



Poplar River First Nation Fire Vulnerability Assessment

DRAFT REPORT

Prepared for Indigenous and Northern Affairs Canada • May 2018
By North/South Consultants Inc. and Poplar River First Nation

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A Draft Report Prepared for

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By:

Poplar River First Nation and North/South Consultants Inc.

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EXECUTIVE SUMMARY

Indigenous and Northern Affairs Canada, now Indigenous Services Canada's, Adapt Program provides funding for First Nation communities to assess and respond to climate change impacts on community infrastructure and emergency management. Poplar River First Nation (PRFN) and its partner, North/South Consultants Inc., have undertaken a two year project to assess vulnerability and develop adaptation strategies for the community under this funding opportunity.

Poplar River First Nation Elders describe a time when fires were uncommon in their traditional territory. More recently, *Binesi ishkode*, or "thunderbird fire" caused by lightning is thought to have become more prevalent. Elders and other land users have also observed the drying of vegetation in summer and higher temperatures throughout the year. High water content in the abundant peat soils in the traditional territory generally reduces fire risk; however, given the drying trend that has been observed, Elders strongly hold the view that the risk of peat fire is increasing, thereby threatening community infrastructure and members.

This vulnerability assessment is the first stage of a two-stage study being undertaken at Poplar River, Manitoba. This study focusses equally on both the traditional knowledge of the PRFN's members and respected Elders and a parallel scientific study. Participants shared traditional knowledge and local observations on changes to precipitation, temperature, the rate of evaporation, changes to vegetation, the timing and duration of freeze up and break up and other related observations within the living memory of the group. The scientific approach was used to measure and identify trends in weather data, climate data, provincial fire history data, and vegetation health and moisture data from satellite imagery spanning almost four decades (1984 – 2017).

Key results from the scientific study spanning from 1984 through 2017 suggest that temperatures are increasing throughout the growing season. Over the same time period, precipitation has increased and evapotranspiration has decreased suggesting overall wetter, non-drought conditions. Other measures of how 'green' vegetation is and surface moisture levels in the canopy show wetter than average years.

The 1984-2017 period has not been without drought, which has led to periodic fire events. A later season drying trend has been detected by Poplar River community members and Elders have noted moisture stress in the vegetation in later summer months. Models predict in the future Manitoba will be wetter in the spring and drier in summer months, making the summer months more susceptible to drought.

It would not be unreasonable to suggest that we are due for a shift towards a decades-long dry cycle according to the historical cycle that has repeated since the 16th century. This cycle, in combination with climate change-induced increases in temperature, decreases in precipitation in summer months, and increases in evapotranspiration may put communities such as Poplar River at increasing risk.

The second stage of this study will be an adaptation plan. Adaptation options have been prepared for community discussion. They include:

- Reviewing the proximity of the rapid attack bases to determine if the communities on the east side of Lake Winnipeg are best served by the Bissett base;
- Re-evaluating decision-making processes that expect peatlands to act as a natural fire break in lieu of deploying firefighting resources;
- Clarifying policy to ensure there are clear understandings and expectations of the provincial response to wildfires;
- Using traditional knowledge about fire behaviour to conduct community outreach on how to contain and control fire started by humans.
- Implementing local prevention options such as conducting community vegetation management and/or installing a fire break;
- Reviewing other preparedness options such as equipment and human resource readiness for local response; and
- Consider preparing a fire management strategy that is based on and serves local needs.

Other activities to be completed include the initiation of a long-term peatland moisture monitoring program and a GIS application that is built for early detection of high-risk factors.

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1.0 INTRODUCTION

Indigenous and Northern Affairs Canada, now Indigenous Services Canada's, Adapt Program provides funding for First Nation communities to assess and respond to climate change impacts on community infrastructure and emergency management. This report documents the first stage of a two-stage study being undertaken at Poplar River, Manitoba. This report contains the results of the vulnerability assessment. The next step – the adaptation plan – will be reported on by the end of the 2018/2019 fiscal year.

What is a vulnerability assessment?

Goals of this assessment are to discover and document the vulnerabilities of the Poplar River First Nation (PRFN) to forest fire hazard. Vulnerability assessment is defined as the process of identifying, quantifying, and prioritizing the vulnerabilities of a community. The outcome is an assessment of the threats from potential hazards to the population and to the infrastructure followed by an action or adaptation plan.

Approach to the vulnerability assessment

This study focusses equally on both the traditional knowledge of the PRFN's members and respected Elders and a parallel scientific study. Typically, these two forms of knowledge inform each other and mutually reinforce each other. This study was initiated because of local observations of drying vegetation and concerns over community safety and security. Further documentation of local observations and knowledge was undertaken.

The scientific approach was used to measure and identify trends in weather data, climate data, provincial fire history data, and vegetation health and moisture data from satellite imagery spanning almost four decades (1984 – 2017). This report contains methods for both studies in Section 2.0, results in Section 3.0 and a summary, comparison, and discussion of the findings, including suggestions for next steps, in Section 4.0.

1.1 STUDY AREA

The Poplar River Traditional Territory / Asatiwisipe Aki Traditional Use Planning Area

Poplar River is a remote First Nation community of 1,200 people on the east side of Lake Winnipeg situated at 52.99°N, -97.27°W. The Poplar River Traditional Territory (PRTT), also known as the Asatiwispipe Aki Traditional Use Planning Area (AATUPA), covers over 8,800 km^2 of boreal shield and peatlands in the Lac Seul Upland Ecoregion (Figure 1). The climate of this area can be characterized as having a dominant winter season of short, clear and bitterly cold days with little precipitation (Weatherbase 2018). Summers are short and mild with precipitation concentrated in summer months. Measured at nearby Berens River and averaged over 30 years from 1981 to 2010 inclusive, monthly rainfall averages are just over 62 mm for each of the four summer months from June to September (Government of Canada 2018a). Average monthly precipitation during the spring, fall and winter months has been only 39 mm (Government of Canada 2018).

Within the Lac Seul Upland Ecoregion, the AATUPA can be classified into three Ecodistricts (Figure 2): Berens River, Wrong Lake and Nopoming. The Berens River Ecosdistrict (#370) is a low-lying, low gradient area of the AATUPA adjacent to Lake Winnipeg in the west and is extensively covered by peat due to poor drainage and low relief. This predominant peatland landscape is broken by periodic large rock outcrops (PRFN 2011). The Wrong Lake Ecodistrict (#371), which covers the eastern portion of the AATUPA, is characterized by bedrock covered by thin glacial mineral deposits with glaciolacustrine sediments in the west. The Nopoming Ecodistrict (#373) is located in the far southeast corner of the AATUPA and is composed of a mixture of exposed bedrock, shallow till deposits, and small peatland deposits (PRFN 2011).

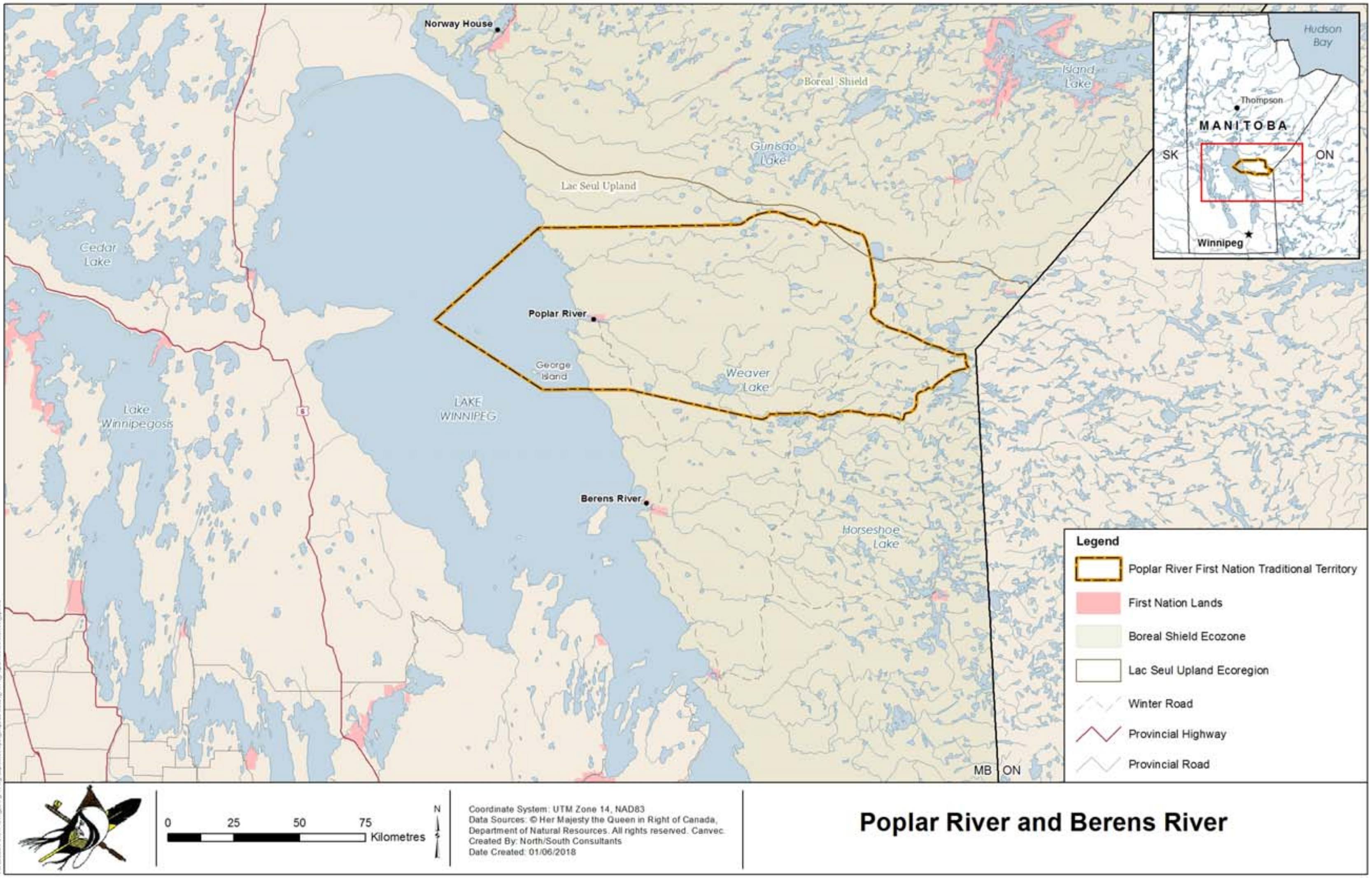

Figure 1. Asatiwisipe Aki Traditional Use Planning Area (AATUPA) and the community of Poplar River on the northeast shore of Lake Winnipeg.

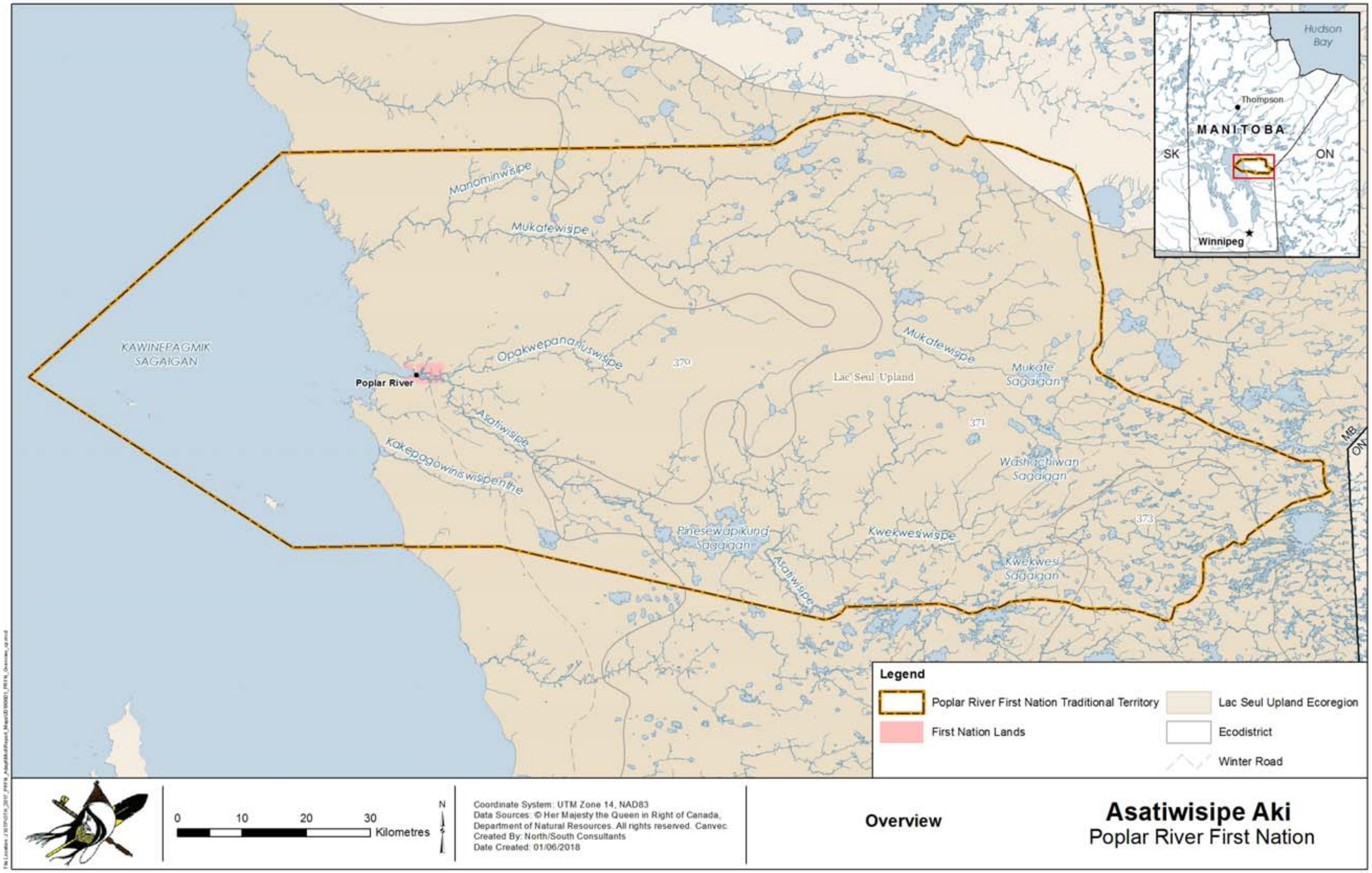

Figure 2. Map of the Asatiwisipe Aki Traditional Use Planning Area and the community of Poplar River complete with Anishinabemowin place names.

1.2 BACKGROUND

What is climate change?

It should be noted that climate is different from weather. Weather can be thought of as short-term conditions. Climate change, on the other hand, refers to the long-term average pattern of weather.

Climate change is widely recognized as the most urgent problem facing humanity. The burning of fossil fuels has increased carbon dioxide (CO_2) in the atmosphere, which creates a greenhouse effect. Overall temperature measurements show that the earth has been warming, particularly over the last 50 years. In fact, 17 of the 18 warmest years have occurred since 2001 (Climate Atlas of Canada 2018).

How might climate change affect the risk of fire?

Long-term analyses of tree rings provides data that show multi-decade cycles on the Canadian prairies that alternate between wet and dry. These cycles have occurred for the past 1000 years. Specific drought periods have been identified such as a period in the 16th century, several timeframes in the 1800s, the 1930s, the early 1960s, the late 1980s, from 1999 to 2004, and individual years including 2012 (Manitoba 2018). Recent exceptionally wet years include most of the 1990s, 2009 and 2011. Natural fluctuations between wet and dry conditions, some of which last decades, require that very long-term datasets be used to understand climate change.

On a national scale since 1990, about 7,500 fires burned an average of 2.4 million hectares of forest in Canada each year. Climate change is expected to increase both the number of fires and area burned by fire annually as unseasonable and extreme weather becomes more common (Natural Resources Canada 2018a, Canadian Council of Forest Ministers 2016). One estimate predicts that the area burned annually in Canada could double by 2040 (Canadian Council of Forest Ministers 2016).

Climate change models predict that Manitoba will become wetter in spring but drier in summer (Prairie Climate Centre 2018). Climate assessments suggest that the central and northern Great Plains may experience a 3.6°C to 6.1°C increase in mean air temperature over the next hundred years (Johnson et al. 2005). Reduced summer precipitation in combination with an increase in the number of days experiencing very hot weather may lead to increased drought (Prairie Climate Centre 2018) and consequently, increased fire risk. Hotter summers are projected for all parts of Manitoba and these conditions are expected to impact forests through an increase in the frequency, intensity, and extent of fires, droughts, and pest outbreaks (Prairie Climate Centre 2018).

Regionally, in northern Manitoba, climate change has been implicated in the melting of permafrost in northern peatlands (Malley 2007). In general, it’s expected that warmer temperatures will increase evapotranspiration in peatlands, lowering the position of the water table and decreasing surface soil moisture content (Roulet et al. 1992; Flannigan et al. 2009). As the peat dries out, it becomes more prone to wildfires that burn longer and smoulder (Malley 2007). This is problematic due to the emission of carbon dioxide and smoke which reduces regional air quality (Malley 2007). Rural communities, many of them Indigenous, are located in remote areas where forests burn frequently. These communities are especially affected, and thousands of people are evacuated each year as a result of forest fires.

What are the community concerns?

Poplar River First Nation Elders describe a time when fires were uncommon in the AATUPA. More recently, *Binesi ishkode*, or "thunderbird fire" caused by lightning is thought to have become more prevalent. Elders and other land users have also observed the drying of vegetation near the community and in their territory.

High water content in peat soils generally reduces fire risk. Given the drying trend that has been observed, Elders strongly hold the view that the risk of peat fire is increasing, thereby threatening community infrastructure and members. In 2017, four communities on the east-side of Lake Winnipeg were completely or partially evacuated due to poor air quality and encroaching wildfires including Poplar River, Garden Hill and Wasagamack First Nations and St. Teresa Point (Figure 3).

Figure 3. View of smoke near Wasagamack First Nation from the St. Teresa Point aerodrome as seen by 2017 evacuees (photo credit- Mark Wood Ganabook).

Peat, Peatlands, Vegetation, and the Risk of Fire

Peatlands, or muskeg, are organic wetlands that contain 40 or more centimetres of accumulated peat covered in a layer of organic soil (National Wetlands Working Group 1997). Peat is composed primarily of moss, herbaceous, woody, or detrital materials (Charman 2002). Peat forms when partially decomposed remains of plants and animals or organic debris accumulate at a rate faster than decomposition (Wieder et al 2006). Peat is formed in water-saturated, low oxygen environments where decomposition is slower than accumulation due to low temperatures, poor drainage, and other complex causes (Tarnocai et al. 2000; Rydin and Jeglum 2006). Peatlands have a great global importance because of their ability to retain, purify and deliver fresh water, store large amounts of carbon, absorb environmental pollutants and support large numbers of floral and faunal species (Tarnocai et al. 2000).

There are two primary classifications of peat-forming wetlands: fens and bogs (National Wetlands Working Group 1997). While swamps and marshes can also form peat, they typically do not contain deposits greater than 40 centimetres in depth and are therefore considered non-peat-forming wetlands (Halsey et al. 1997). Fens have mineral soil waters at or near the surface and are dominated by mosses such as sphagnum and brown mosses and sedges and shrubs. Bogs are peatlands that are typically raised above the surrounding topography and receive all their water from precipitation. Bogs have low water flow with the water table generally 40 – 60 cm below the surface, and the dominant vegetation is *Sphagnum* mosses with the presence of shrubs and black spruce (*Picea mariana*) tree cover (National Wetlands Working Group 1997). Swamps are not found in the AATUPA, while marshes are sparse and located towards the western extent near the shores of Lake Winnipeg. Marshes are open, non-peat forming wetlands that are dominated by sedges and cattails and receive water from both ground and surface waters. Fen and bog peatlands have a common vertical profile structure that includes a living plant layer which is 30 – 50 cm thick and referred to as the acrotelm (Quinty and Rochefort 2003), situated on top of an oxygen-starved slowly decomposing lower layer called the catotelm (Charman 2002). Deposits of peat in this area of the boreal shield can reach 300 – 400 cm in depth (Tarnocai et al. 2000).

