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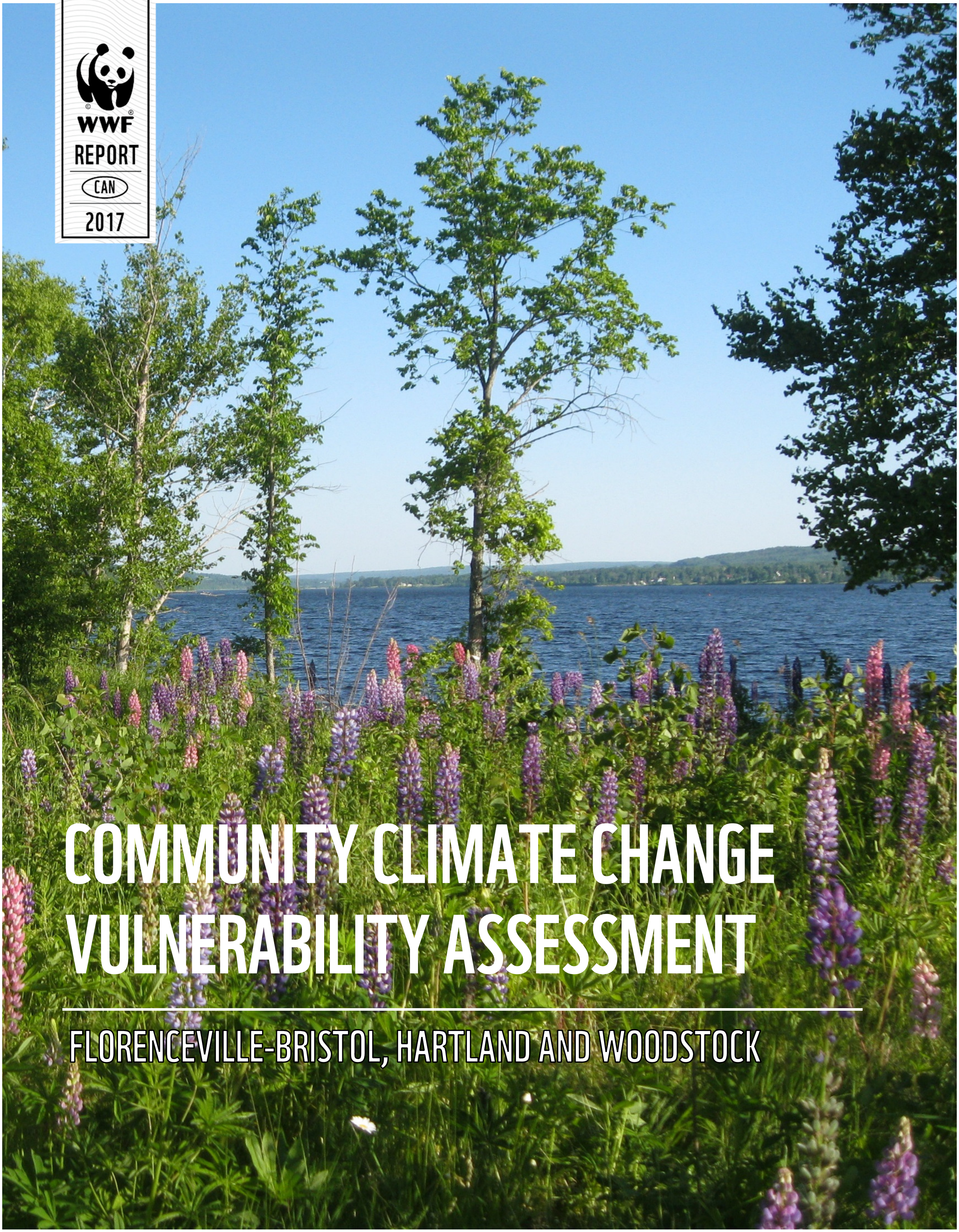

COMMUNITY CLIMATE CHANGE VULNERABILITY ASSESSMENT

FLORENCEVILLE-BRISTOL, HARTLAND AND WOODSTOCK

Acknowledgements*:*

This study is the result of a collaboration with four municipalities in the Western Valley Region, New Brunswick. This work was made possible by the participation of dedicated the residents from each community who formed the working groups, the Western Valley Regional Service Commission's Planning Manager Katelyn Hayden, as well as Mark Castonguay and Dr. Paul Arp of the UNB Forest Watershed Research Centre.

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TABLE OF CONTENTS

List of Figures

List of Tables

1 EXECUTIVE SUMMARY

In recent years, New Brunswick and more specifically the communities within the St. John River watershed, have experienced multiple and significant climate related hazards including floods, blizzards, ice and wind storms (Appendix A). These events have caused health impacts, physical and infrastructure damage, loss of household savings, temporary loss of services resulting in economic disruption and environmental damage. These hazards have impacted a number of communities to varying degrees and proactive initiatives to adapt to future impacts have been lacking.

WWF-Canada's Freshwater program has been active throughout the St. John River watershed over many years, working with a diversity of actors to encourage discussion and actions that support a healthy and resilient river. Early on, it was realized there was a significant disconnect between the many actors in the watershed which was found as a result of a social-ecological inventory and social network analysis undertaken in partnership with Brock University. The disconnect between municipalities, many who share a common and significant resource in the St. John River, was especially apparent with respect to the changing climate and the need to develop strategies that support healthy communities, species, habitats and river.

In response, WWF worked with the Western Valley Regional Service Commission and the municipalities of Woodstock, Hartland and Florenceville-Bristol to facilitate the Community Climate Change Vulnerability Assessment (CCCVA) process during 2014 -2015. The specific vulnerability assessment methodology used, was also used in Charlotte County, NB in 2013. The vulnerability assessment is but one step recommended in many adaptation frameworks. For this and the Charlotte County work, the larger municipal adaptation framework referenced was the guide developed by the International Council for Local Environmental Initiatives – Canada (ICLEI), *Changing Climate, Changing Communities – Guide and Workbook for Municipal Adaptation.*

The main purpose of this initiative was to enable the participating communities and the Regional Service Commission to share knowledge and concerns related to changing climate, while developing a more intimate understanding of local hazards, namely flooding from extreme rain events and the Spring Freshet. With this information, the CCCVA process was able to help shape recommendations for reducing the vulnerability of the participating communities along the St. John River in Western New Brunswick.

The process aimed to determine which community elements are most sensitive to environmental and climatic changes and to support the development of efforts that focus on building resilience. This was accomplished by utilizing community level engagement to aid stakeholders in identifying the locations, groups, and processes most susceptible to climate change hazards and impacts, based on past experience and new local projections for climate change.

The long term objective of the CCCVA and resulting climate change adaptation plan is to increase the resilience of the communities involved, and the broader region, to the impacts of climate change and variability. This report reflects the science, discussions, perceptions and potential actions of these communities regarding their concerns for climate hazard impacts and community vulnerabilities in order to proactively increase their resilience.

Based on the ICLEI methodology, risk (likelihood and consequences of an event, and a contributing factor to vulnerability) is prioritized across the municipalities as follows:

Florenceville – Bristol's

1. Power Outages
2. Telecommunications down
3. Delayed emergency response
4. Flooded routes – immediate fixes necessary
5. Use of staff outside of mandate
6. Assets damaged or lost and businesses impacted by flooding
7. Flooded routes – change in travel routes and Planting\harvesting season impacted and Forestry operations impacted
8. Flooded routes – longer travel times
9. Possible sewage overflows into river
10. Flooded routes – delayed pick up of solid waste

In Hartland, prioritization is as follows;

1. Possible contamination of well field
2. Power outages
3. Basement back ups
4. Increases in ice jam flooding
5. Water delivery lines impacted
6. Homes flooded and Delayed response in emergency management
7. Delayed emergency response and Assets lost or damaged
8. Possible sewage overflows into river
9. Businesses impacted by flooding

In Woodstock, prioritization is as follows;

1. Power Outages
2. Possible well field contamination
3. Telecommunications down
4. Increases in ice jam flooding
5. Businesses impacted by flooding
6. Access to well-house cut off
7. Water delivery lines impacted and Flooded routes – immediate fixes necessary

In these communities no specific vulnerable groups were identified, recognizing that the communities as a whole, experience hardships during impacts. However, various groups will respond in various ways, for example, in response to road washouts caused by heavy rains, seniors may experience stress related to travel – having to take unfamiliar routes or drive on impacted roads and/or experience social isolation due to not being able to participate in regular activities because of travel concerns or due to cancellation. During the same impact, road washouts caused by heavy rain will have different consequences for families. Families might experience extra expenses because of childcare due to school closures or they may experience increased fuel bills due to longer travel routes to work.

Local public works departments and their skilled labour have aided the regions in reducing potential impacts, as well as mitigating those that do indeed take place. The fire departments as well as the province's

Department of Transportation workers have also been on the front lines, contributing to the reduction of harm.

Increased coordination with NB Power and the province's Emergency Measures Organization were identified as actions which could contribute to the improvement of risk categories as well as preventative actions such as:

- Municipal infrastructure
  - locating new water sources – Woodstock.
  - relocation of lagoon - Hartland (reinforcement has already been completed in Florenceville-Bristol in a few instances).
  - building flood barriers/berms – specific suggestions by Woodstock, although could be useful throughout the communities.
- Municipalities ensuring they have back up power as well as provision of community charging stations
- Further developing the Quantity of Leadership Pool.
- Nurturing Voluntary Organizations, and participation at Community Events as they are current assets that can be built upon for increased community resilience building, and improvement regarding neighbours knowing/helping neighbours.
- Considering wildlife resources/habitat – including soils in all land use planning decisions. Arrangements that can benefit the wildlife habitat may also benefit the community and the economy.
- Further developing bridging and linking social capital to aid in;
  - the coordination and timing of mediation actions,
  - awareness regarding provincial action on its newly developing flood strategy
  - the awareness regarding financial aid,
  - awareness regarding the province, non-profit organizations and/or academia's involvement in forecasting and analyzing ice jam-related flood events, and anticipating the potential for increased risks as a result of a changing climate.

The CCCVA results are not, and do not purport to be representative of the views of the entire citizenry of these communities. Rather, the results suggest potential ways forward in terms of priority setting and developing locally-based climate change adaptation plans. The CCCVA provides an analysis of perceived social and economic risks in regard to the social, economic, natural, and built realities of the engaged communities. Throughout the initiative we were able to incorporate numerous science-based components, the most significant being flood projections.

Our results provide a solid platform for the communities to build upon to plan for climate change adaptation. This effort should be seen as the beginning of a long-term strategic community planning effort in the area. The participating municipalities have identified their vulnerabilities to climate related hazards and fostered a desire to build their adaptive capacity, the initial steps in a long-term effort that supports a healthy and resilient St. John River including its communities, species and habitats.

2 BACKGROUND

In recent years, the impacts and consequences of climate-related hazards have become increasingly evident and proactive initiatives to adapt to future impacts have been lacking. This project was therefore designed to identify community climate change related vulnerabilities and build adaptive capacity in participating municipalities based on the ICLEI municipal adaptation framework and the community-based climate change vulnerability assessment process.

Anticipating the effects of climate change and taking adaptive action is a fiscally responsible and effective strategy to aid in managing climate change risk and reduce vulnerability at the local level. Adaptation planning at the municipal level must include the identification of the physical, social, economic, and environmental risks that result from climate hazards; and the development and implementation of strategies to reduce the impact of those hazards. Increasing the adaptive capacity of communities to respond to these vulnerabilities can assist in effective adaptation planning for the long term.

In November 2013, the International Institute for Sustainable Development (IISD) released a report entitled *Climate Change Adaptation and Canadian Infrastructure* which comments:

> In recent years, many government, private sector, and civil society actors in Canada have taken actions to address the cause of climate change (mitigation); but in comparison, limited efforts have been made to address the present and future negative impacts of climate change and to maximize potential benefits (adaptation). There is a pressing need to shift towards forward-looking, long-term planning and investment decision-making that strengthens adaptive capacity and builds resiliency across a number of sectors.

New Brunswick's *Climate Change Action Plan* (2007 – 2012), as well as the updated Plan (2014 – 2020) similarly includes plans to enhance provincial adaptation planning. New Brunswick has experience with climate change related projects, primarily via the Regional Adaptation Collaborative (RAC) Program. A regional effort in New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador, the RAC was envisioned to prepare and help communities adapt to the impacts of climate change and variability. Atlantic RAC projects were administered through the Atlantic Canada Adaptation Solutions Association (ACASA) and results have served as guidance for numerous subsequent efforts, most significantly the Charlotte Country Community Vulnerability Assessment (2013), which in turn has served as the basis for the St. John River effort.

