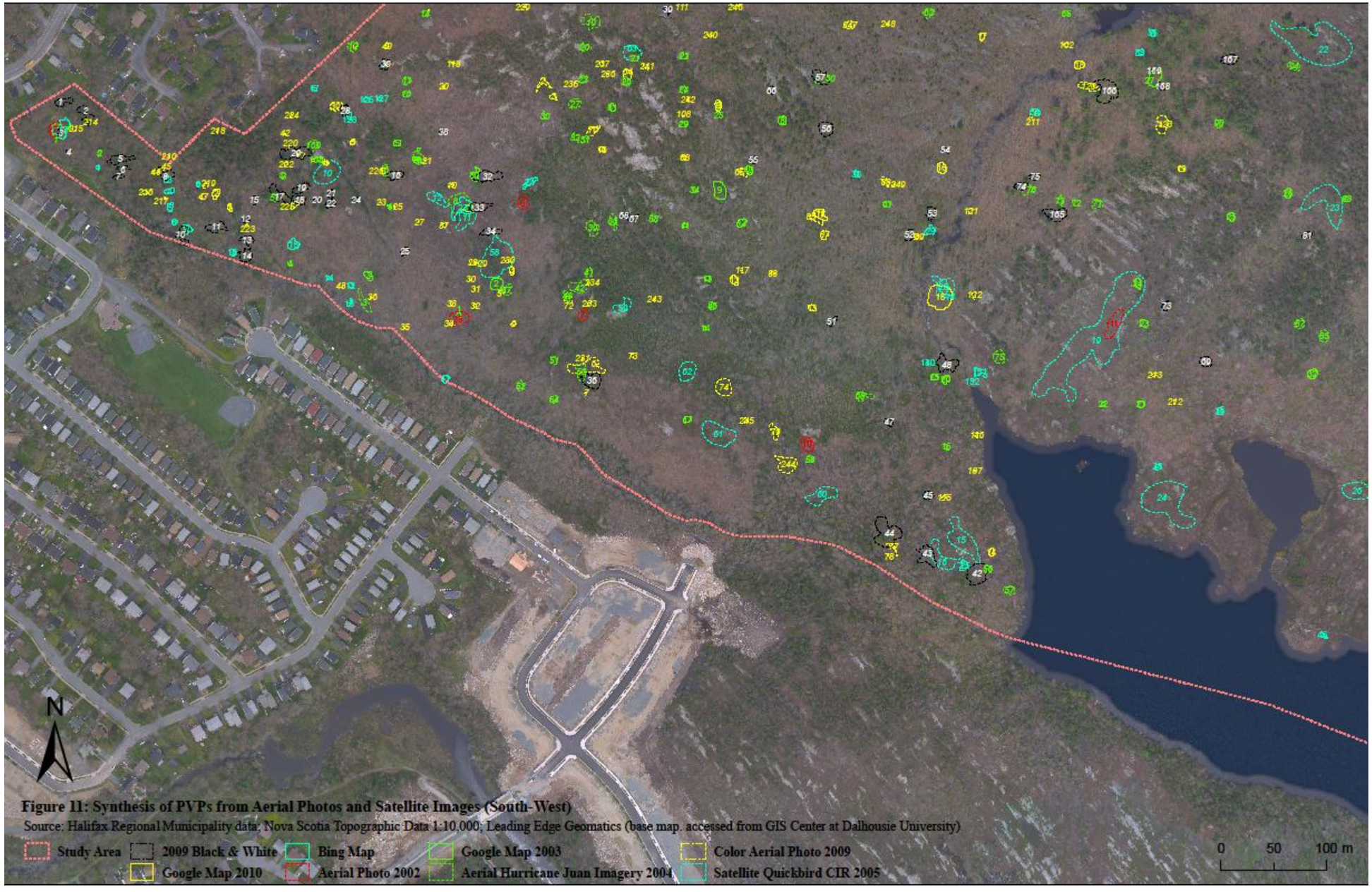
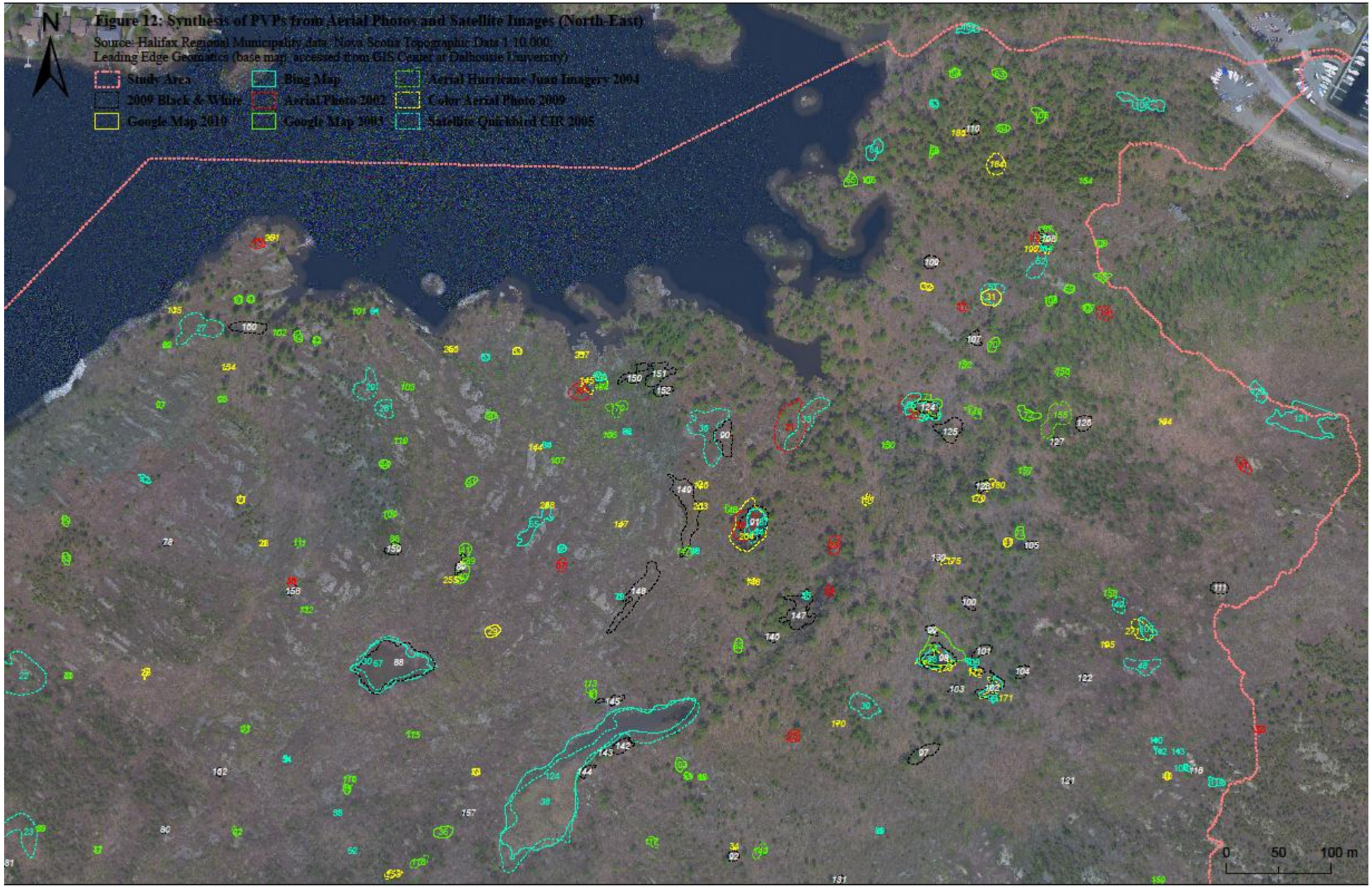


