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Flood History Analysis and Socioeconomic Implications of Flooding for Indigenous Canadian Communities

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ABSTRACT Flooding poses a significant threat to the water security of indigenous communities across Canada. The primary objective of this study is to explore the issue of flooding in indigenous communities across Canada in order to characterize the severity of the problem and investigate the socioeconomic consequences. The issue is quantified and illustrated by assembling a map that depicts the locations and number of floods that occurred in these communities between January 2006 and November 2016. The results of this study reveal that during this period approximately 67 First Nations communities in Canada experienced close to 100 occurrences of flooding, and about half of these floods occurred in Manitoba or Ontario. This analysis is used to propose a framework to identify factors responsible for flooding in these communities, and several of these factors become the focus for further investigation in the Northern Ontario First Nations community of Kashechewan, which has been especially susceptible to flooding. Stream flow in the adjacent Albany River is analyzed over this period to provide a preliminary assessment tool to identify flood risk. To assess the potential socioeconomic impact of flooding in this community, direct consequences of floods are analyzed and linked to potential indirect impacts to health and security. It was found that the community was disrupted by evacuations due to flood warnings during seven of the eleven years over 2006-2016, while property and infrastructure damage, disruptions to education and medical services and mental health issues are consequences of the high flood risk.

Keywords: flood, water security, Indigenous communities, risk, socioeconomic impact

INTRODUCTION Throughout the existence of humankind, water security has been one of the most significant contributing factors to the quality of life and survival of our species. A comprehensive assessment of the state of global water security found that close to 80% of the world's population faces a significant threat to water security (C.J. Vorosmarty, 2010). The term "water security" covers the availability and accessibility of systems that deliver water of sufficient quantity and quality to support overall health, safety and ecosystem survival (Bakker, 2012). It also incorporates the risk, both to the natural environment and to human life, associated with all water-related hazards (Bakker, 2012).

In Canada, floods are among the most devastating water-related hazards that threaten water security (Government of Canada, 2015). Each year, communities across Canada experience flooding brought on by a variety of different causes; however, indigenous populations are especially vulnerable to the impact of flooding. As of 2006, an estimated 1.2 million Aboriginal (indigenous) people inhabited land across each province and territory in Canada, totaling close to 4% of the overall population (Ford, 2010). Approximately half resided in remote communities either on reserves, in the northern territories, or in rural areas (Ford, 2010). Many of these communities experience sub-standard living conditions due in part to the inaccessibility of adequate food and water resources. These small and isolated communities are particularly vulnerable to the economic and social consequences of flooding, yet little has been done to explore the magnitude of this issue and the impact on indigenous peoples.

The goal of this study is to investigate short and long-term socioeconomic impacts of flooding in indigenous communities in Canada. To do so, it is first necessary to examine the historical flood records affecting these communities. This study characterizes flooding events that occurred in indigenous communities between January 2006 and November 2016, and identifies specific regions of concern and common causes of flooding. The study then concentrates on one particularly vulnerable First Nations community (Kashechewan, Ontario) to begin investigating some of the potential socioeconomic impacts of flooding. This research provides a foundation for continued investigation into the direct and indirect socioeconomic consequences of water insecurity caused by flooding in indigenous communities in Canada.

FLOODING EVENTS IN INDIGENOUS COMMUNITIES ACROSS CANADA In the absence of comprehensive data records, incidents of flooding in indigenous communities from January 2006 to November 2016 were found primarily through review of national and local news articles. The dates and locations of flooding incidents in indigenous communities were recorded for each province and territory across Canada, and compiled in the form of a map, shown in Figure 1. Approximately 67 indigenous communities in Canada experienced flooding during the study period. Over 25% of these communities experienced multiple floods, with more than 10% having experienced three or more floods during this period. In total, these 67 communities endured close to 100 instances of flooding over this period.