As part of the process toward building an adaptation plan for the region, vulnerability analysis is one important component. Assessing local vulnerabilities, as well as identifying capacity impediments and strengths provides a critical foundation on which all later stages of the adaptation effort will be based. Not only is information obtained about changes in basic climatic variables such as temperature and precipitation, but also information is gathered on what these changes mean for the resources, infrastructure and residents of the region. This provides a baseline from which to work and enables movement through the adaptation process to increase understanding regarding the level of resulting risk the community faces.

The completion of the Community Vulnerability Assessment and Flood-Risk Mapping for the communities of Meductic, Woodstock, Hartland and Florenceville-Bristol was based on the World Wildlife Fund Canada's (WWF) Senior Specialist - St. John River, Simon J. Mitchell who worked with municipalities along the St. John River Valley, as well as the efforts of numerous partners. Project partners provided relevant tools, information and expertise to help facilitate community understanding of climate change and its impacts. The project contributes to ensuring that these local communities are increasingly resilient to environmental change. The main tools utilized during the project included the Community Climate Change Vulnerability Assessment and the LiDAR-based (Light Detection and Ranging), which provided a more informed assessment of vulnerability, by enabling the creation of hydro risk-mapping. The LiDAR data was provided by the Department of Environment and Local Government of New Brunswick for analysis in this project.

The vulnerability assessment process captured local knowledge about past and current climate change issues; worked to define the priority climate change issues affecting local communities as well as local services that needed to be assessed; aided in the creation of an inventory of vulnerabilities to current and future impacts of climate change; helped to stimulate thinking about how adverse impacts of climate change going forward will require the community to stay diligent with EMO planning and regional planning efforts; ensured decision makers are cognizant of climate change impacts in land use planning and; provided communities with the opportunity to plan to avoid or minimize the negative consequences of hazards. This work has also created an informative benchmark document for community referrals going forward and will be used by the Western Valley Regional Service Commission which was highly involved in the process. As well, this project represents both the first time the communities have come together to work on a particular issue, as well as being the first Community Climate Change Vulnerability Assessment completed on a freshwater system in New Brunswick.

3 Regional Characterization

This study is inclusive of the communities Florenceville-Bristol, Hartland, Woodstock and Meductic, NB. Although, the community of Meductic was unable to fully participate in the process as a result of low capacity, which is likely an issue in many of New Brunswick's rural communities. These communities lie in the central portion of the St. John River valley along the western border of New Brunswick. After the Saint Lawrence River, the Saint John River is the longest river in northeastern North America and has a basin area of over 55,000 km^2. It begins in northern Maine, travels northeast into northern New Brunswick, where it drains water from eastern Quebec, and then flows southeast through New Brunswick to the Bay of Fundy. Fifty-one percent of the St. John River Basin is in New Brunswick, 36 percent is in Maine, and the remaining 13 percent is in Quebec (SJRBB 1975; Cunjak and Newbury 2005). The majority of the St. John River Basin in New Brunswick, and in particular the main river valley itself, lies in New Brunswick Ecological Land Classification system - Ecoregion 5: Valley Lowlands, the largest ecoregion in New Brunswick.

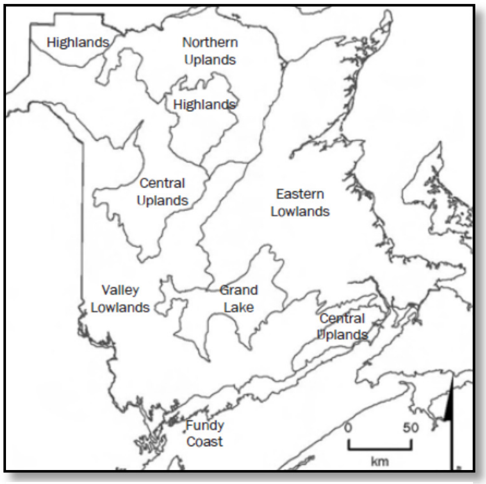

Figure 1.Ecoregion Map of New Brunswick. Source: Our Landscape Heritage, Vincent F. Zelazny

New Brunswick's ecoregions; the Highlands, Northern Uplands, Central Uplands, Fundy Coast, Valley Lowlands, Eastern Lowlands, and Grand Lake ecoregions are defined primarily by their climatic differences as shaped by major landforms, elevation, latitude, marine influences, and broad aspect. They are also distinguished on the basis of species distribution patterns influenced by the various climate-related factors.

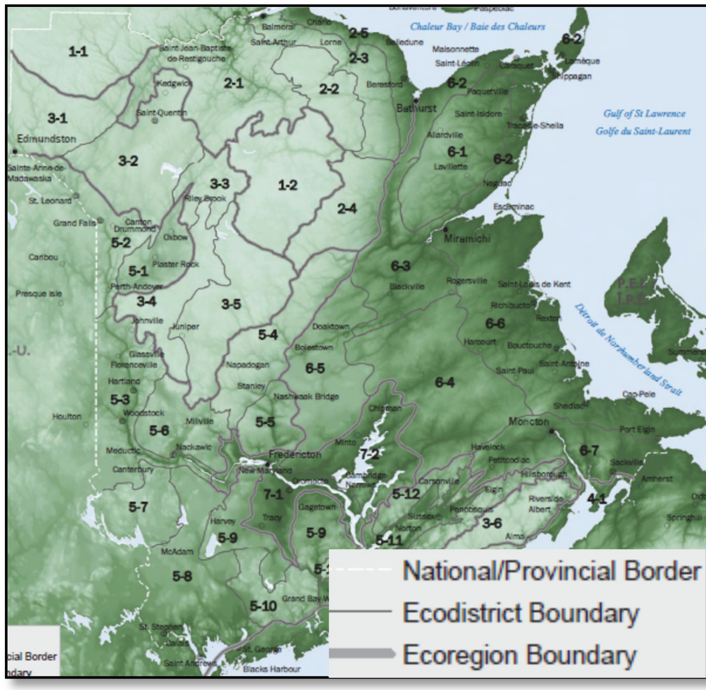

Figure 2. Ecoregion Map of New Brunswick, study communities highlighted in red. Source: Our Landscape Heritage, Vincent F. Zelazny

The communities of Florenceville-Bristol, Hartland, Woodstock and Meductic fall within the Meductic Ecodistrict of New Brunswick. Ecodistricts are category within the New Brunswick Ecological Land Classification system defined according to major breaks in predominant rock type, glacial deposit type, relief, or elevation. The Meductic Ecodistrict is gently rolling lowland. The dominant geographic feature is the expansive Saint John River. Its broad river valley has a pastoral appearance, reflecting the underlying calcareous bedrock and associated arable soils. Relief of the gently rolling landscape rarely exceeds 100 m.

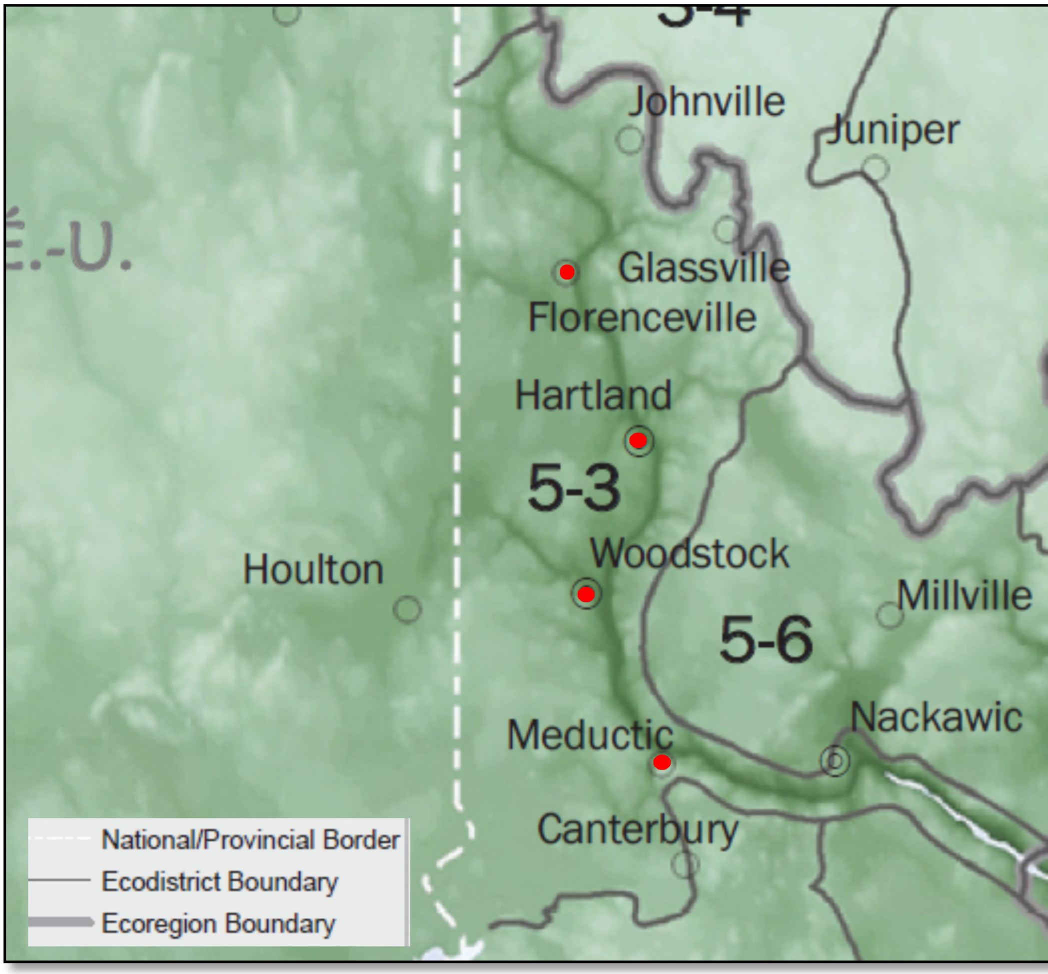

Figure 3. NBELC Ecodistrict 5.3 - Meductic; defined by geomorphology, geology and tree species. Source: Our Landscape Heritage, Vincent F. Zelazny

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3.1 Climate

The distinctive character of this ecodistrict results in part from its relatively dry, warm climate combined with rich calcareous soils. This region has a continental climate that is sheltered from the maritime influences of the Northumberland and Fundy coasts. Summers are warmer and winters are colder than in areas closer to the coast. The well drained, deep, loamy soils contain easily crushed, weathered shale fragments and are among the most fertile soils in New Brunswick.

3.2 Forest

The original forest cover has been greatly disturbed by more than two centuries of settlement. Tolerant hardwood stands once dominated the area. Tree harvesting and agriculture have significantly altered the original forests of this ecoregion since the 1700s. Mixed stands of white pine, tolerant hardwoods, spruce, and hemlock likely were more abundant in the distant past and to some degree, have been replaced by forest communities of aspen, red maple, white spruce, and balsam fir. White spruce and tamarack tend to occupy abandoned farmlands, whereas trembling aspen, balsam fir, red maple, and white birch occur in areas that have been clear cut or burned repeatedly.

3.3 Wildlife and Habitat

The Meductic Ecodistrict one of the richest arrays of unusual plants in the province. The ecodistrict is also one of the primary breeding areas for scarlet tanager, warbling vireo, and wood thrush in the Maritimes. As much of the original forest has been either converted to agriculture or flooded by hydroelectric dam projects, several elements, especially understory plants have become scarce.

3.4 Settlement

The ecodistrict lies within traditional Maliseet territory, and has been inhabited by aboriginals for at least the last 3,500 years. A major First Nations village located near present-day Meductic was strategically situated along the Eel River portage, one of the most ancient and well used overland routes between the Saint John River valley, Passamaquoddy Bay, and New England. Early non-aboriginal settlers lived almost exclusively along the shores of Saint John River rather than inland. The first wave of immigrants in the late 1700s consisted of Loyalists and pre-Loyalists dissatisfied with their original, more southerly New Brunswick land grants. The end of the Napoleonic Wars brought a second wave of newcomers in the early 1800s: mainly Scots, Irish, English, and disbanded soldiers. Settlers relied mainly on agriculture, logging, and mining for their livelihood, and used Woodstock as the commercial hub. The completion of two major railway lines from southern New Brunswick through Woodstock in the 1860s and 1870s put an end to the romantic St. John River steamboat expeditions, but expanded local economic development.

3.5 Economy

Agricultural activities now occupy about 32% of the total land area. The predominant cash crop of potatoes is planted in rotation with grain; livestock and dairy operations round out the mixed farming activities.