Figure 11: Synthesis of PVPs from Aerial Photos and Satellite Images (South-West)

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)


N
Figure 12: Synthesis of PVPs from Aerial Photos and Satellite Images (North-East)
Source: Halifax Regional Municipality data, Nova Scotia Topographic Data 1:10 000
Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)
Study Area
2009 Black & White
Google Map 2010
Bing Map
Aerial Photo 2002
Google Map 2003
Aerial Hurricane Juan Imagery 2004
Color Aerial Photo 2009
Satellite Quickbird CIR 2005
0
50
100 m

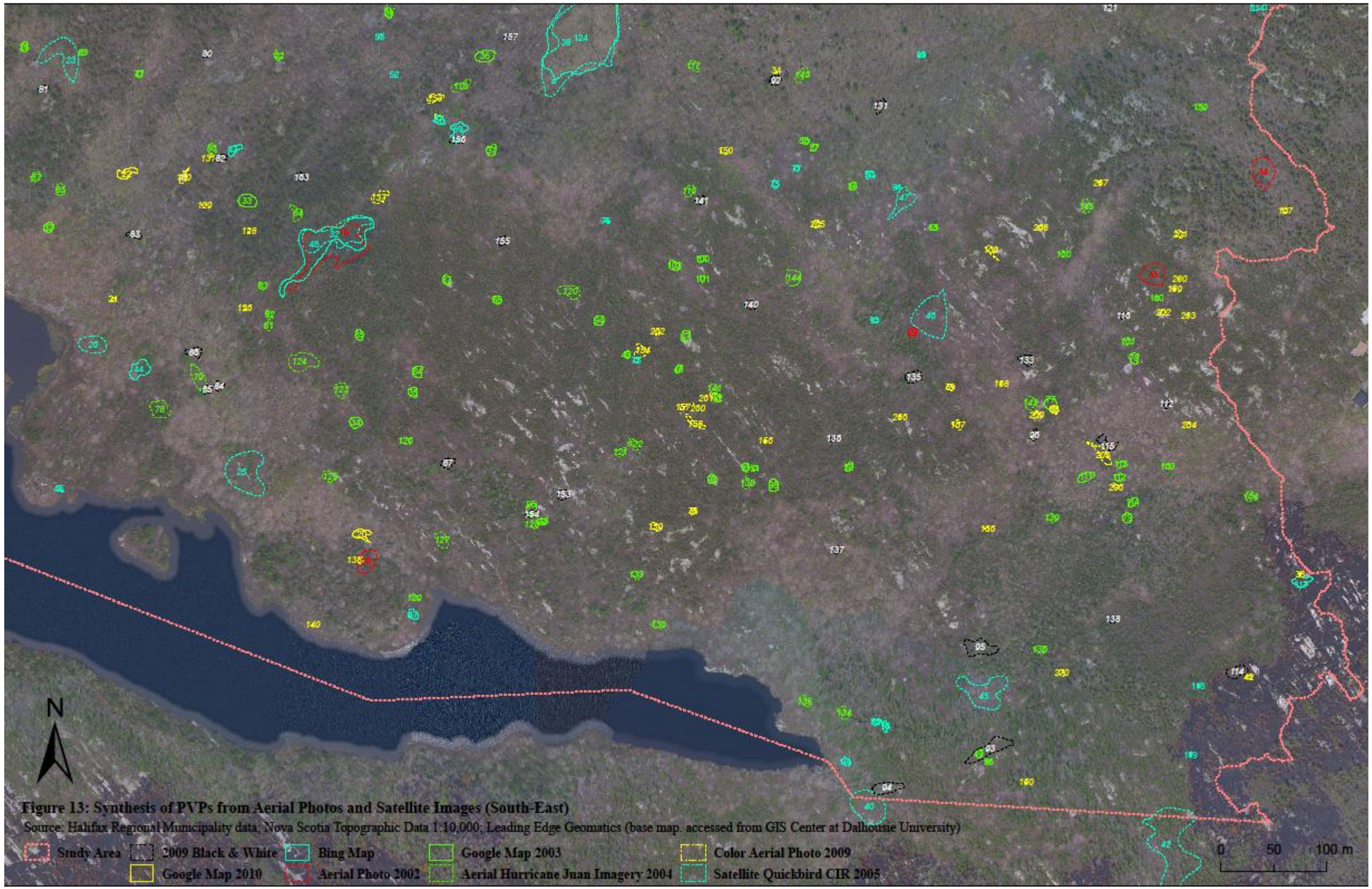


Figure 13: Synthesis of PVPs from Aerial Photos and Satellite Images (South-East)

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)