Approximately half of these floods were concentrated in Manitoba and Ontario First Nations communities alone. In fact, 29 Manitoba First Nations experienced close to one third of the flooding episodes recorded during the study period, while 13 First Nations in Ontario experienced close to 20% of the recorded flooding episodes. Flooding in these regions affects a large proportion of the total indigenous population in Canada. As of 2011 the highest percentage of the total indigenous population in Canada resided in Ontario (21.5%), while the fourth highest percentage of this population resided in Manitoba (14%) (Statistics Canada, 2015). These floods have had a direct impact on indigenous communities in Canada. In the spring of 2011, rivers, creeks and lakes in Manitoba were overwhelmed by floodwaters due to elevated levels of precipitation throughout the year, leading to several of the flooding events displayed in Figure 1 (Manitoba 2011 Flood Review Task Force Report, 2013). More than 7,100 people, primarily from First Nations communities, were evacuated due to flood risk during this period (Manitoba 2011 Flood Review Task Force Report,

2013). As of June 2015, close to 1,900 people were still displaced from their homes, and about 1700 of these evacuees were from the Lake St. Martin, Little Saskatchewan, Dauphin River and Pinaymootang First Nations (Canadian Broadcasting Corporation, 2015). In the Peguis First Nation, pre-fabricated homes were provided for residents that were displaced due to the flooding in 2011, although this solution was ineffective. In 2015, at least 37 of these homes were deemed uninhabitable due primarily to inadequate insulation, plumbing and vapour barriers (CTV Television Network, 2015). Attawapiskat and Kashechewan, both located in Northern Ontario, have faced housing crises and sub-standard living conditions resulting from sewer back-ups and mould growth between 2006 and 2016 (Canadian Broadcasting Corporation, 2013).

Flooding is influenced by a variety of factors, some of which are illustrated in Figure 2. These contributors to flood risk may be due to natural or anthropogenic factors, and include variability in