The vegetation gradient found within the AATUPA (illustrated in Figure 4 and mapped in Figure 5) shows that 54% of the area consists of marsh, fen and bog. Vegetation ecotypes in the AATUPA can be described by Ecodistrict (Figure 2). The Berens River Ecodistrict on the west side of the AATUPA has the highest concentration of fen, bog, and marsh. Vegetation ecotypes include: Lowland Black Spruce (*Picea Mariana*), consisting of black spruce stands on organic deposits with tamarack and white cedar in the canopy, a developed shrub layer, and a continuous cover of *Sphagnum* and feather moss; and Aspen Hardwood and Mixedwood, which is dominated by aspen poplar but also includes white birch, balsam poplar, jack pine, balsam fir, white spruce, and black spruce, and contains dense shrub and herb understories with an underdeveloped moss layer (PRFN 2011). The Wrong Lake Ecosdistrict on the east side of the AATUPA (Figure 2), is spotted with numerous lakes where black spruce is the dominant tree species occupying imperfectly drained uplands and bog peatlands, jack pine and aspen poplar are found on upland sites, and where drainage allows, white spruce balsam fir, aspen poplar, and balsam poplar form productive stands (PRFN 2011). The Nopiming Ecodistrict (Figure 2) in the southeast corner of the AATUPA is dominated by jack pine stands located on shallow sandy soils and bedrock outcrops. Jack pine is found in pure stands or in association with the dominant black spruce in deeper sandy soils (PRFN 2011).

Although there are large continuous areas of non-wetland forest stands within the PRTT, the high concentration of peatlands near the community and in the western portion of the PRTT (Figure 5) presents a strong probability of increased susceptibility to fire as peat vegetation communities potentially dry out due to climate change. As discussed earlier, warmer temperatures have the potential to increase evapotranspiration lowering the position of the water table and decreasing surface soil moisture content in peatlands. The position of the water table relative to the surface of the peatland is of great importance when assessing the susceptibility of peatlands to fire, and a reduction in surface peat moisture content has a direct effect on fire behavior (Zoltai et al. 1998). This risk is aggravated by the nature of peat fires, which in the absence of rapid emergency response, can become virtually inextinguishable and can threaten community infrastructure and quality of life for extended periods of time.

Dried peat can catch fire and spread rapidly; however, the ability of peat to ignite and sustain combustion is a function of its moisture content (Zoltai et al. 1998). A September 2005 bog fire in British Columbia illustrates the persistence of a peatland fire once it takes hold: a fire in the Burns Bog Delta Nature Preserve in British Columbia grew in size from 20 ha to 200 ha in just three days (Malley 2007). Although considered a relatively small peat fire, it was difficult to combat. Many strategies were used to extinguish the fire including the use of water bombers, controlled increase in bog water levels and the rapid and exhaustive efforts by firefighters (Malley 2007). Air quality in the immediate and extended region was strongly impacted despite these efforts (Malley 2007). Fires can also smoulder underground only to emerge again when conditions are favourable. In one anecdotal account of a deep peat fire, a roadside peat fire seen smouldering near Gillam, Manitoba in 1995 was thought to have been ignited by a forest fire that originally swept across the area in 1992 (Zoltai et al. 1998).

Fire Fighting Policy and Capacity

According to the PRFN land use plan, the AATUPA is in a non-commercial forestry zone and within the “green” fire protection zone or a ‘let it burn’ policy (PRFN 2011). Poplar River First Nation works with the provincial fire management authorities to update fire suppression locations as required. In its land management plan, PRFN supports the establishment of fire suppression zones around the community and Weaver Lake by the Province (PRFN 2011).

More recent information on Manitoba Sustainable Development’s website (2018) identified the region as being in the “Primary Protection Zone” (Figure 6), in which the Province “will carry out an immediate initial response on all fires and will carry out an initial attack whenever [property / forest resource] values warrant and suppression resources are available”. Manitoba Sustainable Development’s Fire Program mandate under the Wildfires Act is to directly provide and/or support fire protection in the Primary Protection Zone (Sustainable Development 2018). Sustainable Development is responsible for the detection and suppression of wild fires, and resource allocation to fight fires.

As reported by the community emergency management coordinator, a fire started on August 5th, 2017 and upon speaking to Provincial officials, they predicted the fire would go out by itself due to its proximity to peatlands. It was understood that water bombers were in use elsewhere and none were available to fight the fire.

Despite predictions, fire #EA051 crossed peatlands and spread to within 5 km of the community. On August 10th, 2017, a partial evacuation was ordered and on August 22nd a full evacuation notice was given by community leadership. Residents began returning to the community on September 5, 2017 once the fire was extinguished. No one was injured and no property was damaged by fire.

The major initial attack bases in the Province are located in Bissett (Eastern region), Snow Lake (Northwest Region) and Paint Lake (Northern Region). The Bissett base is considered to be too distant from the community (over 250 km away) which causes a lag in response time. Had a response to fire #EA051 been provided earlier, the community believes that the fire could have been contained to a much smaller area. However, the Province acted within its mandate by delaying an initial attack because at the outset, no property/forest resource values were at risk and the presence of peatlands was thought to be a reliable fire barrier.

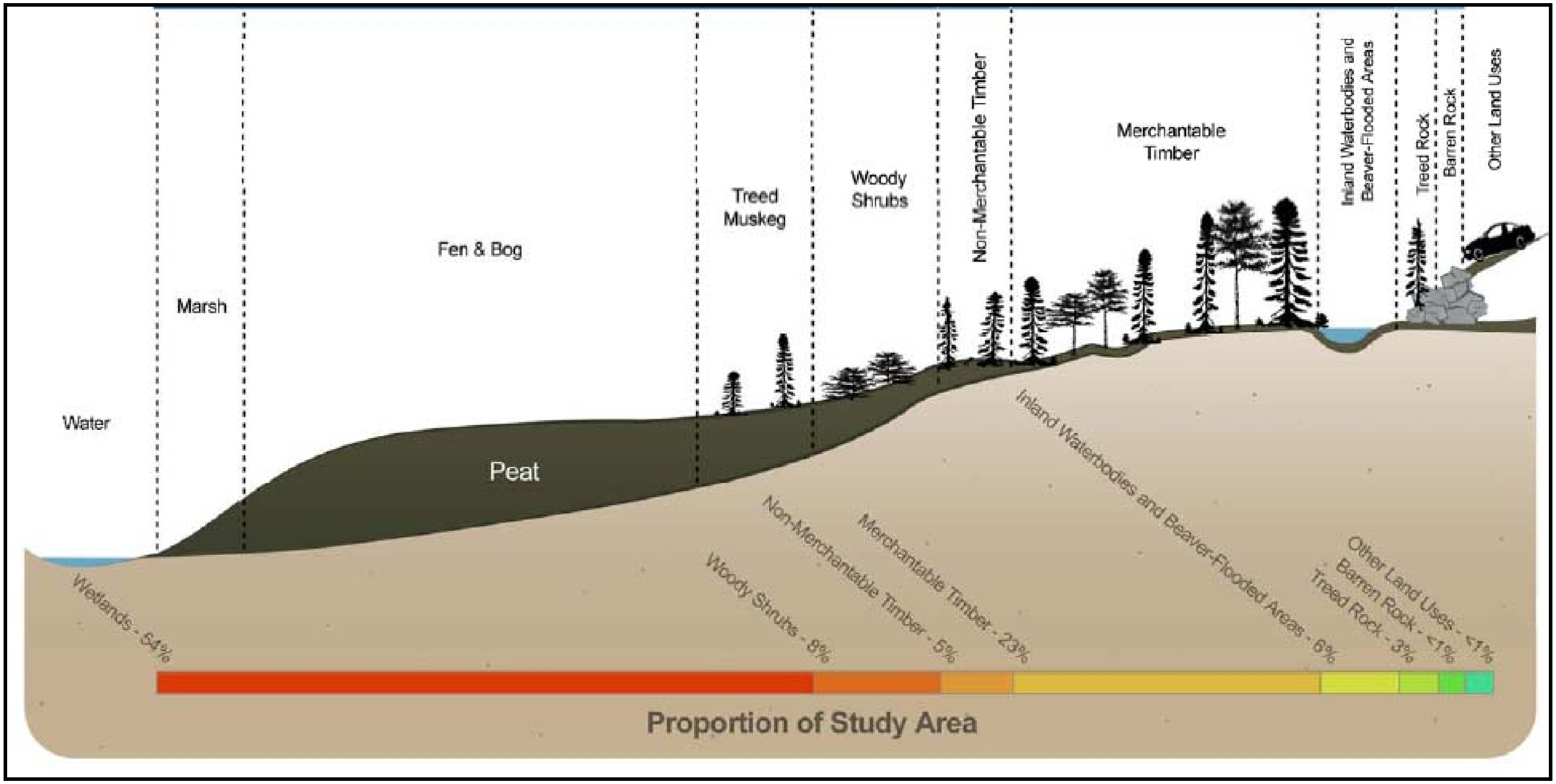

Figure 4. Ecological Land Classes typically found along the topographic gradient from west to east in the PRTT showing the area (%) represented by the main types of land cover in the area (Cooley et al. 2009).

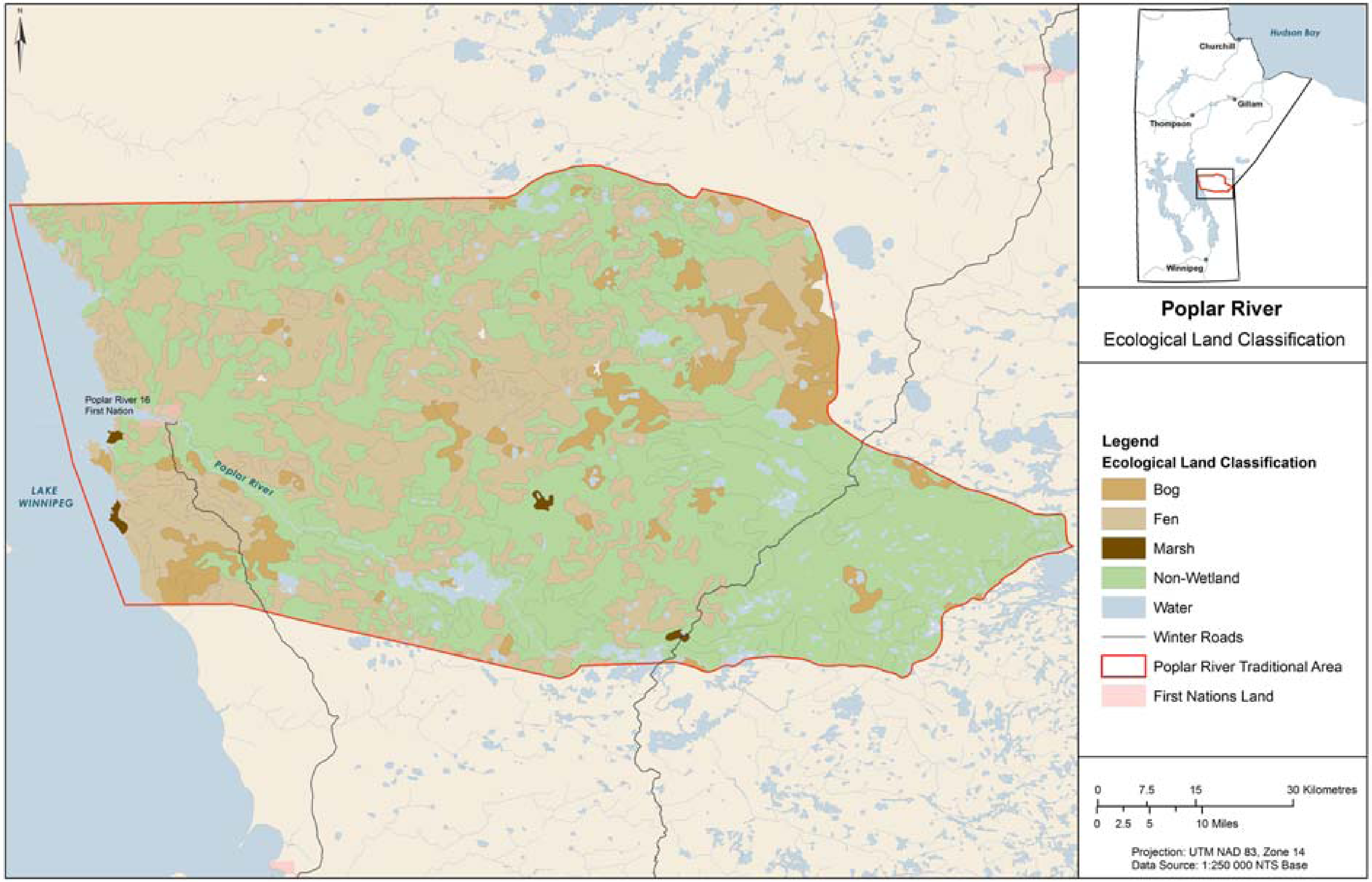

Figure 5. Ecological Land Classes in the AATUPA showing the locations of peatlands and wetlands (Cooley et al. 2009).

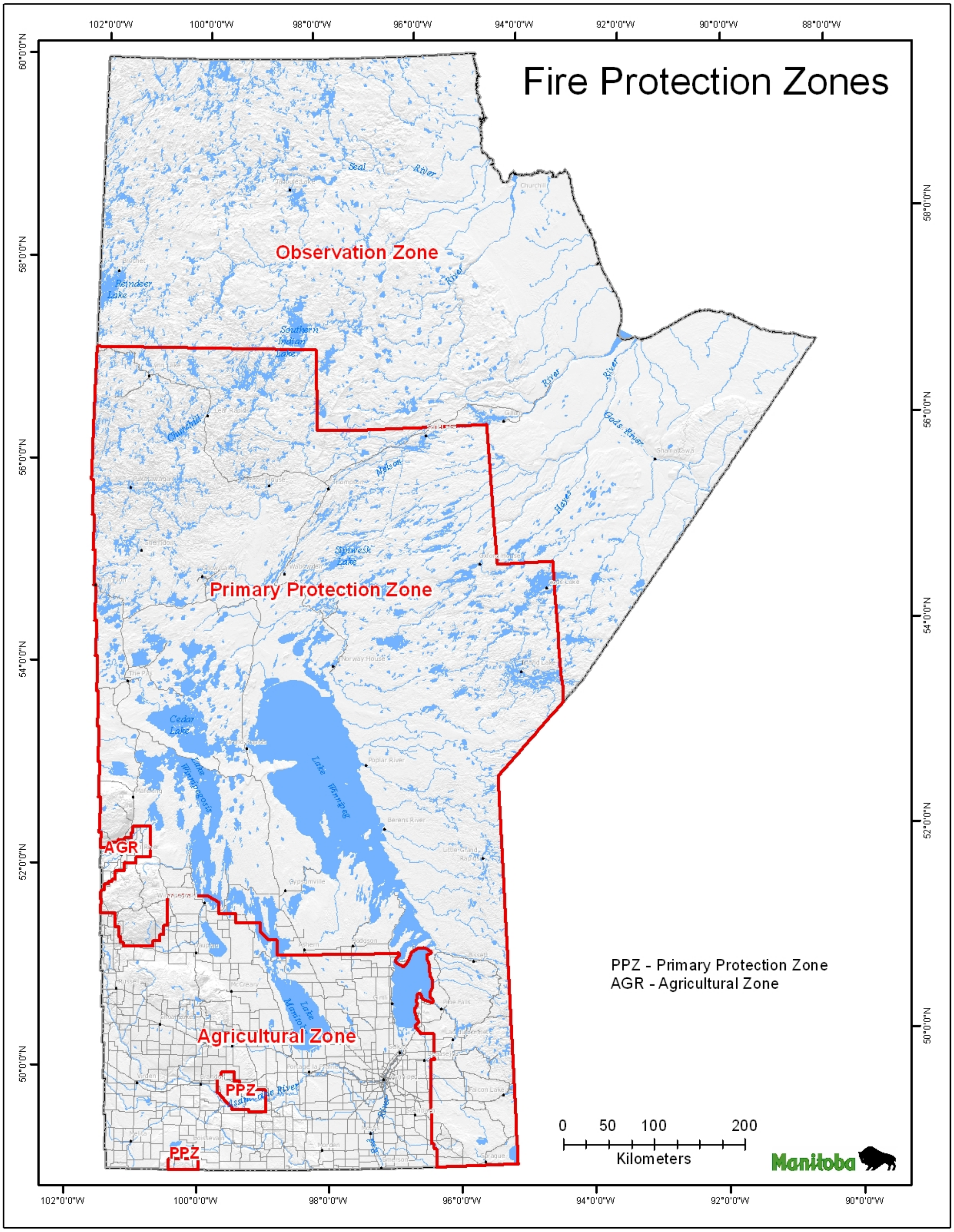

Figure 6. Provincial fire protection zones.

Indicators of Weather, Climate, Vegetation Response, and Remote Sensing

In order to determine whether climatic changes are having an adverse effect or increasing a region's vulnerability to forest and peatland fires, a number of available scientific data sets can be examined. Scientific weather and climate data have been recorded from sensors and gauges over long periods of time. Environment Canada maintains long-term weather records across a network of weather stations throughout Canada. Weather data provides information about the short-term behaviour of the atmosphere, while climate data are ideal for examining long-term trends of the atmosphere in a given location or area of the world. Precipitation and temperature data analyzed over long periods are basic indicators of climate change trends.

Other indicators of climate change include derived data sets that help to identify periods of drought or wetness. For example, the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010) is a global spatial indicator of drought trends or conditions. The SPEI is based on precipitation and temperature data and is sensitive to potential evaporation demand caused by temperature fluctuations and trends. SPEI is well suited for detecting, monitoring, and exploring the consequences of global warming and/or drought conditions (Vicente-Serrano et al. 2010).

Remotely sensed data provide invaluable information over large areas of the Earth's surface that are either inaccessible, or too large to study from the ground. Optical multispectral satellite sensors are used to observe the response of the Earth's surface to the Sun's energy, or electromagnetic radiation (EMR). Different satellite sensors are "tuned" to sense specific ranges or bands of the EMR spectrum. For example, the human eye is able to sense visible light in the blue, green, and red range or bands of the electromagnetic spectrum; we are unable to see the near-infrared (NIR) radiation range. Multispectral satellite sensors are able to detect the varying amount of reflected or absorbed radiation in the NIR range and in ranges with longer or shorter wavelengths from the surface of the earth. Landsat, one of many satellite systems currently orbiting the earth, provides over 40 years of multispectral earth observation imagery, which makes it a valuable tool for monitoring trends in the response of the Earth's surface to the Sun's energy (Figure 7).

Through the use of remote sensing data processing methods, indicators can be developed from different multispectral satellite band image combinations. These derived indicators detect certain characteristics of ground targets. For example, to determine the density of green on a patch of land, we have to observe and record the wavelengths of visible and NIR sunlight reflected by the plants. Chlorophyll, the pigment in healthy living plant leaves, strongly absorbs visible light in the range from 0.4 to 0.7 µm for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects NIR light in the rage from 0.7 to 1.1 µm. The more leaves a plant has, the more these wavelengths of light are affected, respectively (NASA 2018). The combination of these two bands in a simple equation provides us with an indicator known as the Normalized Difference Vegetation Index (NDVI) (Figure 7). By comparing NDVI values for a given year to NDVI of a long-term multi-year average for the same time of year (e.g., August), you can determine dry or wet years based on the greenness or health of the vegetation. NDVI can therefore be used as an indicator of drought (NASA 2018).

Another derived indicator is the Normalized Difference Moisture Index (NDMI) (Figure 7). NDMI provides a measure of canopy water content. This index contrasts the NIR band, which is sensitive to the reflectance of leaf chlorophyll content to the mid-infrared (MIR) band, which is sensitive to the absorbance of leaf moisture. The lower the NDMI value, the lower the moisture content of leaf. Many studies have used NDMI as an indicator of drought in forest ecosystems (Assal et al. 2016).