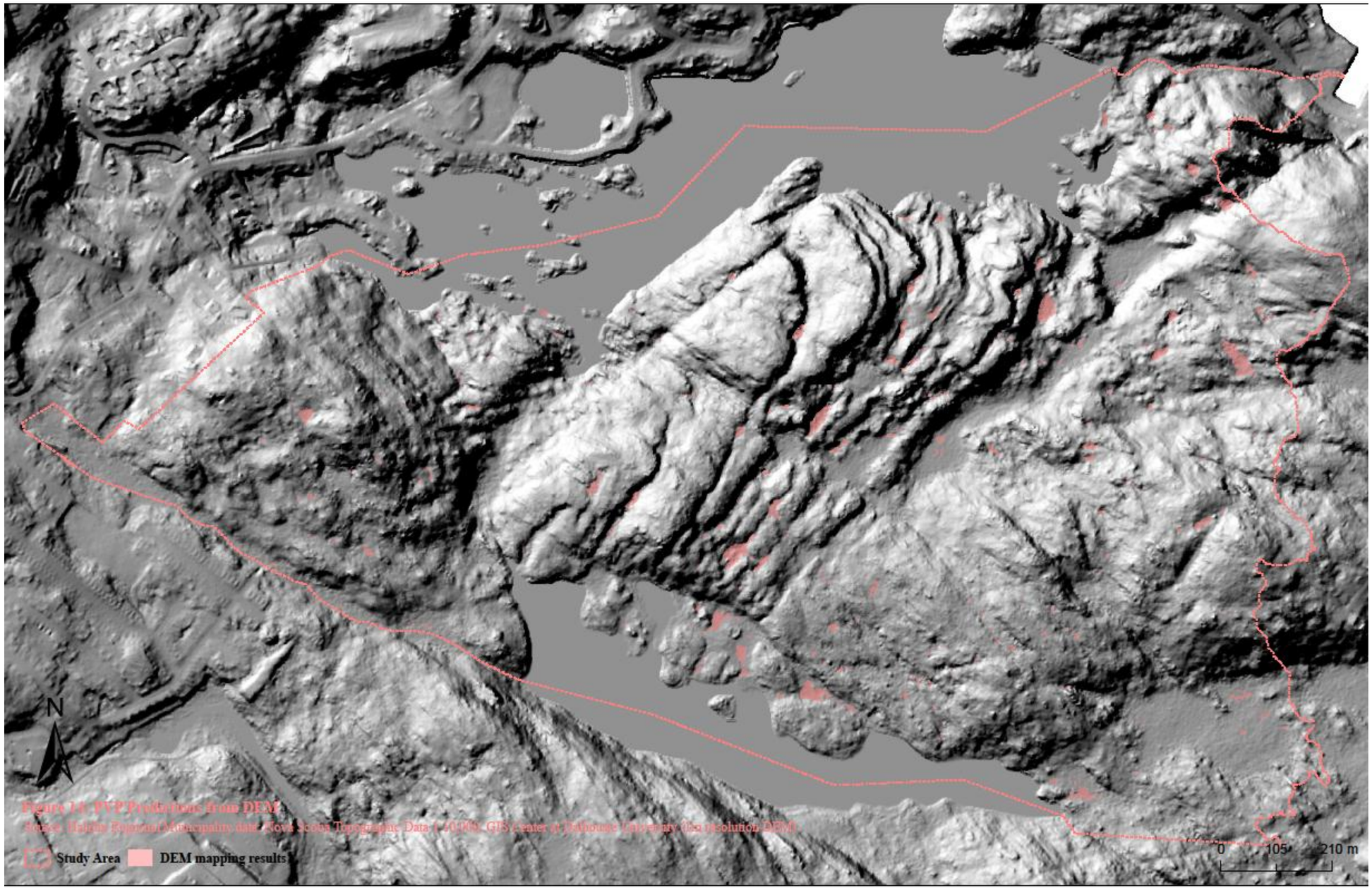
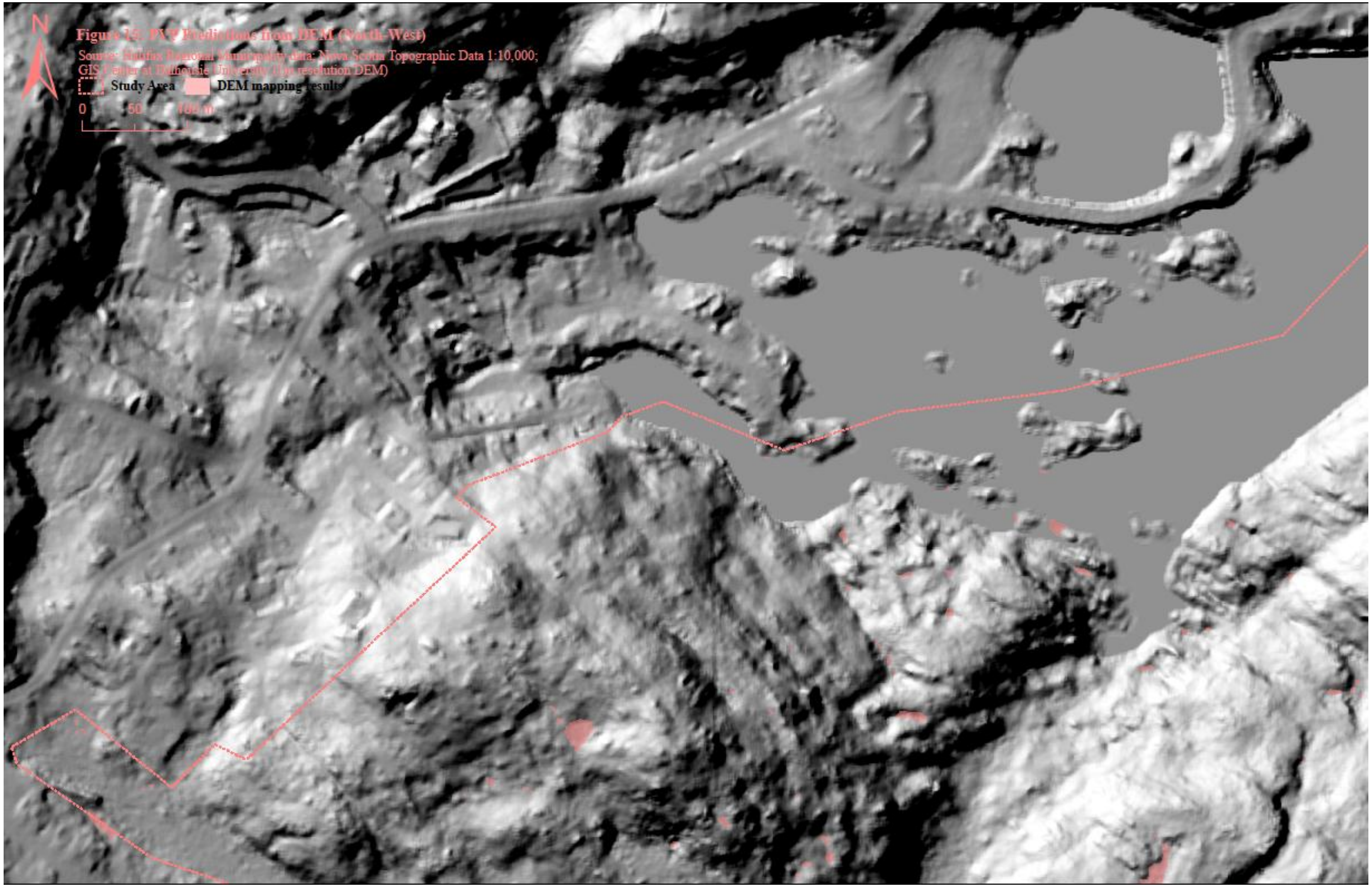


Figure 14: PVP Predictions from DEM

Source: Halifax Regional Municipality data, Nova Scotia Topographic Data (1:10,000), GIS Center at Dalhousie University (low resolution DEM)