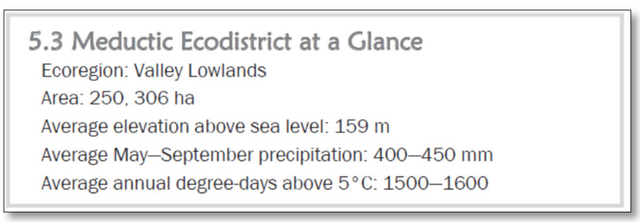
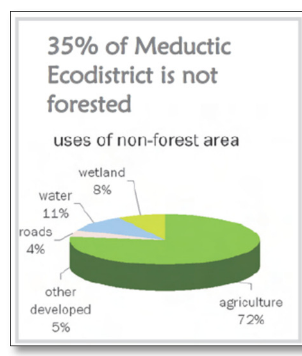

5.3 Meductic Ecodistrict at a Glance
Ecoregion: Valley Lowlands
Area: 250, 306 ha
Average elevation above sea level: 159 m
Average May–September precipitation: 400–450 mm
Average annual degree-days above 5°C: 1500–1600

Figure 4. Source: Chapter 11, Our Landscape Heritage, Vincent F. Zelazny



3.6 Regional Climate Impacts

3.6.1 Observed Impacts

Climate change was identified as an influencing variable following the major 1987 ice jam floods along the Saint John River. Hare et al. (1997) found that mean annual air temperature had raised 1.3° Celsius since 1871, or about 1° Celsius per century. Although no overall trends in mean annual precipitation or streamflow were detected, both appeared to have become more variable since 1950. More recently, it has been determined by work supported by the New Brunswick government, that the majority of the rise in temperature has been over the last 30 years, as opposed to spread evenly over the century. Hare et al. (1197) also identified that freshets had generally commenced earlier since 1972. There had also been several years with high flow compared to a comparable period earlier in the century. Though only a small rise of spring temperatures was detectable, snowy or wet winters, coupled with greater variability, caused earlier thaws and several major flooding and ice-jam events

As reported in 2003 by Bruce et al. there is already evidence of a decline in annual water flow in the Saint John River associated with warming temperatures. They noted a corresponding 13% decrease in the average annual flow of the Saint John River Basin at Fort Kent near Grand Falls from 1970 to 2000.

According to Humes and Dublin, 1988, ice-jam flooding in the St. John River basin is responsible for 70% of total flood damage in the province and there is evidence of increasing, climate-related, severity (Hare et al., 1997a, 1997b; Beltaos, 2002, 2004). Ice jams cause major flooding and severe damages to communities and infrastructure along the St. John River. There is a growing need to develop capability in forecasting and analyzing ice jam-related flood events, and anticipating the potential for increased risks as a result of a changing climate.

3.6.2 Projected Impacts

Utilizing the Atlantic Climate Adaptation Solution's (ACASA) current Climate Futures maps, which presents information on the climate of New Brunswick, both present day, and future projections to 2100, Figures 5 - 16 were generated and Table 1 was created. Based on the ACASA - derived projections, New Brunswick has experienced, and can expect a continuation of increase in mean annual temperature (Figures 5 – 9) and mean annual precipitation (Figures 10 – 13).

Within the Climate Futures maps current climate is defined by measurements made over the period 1971-2000 at weather stations across the province. Projections of future climate were made using the output from 24 climate models developed by national weather services and research organizations in nine countries worldwide. Their results have been pooled and analyzed to provide the most up-to-date and reliable estimates possible. Future projections are presented using higher and lower estimates of future greenhouse gas emissions.

3.6.2.1 Projected Impacts – Mean Temperature

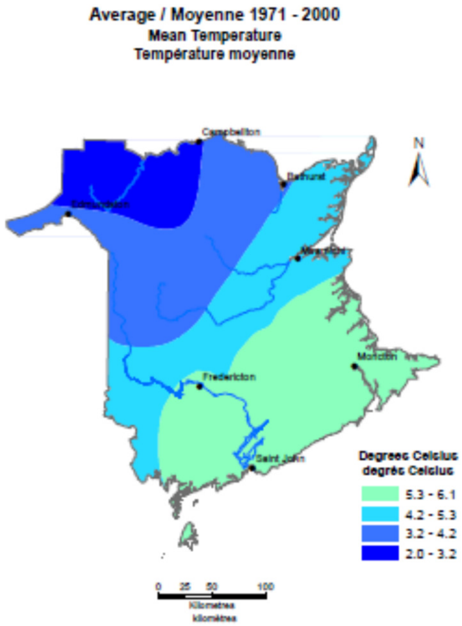


Figure 5. ACASA-derived map of New Brunswick's average annual mean temperature, for the periods 1971 – 2000 utilizing current emissions

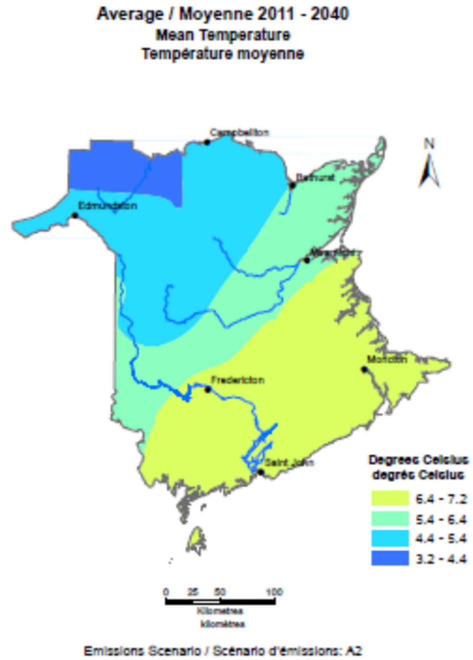


Figure 6. ACASA-derived map of New Brunswick's average annual mean temperature, for the periods 1971 – 2000 utilizing an A2 emissions scenario.

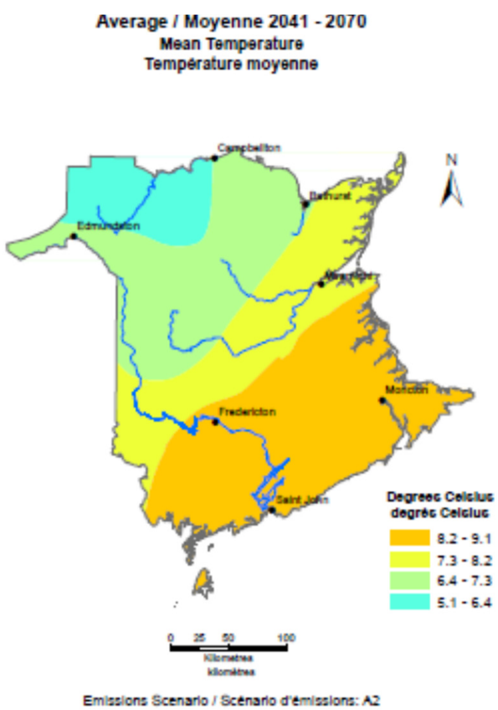


Figure 7. ACASA-derived map of New Brunswick's average annual mean temperature, for the periods 2041 - 2070 utilizing an A2 emissions scenario.

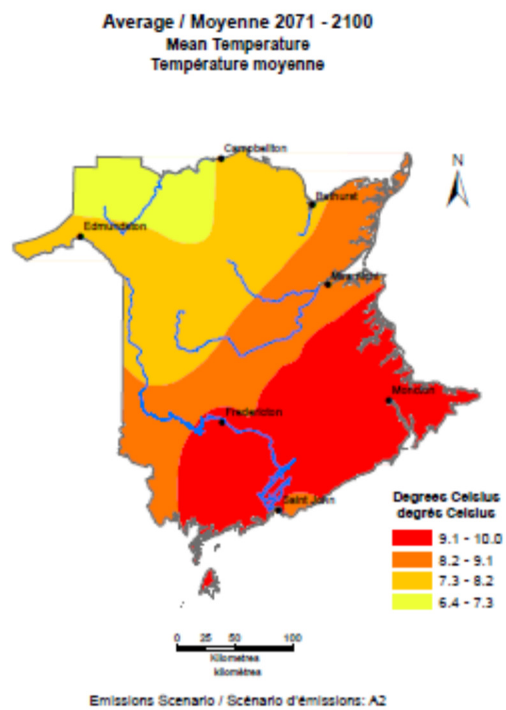


Figure 8. ACASA-derived map of New Brunswick's average annual mean temperature, for the periods 2070 - 2100 utilizing an A2 emissions scenario.

Mean temperature over the year is a measure of how hot or cold the climate is at a given location. Mean temperatures in New Brunswick currently range from around 5 degrees C in the south to 2 degrees C in the north. By the 2080s, mean temperatures are predicted to increase by around 3-3.5 degrees C. This will mean that northern areas of the province will have a temperature climate similar to that in southern New Brunswick today, while southern areas will become as warm as it is currently is in parts of southern Ontario. (ACASA Climate Futures Map)

3.6.2.2 Projected Impacts – Annual Total Precipitation

Annual total precipitation, a measure of how much rain and snow fell, is an important indicator for water management. Presently, New Brunswick receives from about 1,100 to 1,300 mm annually, with the wetter areas in the south and drier areas in the north and inland. With increased temperatures, a greater proportion of precipitation in future will fall as rain, and less as snow. As depicted in Figures 9 – 12, in future decades, precipitation is expected to increase across all areas of New Brunswick.

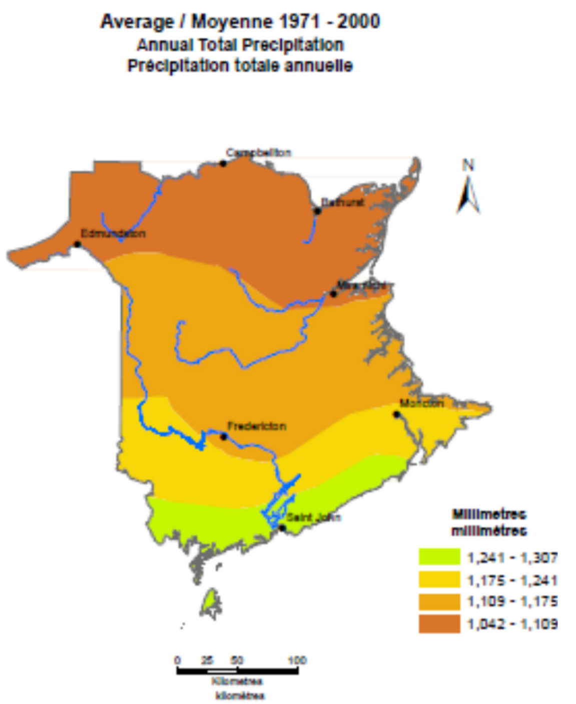


Figure 10. ACASA-derived map of New Brunswick's average annual total precipitation, for the period 1971 - 2000 utilizing current emissions.

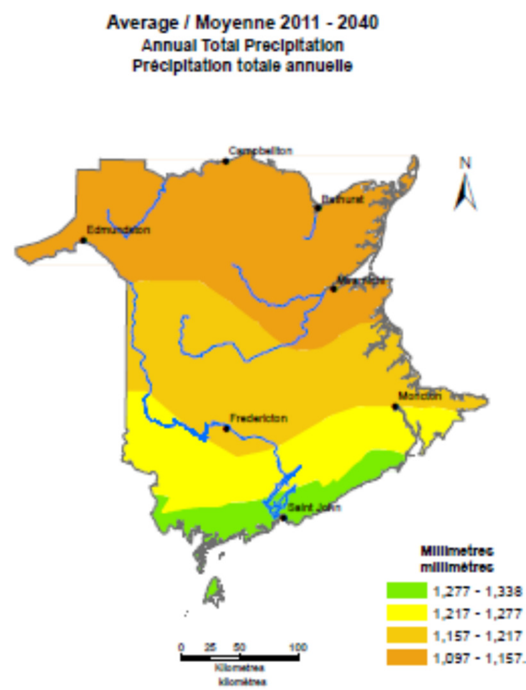


Figure 9. ACASA-derived map of New Brunswick's average annual total precipitation, for the period 2011 - 2040 utilizing an A2 emissions scenario.