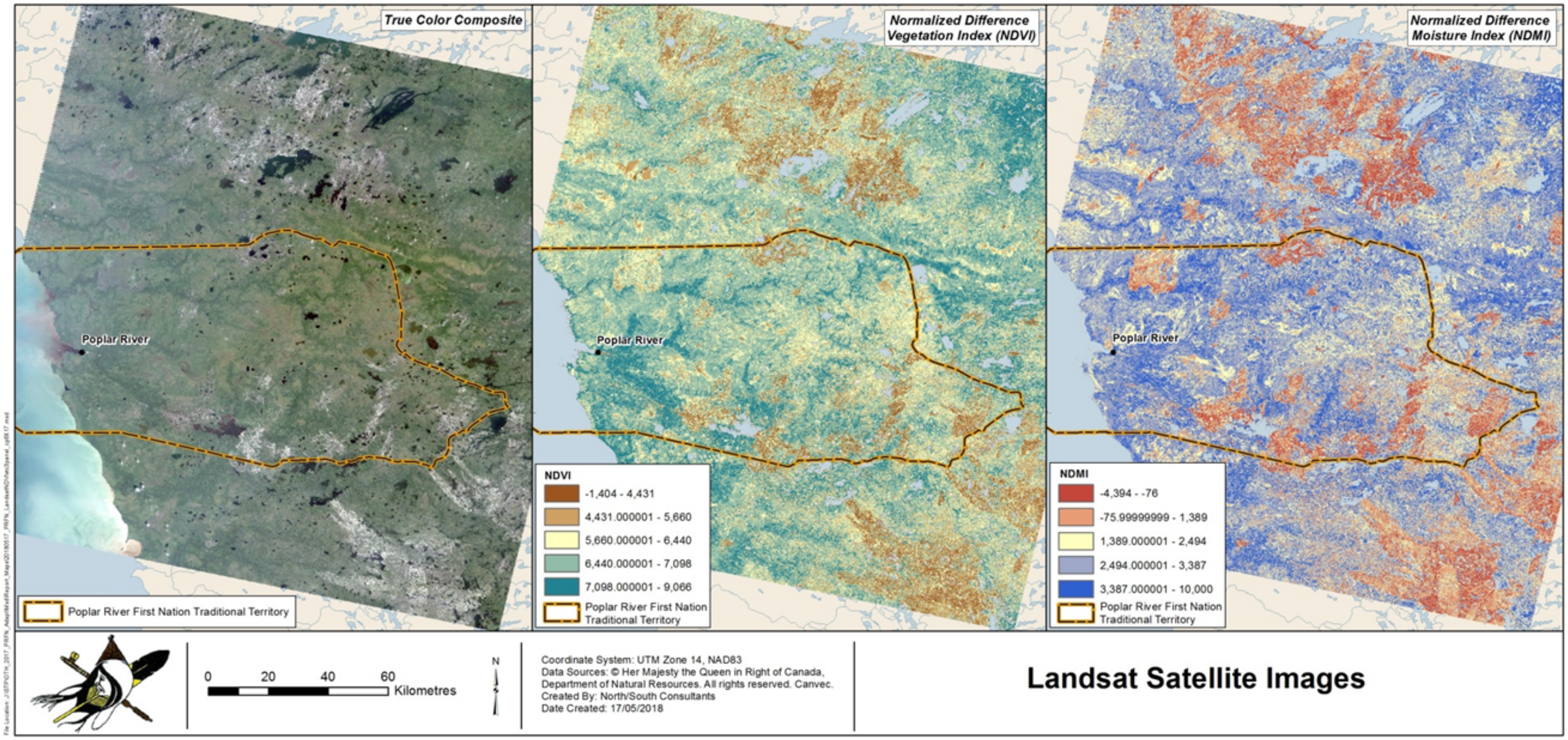

Figure 7. True Color Composite Landsat 5 TM satellite image of the AATUPA, August 20, 1993 (Left Pane); NDVI derived data (Middle Pane); NDMI derived data (Right Pane).In both derived images brown and reddish areas indicate no vegetation growth (barren land, and rock outcrops). Darker green (NDVI) areas represent healthy dense green vegetation, and darker blue areas (NDMI) represent moist conditions.

2.0 APPROACH AND OBJECTIVES

The vulnerability assessment has one primary objective - to verify and assess the degree of vulnerability to fire by drawing upon traditional knowledge and scientific methods. To achieve this objective, two concurrent studies are being undertaken – one to access and document traditional knowledge of community members and one using scientific inquiry. Each is explained below.

2.1 TRADITIONAL KNOWLEDGE AND CLIMATE CHANGE

With collective knowledge of the lands and waters, Indigenous peoples are excellent observers and interpreters of changes in the environment. Community-based and collectively-held knowledge offers valuable insights, and it complements scientific data by providing landscape-specific precision and detail that is critical for verifying climate models.

2.1.1 Traditional Knowledge Workshop

2.1.1.1 Key Questions

The primary questions posed during the traditional knowledge workshop were:

1. *What is the Anishinabek view of fire and what words are used to describe fire?*
2. *Is the community considered to be more at risk from forest fire now than in the past?*
3. *Is it expected that the risk of fire will increase in the future?*
4. *What has been observed in the environment with respect to:*

   - Temperature
   - Precipitation
   - Evaporation
   - Water levels
   - Vegetation
   - Animals and birds
   - Changes to travel, navigation, ice and snow.

5. *Where has change been seen?*
6. *What was learned from the August 2017 fire and the community evacuation?*

2.1.1.2 Methods

A workshop was conducted with community members and respected Elders on March 21st, 2018 from 10:30 am to 1:30 pm to understand the views and experiences of the community. Participants were selected on the basis of their extensive knowledge of the community and region and their experience on the land. Some of the participants were Elders and some held specific community positions with respect to emergency management and fire coordination/response. A total of nine Poplar River community members attended the workshop plus two individuals from North/South Consultants Inc., the project partners. The workshop was conducted informally to allow community members to speak freely on matters of concern or interest.

Detailed notes were taken, reviewed and corrected where necessary. Notes are included with this report in Appendix A.

Additional sources of information incorporated include current documents such as the Asatiwisipe Aki Management Plan, and research and documents related to the UNESCO World Heritage Site nomination bid, known as Pimachiowin Aki.

2.2 SCIENTIFIC STUDY

2.2.1 Weather, Hydrology, and Climate

2.2.1.1 Key Questions

Assessing vulnerability to climate change requires data sets pertaining to weather and climate which can be compared to climatic normals and used as indicators to assess increasing or decreasing trends. The following questions were asked to determine if there are trends in climate data that suggest an increased vulnerability to the threat of wildfire:

1. *Is there an apparent drying trend in the boreal region of Manitoba and more specifically the PRTT? Is there a noticeable increase in temperature and/or decrease in precipitation, leading to overall drying trends?*
2. *Do local weather and hydrological data support or show drying or warming trends that could be linked to an increased risk of forest and/or peatland wildfire?*
3. *Do other derived long-term climate data sets, specifically the Standardized Precipitation Evapotranspiration Index (SPEI), support the idea of increased drying trends in the PRTT?*

2.2.1.2 Methods

Temperature and precipitation are two important weather variables that can be used determine climate change trends over a period of time. Environment and Climate Change Canada (ECCC) historical weather data for Berens River was downloaded from ECCC's website (Government of Canada 2018b). The Berens River weather data set was selected as a representative proxy due to its close proximity, comparable landscape, and long period of record (1905 to present). Another station, George Island, is geographically closer; however, because it is not land-locked, it would be expected to have different readings. The George Island station also lacks data for the years 1984 – 1994.

Data were analyzed, summarized and graphed using Microsoft® Excel. The analyses focused on mean temperature and precipitation in the summer months (June 1 to September 31) for the period 1985 – 2017 in order to align and compare with remote sensing data (Section 2.2.3). Canadian Climate Normals

(1981-2010) (Government of Canada 2018a) for the station Berens River CS was used as baseline comparison for temperature anomaly calculation and percent of normal precipitation.

Local hydrological data were also analyzed in order to provide general hydrological conditions over the period of study. Data from Environment and Climate Change Canada's hydrometric gauging station at Weaver Lake (Weaver Lake at Outlet - 05RE002) were obtained from ECCC's online historical hydrometric data website. Water level data for 1967 to present were available. Data were summarized, analyzed, and graphed in Microsoft® Excel to determine positive or negative trends in water level for the period of 1984 – 2017.

SPEI (Vicente-Serrano et al. 2010) data were acquired from the Global SPEI database website (http://spei.csic.es/database.html). SPEI data is a global modelled gridded spatial data set for the years 1900 – 2015 and is updated annually. SPEIbase v.2.5 is delivered in a netCDF data cube format which contains spatial, temporal, and SPEI index data. Esri's® ArcGIS 10.6 geographic information systems (GIS) software was used to conduct a spatial analysis that extracted average monthly SPEI values for the AATUPA. Microsoft® Excel was used to analyze and graph SPEI index data for the period 1984 to 2015 focusing on potential forest fire months (May to October) in order to determine whether there were underlying positive or negative trends in SPEI over time.

2.2.2 Remote Sensing

2.2.2.1 Key Questions

Remotely sensed data can be used to derive data from the surface of the Earth. Long-term remote sensing data sets can be used to determine trends in vegetation health and growth, and surface moisture content. The following questions address the use of remotely sensed data as a potential tool for monitoring long-term trends in the AATUPA:

1. *Can earth observation science be used to determine whether drying trends are being observed in the PRTT over time? Can indices (NDVI, NDMI) derived from remotely sensed multispectral data be used to determine potential drying or wetting trends in the PRTT?*
2. *Can trends in derived indices be linked to local climate data and local observations and knowledge to support the contention that peatlands in the boreal region of Manitoba are undergoing drying which is increasing risk of forest fire and intractable peatland/muskeg fires?*
3. *Do peat forming land cover types (bog and fen) show a greater drying or wetting trend then other land cover types in the PRTT vs. forest or marsh?*

2.2.2.2 Methods

Landsat multispectral optical satellite imagery was acquired from the United States Geological Survey (USGS) using their EarthExplorer online data archive access site. Landsat Surface Reflectance data products for Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) satellite platforms were accessed for path and row 030/023, 031/023, 030/023 covering the extent of the PRTT. A total of 54 surface reflectance-based spectral index derived image products spanning the period 1984 – 2017 were ordered (Appendix B, Tables B-1 to B-3; Figure B-1). The majority of the images were for the month of August in order to be comparable between years. The surface reflectance-based spectral indices product provides an analysis-ready product for which atmospheric corrections have been applied using specialized software called Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) (Masek et al. 2006).

Images were processed using ArcGIS 10.6 software. NDVI and NDMI spectral index images were masked from cloud cover and shadow using the provided 'pixel_qa' band which classifies pixels according their suitability for analysis, that is pixels that may be contaminated by cloud cover, cloud shadow, water, ice, or snow. Masks were created for each individual scene by reclassifying the image pixels to binary (0 or 1) and then overlaying them on the matching NDVI and NDWI derived data products to eliminate unsuitable pixels from the scenes.

NDVI is a band differencing ratio by which the NIR band is subtracted from the red visible band and divided by the some of the two giving an index value between 1 and -1, with higher positive index values indicating healthy green vegetation:

$$NDVI = \frac{\text{Red} - \text{NIR}}{\text{Red} + \text{NIR}}$$

NDMI provides a measure of canopy surface moisture. This index contrasts the near-infrared (NIR) band, which is sensitive to the reflectance of leaf chlorophyll content to the short wave infrared (SWIR) band, which is sensitive to the absorbance of leaf moisture:

$$NDMI = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$$

The combined Forest Resource Inventory (FRI) of the Province of Manitoba and Ecological Land Classification ELC wetland classification (Halsey et al. 1997) mapping product developed by Cooley et al. (2009) was used to identify dominant cover types of fen, bog, marsh, and forested/non-wetland cover classes in order to produce stratified random sampling sites to be used to extract pixel information from each of the NDWI and NDVI index images. A total of 100 fen, 100 bog, and 100 forested cover type sites, in addition to 30 marsh sampling sites, were generated using a spatial analysis routine in ArcGIS® 10.6 software, which randomly selects a specified number of sites within selected polygons representing land cover types (Figure 8). Because of the volume of imagery a macro routine had to be developed in order to iterate through all of the images to extract all pixels within a 50 metre radius of the sampling sites. All extracted pixel information from the scenes was compiled in Microsoft® Excel.

Microsoft® Excel was used to summarize, analyze, and graph the NDVI and NDWI pixel information extracted from the images. Thirty four images spanning 34 years from 1984 to 2017 were selected from the 54 images originally downloaded. The majority of the images used were from August, with nine images from July and September used when August was not available. In addition to analysis of the NDVI and NDMI index values an anomaly data set was produced by calculating the mean NDVI and

NDMI values for each cover type for the full duration 1984 – 2017 and subtracting from the mean value for each year. Additional monthly satellite images acquired in 2017 were used to demonstrate seasonal variability in NDVI and NDMI values for each of the cover classes.

Finally a spatial analysis of NDVI and NDMI values across the AATUPA between two years with opposing average temperature and precipitation values was conducted using ArcGIS® 10.6 by differencing the NDVI and NDMI derived images between the years of 1993 (wetter and cooler) and 2003 (drier and warmer).

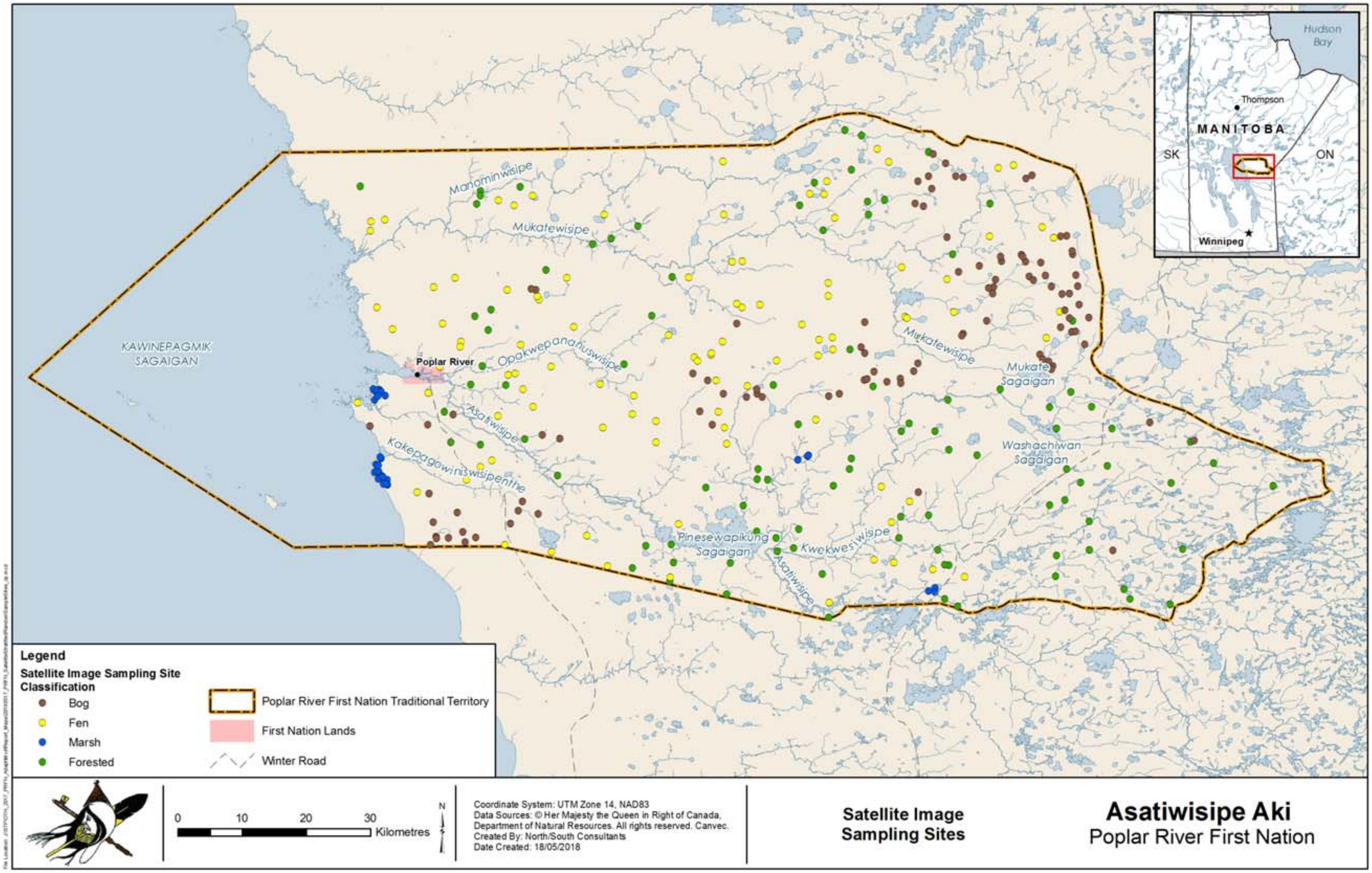

Figure 8. Stratified random sampling sites used to extract derived satellite image NDVI and NDWI indices in bog, fen, marsh, and forested/non-wetland cover types across the AATUPA.

2.2.3 Fire History

2.2.3.1 Key Questions

An understanding of past fire history in a given region is important in determining whether or not vulnerability to wildfires for a particular region is increasing over time. The following questions are asked to determine whether there is an increasing trend of wildfire in the AATUPA:

1. *Has there been an increase in the frequency of wildfire in the boreal region of Manitoba and more specifically the AATUPA? Has there been an increase in the size or perimeter of fires in the AATUPA over time?*
2. *Can overall regional climate trends be linked to an increase in frequency and/or size of fire in the AATUPA?*

2.2.3.2 Methods

Provincial fire history mapping for the years 1928 – 2016 was obtained from the Province of Manitoba's Manitoba Land Initiative (MLI) website. The Esri® shapefile format file named 20160824, Manitoba Fires: 1928 – 2016, contains spatial polygon representations of forest fire perimeters in the province dating back to 1928. An additional shapefile data set for 2017 was obtained from Manitoba Sustainable Development's Fire Program website (Sustainable Development 2018). An additional point feature data set indicating fire occurrence and cause (human vs. lightning) was also obtained from the Canadian National Fire Database (CNFDB).

The AAATUPA GIS mapping polygon dataset obtained from the MLI was used to clip the fire area mapping within the AATUPA using ArcGIS 10.6 software. Data were then imported into Microsoft® Excel for summary, graphing, and trend analysis. Data specific to the AATUPA were analyzed in addition to the data for the entire province.

3.0 RESULTS

3.1 TRADITIONAL KNOWLEDGE WORKSHOP

The workshop documented community knowledge on climate change observations in and around the community, especially as these observations relate to fire.

Fire

The Anishinabemowin name for fire in tree tops, or crown fires, is ***tatepepanaketek***, or 'swirling fire up top' or 'fire that rolls from tree to tree'. Spruce trees were observed to burn like gas or oil, catching fire quickly and burning hot.

The Anishinabemowin name for fire in peat is ***apethatawakatek,*** which translates to 'a fire in the ground' or a 'peat moss fire'. These fires were noted to spread very fast and they had to be dug out of the ground to extinguish them.

Two types of ignition were described – one started by "Thunderbird" or lightening and the other set by humans. Thunderbird fires are known to start in the ground at the roots of the tree as ground fires rather than crown fires. It might take 2-3 days to detect these types of fires because they begin underground. Afterwards, they are "unstoppable". Smoke from muskeg fires is heavy and lingers. Human set fires are known as 'careless' or 'crazy' fires which spread quickly and unpredictably, and have no purpose. Thunderbird fire, on the other hand, is meant to clear the land of dead brush and renew the land.

The Elders talk about and teach about fire. When the Thunderbirds make lightening and the bush burns, there is a purpose for that. The fire cleanses the earth by burning off the undergrowth. The fire creates new growth and some trees need the fire to create new plants. Regrowth happens fast. Thunderbirds bring the rain when they are ready to put the fire out. The Elders do not worry about putting that fire out unless it is close to the community. They never say the land is ruined or spoiled. Human-made fires are dangerous and should be put out.

The Elders mention a fire in 1917 that covered a vast area. This fire occurred prior to the commencement of provincial fire records.

Climate Change

Workshop participants shared traditional knowledge and local observations on changes to precipitation, temperature, the rate of evaporation, changes to vegetation, the timing and duration of freeze up and break up and other related observations within the living memory of the group. All participants agreed that there was a trend towards higher temperatures year-round.

Seasonal observations were offered. Winter observations include thinner ice on the Poplar River: now only two feet of ice is present on the river whereas the ice thickness used to be double that. This has also been observed on Lake Winnipeg during winter fishing operations where ice augers are not drilling very deep to get through the ice. Snow texture has also changed from a hard crystalline form to a powder and less snow overall. Changes were noted to have first been observed in the early 2000s with additional change being observed in subsequent years.

Late winter/spring observations included an earlier thaw as evidenced by an earlier winter road closure: it now typically closes during the first week of March when, 15 years ago, it operated into April. The commercial fishery also shuts down earlier (by March 15th). Late winter trips up the Poplar River to Weaver Lake are also restricted due to unsafe ice appearing earlier in the season. Snow melt also has been observed to occur more rapidly and earlier in spring.