N
Topographic Data 1:10,000;
Study Area
DEM mapping results
0
50
100 m

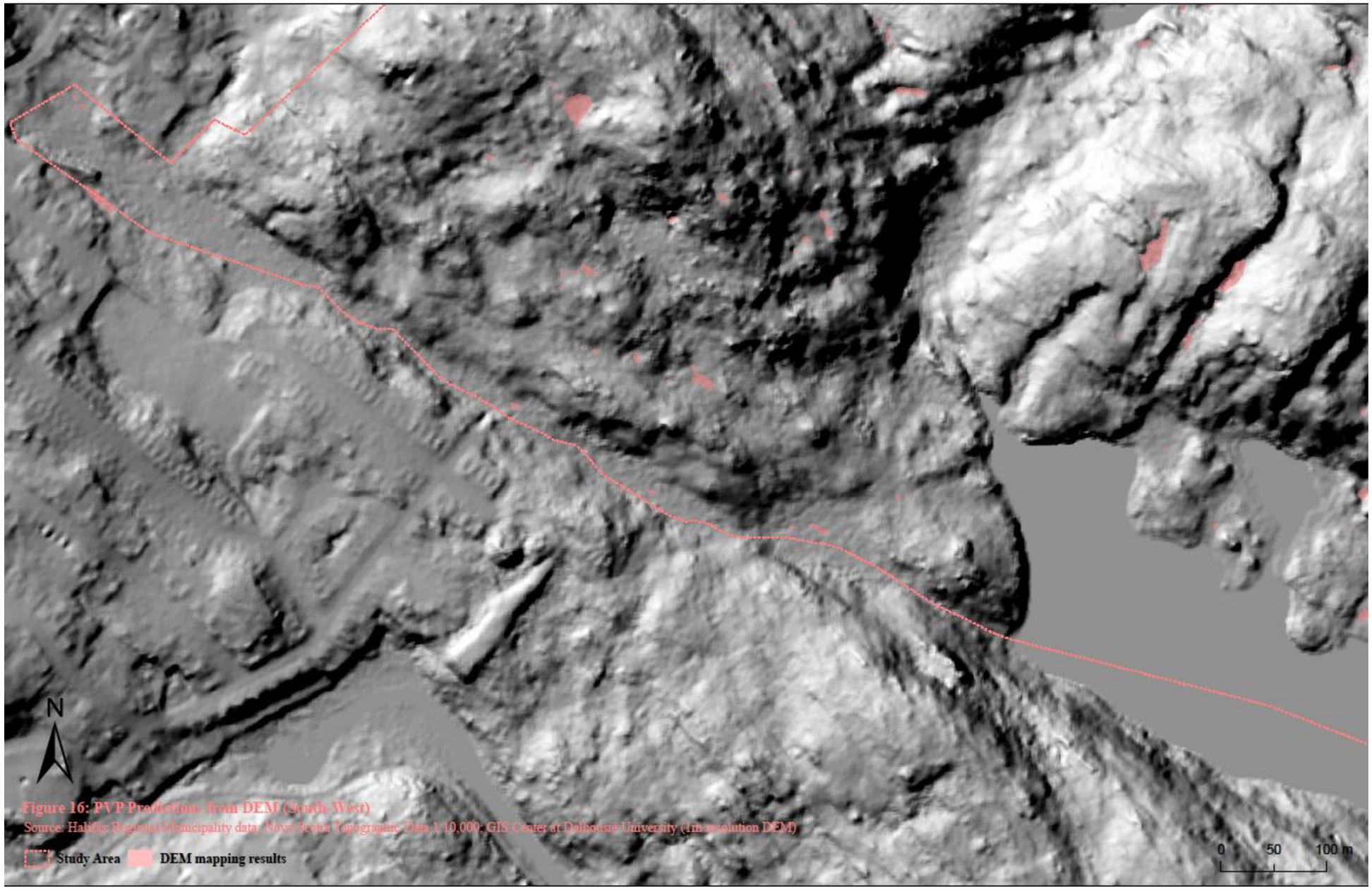


Figure 16: PVP Predictions from DEM (South West)

Source: Halifax Regional Municipality data, Nova Scotia Topographic Data 1:10,000, GIS Center at Dalhousie University (1m resolution DEM)