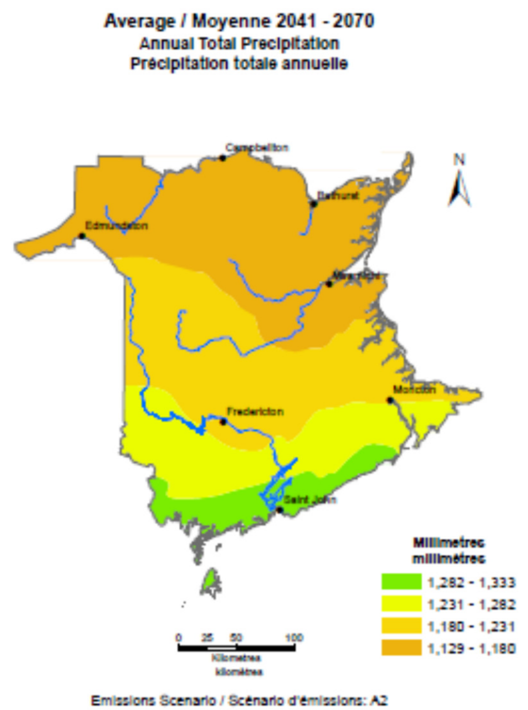


Figure 11. ACASA-derived map of New Brunswick's average annual total precipitation, for the period 2041 - 2070 utilizing an A2 emissions scenario.

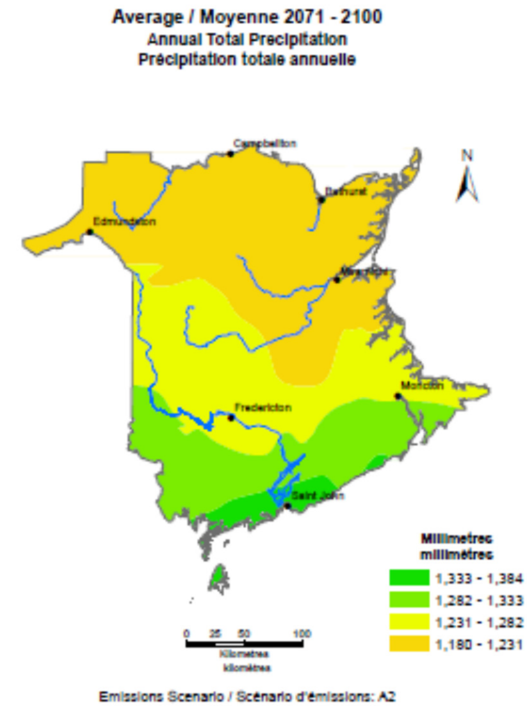


Figure 12. ACASA-derived map of New Brunswick's average annual total precipitation, for the period 2071 - 2100 utilizing an A2 emissions scenario.

Hare et al. (1997) stated that one-day heavy rain or snowfall events had increased in intensity over the St. John River Basin. Major precipitation events, not always associated with tropical disturbances crossing the region, occasionally occurred in late summer and fall. A further conclusion was that large amounts of precipitation might also occur during the period of spring ice breakup and flooding, as demonstrated by storms in 1961 and 1987 that just missed the Basin (Hare et al., 1997). The potential for major storms to occur simultaneously with the spring thaw and the onset of the freshet confirmed a need for precautionary measures to lessen the likelihood of future flood damages.

As part of the St. John River Ice and Sediment Study (a joint project of Environment Canada, NB Environment and NB Power), the ice regime of the upper Saint John River was documented during the period 1992-1997. Three winter breakup events took place during this time, one in 1995 and two in 1996. This was unexpected, as the upper St. John River was not known to have many mid-winter breakups. During the same period (1992 to 1997), very high flows occurred during spring break-up events of 1993 and 1994. To determine whether such occurrences were random, a hydro-climatic analysis was carried out. Using long-term climatic and flow records, it was found that a small rise in winter air temperatures over the past 80 years had resulted in a large increase in the number of mild winter days, a relatively rare occurrence in the upper basin (Beltaos, 1999). As a result of milder winter days, winter rainfall (as opposed to snowfall) had increased, augmenting flows sufficiently to cause breakup of the ice cover. In such situations, resulting ice jams may freeze in place, posing a greater risk of major flooding during the spring freshet. In addition, flow peaks were found to have increased during April, further increasing the risk of ice-jam flooding (Beltaos, 1999). Beltaos et al. (2003) suggested that the increased frequency of mid-winter breakup along the upper St. John River within the last 40 years could be an indicator of a changing climate in the region.

3.6.2.3 Projected Impacts – Mean Winter Temperatures, Freeze-free and Freeze-thaw days

According to ACASA Climate Futures mapping, mean winter temperatures in New Brunswick currently range from around -6 degrees C in the south to -12 degrees C in the north (Figure 13). Mean winter temperature is the average temperature for the months of December, January and February is a measure of how cold or mild the winter climate is at a given location. By the 2080s, mean winter temperatures are predicted to increase by around 3 degrees C (Figures 14 – 16). This will mean that northern areas of the province will have a winter temperature climate similar to that in central New Brunswick today, while southern areas will become as warm as it is currently is in parts of Nova Scotia, such as Halifax. Also, freeze-free days, the average number of days per year that can be expected to have a minimum temperature above zero Celsius are expected to increase with time in all areas. By the 2080s the colder northern parts of New Brunswick are expected to gain an additional two month period of the year (on average) free of frost. Southern districts will have a frost-free day total approaching 250 days. An increase in freeze-free days means a decrease in days when the daily maximum temperature equals or exceeds 0^{o} Celsius and the daily minimum temperature is less than 0° degrees Celsius (freeze-thaw days). Freeze-thaw activity in winter can be harmful for plants and wildlife by breaking dormancy and increasing the damage caused by subsequent cold spells. The full range of impacts though, is hard to predict but effects are likely on the maple syrup industry, forest management, road maintenance and weight restriction periods.

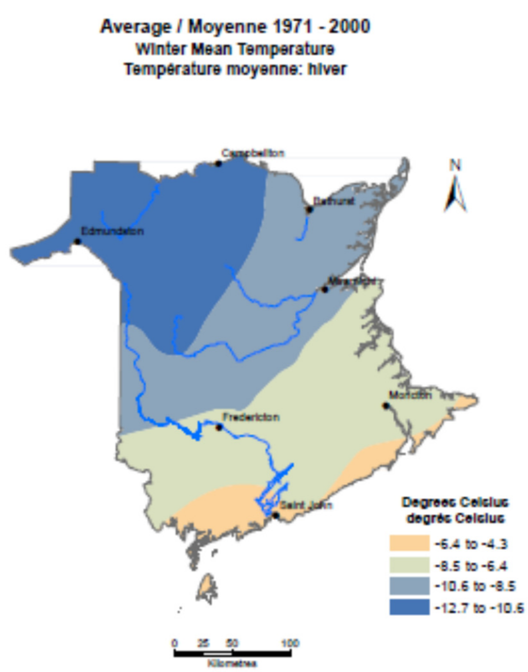


Figure 14. ACASA-derived map of New Brunswick's average winter mean temperature, for the period 1971 - 2000 utilizing current emissions

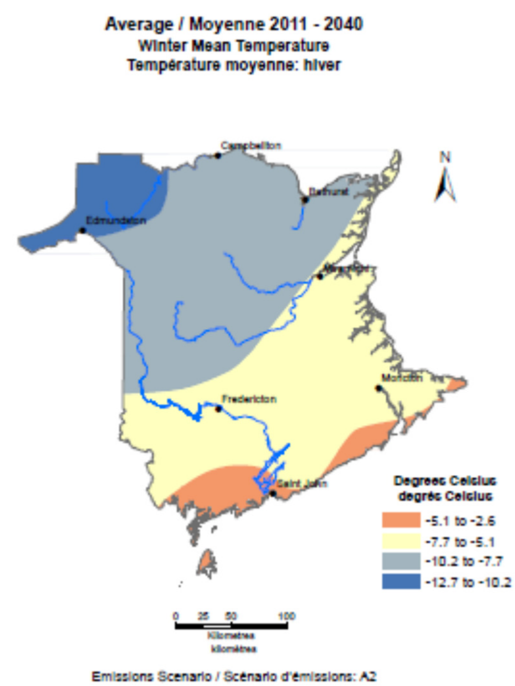


Figure 13. ACASA-derived map of New Brunswick's average winter mean temperature, for the period 2011 - 2040 utilizing an A2 emissions scenario..

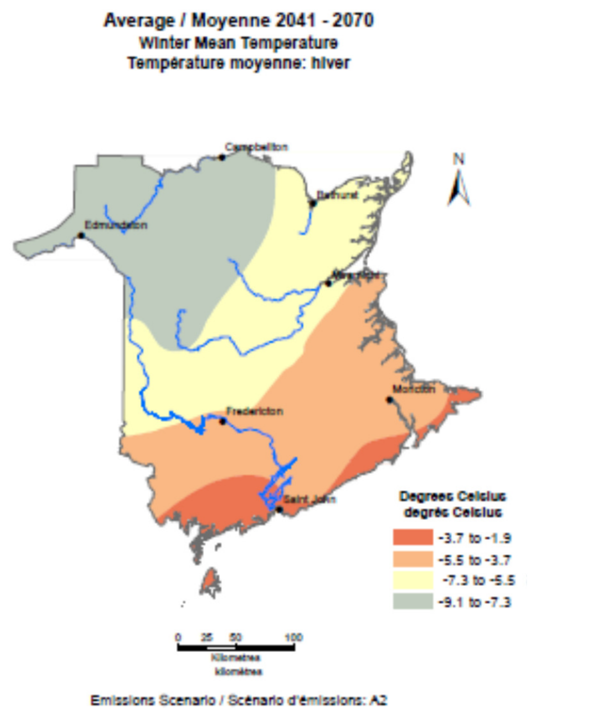


Figure 16. ACASA-derived map of New Brunswick's average winter mean temperature, for the period 2041 - 2070 utilizing an A2 emissions scenario.

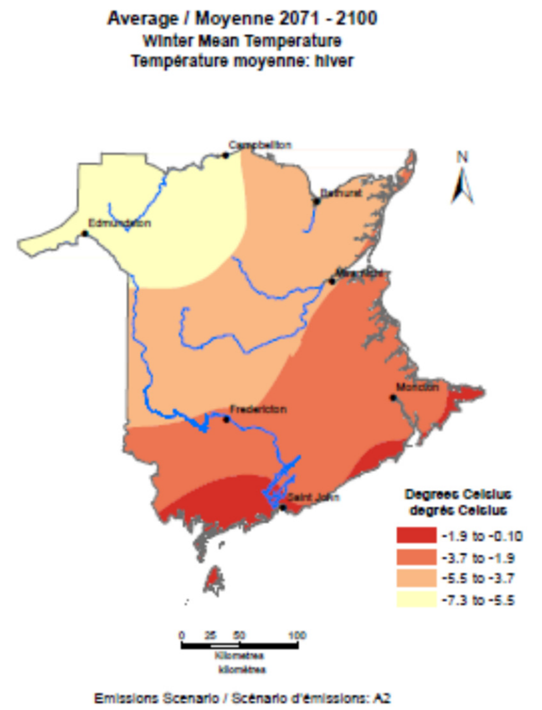


Figure 15. ACASA-derived map of New Brunswick's average winter mean temperature, for the period 2071 - 2100 utilizing an A2 emissions scenario.

3.6.2.4 Projected Impacts – Hydrometric Conditions

In addition to temperature and precipitation, Swansburg et al. (2003) performed downscaling of hydrometric records. Using this approach, they found that average annual discharge would increase 16% to 45% compared to average discharge conditions from 1961 to 1990. Winter and spring discharge would increase significantly at all hydrometric stations, with the largest increases likely towards the end of the 21st century. Summer discharge would decrease significantly at all stations, while autumn discharge was predicted to decrease significantly in all rivers except the upper St. John and Restigouche.