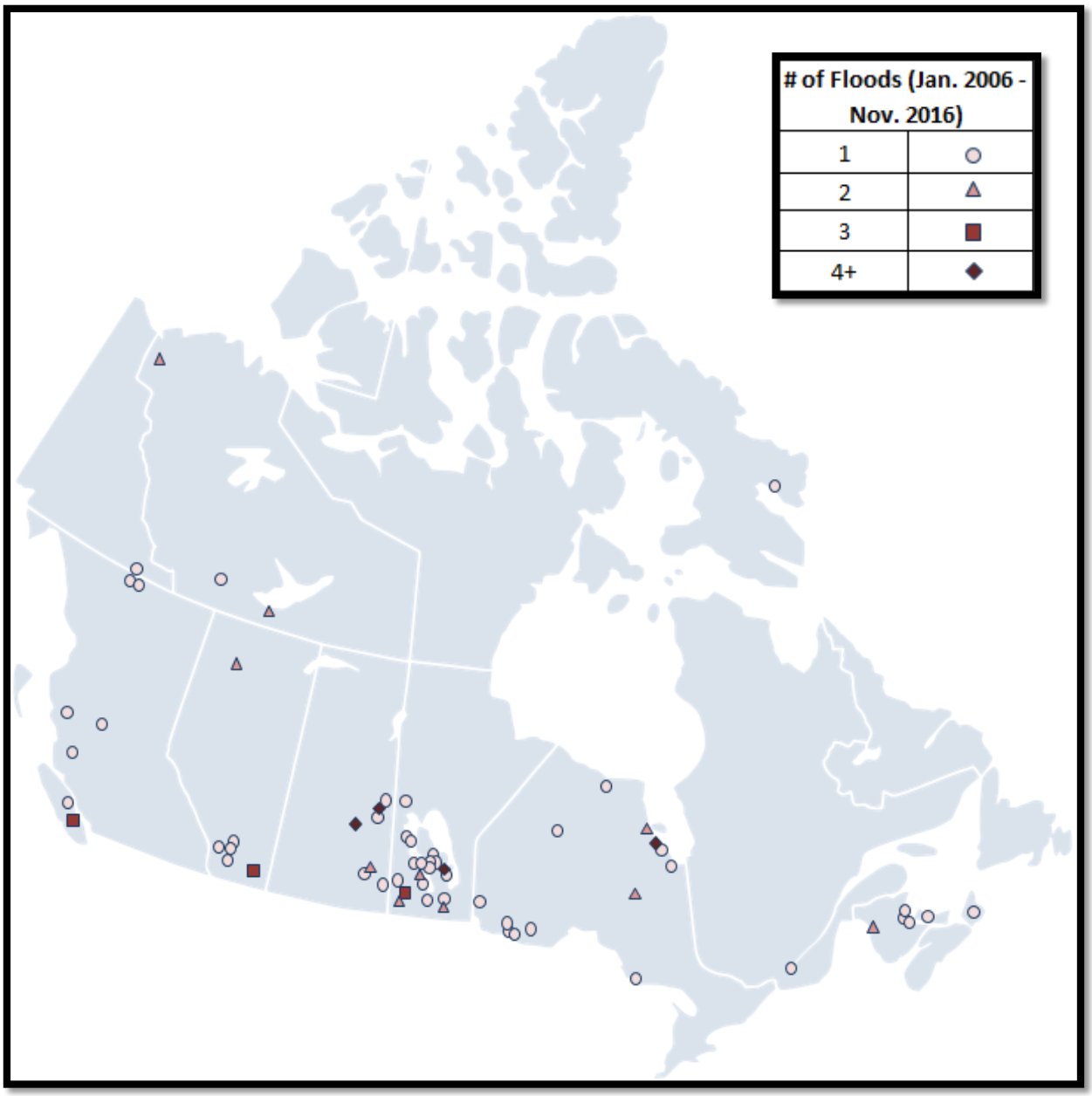

Figure 1. Locations and frequency of flooding events in indigenous communities across Canada from January 2006 to November 2016 (after Wikimedia Commons, 2007)

climate data and water levels, planning, policies and mitigation techniques. Social issues including social status, average income and community acceptance are also factors that influence risk associated with flooding. Flooding in the North-West Territories has been caused by natural phenomena such as ice jamming (as observed in Hay River, N.W.T. (Aboriginal Affairs and Northern Development in Canada, 2014)), however, anthropogenic factors often also affect the magnitude and occurrence of floods. Both the Peguis and Ebb and Flow First Nations have alleged that during the extreme flooding in Manitoba in 2011, their territory was flooded due to mismanagement of floodwaters as they were diverted away from other areas in the province (Thomson, 2011). The Cheslatta Carrier Nation in B.C. has had sacred territory, including burial sites, flood due to the operation of a hydroelectric dam (Canadian Broadcasting Corporation, 2016).

The compilation of dates and locations of flooding episodes in Figure 1 demonstrates that floods have affected many indigenous communities across Canada over the duration of the study period. Still, the social and economic impacts of these floods on communities remain unclear. To evaluate short and long-term socioeconomic impacts of flooding, this investigation focuses the next portion of the analysis to one key community currently in crisis in Northern Ontario.