In summer, observations were mostly related to evidence of moisture stress. For example, drying of the muskeg has been observed, with the severity increasing in recent years. One participant noted the yellowing of muskeg as it dries in summer, an observation he made for the first time in 1988. One participant observed increased strength in the sun, causing yellowing of willow leaves in mid-summer (June, sometimes July). Fewer ***mushkeegominan***, or cranberries, as well as blue mossberries (crowberries) are being observed. Saskatoon berries have been seen dried on the plants prior to ripening. One participant noted that trees have the ability to start fires through friction during windy days and that the jack pine are dryer than in the past. It was also observed that it does not take long for vegetation and the ground to dry following a rain, which suggests an increase in evapotranspiration.

There was no agreement on whether there may be increased rainfall in autumn or in the timing of freeze-up being either earlier or later. In the fall of 2017, freeze-up was early as the normal timeframe is typically early November.

Wildlife and Fish

Observations of reduced numbers of specific birds were provided. Whiskey Jacks (grey jays), seagulls, sparrows and sand pipers have been seen less often in recent years. Frogs also are not frequently seen. Magpies, turkey vultures and bald eagle numbers are considered to be increasing.

Changes in the abundance of furbearers were also noted. Increased numbers of wolverine, marten and beaver have been observed. Marten were not seen in these numbers since before the 1930s and beaver are thought to be more abundant because they are not trapped in the same quantities as previously when their fur was worth more.

Changes to fish have also been observed: there has been a decline in smelt over the past 4 to 5 years which has led to smaller-bodied and fewer pickerel (Walleye). Lake Whitefish are still the same size and plentiful but they are noted to taste different.

Water Levels

Over a period of seven decades, a trend towards lower water levels on Lake Winnipeg has been observed. During the 1950s and 1960s, water levels were noted to be higher than contemporary levels. A drop, not likely to be related to climate change, was noted in the early 1970s when water regulation on Lake Winnipeg began. Hydroelectric dams built on the Nelson River in the 1990s are also thought to be affecting water levels because of the dams being run as a system. It was noted that the Province does not agree with this view. Algae was observed to be more prominent in Lake Winnipeg. No observations regarding water levels on Weaver Lake were provided.

3.2 SCIENTIFIC STUDY

3.2.1 Weather, Climate, and Hydrology

Analysis of temperature data revealed that there is an increasing linear trend in the May through October mean temperature at the Berens River weather station (Figure 9). Temperature anomaly analysis reveals that 20 of the 34 years analyzed were warmer than normal (Canadian Climate Normal 1981 – 2010) (Table 1). Notable warm years include the five year period of 1987-1991, in which four of the five years were above normal, 2003 which was the warmest in the study period, and the last eight years (2010 – 2017), in which seven of the eight years were warmer than normal. Notable cool years include 1984 through 1986, 1992 and 1993, 2000, 2004 and 2009.

Analysis of precipitation data for the same period also showed an increasing linear trend over the study period (Table 1; Figure 10). The period 1987 –1989 showed above-normal precipitation which appears to coincide with above-normal temperatures for the same period. Precipitation was below normal in 1990 but remained above normal until 1995. Other below-normal years for precipitation include: 1999, 2000, 2003, 2006, 2007, 2009, and last year (2017).

Annual mean May through October SPEI data also reveal an increasing linear trend for the period 1984 – 2015 (Table 1; Figure 11). Positive index values are generally indicators of wetter non-drought conditions, while negative values are indicators of drought or drier conditions. Notable drought conditions were recorded in 1988, 1990, 2003, 2006 – 2008, and 2013. Since 1995, there has been a steady positive increase in SPEI.

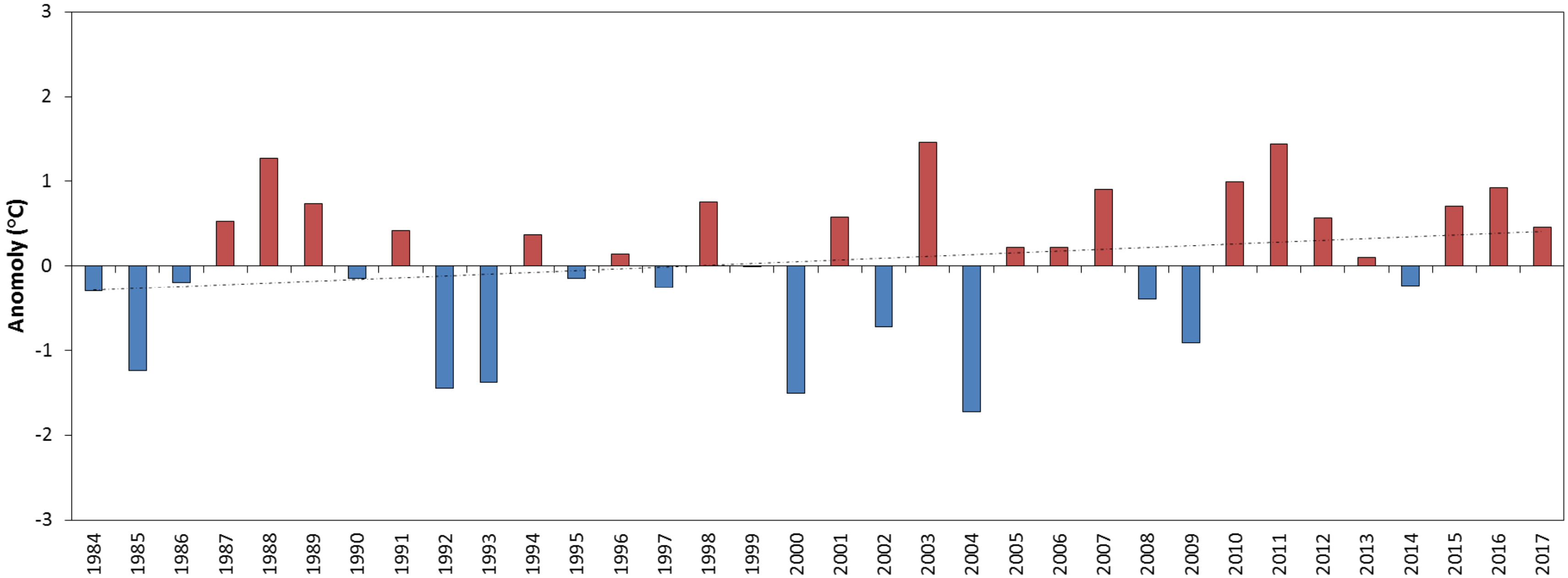

Figure 9. May through October mean temperature anomaly for Berens River CS Environment Canada weather station for the study period 1984 – 2017. Red bars indicate temperatures greater than the Canadian Climate Normal (1981 – 2010) baseline; blue bars indicate temperatures lower than the baseline. The trend line indicates a linear increase in temperature over the study period. Note: data for 1984, 1995, 1996 and part of 1985 have been supplemented with data from the next closest Environment Canada station, Norway House A.

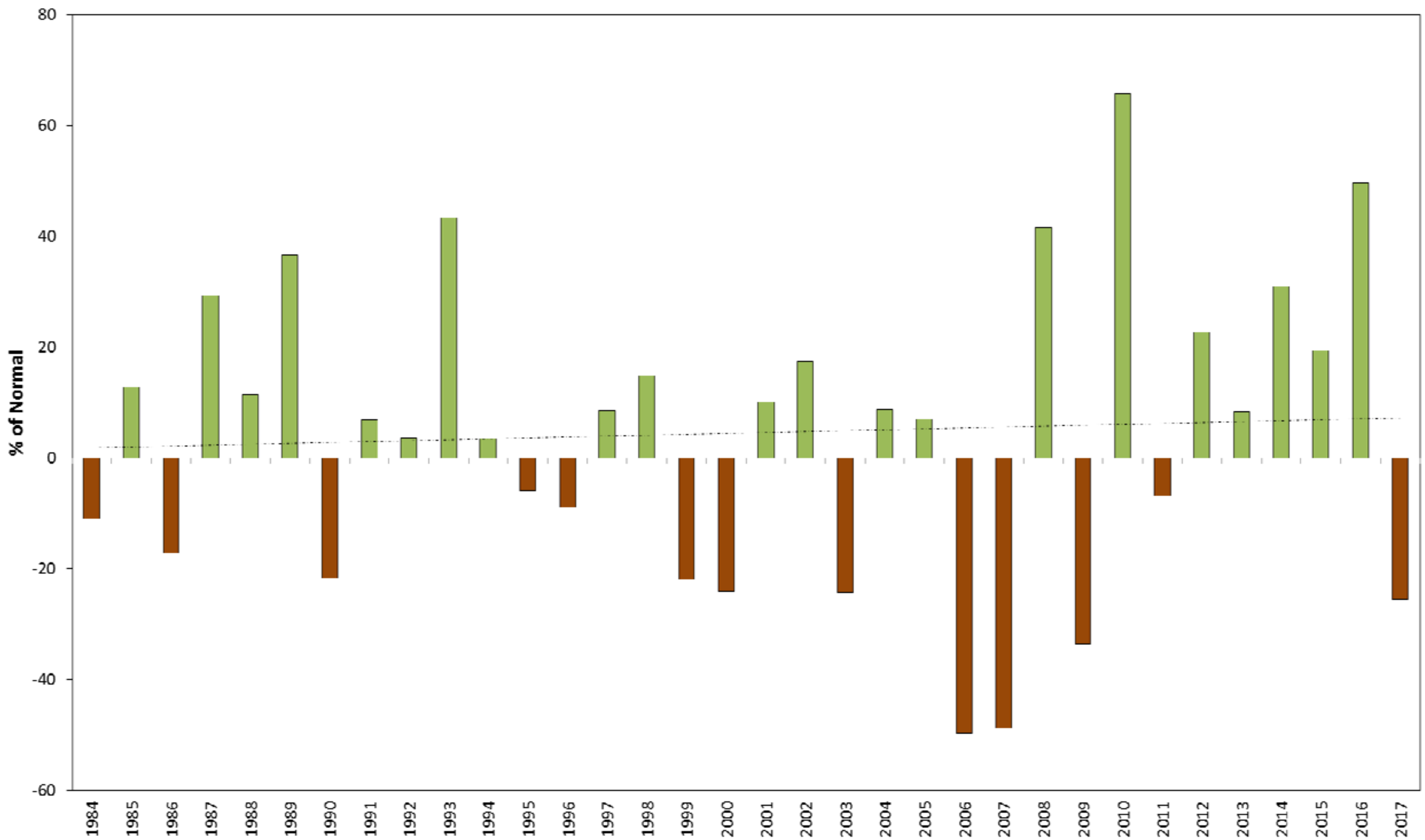

Figure 10. May through October percent of normal precipitation for Berens River CS Environment Canada weather station for the study period 1984 – 2017. Green bars indicate precipitation greater than the Canadian Climate Normal (1981 – 2010) baseline; brown bars indicate precipitation lower than the baseline. The trend line indicates a linear increase in precipitation over the study period. Note: data for 1984, 1995, 1996 and part of 1985 have been supplemented with data from the next closest Environment Canada station, Norway House A.

Table 1. Annual May through October summary of temperature, precipitation, and standardized precipitation evapotranspiration index (SPEI) for the study period (1984 – 2017).

Year	Mean Temperature (°c)	Total Precipitation (mm)	Temperature Anomaly (°c)	Temperature Class	Precipitation (% of Normal)	Precipitation Class	Mean SPEI Index Value	SPEI Class
1984	11.62	303.6	-0.29	cooler	-11.0	drier	0.08	wet
1985	10.68	385	-1.24	cooler	12.8	drier	2.79	wet
1986	11.72	282.8	-0.19	cooler	-17.1	drier	9.38	wet
1987	12.43	441.3	0.52	warmer	29.3	wetter	0.38	wet
1988	13.18	380.3	1.27	warmer	11.4	wetter	-2.76	drought
1989	12.65	466.5	0.74	warmer	36.7	wetter	2.98	wet
1990	11.77	267.3	-0.14	cooler	-21.7	drier	-7.77	drought
1991	12.33	364.7	0.42	warmer	6.9	wetter	-0.78	drought
1992	10.47	353.8	-1.44	cooler	3.7	wetter	2.43	wet
1993	10.53	489.3	-1.38	cooler	43.4	wetter	2.68	wet
1994	12.28	353.1	0.37	warmer	3.5	wetter	-0.76	drought
1995	11.76	321.4	-0.15	cooler	-5.8	drier	4.12	wet
1996	12.05	310.8	0.14	warmer	-8.9	drier	5.44	wet
1997	11.65	370.2	-0.26	cooler	8.5	wetter	4.34	wet
1998	12.67	392.2	0.76	warmer	14.9	wetter	4.80	wet
1999	11.90	266.4	-0.01	cooler	-21.9	drier	0.95	wet
2000	10.40	259	-1.51	cooler	-24.1	drier	5.85	wet
2001	12.48	375.7	0.57	warmer	10.1	wetter	13.38	wet
2002	11.18	400.9	-0.73	cooler	17.5	wetter	0.76	wet
2003	13.37	258.5	1.46	warmer	-24.3	drier	-2.44	drought
2004	10.18	370.9	-1.73	cooler	8.7	wetter	6.85	wet
2005	12.13	365	0.22	warmer	6.9	wetter	9.63	wet
2006	12.13	171.6	0.22	warmer	-49.7	drier	-1.04	drought
2007	12.82	174.8	0.91	warmer	-48.8	drier	-4.19	drought
2008	11.52	483.2	-0.39	cooler	41.6	wetter	-2.12	drought
2009	11.00	226.8	-0.91	cooler	-33.5	drier	9.00	wet
2010	12.91	565.6	1.00	warmer	65.7	wetter	9.37	wet
2011	13.35	317.8	1.44	warmer	-6.9	drier	1.61	wet
2012	12.48	418.7	0.57	warmer	22.7	wetter	1.60	wet
2013	12.01	369.9	0.10	warmer	8.4	wetter	-1.95	drought
2014	11.68	447.3	-0.23	cooler	31.1	wetter	6.09	wet
2015	12.62	407.4	0.71	warmer	19.4	wetter	-0.08	drought
2016	12.84	511.3	0.93	warmer	49.8	wetter	-	-
2017	12.37	254	0.46	warmer	-25.6	drier	-	-
Mean	11.98	356.7	0.07	-	4.5	-	2.52	-

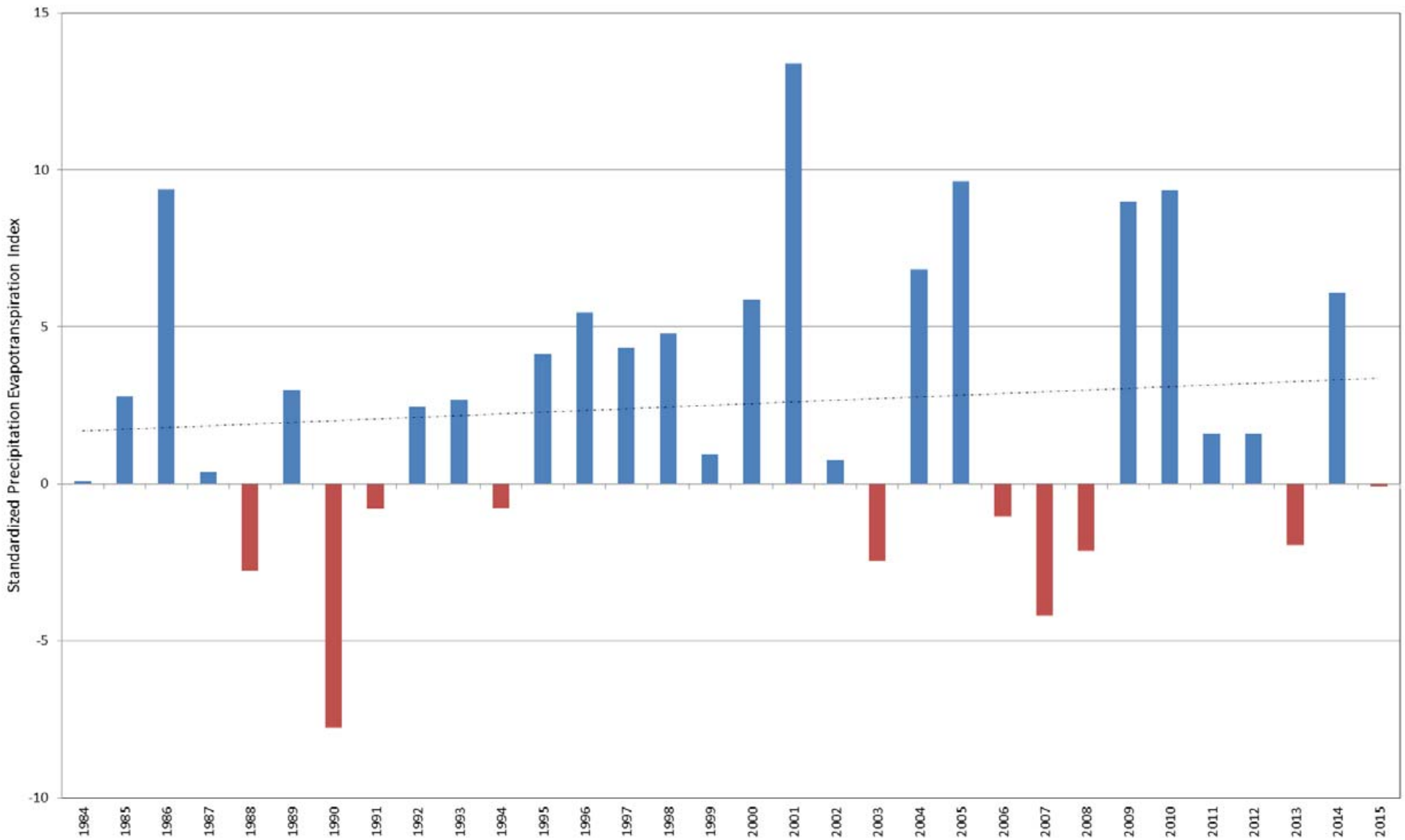

Figure 11. Mean Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010) values for the AATUPA (May through October, 1984 – 2015). Blue values (positive values) indicate periods of relatively wet conditions, whereas red (negative values) indicates periods of drought. The trend line shows an overall increasing trend towards wetter conditions for the region. Note: Data for 2016 and 2017 were unavailable at the time of analysis.

Hydrometric data for Weaver Lake (*Pinesewapikung Sagaigan*) indicates an overall increasing linear trend for water levels May through October, 1984 – 2017 (Figure 12). The data appear to correlate with increases in precipitation and SPEI over the same period. An extended low water period occurred between 1986 and 1991, with other notable low water years occurring in 1999 and 2006. Since 2001 there has been a noticeable increasing trend in water level, although water levels dropped in 2016 and 2017.

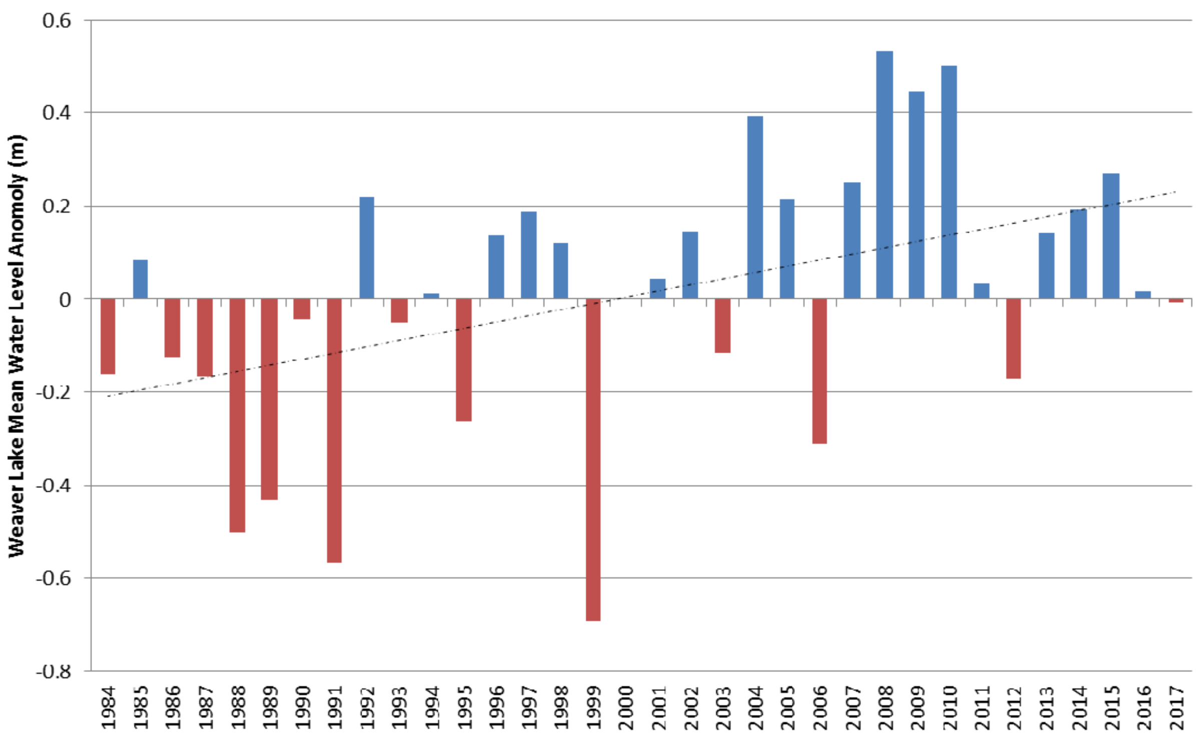

Figure 12. May through October water level anomaly data for the Environment Canada hydrometric gauging station at Weaver Lake (05RE002) for the period of study (1984 – 2017). Red bars indicate lower than average water levels, while blue bars indicate higher than average water levels. The black line indicates an increasing linear trend in water level for the period of study.