Table 1. Specific to the study area, ACASA Climate Futures maps – generated climate expectations

	2011 - 2040	2041 - 2070	2071 - 2100
Annual Mean Temperature	5.4 - 6.4	7.3 - 8.2	8.2 - 9.1

Spring Mean Temperature	4.1 - 5.1	5.1 - 6.1	6.8 - 7.4
Summer Mean Temperature	17.4 - 18.3	18.9 - 19.9	19.9 - 21.1
Autumn Temperature	7.1 - 8.1	7.4 - 8.7	10.1 - 11.2
Winter Mean Temperature	-7.7 to - 5.1	-7.3 to - 5.5	-5.5 to - 3.7
Annual Precipitation	1157 - 1217	1180 - 1231	1231 - 1282
Spring Total Precipitation	294 - 317	286 - 306	317 - 335
Summer Total Precipitation	291 - 303	295 - 308	291 - 303
Autumn Total Precipitation	309 - 336	309 - 327	301 - 325
Winter Total Precipitation	272 - 323	294 - 330	317 - 348
Annual Number of Days with Maximum Temperature > 25°C	38 - 58	61 - 71	77 - 88
Annual Number of Days with Maximum Temperature > 30°C	8* - 11*	0 - 10	13 - 26
Annual Number of Days with Maximum Temperature -20°C	0 - 0.4	0.2 - 0.3	0.1 - 0.4
Annual total rain days	111 - 121	114 - 126	122 - 132
Annual Total Snow Days	31 - 41	45 - 53	29 - 39
Freeze-Free Days	191 - 199	207 - 214	227 - 234
Annual Freeze-Thaw Days	89 - 93	82 - 84	73 - 76
Spring Freeze-Thaw Days	34 - 36	29 - 31	20 - 23
Autumn Freeze-Thaw Days	20 - 22	20 - 22	14 - 17
Winter Freeze-Thaw Days	20 - 25	30 - 37	34 - 39
Annual Cooling Degree Days	124 - 160	202 - 265	306 - 379
Annual Corn Heat Units	2289 - 2429	2638 - 2786	3033 - 3191
Growing Season Length	162 - 172	172 - 183	197 - 207
Annual Heating Degree Days	4355 - 4736	3974 - 4355	3509 - 3805
Annual Growing Degree Days > 5°C	1681 - 1794	2021 - 2157	2248 - 2400
Annual Growing Degree Days > 10°C	872 - 947	872 - 947	1380 - 1461

3.7 Response to Impacts

There are some adaptation actions that have occurred as a result of repairs due to storm or flood impacts; examples include greening and reinforcing banks by Route 105 (near Home Hardware parking lot) as well as reinforcing the causeway crossing route 105 in Florenceville-Bristol. Also in Florenceville-Bristol they have recently (summer 2015) completed a culvert replacement in an area of high erosion, where the Shiktehawk enters the downtown area, the new culvert is also much larger. The two stream repairs on Big and Little Shiktehawk also involved upstream reinforcement of banks and in-stream arrangement of boulders. The Town also purchased a piece of land by the Shiktehawk trailhead, which floods commonly, for use in the summer as public space and have added a picnic table.

In Hartland, due to power outage last year, the Town has begun to update the electrical panels at the booster station and the well house to allow quicker action for the implementation of a secondary power supply, so water quality and supply are not affected as harshly during outages. The Town has also (with the financial support of the Province) installed a second culvert on Main Street to handle the run off from the industrial park to prevent future flooding to homes in the affected area. As part of the culvert project the Town has also rip-rapped the drainage ditch both above and below the culvert to prevent build-up of debris, which would slow down the movement of water.

The Town has also requested from the Department of Environment and Emergency Measures that bathymetry be conducted of the river bed, so shallow areas, where the ice typically dams can be identified and remediated.

The Town has also made strides toward improving the EMO plan specific to flooding along Main Street, and have a separate plan in place for this event, rather than the broad EMO plan. The need to address this component is further emphasized by the hydro-risk mapping completed by the UNB Watershed Research Centre completed during this project.

There are a few areas that Hartland is still trying fix. Along the river bank, due to repeated flooding and jams, a small portion of the Town's sewer line has become exposed. The Public Works Supervisor is working with the Municipal Engineer to find a remedy for this problem. Also in conjunction with the Municipal Engineer the Public Works Supervisor is trying to determine the best practice to prevent the river from flooding the Town's sanitary sewer system during the high waters, in the spring thaw. Which usually results in a 2-3 day shut-down (shorter depending on the high water), of the sanitary sewer system, which allows raw sewage to flood to the river.

In Woodstock, the results of the 2014 roadway washout to the well house has re-motivated a search for a new water source as well, due to various impacts they will be purchasing a generator for its Town Hall. The Town is in the midst of the site selection process for the new well, aiming to begin actual site development in 2016.

Throughout the area, the lengthiest power outages lasted seven days, but on average were one day in length. All communities have received some financial assistance from Disaster Financial Assistance.

4 Assessment Methodology

4.1 Community Vulnerability Assessment (CVA) Process

The CVA project incorporated proven vulnerability assessment methods with community concerns to identify local vulnerabilities and aid in defining options for local adaptation. The overall methodology of this project was based on the International Council for Local Environmental Initiative (ICLEI) Canadian document, *Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation*. ICLEI is an international association of local governments, and national and regional local government organizations that have made a commitment to sustainable development. The document, *Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation* is a compendium of resources that provides a milestone based framework to assist local governments in the creation of adaptation plans to address the relevant climate change impacts associated with their communities. This guide profiles a straightforward methodology to adaptation planning using a five-milestone approach (Figure 17). Each milestone represents a fundamental step in the adaptation planning process, starting with the initiation of adaptation efforts (by building an adaptation team and identifying local stakeholders) and culminating with a monitoring and review process that analyzes the successes, and reviews the challenges of the adaptation plan and its implementation.

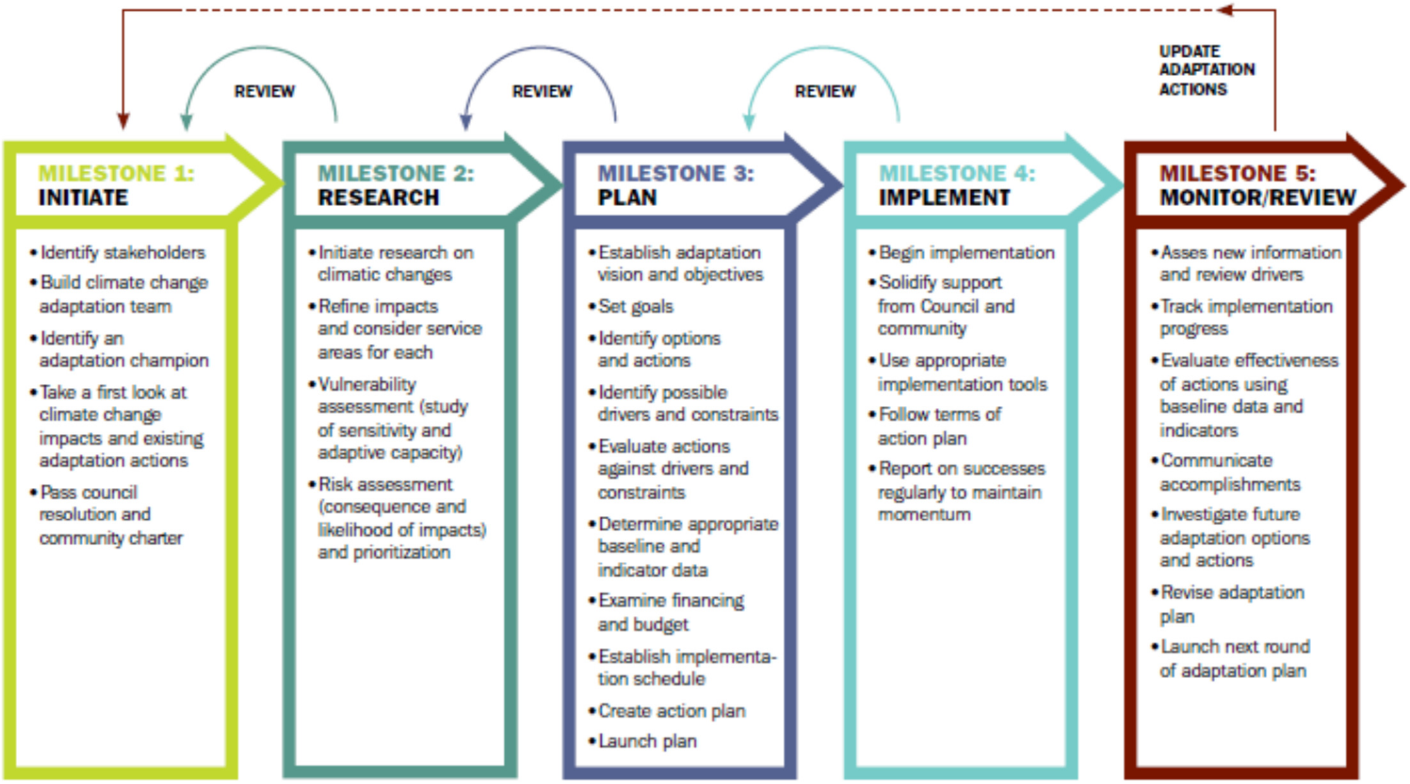


Figure 17.The ICLEI Changing Climate, Changing Communities: Guide and Workbook for Municipal Climate Adaptation Five Milestone Framework

The St. John River's Community Vulnerability Assessment Process fits within ICLEI's Milestone 2, but was customized for local needs based on a number of frameworks and resources which include;

- a CVA process developed by the National Oceanic and Atmospheric Administration (NOAA)
- NOAA's CVA process adapted during the Federal Regional Adaptation Collaborative (RAC) Program for use in rural communities by the Department of Geography at Memorial University in Newfoundland and Labrador (Leone Pippard & Associates 2012)
- the United Nations Framework Convention on Climate Change's (UNFCCC) *Compendium on methods and tools to evaluate impacts of, and vulnerability and adaptation to, climate change* and
- *From Vulnerability to Resilience, A framework for analysis and action to build community resilience* by Katherine Pasteur, 2011.

This customized hybrid methodology was first used in Charlotte County New Brunswick during the Charlotte County Community Vulnerability Assessment completed by the St. Croix Estuary Project Inc. in partnership with Eastern Charlotte Waterways Inc. Though the general methodology was followed in the St. John River Communities project, lesson learned by the Charlotte County partnership were integrated and the St. John River process continued to be adapted to fit circumstances and local needs, specifically, this is the first time in New Brunswick that the Vulnerability Assessment process has been used for a freshwater system.

This project's primary action was a series of facilitated consultations with community members, designed to identify local climate hazards and the associated impacts, and identify and prioritize community values and services. The community members were formed into working groups in each participating municipality and each working group was guided through a five step process, outlined below in Table 2.

Table 2. Stakeholder engagement process used in CVA

1. • Define the climate hazards
2. • Identify the physical impacts (past and future)

Through the spring of 2015, four working group meetings were held, with a minimum of one in each of the three participating municipalities. Meeting on a monthly basis, the working group members took part in interactive community mapping exercises, questionnaires and discussions to identify physical, social, economic, and environmental climate hazard impacts. This process captured the complex network of factors that exist and operate on varying spatial and temporal scales, giving rise to vulnerability. It is these complex interactions between physical, social, economic, and environmental factors that affect the ability of individuals and communities to prepare for, cope with, and recover from climate related hazards (Thomalla *et al.* 2006). Throughout the process, background information and scientific research was provided to the working groups to prompt discussions, assist with mapping activities, and develop recommendations for future climate change adaptation planning.

4.2 Selection of the Working Group Members

Due to local knowledge being considered a key source of information on changing climate conditions, presentations and discussions were held with community councils in order to attain representation in the CVA working group. Each community was asked for both an elected and staff person to join the working group (Figure 18). Residents have knowledge of changing weather and climate patterns that can be integrated with observations made by climatologists to better understand the changing climate of a community (Vodden 2012).

Figure 18. Working group members, June 25, 2015. Hartland.

The villages and towns of Woodstock, Hartland and Florenceville-Bristol each appointed delegates for the duration of the Community Vulnerability Assessment process and Regional Service Commission 12 was represented by Planning Manager Katelyn Hayden. Delegates included Woodstock's Chief Administrative Officer (CAO) Ken Harding, Councillor Catherine Sutherland and Director of Public Works Andrew Garnett. Hartland's representation was held by Deputy Mayor Travis Dickinson and Public Works Supervisor Jason Green. Florenceville-Bristol was represented by Fire Chief Andrew Cougle and Councillor Daniel Guest. Part way through the process, after it was identified that the communities lack in-house Geographic Information Systems (GIS), Rory Pickard, a representative from Dillon, the engineering consulting firm currently engaged by all communities was invited to participate in the remaining meetings. This action reflects the ability of the process to adapt to local conditions to reflect community need and proved to be quite useful for all involved.

The community of Meductic was unable to participate in the Community Vulnerability Assessment process, but flood-risk mapping was nevertheless completed for the community and will be shared with community leaders. This reflects the on-going issue in New Brunswick related to the lack of capacity of small rural communities and the issue's impact on the ability to improve community circumstance.

This working group of delegates was responsible to assist with the provision of background information, such as: community maps and plans, emergency plans and relevant bylaw information, historical flood information or reports of infrastructure damage/budgets. They also provided venue and administrative support for working group meetings. Throughout the working group meetings the participants became familiar with the issues surrounding climate change, chose priority climate change concerns and timeline for which to base discussions, they became familiar with the uses of the decision-support tools, the approach used to produce the digital elevation models, flood scenarios and the analysis of risk to infrastructure. They also validated the relevance of the planning process and draft flood risk maps.