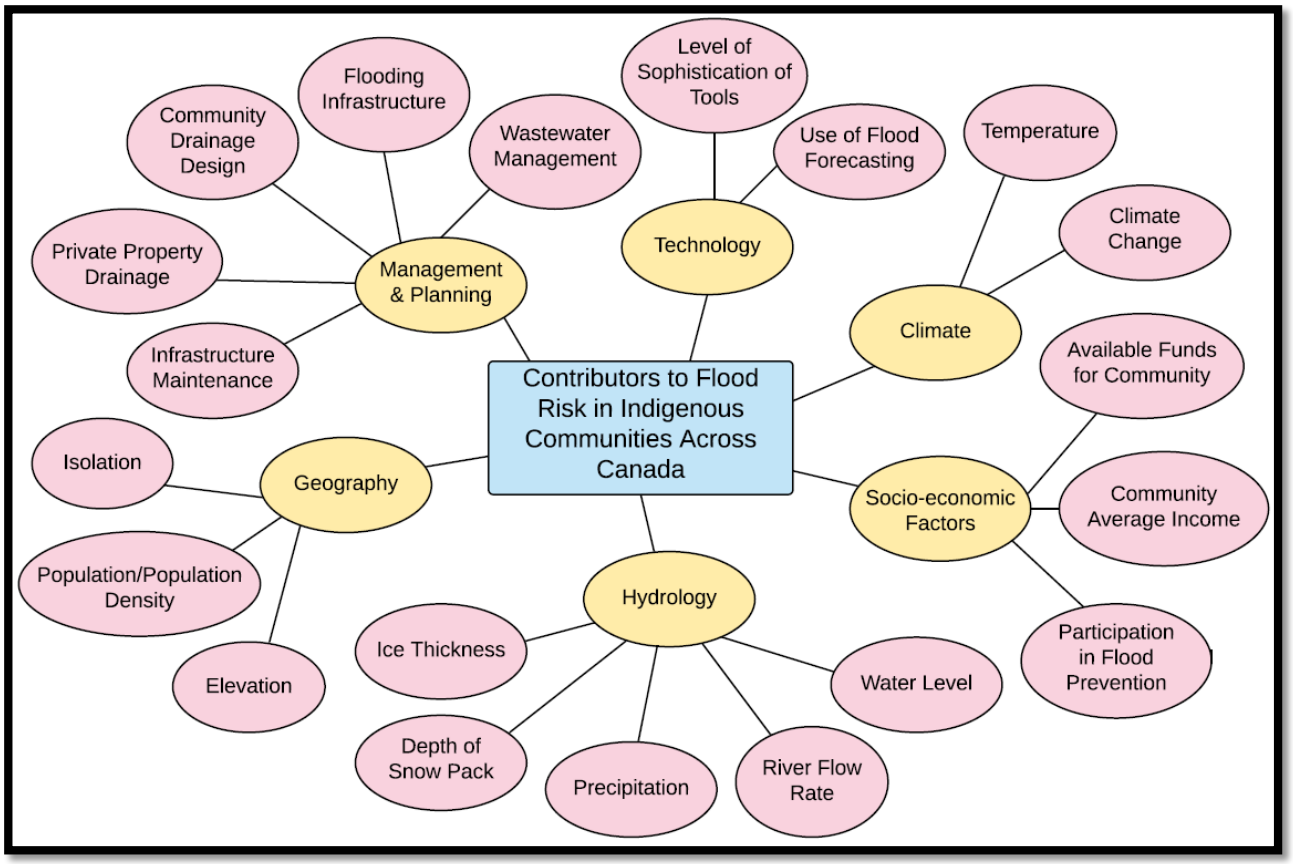

Figure 2. Diagram depicting contributors to flood risk for indigenous communities in Canada

ASSESSMENT OF FLOODING IN KASHECHEWAN FIRST NATION Kashechewan is located on the western side of James Bay close to the mouth of the Albany River. As of 2012, the population of the reserve was approximately 1700 (Fort Albany and Kashechewan, n.d.), although it is more recently estimated closer to 2000 (Canadian Broadcasting Corporation, 2015). Flooding is not unfamiliar for long-time Kashechewan residents. In 1957, Cree hunters were forced by the federal government to move to the flood-prone plain where Kashechewan now resides (Canadian Broadcasting Corporation, 2007). Since that time, several major floods have devastated the community. In 1976, heavy rainfall induced ice jam-related flooding in the community (Abdelnour,

2013). In 1985, higher temperatures accompanied with rainfall once again caused snowmelt and ice jam-related flooding (Abdelnour, 2013). Between January 2006 and November 2016, the community experienced floods in 2006, 2008, 2013, and 2014. In fact, residents of the Kashechewan First Nation were evacuated throughout seven of the eleven spring flooding seasons between 2006 and 2016 (Canadian Broadcasting Corporation, 2006; Canadian Broadcasting Corporation, 2008; Canadian Broadcasting Corporation, 2013; Canadian Broadcasting Corporation, 2014; Canadian Broadcasting Corporation, 2015; Canadian Broadcasting Corporation, 2016; D'Aliesio, 2012).