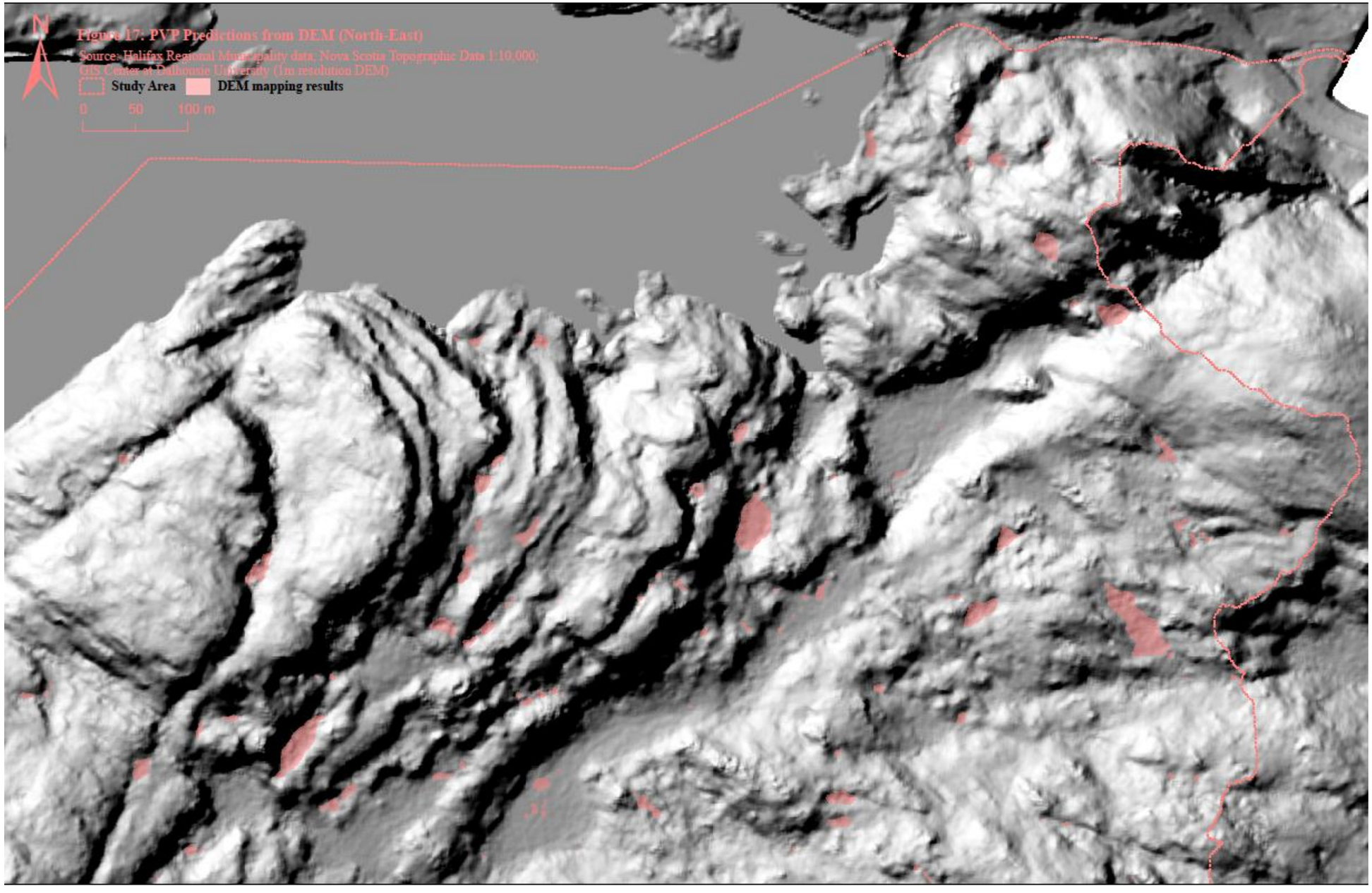


Figure 17: PVP Predictions from DEM (North-East)
Source: Halifax Regional Municipality data, Nova Scotia Topographic Data 1:10,000,
GIS Center, at Dalhousie University (1m resolution DEM)
Study Area
DEM mapping results
0
50
100 m