Participating in the Climate Vulnerability Assessment process enabled municipal leaders in becoming better informed about the hazards in question. The mapping component of the project provided reusable resources for the communities and solidified the understanding of vulnerabilities as they impact the social, economic, ecological and built environment in the communities. The outcomes of this work represent significant step in the regions' long-term adaptation process.

The WWF Senior Specialist - St. John River, Simon J. Mitchell, and contractor Kim Reeder were responsible to meet with community representatives to determine the approach and timelines; assist the communities with organizing their representatives for the working group; plan the process and structure of the working sessions; prepare and deliver the content presented during working sessions in association with the other project partners; translate the scientific and technical information provided by the project partners into everyday language for the members of the working group; provide background information – relevant historical flood and weather data, flood risk and climate scenario's; acquire and assemble maps; as well as to summarize and report on the process, working group outcomes and the flood scenario mapping.

4.3 Data Inputs

4.3.1 LiDAR

LiDAR-based digital elevation modelling (DEM) and flood risk mapping was completed for the communities of Meductic, Woodstock, Hartland and Florenceville-Bristol by project partners at the University of New Brunswick's (UNB) Forest Watershed Research Centre, including Dr. Paul Arp, Mark Castonguay, Jae Ogilvie and students. LiDAR is an optical technology that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light. Results map physical features with very high resolution and are the basis for flood modelling tools and maps that can serve as "predictive capability" for communities.

For this project, LiDAR-based (Light Detection and Ranging) bare-earth elevation data was acquired. The areas selected for LiDAR and thus, the UNB team's analysis was determined by the Province (Figure 19). LiDAR was first used in New Brunswick in 2004. Outputs are used to generate terrain elevation models of a selected area. The technology requires scanning a laser combined with both GPS and inertial technology to create a three dimensional set of points, referred to as a point cloud. It can detect changes in elevation to within 15 centimeters (cm). LiDAR data reflects what is referred to as Full Feature Digital Elevation, which means it includes items such as tree tops and buildings. Then, the Bare Earth Digital Elevation (the ground) is able to be produced by manually editing the Full Feature DEM to remove vegetation and cultural features (built infrastructure), leaving only elevations of natural terrain features.

The Bare Earth DEM is then used to determine the Depth-to-Water Index and Wet-areas Maps. Surface waters (blue) are given a reference of zero, and referred to as flow channels. Those areas of surface water are joined digitally at the high water mark and soil, geological and elevation information is considered in order to determine where the water likely sits below the surface, between the surface water showings (Figure 20). The difference between the Bare Earth DEM and the determined subsurface water is called the Depth-to-Water Index and is indicated on a visualization where surface water is zero, and other depths of water below the surface are classified by blue hues, in our case representing 0-10 centimetres (cm) below the surface, 10cm – 25cm below the surface, 25 – 50cm below the surface and 50cm – 1 metre below the surface. The result of this process is referred to as Wet-areas Mapping (WAM).

Figure 19. This Bare Earth Digital Elevation Map (DEM) representative of ground elevation (blue – open water, green low elevation to red highest elevation).The red outlines indicate the land area to which the Wet-areas Mapping and Hydro-risk analysis has been applied. Source: Arp et al. 2015

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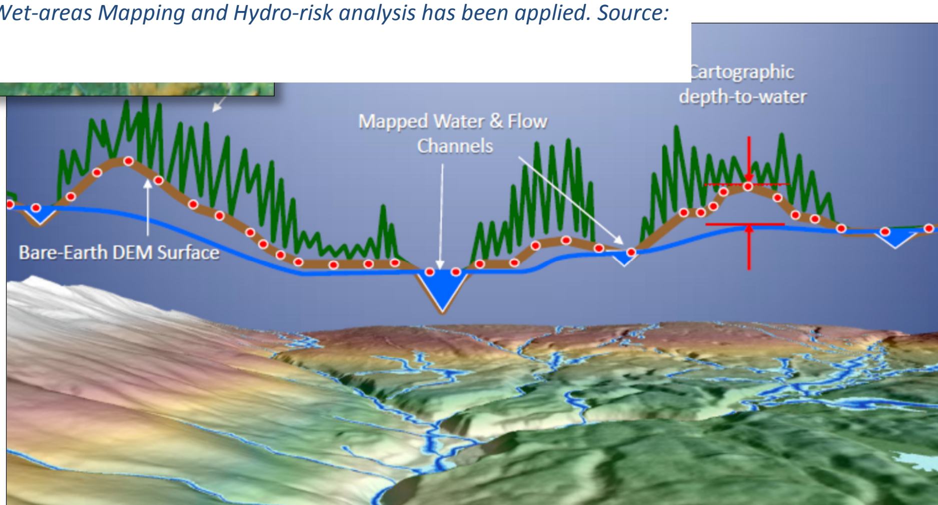

Figure 20. Visualization created by the UNB team for explanatory purposes regarding how Depth to Water Mapping, also referred to as Wet Areas Mapping is derived after attaining LiDAR data.

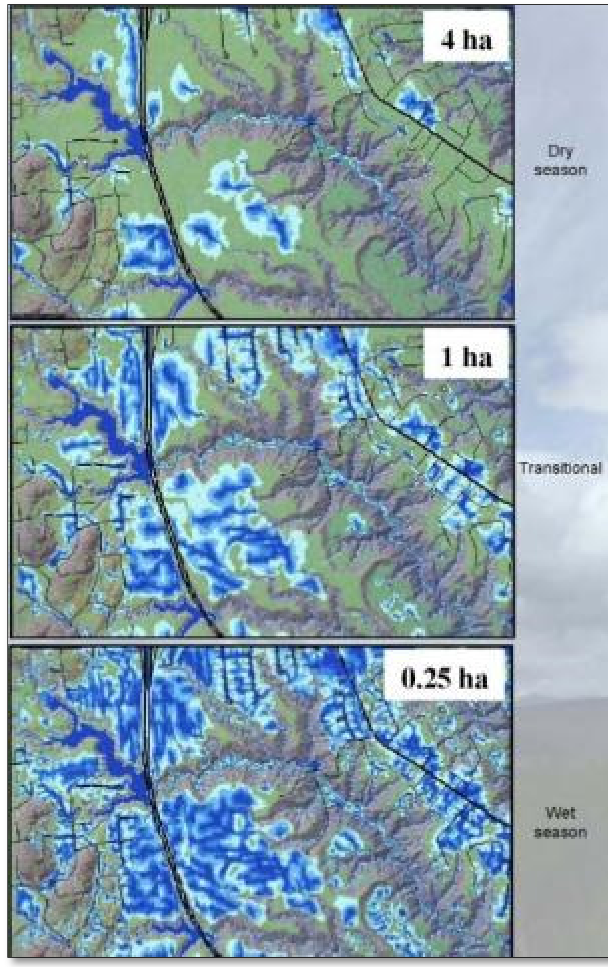

Figure 21. Varying flow rate initiations used to visualize seasonal ground saturation. Source, Arp 2013.

However, both surface and subsurface water levels change throughout the year. To map the expansion and contraction of both the flow channels (surface water) and the resulting wet-areas (surface and sub-surface), the appropriate season and weather variables must be selected. Seasons produce variety in flow channels and ground saturation. The seasonal conditions are assigned a Flow Rate Initiation Value. Flow rate initiation is the amount of land that must be drained to create a flow channel (surface water).

In the late summer season, when the ground is dry, the flow rate initiation selected is 4 hectares (ha), as more land needs to be drained in order for water to create a flow but during the spring freshet, when the ground is saturated, the flow rate initiation selected is 0.25 ha, (as less land needs to be drained in order for water to create a flow at the surface) see Figure 21, right. Wet Areas Mapping (WAM) assumes all flow channels to carry water once the above-slope water-contributing areas exceed the Flow Rate Initiation Value selected, whether it is 4 ha or 0.25ha, to approximate the general stream flow conditions. So, in the spring it would not take very much land area on higher ground to start water flowing at low points, while in the dry season, it would take much more high ground to be drained before water started flowing in the low areas.

4.3.2 Results from Community Assessment Meetings

4.3.2.1 Meeting 1 – March 19, 2015

The first working group meeting was held on March 19 in the community of Florenceville-Bristol. The agenda (Appendix B) for this meeting included group introductions and discussion regarding project background as well as an introduction to; the CVA process, climate change related terms and definitions (Appendix C), the IPCC and use of scenarios, and projected climate changes and impacts for New Brunswick. The group then moved onto defining the desired scope of the project including the time periods with which we would work as well as the major hazards which would be considered. Mapping, identification of specific concerns and a questionnaire were then completed to reinforce discussion topics. The results of the questionnaire (Appendix D) and mapping at this meeting verified and further prioritized issues and started identification and inventory of vulnerabilities.

Outcomes

After providing back ground relating to the project as well as the projected impacts of climate change, facilitators held a discussion and provided a display of projected impacts of climate change in New Brunswick. Participants were asked to place a sticker beside each of the impacts for which they had concern relative to their region. The exercise was completed not only to get an idea of what community representatives were concerned with regarding present and potential implications, but also to be exposed to the various projected climate impacts. Some of the predicted impacts of climate change in New Brunswick were not of concern to the working group and therefore, are not listed below. The highest priority concerns (bold # in brackets), prioritized by how many individuals indicated it was a concern included;

6 Flooding may become more frequent and more severe. Mid-winter thaws and ice breakups, with the potential for ice-jam flooding, will become more widespread and frequent, resulting in more ice jam floods during the winter months. If the mid-winter jams re-consolidate, then spring ice breakup is likely to have more severe impacts.

6 Drinking water quality will likely be affected by the change in the quantity and quality of water at the source, as well as from the problems of old water infrastructure.

5 Precipitation patterns will become more erratic, with an increased frequency of intense storm events, such as summer convective storms (thunderstorms, hailstorms and tornadoes). Associated impacts from erosion and siltation.

5 More summer rainfall is expected to fall in high intensity rainfall events. This means an increased probability of soil erosion.

4 Increased risk of wind damage (forestry).

4 Aquatic ecosystems will change as water levels become lower and water temperatures become higher during the summer months. Algal blooms and eutrophication expected to increase.

4 Changes in climatic conditions (such as rainfall intensity, duration and frequency) might make some land (e.g. flood plains, steep sites) unsuitable for some types of development, and might require changes in development patterns and the types of development.

3 Drainage infrastructure will be overloaded more often. Associated risk of contamination from sewage.

3 River flows will become more variable. Spring peak flows will occur earlier and be reduced in duration. Summer minimum flows will be lower. Periods of very low or zero flow are expected to become more frequent.

2 The precipitation distribution through the year will change. Water supply will diminish, especially in inland districts, due to higher temperatures.

2 The duration of dry spells between rainfall events is expected to increase, with an associated increase in drought frequency, duration, and severity.

2 Cold-water species such as salmonids will become increasingly stressed as water levels become lower and water temperatures become higher during the summer months. Suitable freshwater habitat for some aquatic species, such as salmonids, may be lost. Increased water temperatures and reduced dissolved oxygen is expected to harm cold water fish species.

2 Temperatures will continue to increase on average, with a more pronounced upward trend in inland districts and in summer.

2 The ice-free season will lengthen in most areas. Examine implications for recreation, public safety and flood risk.

2 Snowfall and duration of snow cover likely to decrease, affecting winter recreation including skiing and snowmobiling.

2 "Surprise" changes.

2 Increased incidence of freeze-thaw winter injury (forestry).

2 Due to changing climatic conditions, municipal designed to have long life spans might be damaged or become incapable of functioning properly.

2 Increased temperatures may change requirements for heating and air conditioning.

1 Increased fire hazard expected to threaten key habitats and associated species.

1 Invasion of new ("exotic") plants and animals extending their ranges into NB.

1 Altered ecosystem characteristics and productivity. Some species and ecosystems may be reduced or disappear altogether, causing a loss of biodiversity.

1 Increased fire hazard – forestry.

1 Potential for increases in pests and diseases, including novel or exotic varieties.

1 Resource availability might change as commodity supplies and markets respond to changing environmental conditions.

A questionnaire and discussion followed which resulted in information regarding experiences, impacts and planning. The largest impacts experienced from recent storms by these communities included May 1, 2008, post-tropical storm Arthur and the spring freshet of mid-April 2014. There has not yet been an instance when the Provincial Emergency Management Organization has had to help manage the situation. However, as stated by one community representative, "…we are on their radar…"Currently EMO plans and informal mutual aid agreements are the tools in use to deal with flood situations.