For Kashechewan, many of the socioeconomic issues that residents have faced may be linked to flooding and its associated consequences. Due to the proximity of this community to the Albany River, water flow is a significant contributor to flood risk (see Figure 2), and is used to analyze flood patterns, identify potential indicators for flooding and begin to quantify flood risk for the community. This assessment leads to an evaluation of the direct consequences of flooding in Kashechewan, followed by a critical analysis of some additional socioeconomic consequences of floods for the community.

Flow Pattern Analysis The Government of Canada's historical hydrometric database (Government of Canada, 2016) provides river discharge data from two flow gauges located along the Albany River upstream of Kashechewan. River Station 04HA002 is located approximately 100km upstream of Kashechewan; however, flow data at this river station is only available from 2011 to 2016. River Station 04HA001 is located about 200km upstream of Kashechewan, and since data is available at this location throughout the entire study period, this flow gauge is used to analyze flow patterns and assess flood risk in Kashechewan.

In a northern location such as Kashechewan, the first major peak in the river discharge each year is generally an indication of snowmelt induced by rising temperatures. Figure 3 plots the first major peak in the flow rate at River Station 04HA001 from 2006 to 2016. Several data points are distinguished in years where floods occurred in the community of Kashechewan. During this period, flooding did not occur with a peak flow rate below 5,020 m^3/s, which is illustrated with the threshold line in Figure 3. The threat of flooding in Kashechewan may be assessed using this threshold value as an indicator above which flood risk increases. Analysis of daily changes in temperature, snow pack/snowmelt, weather forecasts and other related variables allow for determination of the potential for the peak flow rate in the Albany River to reach the indicated threshold value. It should also be noted that the peak flow rate in 2011 meets this threshold value, although there was no flooding in the community that year. This is an indication that evaluation of the peak flow rate according to this threshold value should not be the only factor considered in the assessment of flood risk for Kashechewan and suggests that other factors also play a role.

Another important indicator of potential flooding is the rate of change of the discharge as it increases to a peak value in early spring. To estimate this rate of change for each year in the study, the slope of the flow rate graph for each year was estimated between a value where the rate of change of the discharge was sufficiently small and the peak flow value. The former value was determined by locating the point where the rate of change of the discharge was less than 0.5% of the peak flow rate for that year. Figure 4 illustrates the average rate of change of the discharge for each year at River Station 04HA001. Over the study period, no flooding occurred with an average rate of change less than the threshold line at $366 m^3/s$ per day. The only outlier is the data point for the year 2012, which is higher than the threshold although flooding did not occur in that year. The peak flow rate for the year 2012, however, is much lower than the threshold indicated in Figure 3. Conversely, although the peak flow rate for the year 2011 meets the threshold indicator in Figure 3, the average rate of change of the discharge for this year is far below the threshold indicator shown in Figure 4. The results from these two cases indicate that a combination of the two flooding indicators shown in Figures 3 and 4 may provide a reasonable indication of a high flood risk for the community of Kashechewan. This analysis has shown that the community of Kashechewan is at an elevated flood

risk as factors such as temperature change, ice and snow melt affect river flow during the spring each year.