3.2.2 Remote Sensing

The NDVI derived from Landsat data generally indicates vegetation health (greenness) as a number between 1 (dense healthy vegetation) to 0 (dry desiccated vegetation or barren land) and can be used as a drought indicator. Higher NDVI values indicate vegetation is more lush and dense. Figure 13 illustrates the increase and decline of NDVI values over the growing season for the four cover types. Seasonally, May has the lowest overall NDVI values for all cover types, as the vegetation has not yet begun to grow, June is typically the peak month when vegetation starts to leaf out and precipitation is generally higher, followed by a gradual decline in overall NDVI values from July through October. Generally, there is an increasing positive linear trend for each of the four land cover types sampled for the period of record

1984 – 2017 (Figure 14). Appendix B details the annual mean NDVI for each cover type separately. There also appear to be increasing and decreasing cycles of NDVI variation, which for the most part coincide with wet and dry years. In 1989, NDVI values were affected by extensive forest fires burning in the AATUPA and appear as a large negative. Recent burns caused extreme low NDVI values for many of the cover type samples that would have normally had healthy vegetation. Limited cloud-free satellite images were available for the study area in 1989 in order.

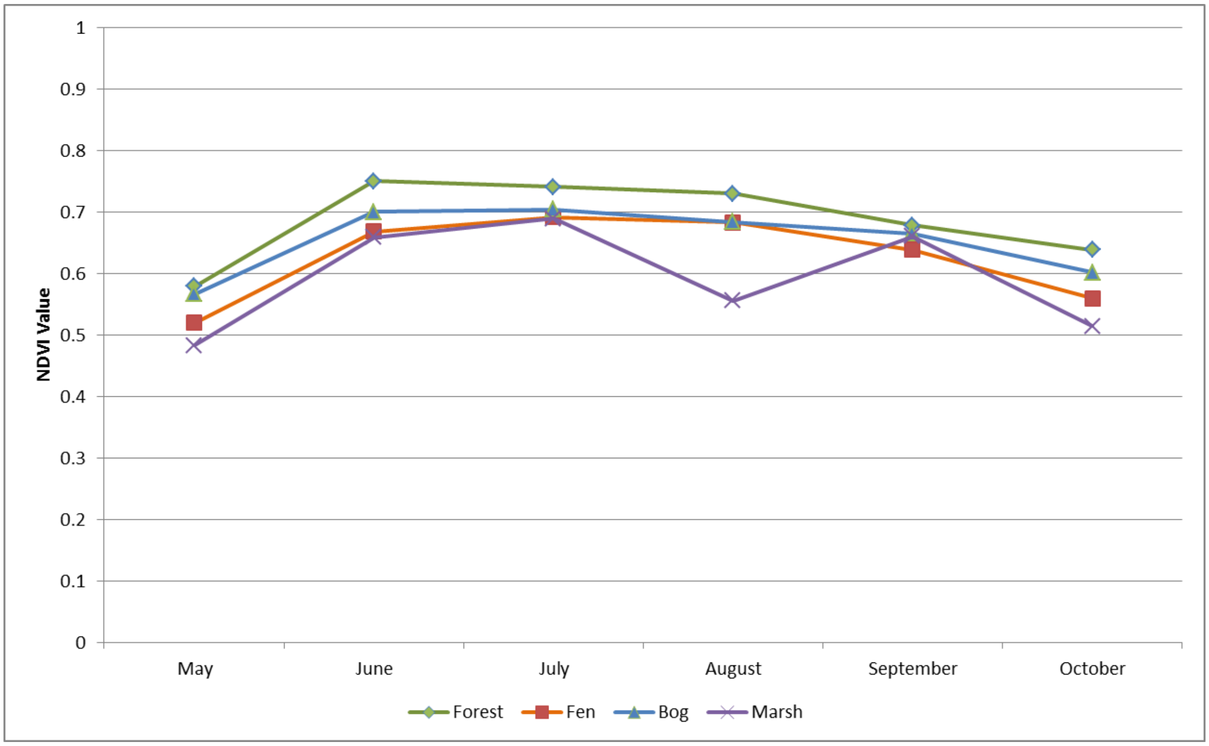

Figure 13. Monthly variation in NDVI values for each of the four cover types in the AATUPA in 2017.

Forest/non-wetland cover types tend to have the highest overall mean NDVI value, which is likely attributed to the density of the vegetation canopy of forest versus wetlands. Overall, mean NDVI values are highest for forest, followed by bog, which tends to have more tree cover (e.g., black spruce), fen, and then marsh (Figure 15). Notable above-normal NDVI years include 1986, 1990, 1996 – 1997, 2000 – 2001, and 2012 –2017. By contrast, 1984 – 1985, 1989, 1991-1994, 1999, 2006, 2009 – 2010, were all below- normal NDVI years.

The NDMI generally indicates moisture content in the surface layer of vegetation of a given landscape and can be used of an indicator of drought. The higher the vegetation moisture content in the leaves, the higher the index value. Overall there is an increasing positive trend for each of the four land cover types sampled for the period of record 1984 – 2017, based on analysis of NDMI anomaly (Figure 16). Appendix B details the annual mean NDMI for each cover type separately. The graphs for each cover type indicate an increasing trend over the study period. There also appear to be increasing and decreasing cycles of variation, which generally follow periods of wet and dry years. NDMI values appear to be much more variable from year to year then the NDVI values (Figure 17). Below-normal NDMI value years include: 1984 – 1985, 1989, 1991 – 1995, 1999, 2002 – 2003, 2009 – 2011, and 2013. Above-normal NDMI value years include: 1986, 1996 – 1998, 2004 –2008, 2012, and 2014 – 2017.

NDVI values for 1993 were generally lower than in 2003 (Figure 18). The NDVI spatial change differencing analysis between the two years showed that 56 % of the AATUPA vegetation canopy had higher NDVI values in 2003 than in 1993.

NDMI values were higher in 1993, when conditions were generally cooler and wetter (Figure 19). The spatial change differencing analysis between the two years showed that 77% of the AATUPA vegetation canopy surface moisture was wetter in 1993 than in 2003. Only 23 % of the canopy surface moisture was wetter in 2003 than in 1993.

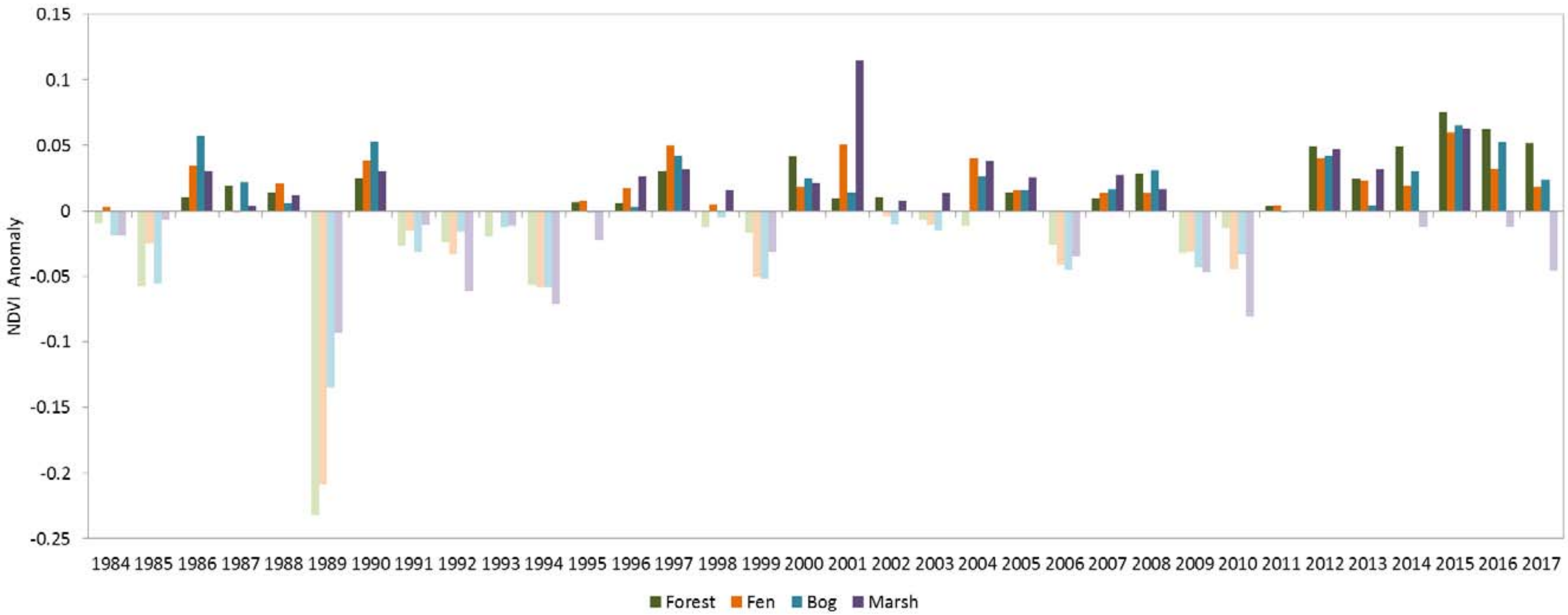

Figure 14. NDVI anomaly (based on the long term mean 1984 – 2017) for forest/non-wetland, fen, bog, and marsh cover types in the AATUPA for the period of study 1984 – 2017. A review of individual cover types (Appendix B) indicates an increasing linear trend in NDVI for each of the four cover types for the period of study.

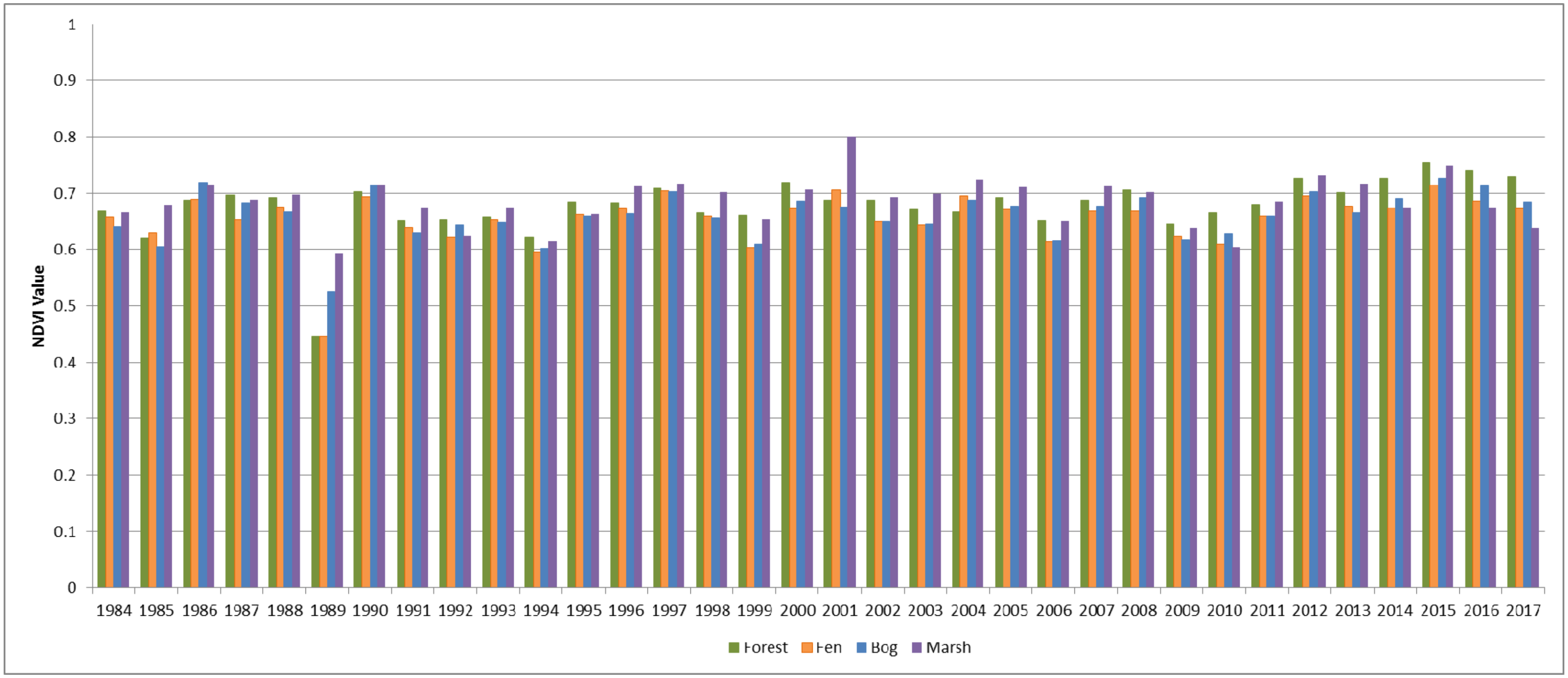

Figure 15. NDVI values for forest/non-wetland, fen, bog, and marsh cover types in the AATUPA for the period of study 1984 – 2017.

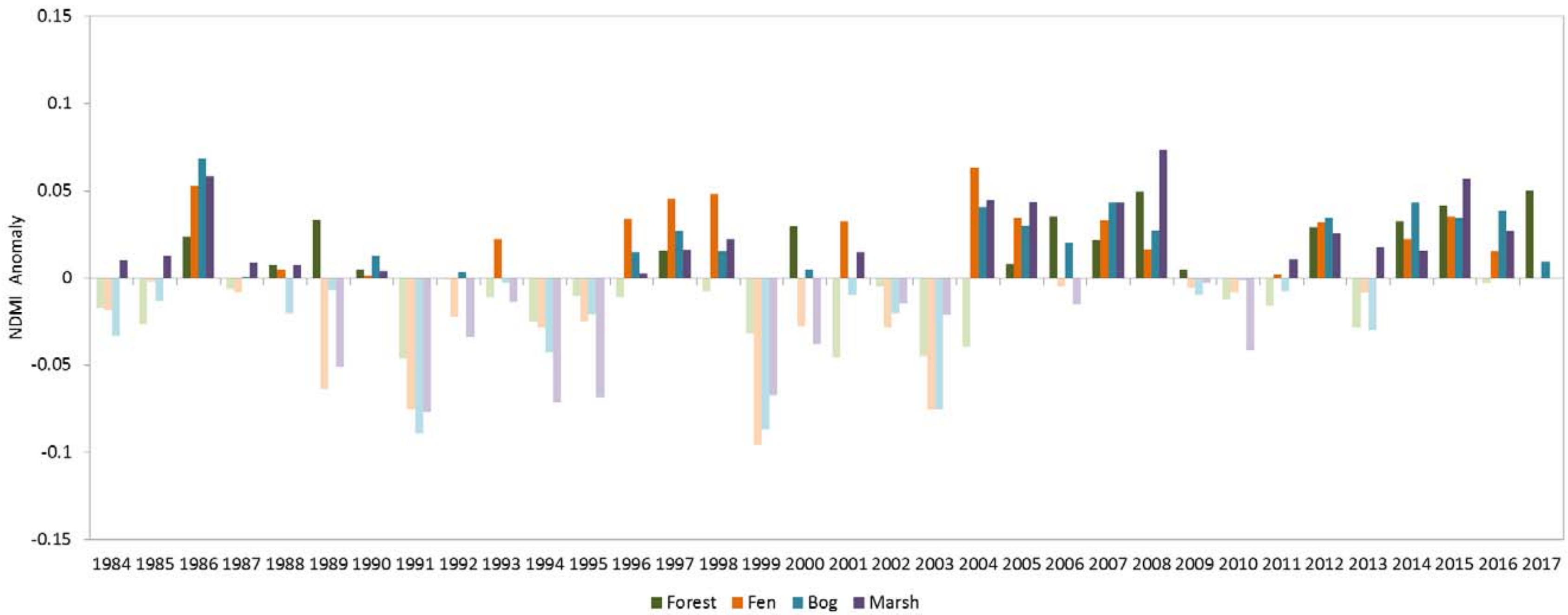

Figure 16. NDMI anomaly (based on the long term mean 1984 – 2017) for forest/non-wetland, fen, bog, and marsh cover types sampled in the AATUPA for the period of study 1984 – 2017. A review of individual cover types (Appendix B) indicates an increasing linear trend in NDMI for each of the four cover types for the period of study.

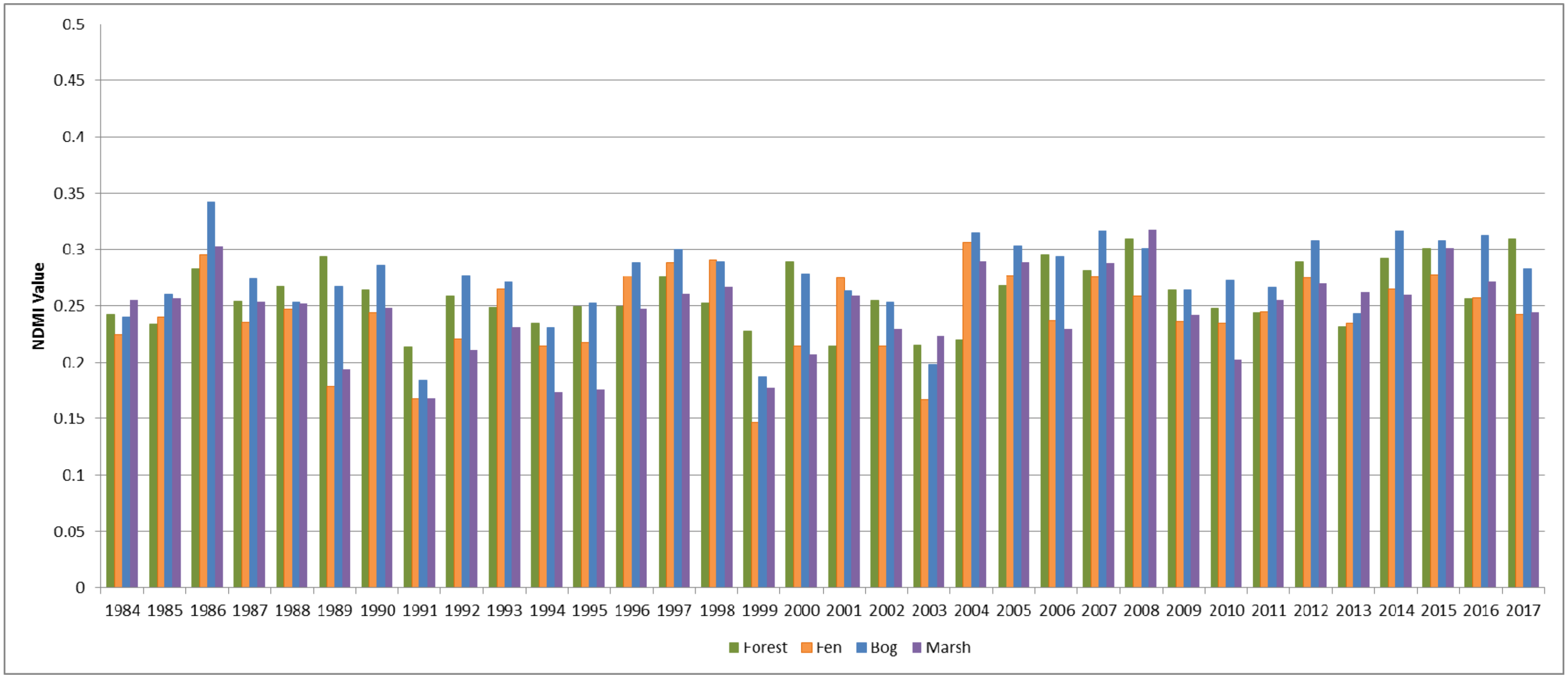

Figure 17. NDMI values for forest/non-wetland, fen, bog, and marsh cover types in the AATUPA for the period of study 1984 – 2017.