While the municipalities of Hartland and Woodstock ranked these impacts in order of concern;

1. Drinking water quality & quantity
2. Power outages
3. Flooding – Homes
4. Flooding – Businesses
5. Flooding – Streets
6. Road maintenance and snow removal
7. Stormwater Management
8. Agricultural impacts

9. Erosion

Florenceville-Bristol's citizens are all on individual wells and at this point their only major concern is flooding. Various locations that suffered erosion have been repaired in Florenceville-Bristol.

The working group then identified and confirmed their major, region-wide, hazard concerns;

- **Increased frequency and intensity of storms**
- **Increased precipitation in all seasons**

As well, during the first meeting the participants discussed focusing on 25 year impacts with a 10 year planning horizon concentrating on municipal concerns, followed by community and industry concerns as they came up.

At the end of this meeting representatives were presented with large format maps of their communities on which to indicate geo-referenced locations of current physical vulnerability and or areas of concern for the future (Figures 22 – 24).

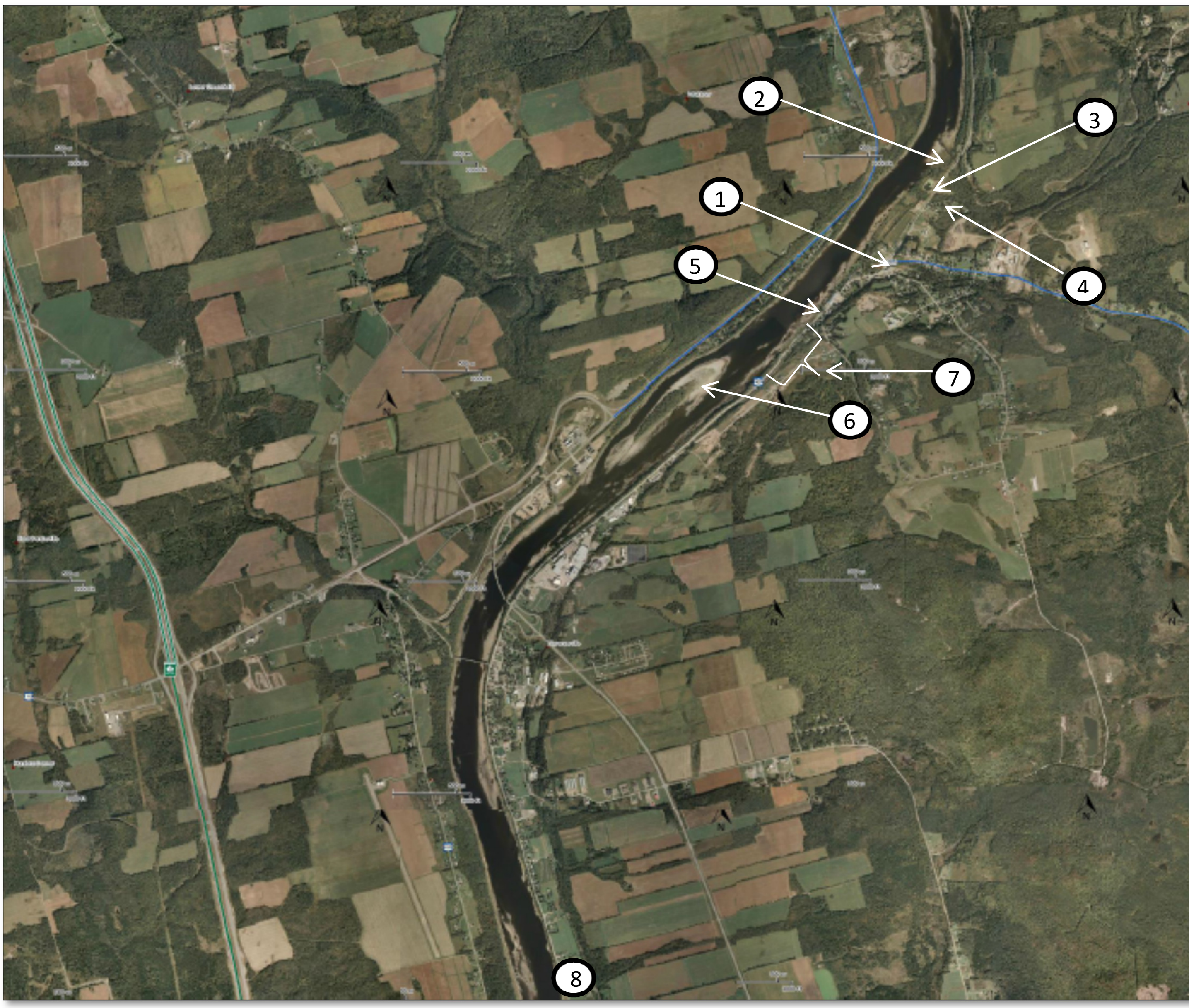

Figure 22. Florenceville-Bristol map indicating impact areas 2008 – present.

1 = Home Hardware Building & Parking Lot - flooding – lost facility, reinforced bank & rebuilt. Water was on the main floor to a depth of 1.5’
2 = Ice Jam at Lagoon = lost lagoon in 2008, rebuilt (2009 specs) including new pumps - has happened at least 4 times in the past.
3 = Causeway out at Big Shiktehawk - causeway across 105, lost in Arthur, out 6 weeks, caused major socio-economic issues
4 = Shiktehawk Trailhead - unusable land because of flooding – town took over, added picnic table
5 = Gazebo, where little Shiktehawk enters downtown, by NB trail and turning lane - eroding but bigger culvert installed summer 2015
6 = Island - sediment build up, ice buildup anywhere streams empty in SJR, same situation
7 = Six or seven houses evacuated in 2008 (not mandatory)
8 = Florenceville lagoon (just off map) - overflowed in the past but has since been fixed
AND Main street closure impacts noted, once in 80’s once in 90’s, in early 2000, and in 2008

Figure 23. Hartland map indicating impact areas 2008 – present.

1 = Sewage Lagoon - potential for break
2 = Flood Area - area floods almost yearly – low ground
3 = Flood Area - area floods almost yearly – low ground
4 = Library - basement floods every few years

5 = Baptist Church - basement floods
6 = Covered Bridge – concern for damage to bridge due to ice or flooding
7 = Sproul's Island - silt around island has made the river very shallow
8 = Well Field - water supply - potential problem
9 = School/Summer camp – concern for flooding risk
10 = Fire Station - access problem in flooding
11 = Arena – snow load risk
12 = Greenbelt - helps to stop erosion of agriculture areas

Figure 24. Woodstock map indicating impact areas 2008 – present.

1 = Well house - flood – roadway wash out 2014
2 = NBCC Main/Broadway – flooding – average 1 time/year
3 = Lower Main/Upham St area – flooding - average 1 time/year
4 = Rose Court - power outages – extended time due to backlot services, approximately 7 residents
5 = Pleasant St – power outages, small number of residents impacted
6 = Water St – flooding
7 = Water St - flooding – lift station

8 = Slipp Subdivision - flooding low area, water backs up culvert from SJR
9 = Eastwood Heights - run off flooding
10 = Main St bridge crossing Meduxnekeag - flooding & water line running underneath

4.3.2.2 Meeting 2 – April 23, 2015

The second working group meeting was held on April 23 in the community of Hartland. The agenda (Appendix F) for this meeting included group introductions and discussion regarding project background as well as an introduction to the LiDAR process and, hydro-risk mapping focused on Hartland, by Dr. Paul Arp and Mark Castonguay. Their presentation described the aim of producing maps was to enable the communities to visualize the hydrological conditions within and around their areas, at high resolution. Having such maps enables collaborative communications and actions to restore and sustain the health of the St. John River and its water-contributing watersheds. As reported in *Flow and Flood Extent Mapping For Select St. John River Valley Communities* (Castonguay et al. 2015) the objective of the LiDAR analysis component of the project refers to the mapping of drainage-challenged and flood-prone areas using Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) data, as outlined and analyzed by Murphy et al. (2009, 2001). In detail, the mapping effort refers to:

- Delineating all areas that would flood, with and without roads and bridges being completely blocked.
- Delineating depressed areas where water would pool.
- Extending the mapping beyond the LiDAR DEM coverage, using best available provincial DEM at 10 m resolution.
- Refining the mapping with community information regarding hydrological infrastructure (culvert locations, ditches, stormwater lines).
- Presenting the project results to community representatives, and delivering the project results to WWF (c/o WWF Senior Advisor – St. John River, Simon J. Mitchell)

Figure 25.Topographical map identifying communities and their primary contributing watersheds. Orange highlighted boundaries represent the extent of high-resolution DEM data (LiDAR). Red dots represent the flow-point at which major contributing watersheds. Orange highlighted boundaries represent the extent of high resolution DEM data (LiDAR). Red dots represent the flow-point at which major contributing watershed areas were delineated. Source: Castonguay et al. 2015

The following five figures locate the following hydrologically relevant features:

- Wetlands
- Flood extent 2008
- Roads and culvert sizes
- Depression depths
- Cartographic depth to water along stream channels, also indicative of the extent of stream-based flooding at 0.1, 0.25, 05, and 1 m depth
- Riverine flood extent, in 1 m intervals, up to 12 m
- LiDAR DEM extent, graded by elevation, showing elevation of all features (bareground, houses, trees)
- LiDAR DEM extent surrounded by NB satellite imagery (GeoNB), roads, and culvert locations and size.

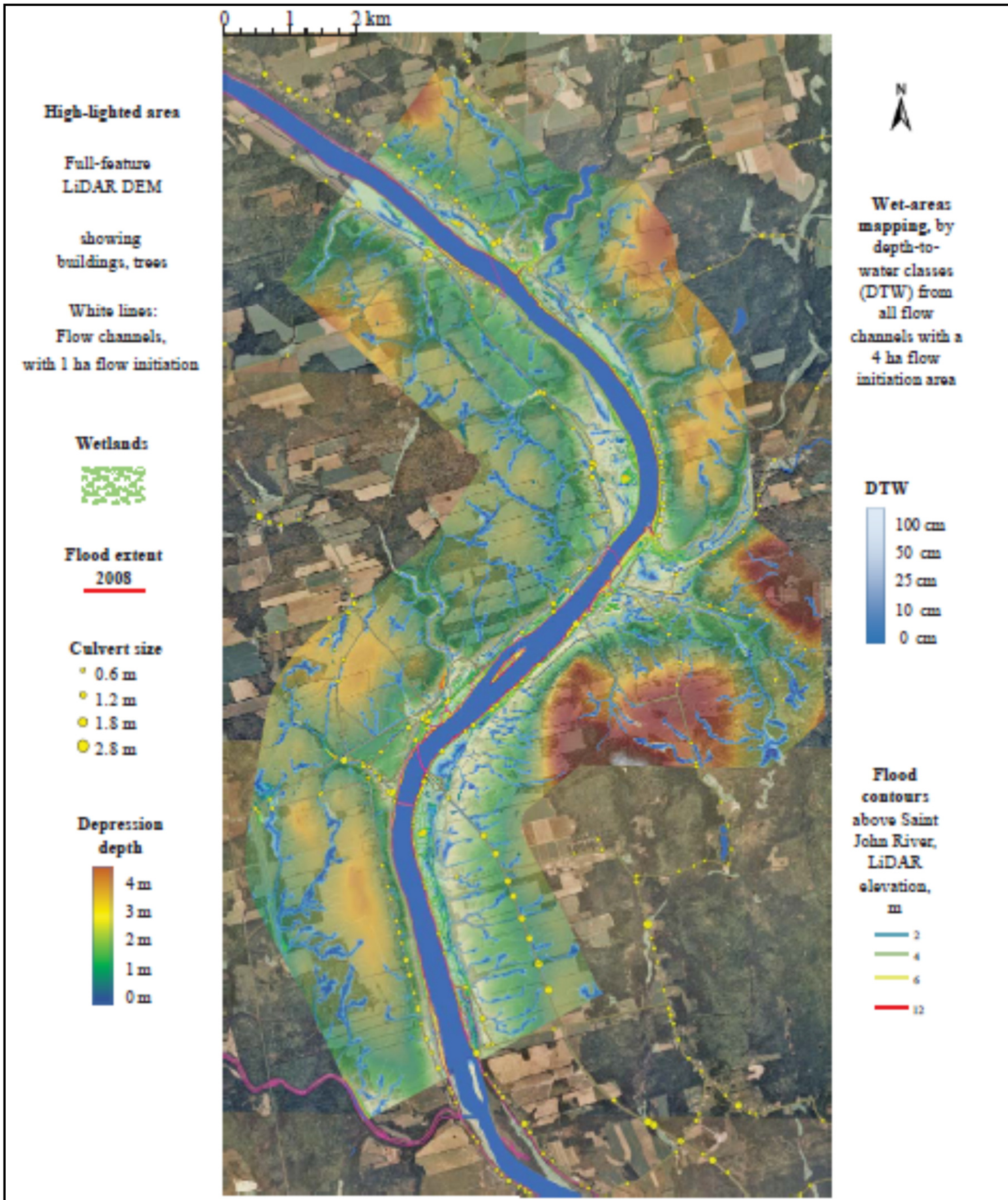

Figure 26. Flood extent, depressions, and wet areas mapping: Florenceville-Bristol. Source: Castonguay et al. 2015