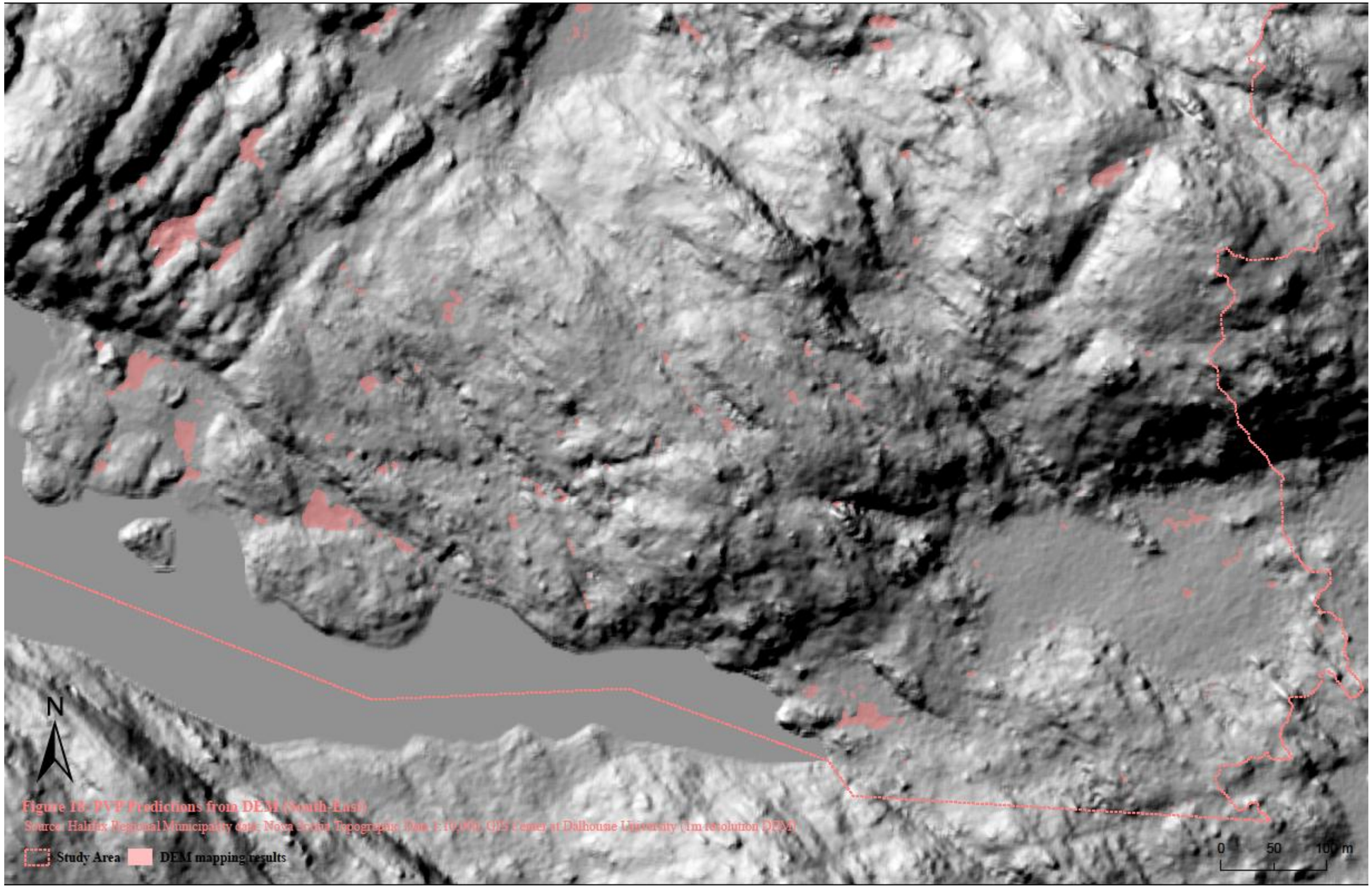


Figure 18: PVP Predictions from DEM (South-East)

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; GIS Center at Dalhousie University (1m resolution DEM)