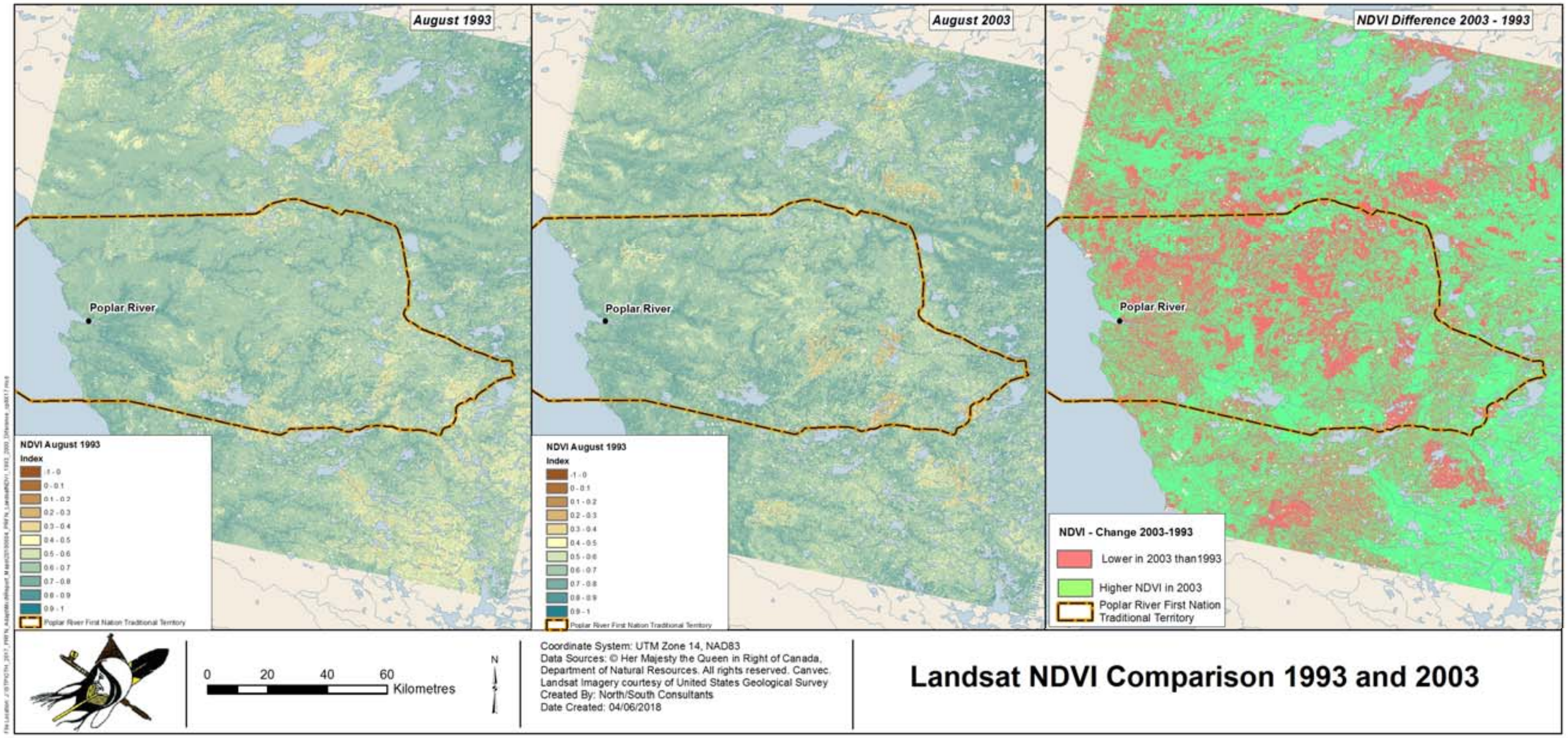

Figure 18. NDVI change map showing change in NDVI between 1993, a relatively wet year with limited fire activity, and 2003, a relatively dry year in which fire activity was increased.

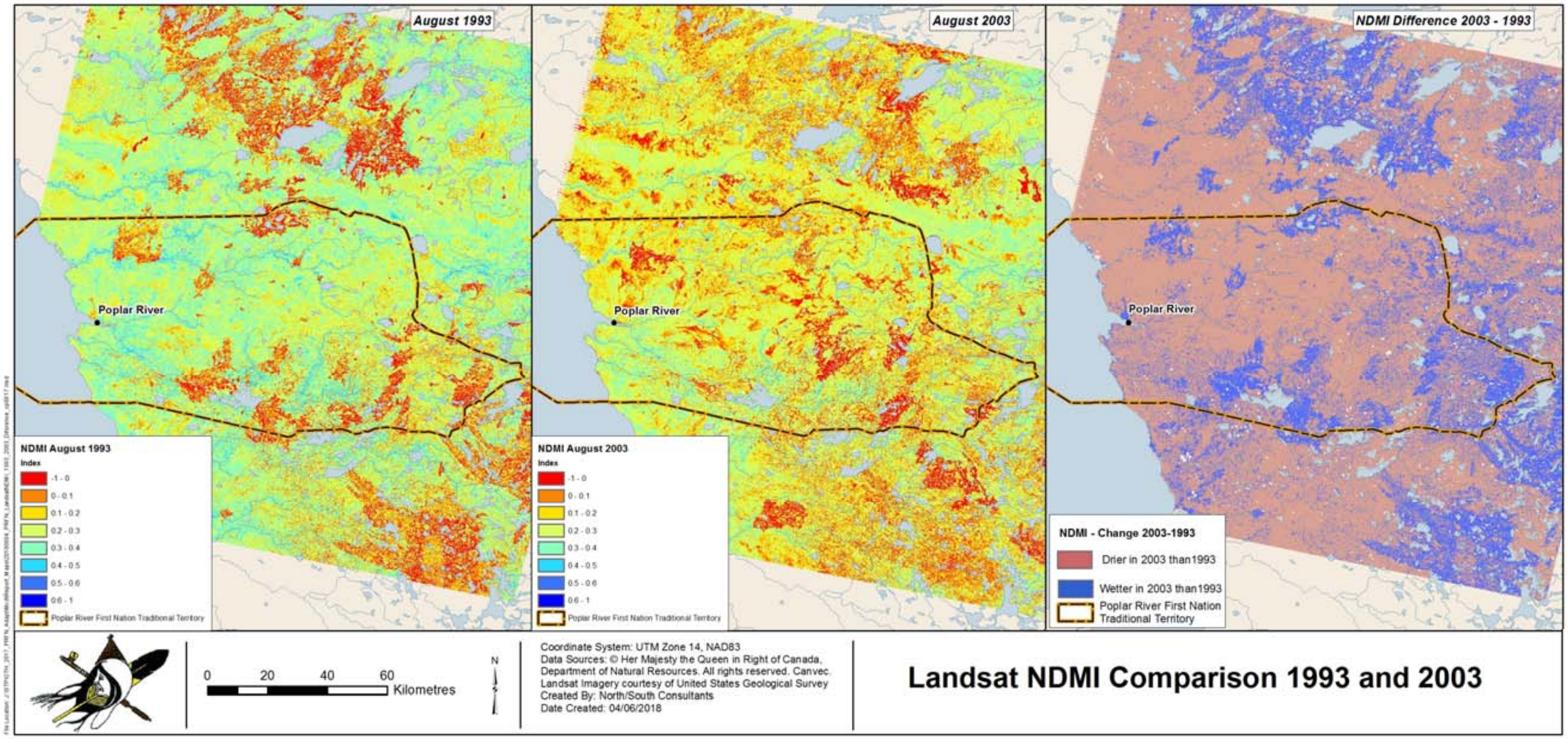

Figure 19. NDMI change map showing change in NDMI between 1993, a relatively wet year with limited fire activity, and 2003, a relatively dry year in which fire activity was increased.

3.2.3 Fire History

Analysis of the forest fire history records indicates an overall increasing linear trend in both forest fire occurrence and total burn area for the period 1914 – 2017 (Figures 20 and 21). In 1989, the highest ranking fire year, the province had 1,226 fires that burned a total estimated area of 3,567,947 ha. Of the 1,226 fires, 42% were estimated to be human initiated fires, while 58% were caused by lightning. In 2003, a relatively dry year, Manitoba had 1,214 fires; however the total burned area only amounted to 918,845 ha. In that year it was estimated that 56% of the fires were caused by humans while the remaining 44% were caused by lightning. By contrast, in 2009, there were only 184 fires recorded in Manitoba, burning only 2,872 ha, of which 64% were caused by humans and the remaining 36% initiated by lightning. Other low-fire years in the recent past include 1986, 1993 and 2016. Last year, 2017, was an above-average year for forest fire counts, but the total area burned was below the long-term average of 202,290 ha. When analyzing the study period 1984 – 2017, there is a decreasing linear trend in forest fire occurrence and total burned area across the province, indicating an overall decline in forest fire activity in the last 34 years.

Analysis of the forest fire history mapping in the AATUPA indicates an overall decreasing linear trend in forest fire occurrence and total burned area during the study period 1984 – 2017 (Figures 22-25), which is consistent with the provincial trend over the last 34 years. A total of 602 fires occurred with a total burned area of 200,559 ha (Table 2). Similar to the complete provincial record, 1989 was the highest ranking fire year by both count and total area burned in the AATUPA, accounting for approximately 25% of the burned area in the 34-year study period. With 1989 removed from the analysis, the overall trend shows an increasing trend in total burned area for the study period, however there is still a decreasing linear trend in forest fire occurrence. Three of the top five fire activity years in the AATUPA occurred between 1988 and 1991. Other significant fire activity years in the AATUPA include: 2003, 2006, 2011 and 2017.

Historically, fires have occurred most frequently in the southeast corner of the AATUPA, which is predominantly forested and non-wetland cover types (Figure 4). Fires occurring during the study period (1984 – 2017) primarily burned predominantly forested/non-wetland cover types, accounting for 83.7% of the total burned area (Figure 26). Predominantly fen land cover types accounted for 13.7% of the total burned area, followed by predominantly bog cover types at 2.4% and marsh at 0.4%. Large fires burned close to the community in 1989 and again in 2017, both of which burned in areas that are predominantly comprised of fen peatland.

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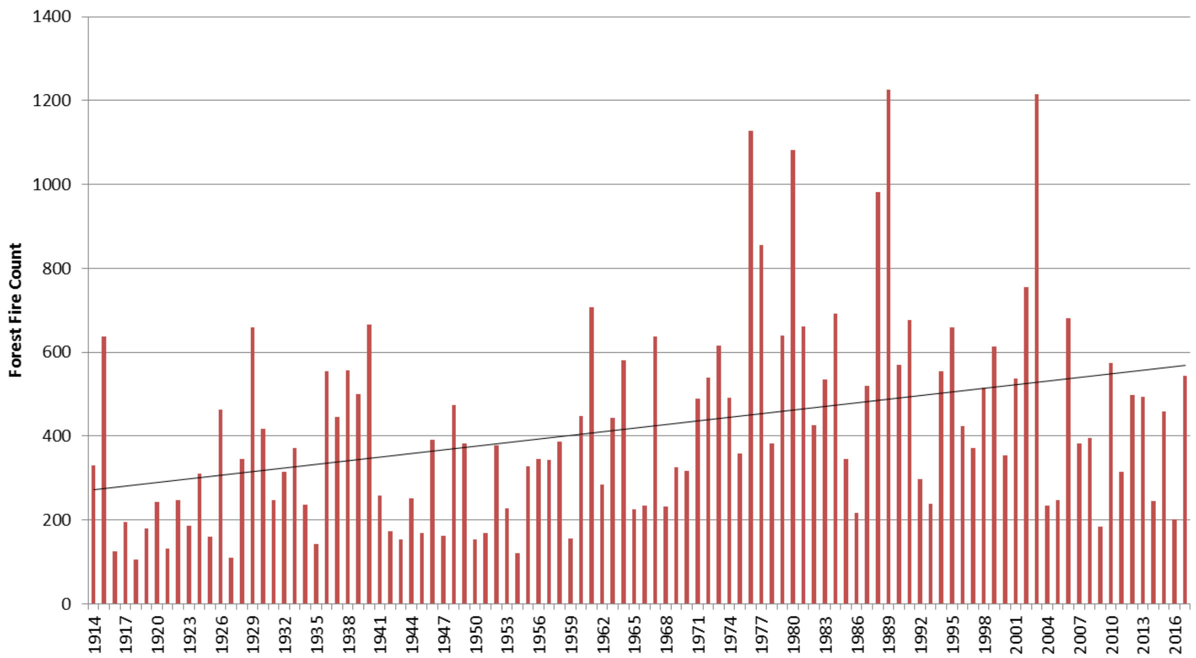

Figure 20. Province of Manitoba forest fire counts 1914 to 2017 showing an increasing linear trend over the time period.

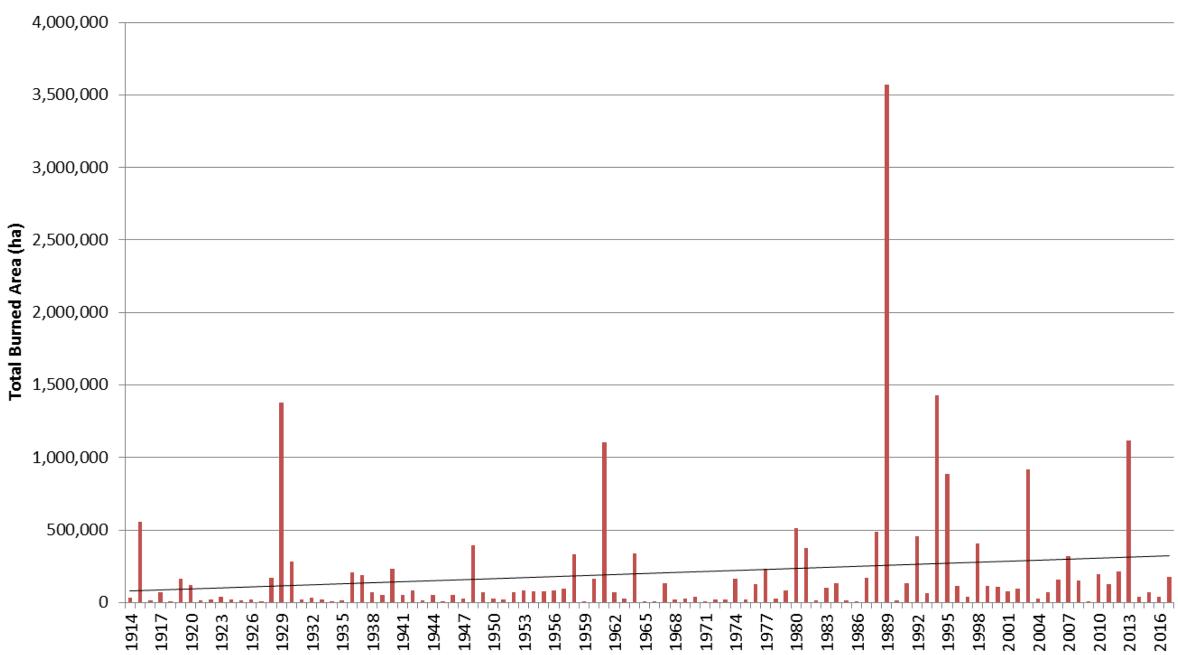

Figure 21. Province of Manitoba total forest fire burn area in hectares 1914 to 2017, showing an increasing linear trend over the time period.

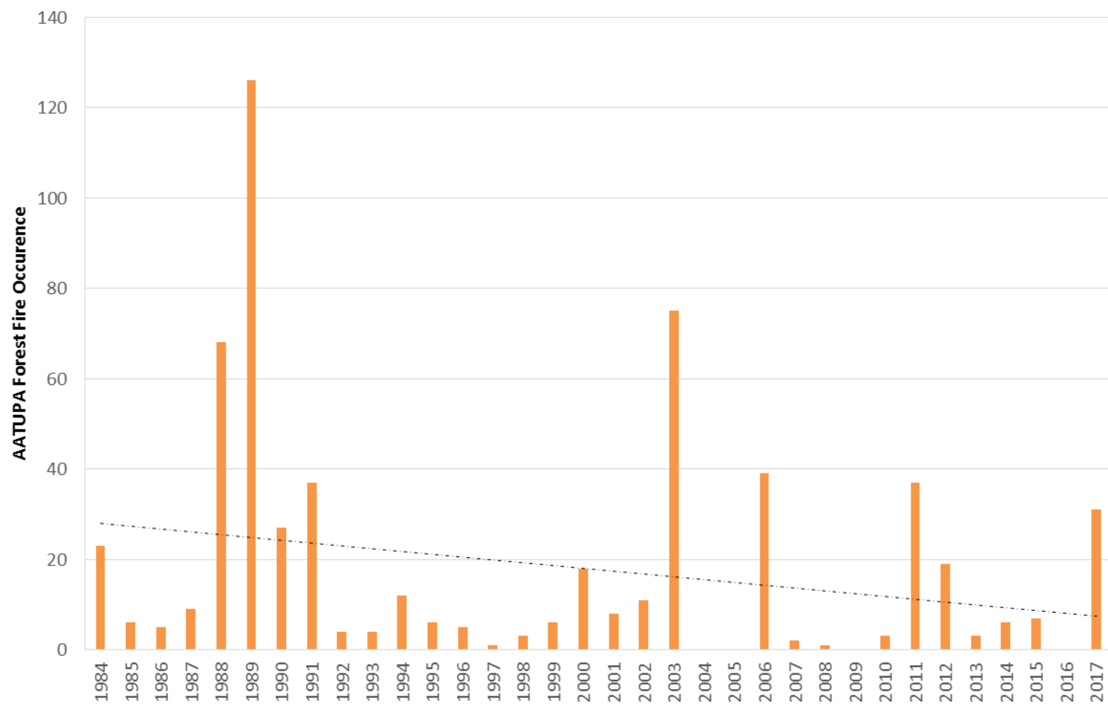

Figure 22. AATUPA forest fire counts 1984 to 2017 showing a decreasing linear trend (black dotted line) over the study period.

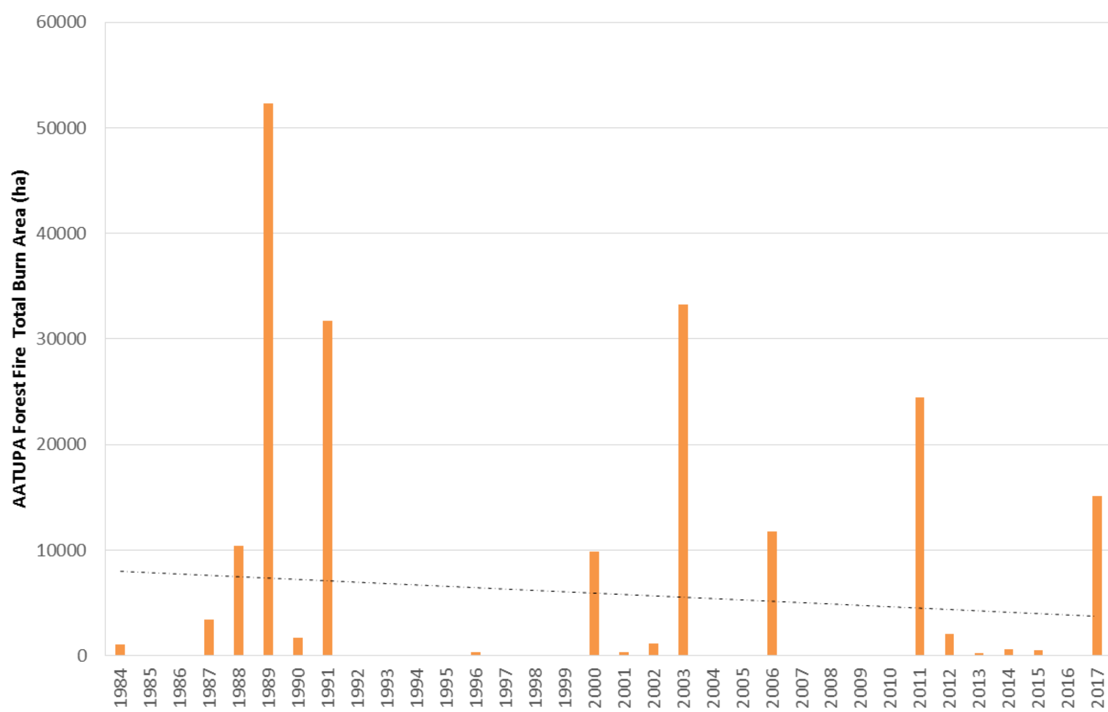

Figure 23. AATUPA total area burnt from 1984 to 2017 and showing a decreasing linear trend (black dotted line) over the study period.