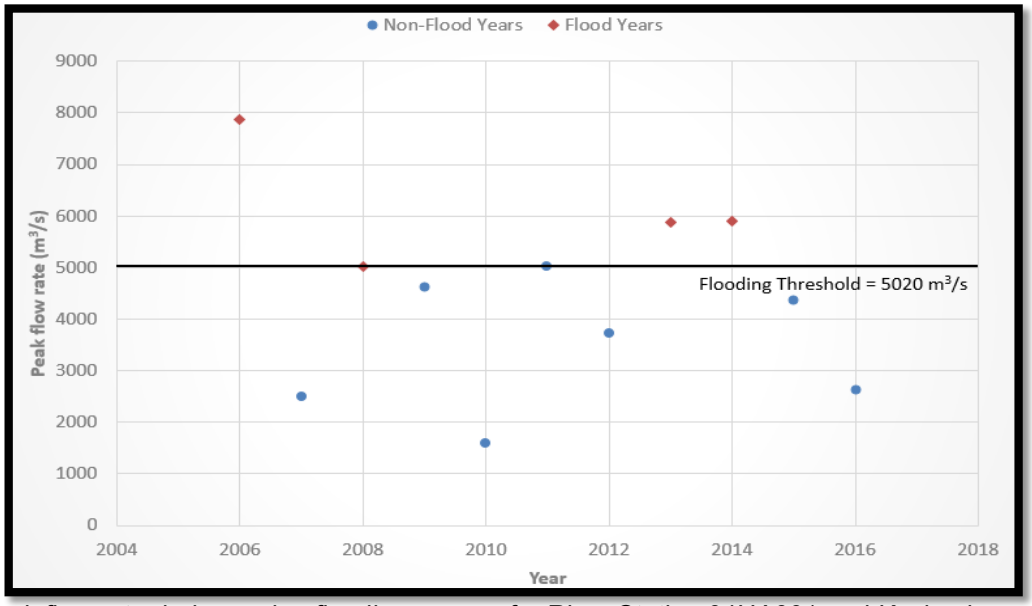

Figure 3. Peak flow rate during spring flooding season for River Station 04HA001 and Kashechewan, Ontario

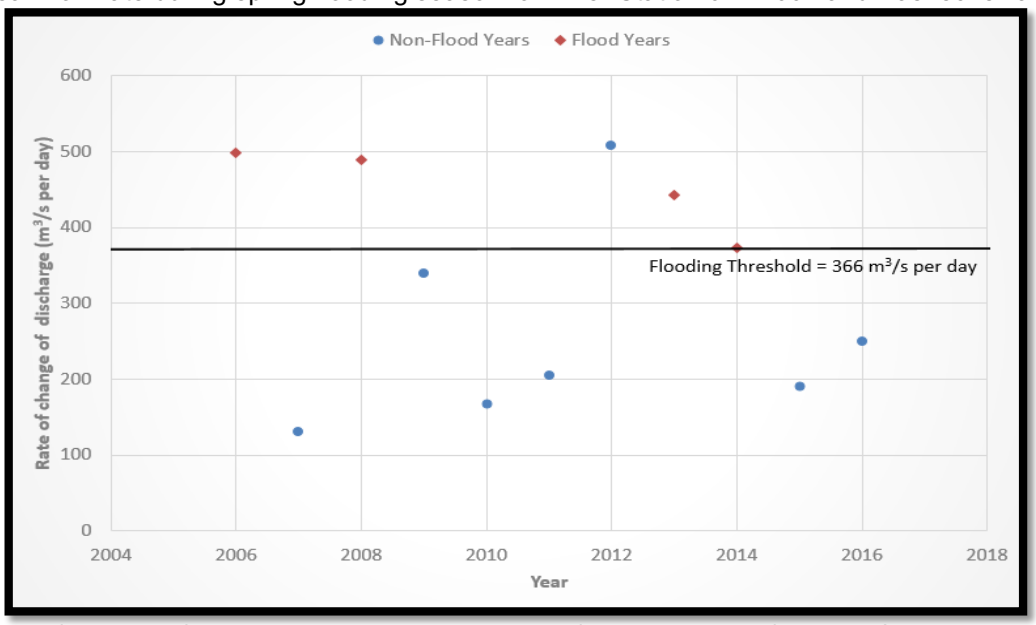

Figure 4. Rate of change of discharge to peak during spring flooding season for River Station 04HA001 and Kashechewan, Ontario

Direct consequences of flooding events in Kashechewan The degree of impact of a flooding event depends on multiple factors including the geographic size, population intensity or isolation of a region, and the socioeconomic conditions. The Kashechewan First Nation is a small and isolated community that faces challenges of poverty, food and water insecurity and inadequate housing and infrastructure. Due to these and other factors, the residents of Kashechewan are increasingly vulnerable to the threat of flooding.