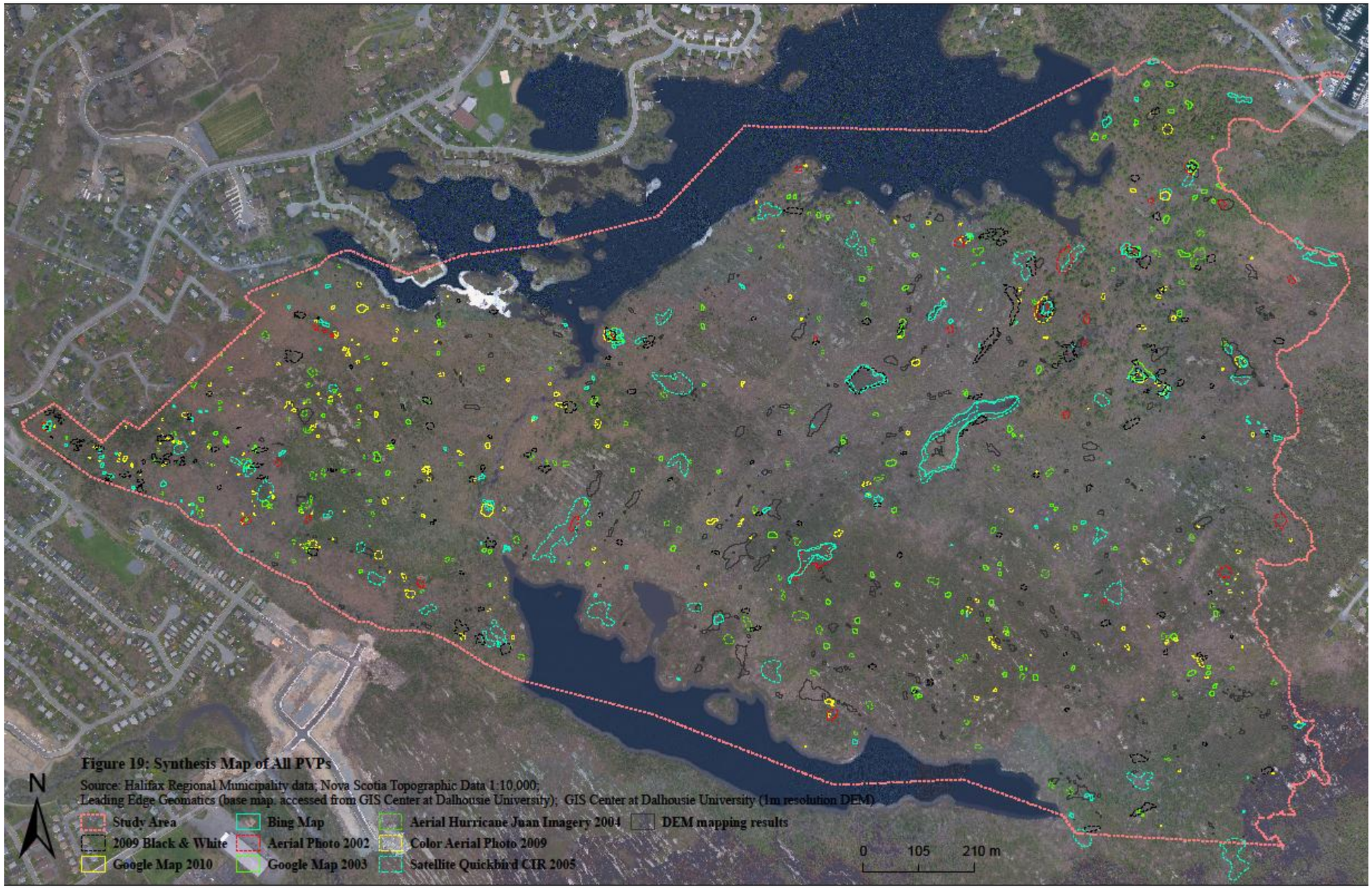


Figure 19: Synthesis Map of All PVPs

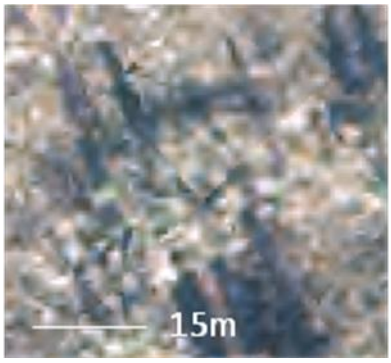
Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University); GIS Center at Dalhousie University (1m resolution DEM)

Figure 20: A PVP on Aerial Photos, Satellite Images, and DEM (at the mapping scale)

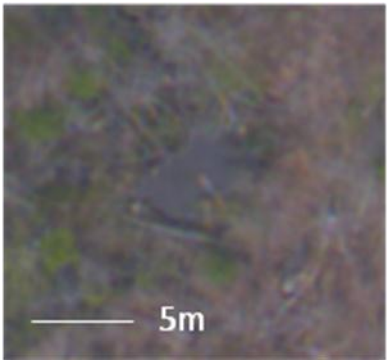
(Site 10 from 2009 Color Aerial Photo)

2002 Aerial Photograph (unavailable in digital format)

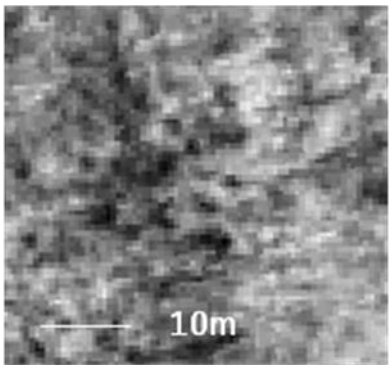
2003 Aerial Hurricane Juan Imagery



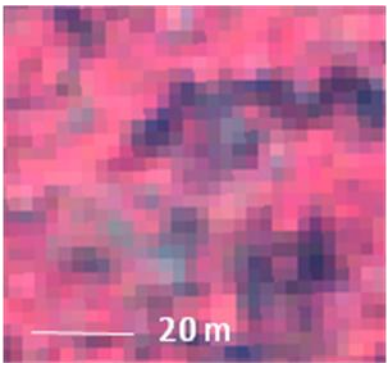