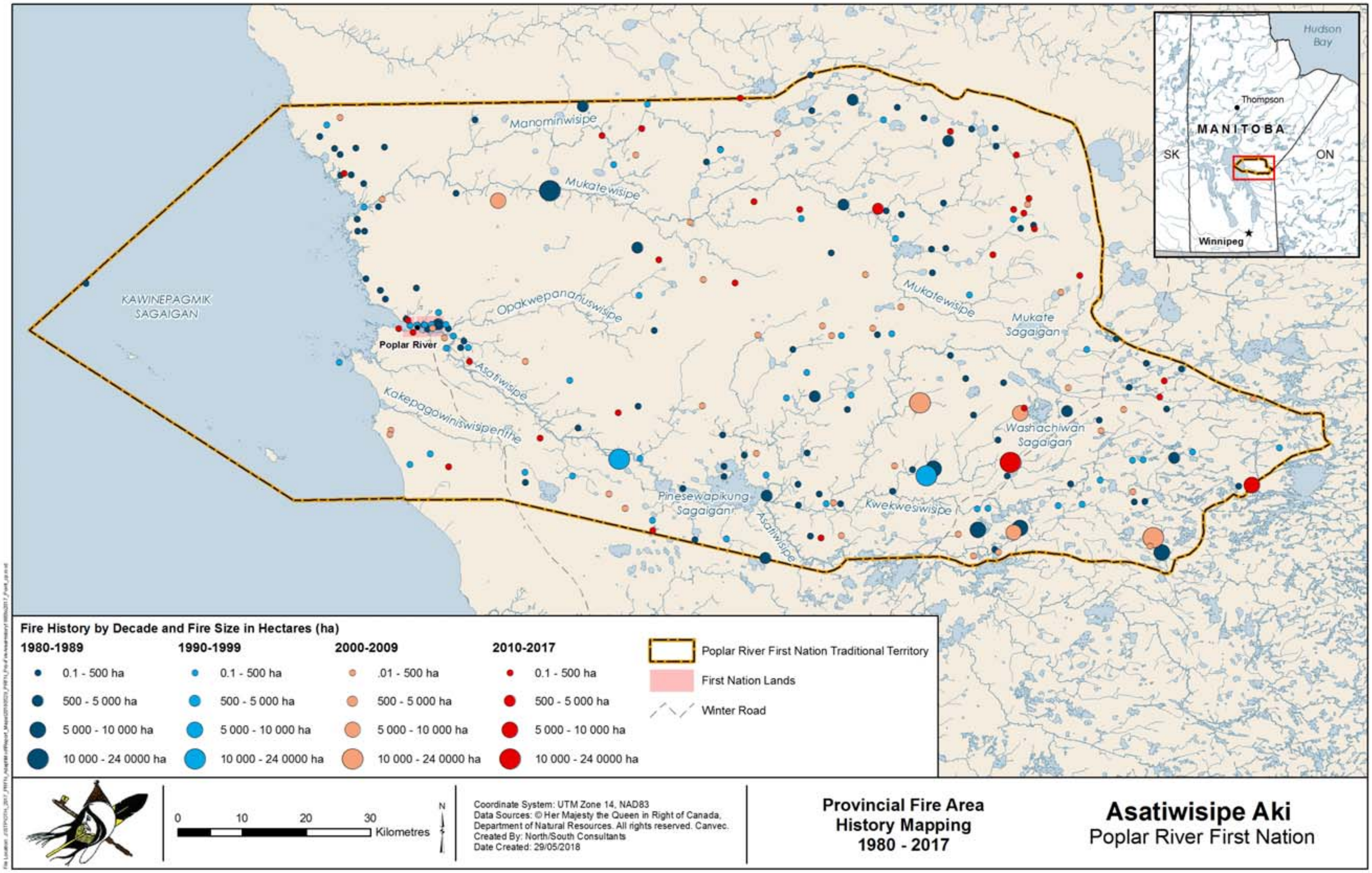

Figure 24. Forest fire occurrence and relative size for the AATUPA symbolized by decade for the study period 1984 – 2017. Fire occurrence data provided by the Government of Canadian National Forest Database (CNFDB).

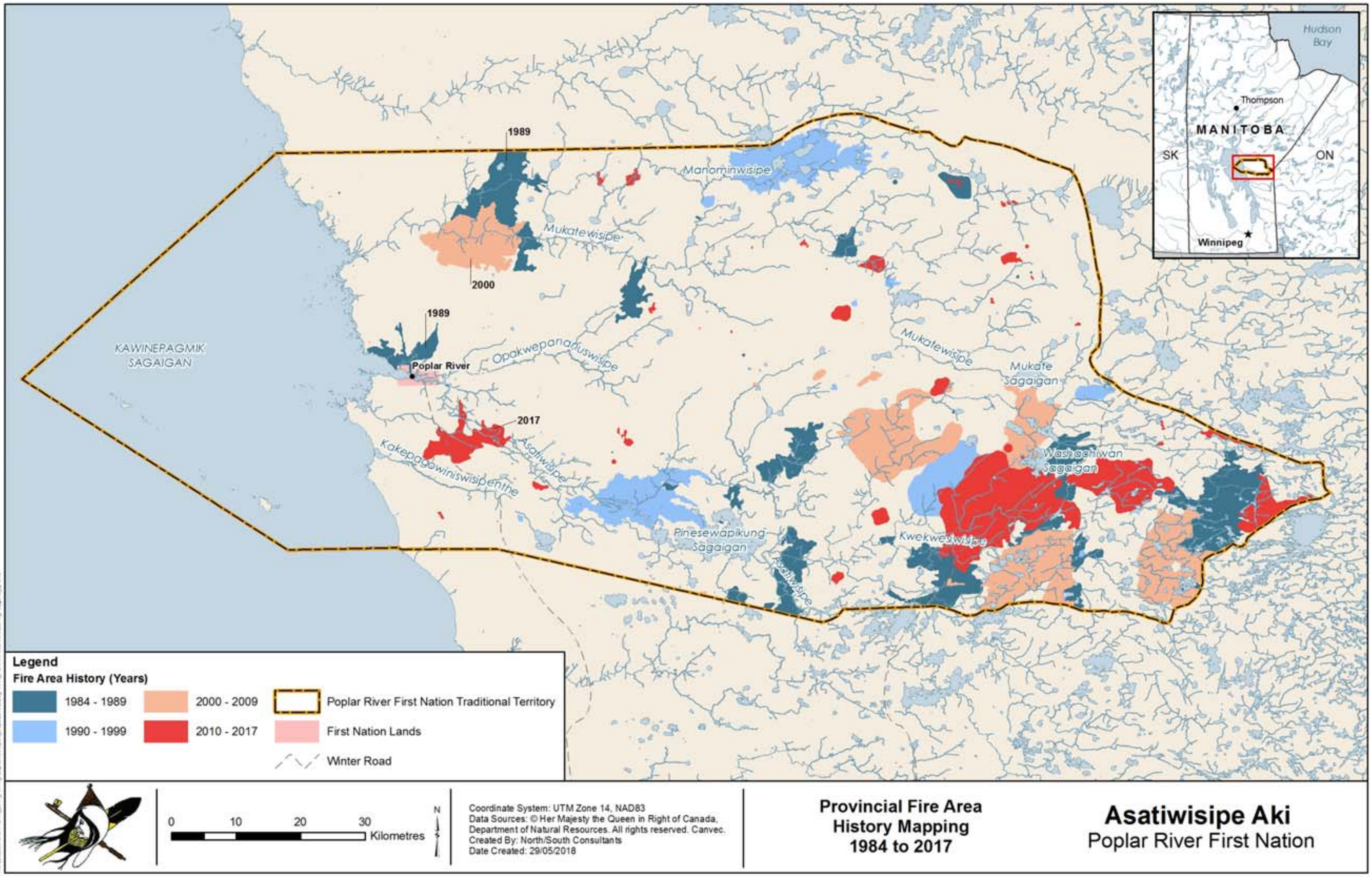

Figure 25. Provincial forest fire area mapping for the AATUPA symbolized by decade for the study period 1984 – 2017. Forest fire area mapping provided by the Province of Manitoba's Manitoba Land Initiative (MLI).

Table 2. Summary of forest fire occurrence, total burned area, and combined fire activity rank in the AATUPA for the study period 1984 – 2017.

Year	Area (ha)	Count	Overall Rank
1984	1,037	23	9
1985	6	6	19
1986	5	5	22
1987	3,380	9	14
1988	10,426	68	3
1989	52,309	126	1
1990	1,662	27	8
1991	31,717	37	5
1992	80	4	23
1993	1	4	24
1994	79	12	12
1995	4	6	20
1996	350	5	21
1997	12	1	29
1998	23	3	26
1999	12	6	18
2000	9,826	18	11
2001	343	8	15
2002	1,161	11	13
2003	33,296	75	2
2004	0	0	31
2005	0	0	32
2006	11,768	39	4
2007	13	2	28
2008	1	1	30
2009	0	0	33
2010	3	3	27
2011	24,424	37	6
2012	2,093	19	10
2013	238	3	25
2014	597	6	17
2015	535	7	16
2016	0	0	34
2017	15,159	31	7
Total	200,559	602	-

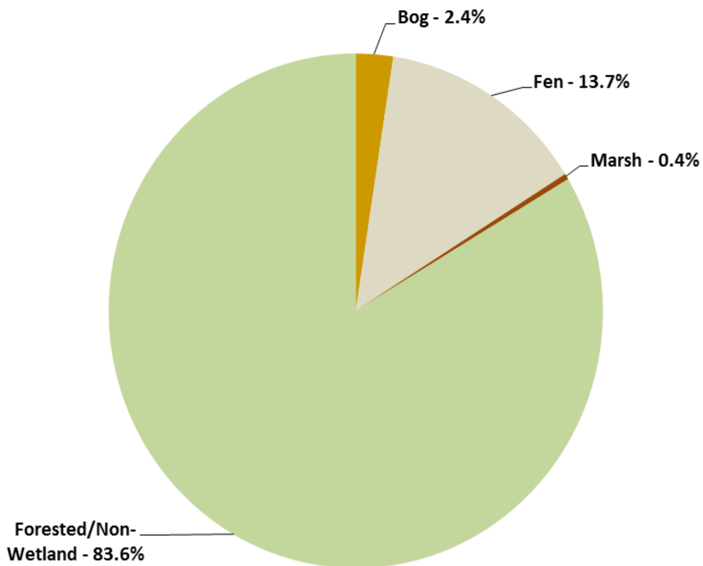

Figure 26. Total area burned by predominant cover type in the AATUPA for the period 1984 – 2017.

4.0 DISCUSSION AND NEXT STEPS

4.1 DISCUSSION

Temperature is increasing in the AATUPA. Twenty of the last 34 years analysed were warmer than normal and seven of the eight most recent years (2010 to 2017) have been warmer than the long-term average. Similar observations were provided by Poplar River community members and Elders. Models predict that temperature increases will continue over the next 100 years reflecting an increase between 3.6°C to 6.1°C.

Historically, multi-decadal cycles of wet years or drought years have occurred. Over the period of study (1984 – 2015), wetter years have dominated the records with a few exceptions (e.g., 1988, 1990, 2003, 2006 – 2008 and 2013). Overall during this time, precipitation has increased and evapotranspiration indices have increased suggesting overall wetter, non-drought conditions.

The NDVI and the NDMI measures of how 'green' vegetation is and surface moisture levels in the canopy, respectively, show wetter than average years. Models predict that Manitoba will be wetter in the spring and drier in summer months, making the summer months more susceptible to drought. A later season drying trend has been detected by Poplar River community members and Elders who noted moisture stress in the vegetation in later summer months.

Predictably, given wetter years in the recent record, the overall trend in forest fire activity, number of fires and area affected, in Manitoba and in the AATUPA has declined during the period of study (1984 – 2017). In years experiencing drought, the number of fires and area burned increase. In 1989, the AATUPA had numerous fires that burned for long periods of time; 1989 was an unprecedented forest fire activity year and one of the most severe in Manitoba's history (Hirsh 1991). The lead-in to 1989 was a period of extended drought in Manitoba that peaked in 1988. As evidenced by the results of this report, the region affected by drought included the AATUPA, which likely played a role in 1989 being the most active fire year in the Area's history. Drought occurring from 1999 to 2004 led to an active fire year in 2003. Most recently, 2017 was a relatively active fire year related to a sharp decline in May through October precipitation from the previous year. Drought and fires are unequivocally linked.

The validity of the remote sensing analysis is supported by triangulation of multiple sources of information such as climate change models, local observation, traditional knowledge, climate station data and fire history. In 2003 for example, each of the scientific indicators analyzed showed a correlation with increased fire activity in the AATUPA, which was the second highest for the study period. Temperature data was above normal and precipitation was below normal, indicating warmer and drier conditions; SPEI indicated drought conditions; water levels in Weaver Lake were below normal, indicating below normal hydrologic conditions; NDMI values for all four cover types analyzed were below the study period average, indicating low surficial moisture content in the vegetation canopy and potentially low water tables; and NDVI values for all but marsh cover types were below normal indicating stressed vegetation due to dry conditions; and finally change detection analysis showed a 77%

decrease in NDMI values across the entire AATUPA when compared to 1993, a relatively cool wet year with limited fire activity. However, overall, the years examined appear to represent a multi-decadal wet cycle. In the isolated drought years, such as in 2003, fire susceptibility has increased dramatically. It would not be unreasonable to suggest that we are due for a shift towards a dry cycle according to the historical cycle that has repeated since the 16th century. This cycle, in combination with climate change-induced increases in temperature, decreases in precipitation in summer months, and increases in evapotranspiration may put communities including Poplar River at risk.

In 2018, Little Grand Rapids and Pauingassi First Nations each experienced a full evacuation, which means that all of the fly-in east-side First Nations were subject to community evacuations in either the 2017 or 2018 fire season, with the exception of Red Sucker Lake. Should these conditions continue to repeat in future years, adaptations to reduce hazards and risks will be essential.

4.2 NEXT STEPS

4.2.1 Adaptation Plan

The next step is to prepare an adaptation plan. This is expected to improve the resilience of the community by preventing and mitigating hazards where possible, and increase preparedness by having response and recovery plans in place. This shifts the focus from response to prevention efforts that will reduce the risk of hazards before disaster occurs.

The community has been working with the Red Cross to expand its Community Emergency Response Plan and incorporate the knowledge and lessons learned from the community's experience with the 2017 fire and the subsequent community-wide evacuation. However, some additional options related to prevention and hazard reduction remain outside of the Red Cross' purview. A list of potential options is provided below for discussion. These will be presented at a community meeting in June 2018 that will review the results presented in this report and the feasibility of these options for adaptation planning.

Location of firefighting resources – Concern has been expressed given that the community is located more than 250 km from the eastern rapid attack base out of Bissett. Further analysis is recommended to determine if this distance affects service response time and / or the decision to respond with a rapid attack assessment or not. Follow-up discussions could be held with the Province to consider if a rapid attack base situated in Poplar River would better serve the communities on the east-side of Lake Winnipeg.

Re-evaluating reliance on peatlands as a fire break– One of the key decision-making factors with respect to the delayed response to the 2017 fire near Poplar River occurred because the fire was initially surrounded by peatlands (i.e., areas considered to have water-saturated soils). Should a shift to a dry cycle occur, a re-evaluation of the capability of peatlands to supress fire may be warranted. This may be a shift in thinking, as Manitoban fire officers have spent the past 35 years responding to fires during a wet-dominated cycle.

Clarifying policy – There is some disparity between the community understanding of fire response zones (and therefore expectations of the Provincial response) and two Sustainable Development websites. The community understanding is that the AATUPA, including the community and Weaver Lake, is in a "green" or "let it burn zone". The interactive fire map defines colour coded zones as green, red, white and yellow, and Sustainable Development's Fire Program Mandate identifies the AATUPA as a "primary protection zone". Discussions with the Province would help to clarify the policy and therefore community expectations about wildfire response in the AATUPA.

Prevention Options – Vegetation management and a fire break are two options being considered in the community. One forested area in the north-central region of the community is considered to have a very heavy fuel load that, if ignited, is expected to be difficult to extinguish. This is the area where the new school is planned. A feasibility study on vegetation management could be conducted to understand the effort required to conduct thinning activities there. The second option is to establish a fire break along the boundaries of the reserve lands. The east edge of the reserve already has a cleared corridor but this could be widened and extended to become a perimeter around the reserve. Applying the FireSmart model may also reduce fuel loads in the community and close to dwellings.

Community Education – Given the Anishinabe view of fires ignited by humans – that they are unpredictable and have no purpose or benefit, community outreach by Elders or other members could occur to teach members, particularly youth, the traditional Anishinabe view of fire. This may include appropriate ways to manage, contain and extinguish human fires.

Other Preparedness Measures – Other measures may include increasing the community's capacity for rapid response to local fires before they spread. Recently the community acquired an Argo all-terrain vehicle and water pumps to respond to local fires. The community could review the readiness of this equipment for completing a rapid response. Identifying additional equipment needs and personnel training may also be desired.

Development of a Fire Management Strategy – Fire management strategies are in use across Canada and the Canadian Wildland Fire Strategy is one key example. Such a plan can be customized to local circumstances. For example, Pikangikum First Nation (PFN) and Ontario Ministry of Natural Resources (OMNR) are currently discussing the future role of fire within the Whitefeather Forest landscape (Miller et al. 2008). The Whitefeather Forest Management Corporation (WFMC) of PFN and OMNR are engaging to develop a fire management strategy (Miller and Davidson-Hunt 2010).

4.2.2 Peatland Monitoring

As part of an adaptation strategy, a monitoring program will be initiated to develop an understanding of peatland moisture conditions. PRFN community members will receive training and technology transfer from their partner to conduct ground-based monitoring of selected peatland sample sites. Each site will be characterized (e.g., wetland class, depth to mineral soil, vegetation type, etc.) and will be monitored for moisture content at selected depth and peat soil horizons using sample cores and research grade soil moisture sensors.

4.2.3 Geographic Information System

This component will include a review of existing information systems that provide data related to forest fire risks and the development of a community GIS for early detection of high-risk factors. It is expected that spatial data will include but not limited to:

- Real-time federal and provincial fire danger/hazard mapping for the region;
- Community infrastructure (e.g., buildings, local addressing, roads, trails);
- Real-time lightning strike data;
- Real-time weather data (e.g., Berens River wind, temperature, precipitation); and
- Contemporary high resolution imagery of the immediate community area that will be used to map community infrastructure and other assets.

It is anticipated that these data sets combined in a GIS will provide a means of early detection which can assist with timely initiation of the emergency response plan, thereby improving community readiness.

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APPENDIX B: TECHNICAL SUPPLEMENT

Table B-1. Landsat 5 TM satellite images and acquisition dates used in the analysis. Satellite images are courtesy of the USGS.