Between 250 (D'Aliesio, 2012) and 2000 (Canadian Broadcasting Corporation, 2014) residents of the Kashechewan First Nation were evacuated during seven spring flooding seasons between 2006 and

2016. During the 2006 flood, the dike along the Albany River leaked, resulting in basement floods and damage to roads and the airport runway (Canadian Broadcasting Corporation, 2006). The community water treatment plant went out of service due to ice build-up, and residents were required to drink water that was delivered from outside of the community (Canadian Broadcasting Corporation, 2006). In 2008, flooding caused residents to be displaced for up to eight weeks while the continued threat of flooding was assessed (Canadian Broadcasting Corporation, 2008). During flooding in 2013, at least 40 homes were flooded with water and sewage, prompting evacuations of the community once again (Canadian Broadcasting Corporation, 2013). Heating sources for individual houses were affected, and a boil-water advisory was put in place in the community due to the effect of flooding on the water treatment systems (Canadian Broadcasting Corporation, 2013). In May of 2014, 40 houses were affected as flooding damaged the sewer systems and caused sewage back-ups into basements (Canadian Broadcasting Corporation, 2014). The nursing station in the community was also damaged due to the flooding (CTV News, 2014). Over two years later, approximately 454 residents remained displaced following the damage caused by the 2014 flood (CNW Group, 2016). In April of 2016 many residents, primarily the young and elderly, were displaced for more than one week as a precautionary measure due to flood risk (Canadian Broadcasting Corporation, 2016).

Frequent evacuations due to flooding promote inconsistent living conditions, and can have harmful impacts for community members. Due to these evacuations, education is often interrupted along with access to other familiar community services. In addition, families can be separated for extended periods of time. The potential links between the direct consequences of flooding events mentioned above, and other crises that affected the living conditions of community members during this study period are examined in the following section.

Socioeconomic crises in Kashechewan and the connection to flooding and water insecurity In Canada, a state of emergency may be declared by any jurisdiction of government, from federal to municipal, in the case of potentially devastating events that include natural disasters (Findlaw Canada, n.d.). The Emergencies Act was implemented in Canada in 1988, and it gives the government the ability to use additional or uncommon measures to ensure the health, safety and security of citizens during troubled times (Findlaw Canada, n.d.). During a crisis, it is therefore the responsibility of the federal government to ensure the protection of citizens, as well as to ensure necessary remediation or repair to infrastructure, property and the environment (Government of Canada, 2016). In Kashechewan, states of local emergency have been declared at least seven times between 2006 and 2016, and most have been flood-related. Two other significant states of emergency were declared in 2005. The primary causes and dates of these events are summarized in Table 1.

In October of 2005, a state of emergency was declared in the community of Kashechewan that was linked to a principal element of water security: water quality and contamination. This incident was included in this assessment due to its potential connections to the flooding crisis in Kashechewan. The community's water supply had tested positive for the bacteria *E. coli* (Canadian Broadcasting Corporation, 2005), prompting the evacuation of close to 1,000 people with a total relocation cost of $16 million (Canadian Broadcasting Corporation, 2006). As chlorine levels in the water supply were increased in an attempt to combat the bacteria, higher rates of skin problems including scabies and impetigo affected members of the community (Canadian Broadcasting Corporation, 2006). Contamination to drinking water may be caused by a variety of issues, including the occurrence of natural disasters such as floods. Flooding in Kashechewan could potentially introduce sewage and other contaminants into the drinking water supply or affect the operation of the community's drinking water treatment plant, thereby increasing the potential for the water supply to become compromised.

In 2007, no declaration of emergency was made in Kashechewan; however, the local elementary school was closed at the beginning of the year due to reports of mould (Harries, 2007). Mould may be introduced into a building due to inadequate remediation after flooding. In Kashechewan, it is

possible that impacts of flooding contributed to the presence of mould in the local school building. During the school closure, elementary and secondary students were required to share the high school premises (Harries, 2007). Recess for the younger students was eliminated, and gyms and libraries had to be used as classrooms (Harries, 2007). These changes appeared to primarily affect high school students, with attendance dropping below one third (Harries, 2007). Due in part to the revised schedule that was put in place, sleeping patterns of high school-aged youth shifted, and health workers were often inaccessible to teenagers put in place to provide support (Harries, 2007).