2009 Color Aerial Photo



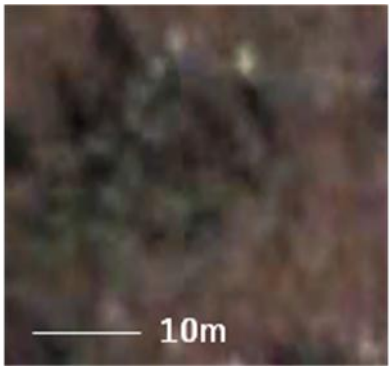
2009 Black and White Aerial Photo



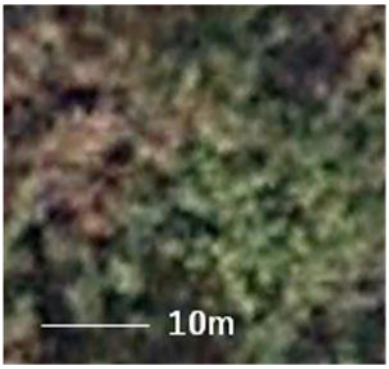
2005 Satellite Quickbird CIR



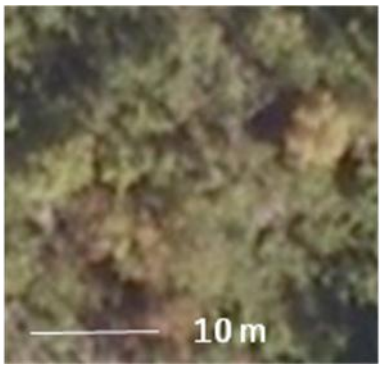
2003 Satellite Google Earth Map



2010 Satellite Google Earth Map



Satellite Bing Map



Digital Elevation Model

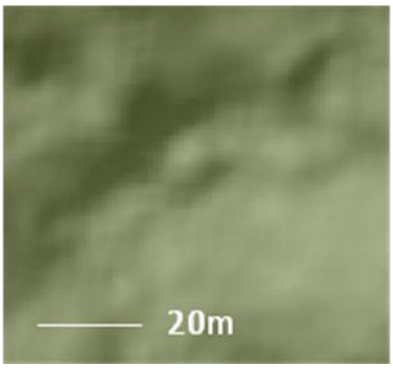


Figure 21: Field Trip Routes and Visited Sites

Source: Halifax Regional Municipality data; Nova Scotia Topographic Data 1:10,000; Leading Edge Geomatics (base map, accessed from GIS Center at Dalhousie University)