Image File Name	Sensor	Level	Path/Row	Year	Month	Day
LT05_L1TP_031023_19840811_20170220_01_T1	LT05	L1TP	31/23	1984	August	11
LT05_L1TP_031023_19850830_20170218_01_T1	LT05	L1TP	31/23	1985	August	30
LT05_L1TP_032023_19860808_20170217_01_T1	LT05	L1TP	32/23	1986	August	8
LT05_L1TP_032023_19870726_20170211_01_T1	LT05	L1TP	32/23	1987	July	26
LT05_L1TP_032023_19870827_20170211_01_T1	LT05	L1TP	32/23	1987	August	27
LT05_L1TP_031023_19880721_20170208_01_T1	LT05	L1TP	31/23	1988	July	21
LT05_L1TP_032023_19890816_20170202_01_T1	LT05	L1TP	32/23	1989	August	16
LT05_L1TP_032023_19900904_20170129_01_T1	LT05	L1TP	32/23	1990	September	4
LT05_L1TP_031023_19910815_20170125_01_T1	LT05	L1TP	31/23	1991	August	15
LT05_L1TP_032023_19920723_20170122_01_T1	LT05	L1TP	32/23	1992	July	23
LT05_L1TP_031023_19930820_20170117_01_T1	LT05	L1TP	31/23	1993	August	20
LT05_L1TP_031023_19940908_20170112_01_T1	LT05	L1TP	31/23	1994	September	8
LT05_L1TP_031023_19950826_20170106_01_T1	LT05	L1TP	31/23	1995	August	26
LT05_L1TP_031023_19950911_20170106_01_T1	LT05	L1TP	31/23	1995	September	11
LT05_L1TP_031023_19960828_20170103_01_T1	LT05	L1TP	31/23	1996	August	28
LT05_L1TP_031023_19970730_20161230_01_T1	LT05	L1TP	31/23	1997	July	30
LT05_L1TP_032023_19970806_20161230_01_T1	LT05	L1TP	32/23	1997	August	6
LT05_L1TP_031023_19980802_20161223_01_T1	LT05	L1TP	31/23	1998	August	2
LT05_L1TP_032023_19980910_20161222_01_T1	LT05	L1TP	32/23	1998	September	10
LT05_L1TP_031023_19990821_20161216_01_T1	LT05	L1TP	31/23	1999	August	21
LT05_L1TP_030023_20010803_20161211_01_T1	LT05	L1TP	3//23	2001	August	3
LT05_L1TP_031023_20020829_20161207_01_T1	LT05	L1TP	31/23	2002	August	29
LT05_L1TP_031023_20030816_20161205_01_T1	LT05	L1TP	31/23	2003	August	16
LT05_L1TP_031023_20040701_20161201_01_T1	LT05	L1TP	31/23	2004	July	1
LT05_L1TP_030023_20040726_20161201_01_T1	LT05	L1TP	3//23	2004	July	26
LT05_L1TP_031023_20050704_20161125_01_T1	LT05	L1TP	31/23	2005	July	4
LT05_L1TP_031023_20050821_20161125_01_T1	LT05	L1TP	31/23	2005	August	21
LT05_L1TP_031023_20060808_20161119_01_T1	LT05	L1TP	31/23	2006	August	8
LT05_L1TP_031023_20070726_20161112_01_T1	LT05	L1TP	31/23	2007	July	26
LT05_L1TP_032023_20080820_20161030_01_T1	LT05	L1TP	32/23	2008	August	20
LT05_L1TP_031023_20090901_20161021_01_T1	LT05	L1TP	31/23	2009	September	1
LT05_L1TP_031023_20100904_20161013_01_T1	LT05	L1TP	31/23	2010	September	4
LT05_L1TP_031023_20110907_20161006_01_T1	LT05	L1TP	31/23	2011	September	7

Table B-2. Landsat 7 ETM+ satellite images and acquisition dates used in the analysis. Satellite images are courtesy of the USGS.

Image File Name	Sensor	Level	Path/Row	Year	Month	Day
LE07_L1TP_031023_20000714_20170210_01_T1	LE07	L1TP	31/23	2000	July	14
LE07_L1TP_031023_20000831_20170210_01_T1	LE07	L1TP	31/23	2000	August	31
LE07_L1TP_031023_20120816_20161130_01_T1	LE07	L1TP	31/23	2012	August	16
LE07_L1TP_031023_20130819_20161122_01_T1	LE07	L1TP	31/23	2013	August	19

Table B-3. Landsat 8 OLI satellite images and acquisition dates used in the analysis. Satellite images are courtesy of the USGS.

Image File Name	Sensor	Level	Path/Row	Year	Month	Day
LC08_L1TP_031023_20130726_20170309_01_T1	LC08	L1TP	31/23	2013	July	26
LC08_L1TP_031023_20140915_20170303_01_T1	LC08	L1TP	31/23	2014	September	15
LC08_L1TP_032023_20140922_20170303_01_T1	LC08	L1TP	32/23	2014	September	22
LC08_L1TP_031023_20150817_20170226_01_T1	LC08	L1TP	31/23	2015	August	17
LC08_L1TP_032023_20150824_20170225_01_T1	LC08	L1TP	32/23	2015	August	24
LC08_L1TP_031023_20160702_20170222_01_T1	LC08	L1TP	31/23	2016	July	2
LC08_L1TP_031023_20170518_20170525_01_T1	LC08	L1TP	31/23	2017	May	18
LC08_L1TP_032023_20170626_20180125_01_T1	LC08	L1TP	32/23	2017	June	26
LC08_L1TP_031023_20170705_20170716_01_T1	LC08	L1TP	31/23	2017	July	5
LC08_L1TP_032023_20170712_20170726_01_T1	LC08	L1TP	32/23	2017	July	12
LC08_L1TP_031023_20170721_20170728_01_T1	LC08	L1TP	31/23	2017	July	21
LC08_L1TP_032023_20170728_20170810_01_T1	LC08	L1TP	32/23	2017	July	28
LC08_L1TP_032023_20170813_20170825_01_T1	LC08	L1TP	32/23	2017	August	13
LC08_L1TP_032023_20170829_20180125_01_T1	LC08	L1TP	32/23	2017	August	29
LC08_L1TP_031023_20170907_20170926_01_T1	LC08	L1TP	31/23	2017	September	7
LC08_L1TP_032023_20170930_20171013_01_T1	LC08	L1TP	32/23	2017	September	30
LC08_L1TP_032023_20171016_20171024_01_T1	LC08	L1TP	32/23	2017	October	16

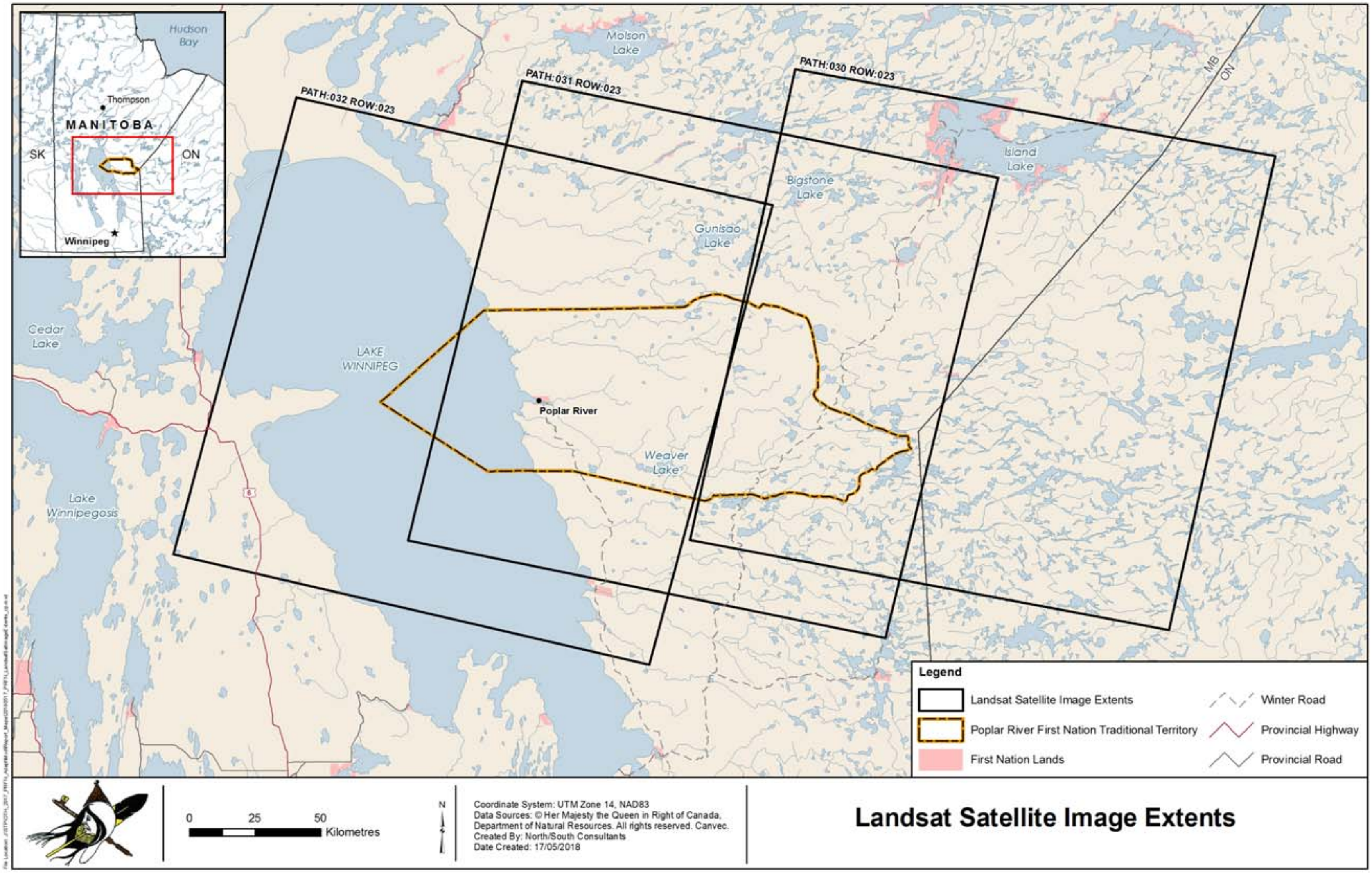

Figure B-1. Landsat satellite path and row image extent options for the AATUPA region.

Figure B-2. NDVI and NDMI anomaly values for forested/non-wetland cover types sampled in the AATUPA.

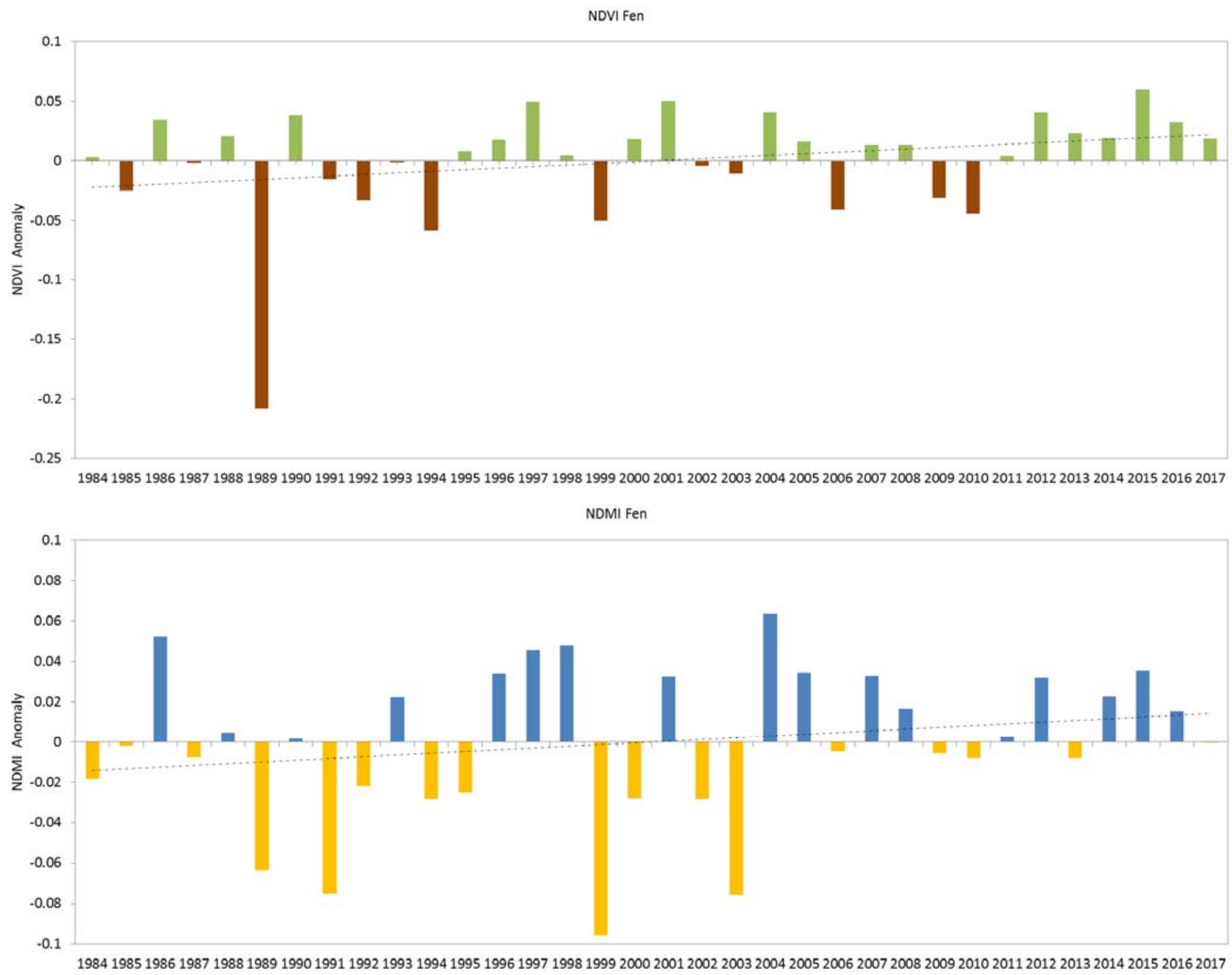

Figure B-3. NDVI and NDMI anomaly values for fen cover types sampled in the AATUPA.

FigureB-4. NDVI and NDMI anomaly values for bog cover types sampled in the AATUPA.

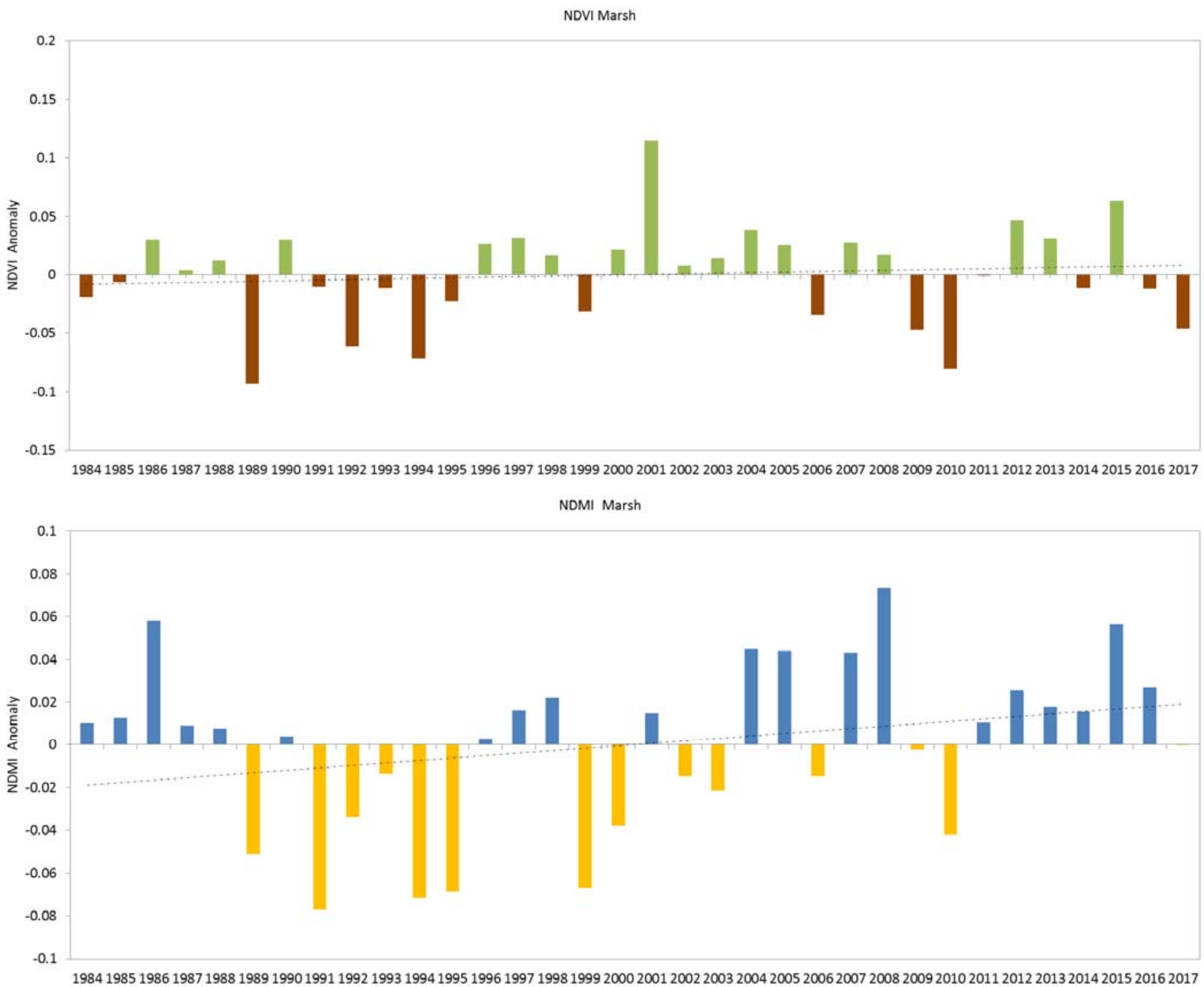

Figure B-5. NDVI and NDMI anomaly values for marsh cover types sampled in the AATUPA.

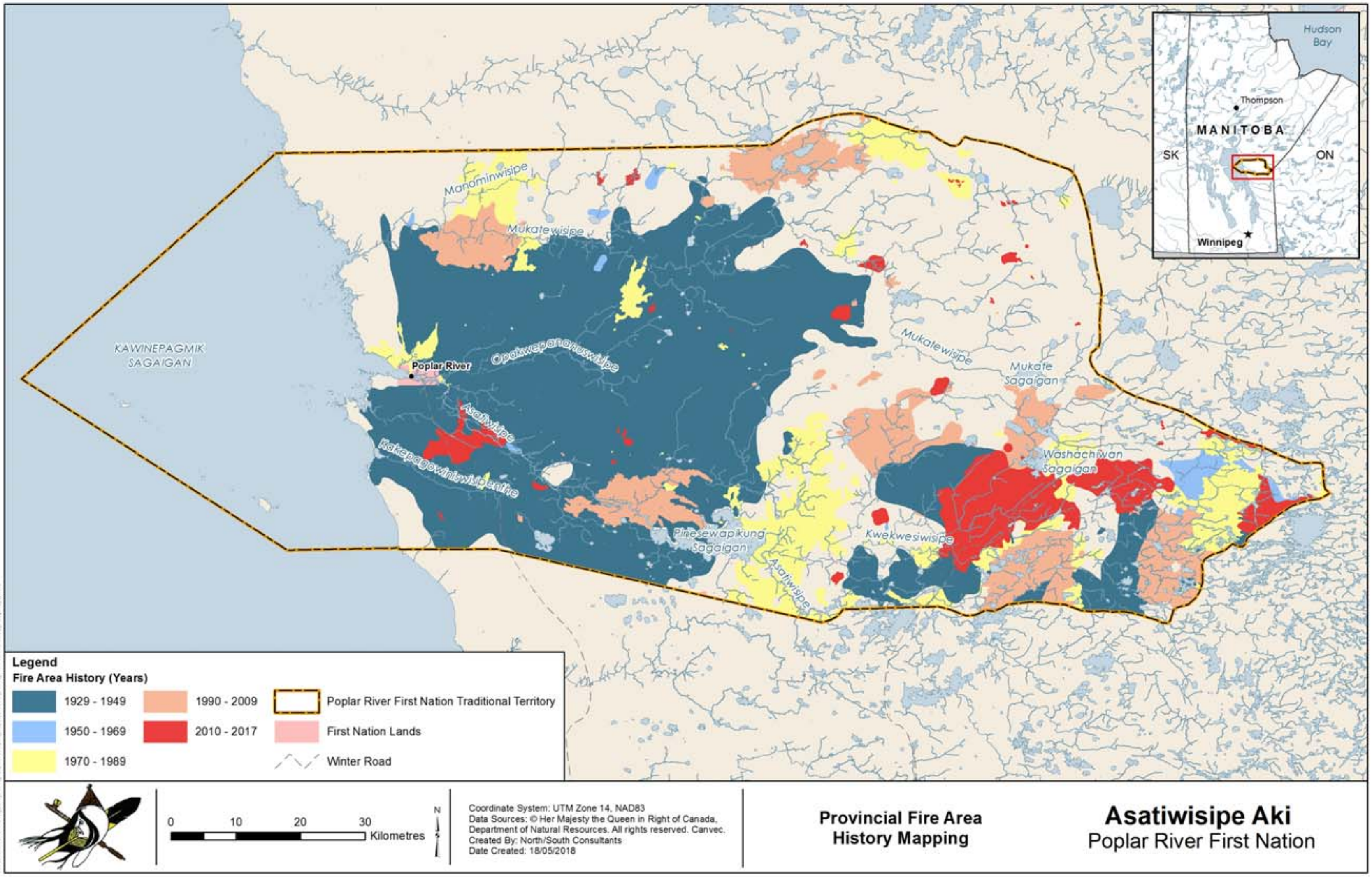

Figure B-6. Manitoba Forestry Branch (Manitoba Sustainable Development) forest fire area mapping dating back to 1928. The large fire (blue) covering half of the AATUPA occurred in 1929.