In 2015, the community reported higher rates of depression and suicide attempts, and blamed these issues in part on repeated evacuations and disruptions to the schooling of young members of the community (Canadian Broadcasting Corporation, 2015). It is possible that issues related to mental health may be linked to some of the direct consequences of flooding in Kashechewan, including repeated evacuations. The lack of consistency in terms of education, housing and access to family and other forms of support can have harmful impacts, especially on youth living in isolated communities. The political organization Nishnawbe Aski Nation declared another state of emergency on behalf of northern Ontario communities at the beginning of 2016, which included Kashechewan (Canadian Press, 2016). Kashechewan was experiencing a shortage of medical services including physicians, nurses and support services for mental health (Canadian Press, 2016). This shortage could also be linked to a lack of stability, acceptable housing or infrastructure available for healthcare workers due to damages caused by flooding.

Table 1. State of emergency declarations in Kashechewan First Nation since 2005

State of Emergency Declarations in Kashechewan	
DATE	**CAUSE**
Apr. 2005	Spring flooding on Albany River resulting in sewage back-up (Government of Canada , 2013)
Oct. 2005	Contaminated drinking water supply (Government of Canada , 2013)
Apr. 2006	Rapidly rising water levels on Albany River resulting in flooding (Government of Canada , 2013)
Mar. 2012	Risk of flooding due to ice break-up on Albany River (Government of Canada , 2013)
Apr. 2013	Sewage back-ups and flooding into homes (Canadian Broadcasting Corporation, 2013)
May 2014	Rising flood waters and risk of flooding to community (Canadian Broadcasting Corporation, 2014)
Apr. 2015	High water levels on Albany River resulting in flooding (Government of Canada , 2013)
Feb. 2016	Declining health standards and access to health services (Canadian Press, 2016)
Apr. 2016	Precautionary evacuations due to risk of flooding (Government of Canada , 2013)

CONCLUSION Indigenous communities in Canada are particularly vulnerable to threats to water security due in part to community isolation, lack of infrastructure and planning and inadequate supply of resources. Some of these communities face a variety of socioeconomic challenges that are linked to water insecurity, and may be associated with the implications of flooding. It is therefore necessary to investigate some of these connections in order to guide communities and government resources toward effective decision-making tools and strategies. Engineering, policy and management solutions should strive to mitigate, prepare for, respond to and recover from flooding events with minimal impact to communities. Successful approaches must be collaborative efforts with community members and leaders in order to provide effective and sustainable solutions for the socioeconomic issues caused or intensified by flooding.

This study has several limitations. First, data availability with regards to cataloguing flooding episodes in indigenous communities across Canada introduced some uncertainty into the study. Records of flooding events were found primarily through analysis of news articles, which may contain bias and

uncertainty in data collection. It is also possible that some floods were not found or reported, and are thus missing from the results of this study. Another limitation of this analysis of flooding is that in cataloguing flooding events, this study does not consider flood threats or warnings that did not result in actual floods with physical damage. In compiling the data for this research, however, it became apparent that some of these communities may face more frequent flood threats than are included in the flood records illustrated in Figure 1. The temporal scale of this study is another potential limitation; an analysis of the results of this study could be improved by extending the total duration to 20 or more years, thereby allowing for more realistic patterns to develop. Finally, a more accurate depiction of the flow patterns near Kashechewan would emerge using data from a flow gauge closer to the community.

Indigenous communities in Canada that are especially susceptible to flooding should be adequately protected with infrastructure and emergency response planning. Post-disaster responses by all levels of government should be concerned with both short and long-term remediation as well as with plans for mitigation in terms of flooding. Further research should assess water security due to flooding and the potential socioeconomic implications for other highly vulnerable indigenous communities in Canada. Studies should also work toward developing tools and strategies to mitigate and protect against socioeconomic threats due to flooding.

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