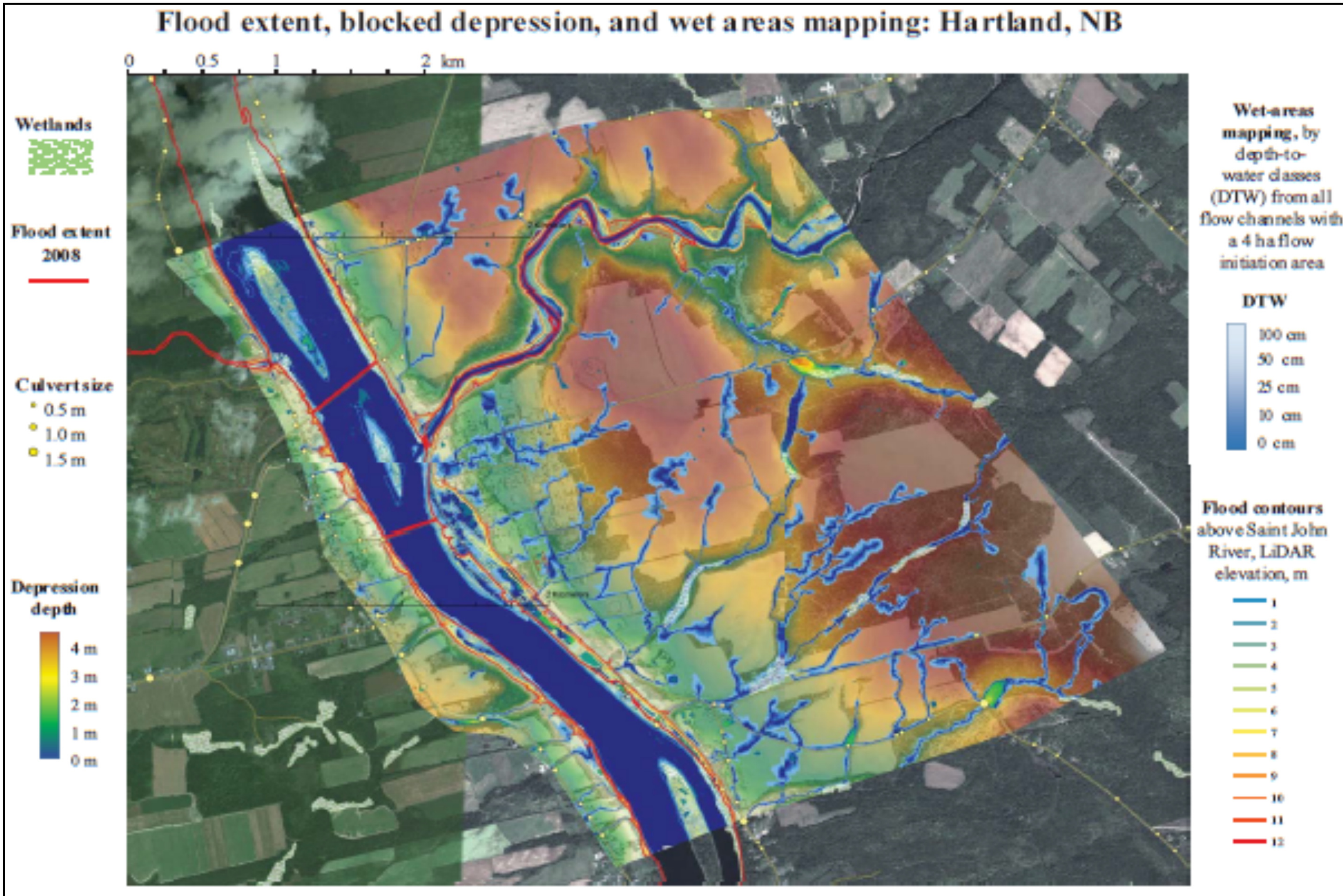

Figure 27. Flood extent, depressions, and wet areas mapping: Hartland. Source: Castonguay et al. 2015

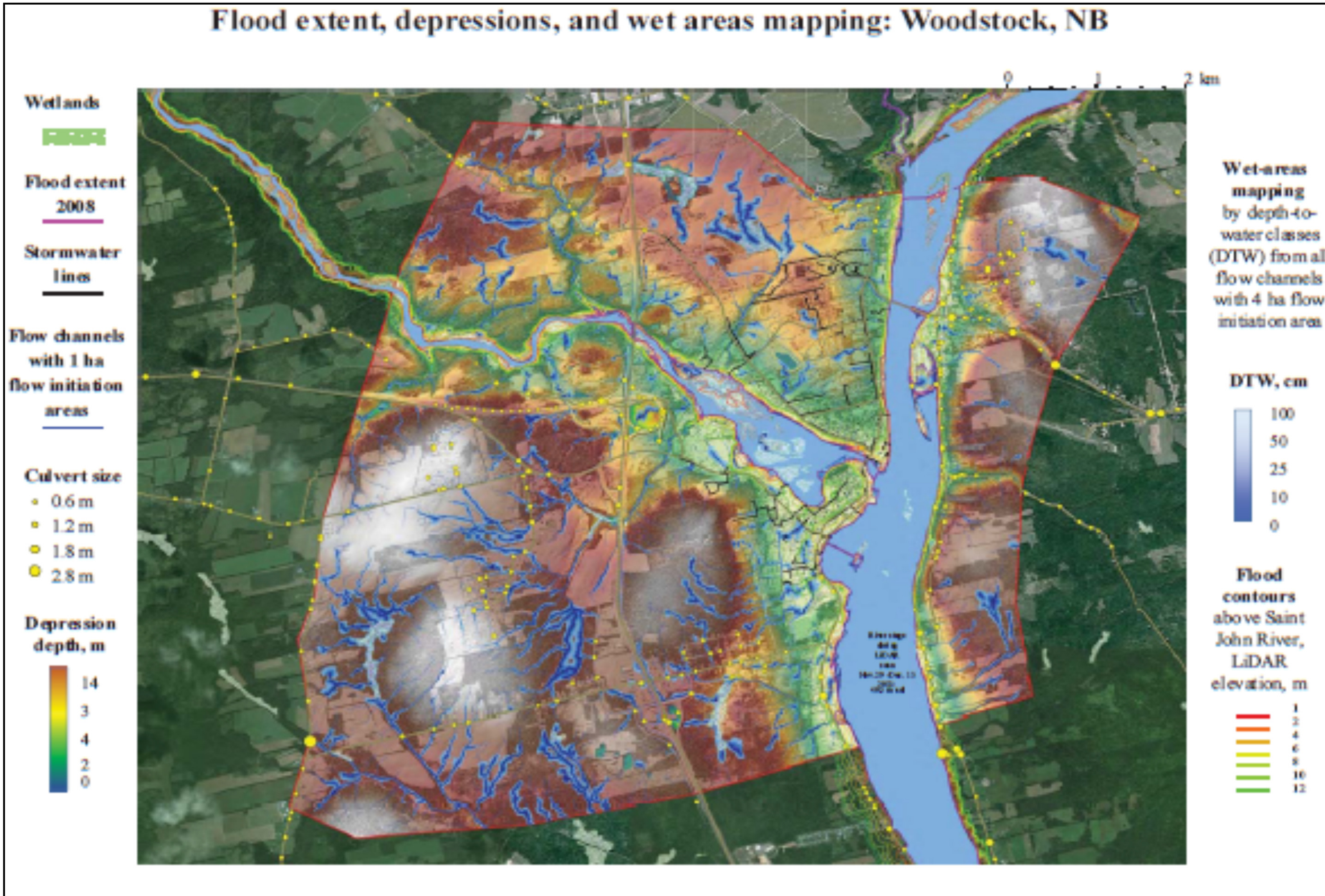

Figure 28. Flood extent, depressions, and wet areas mapping: Woodstock. Source: Castonguay et al. 2015

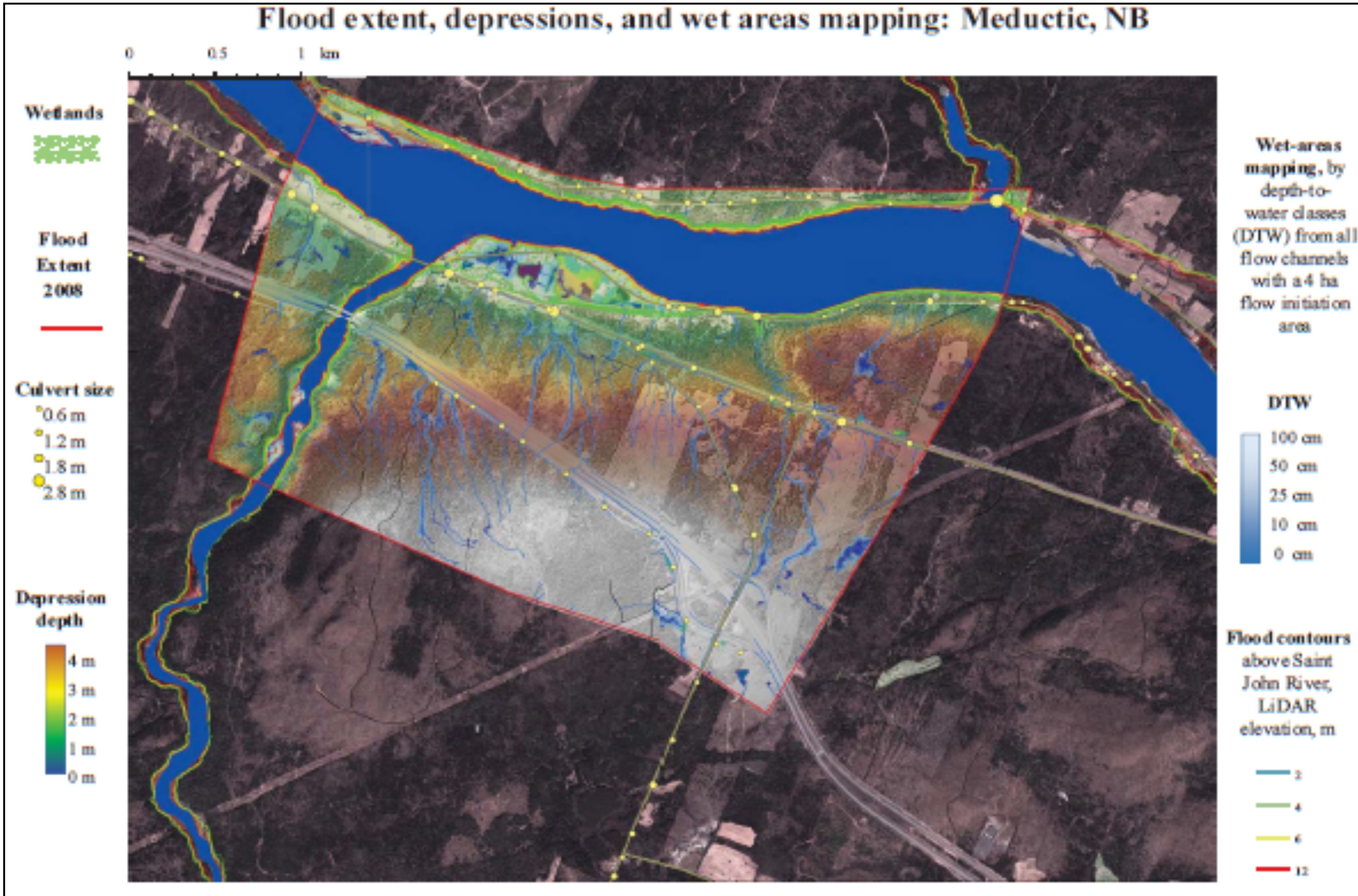

Figure 29. Flood extent, depressions, and wet areas mapping: Meductic. Source: Castonguay et al. 2015

Following the presentation there was a question and answer period. The UNB team provided commentary on analysis of culverts location and drainage areas (Figure 30).

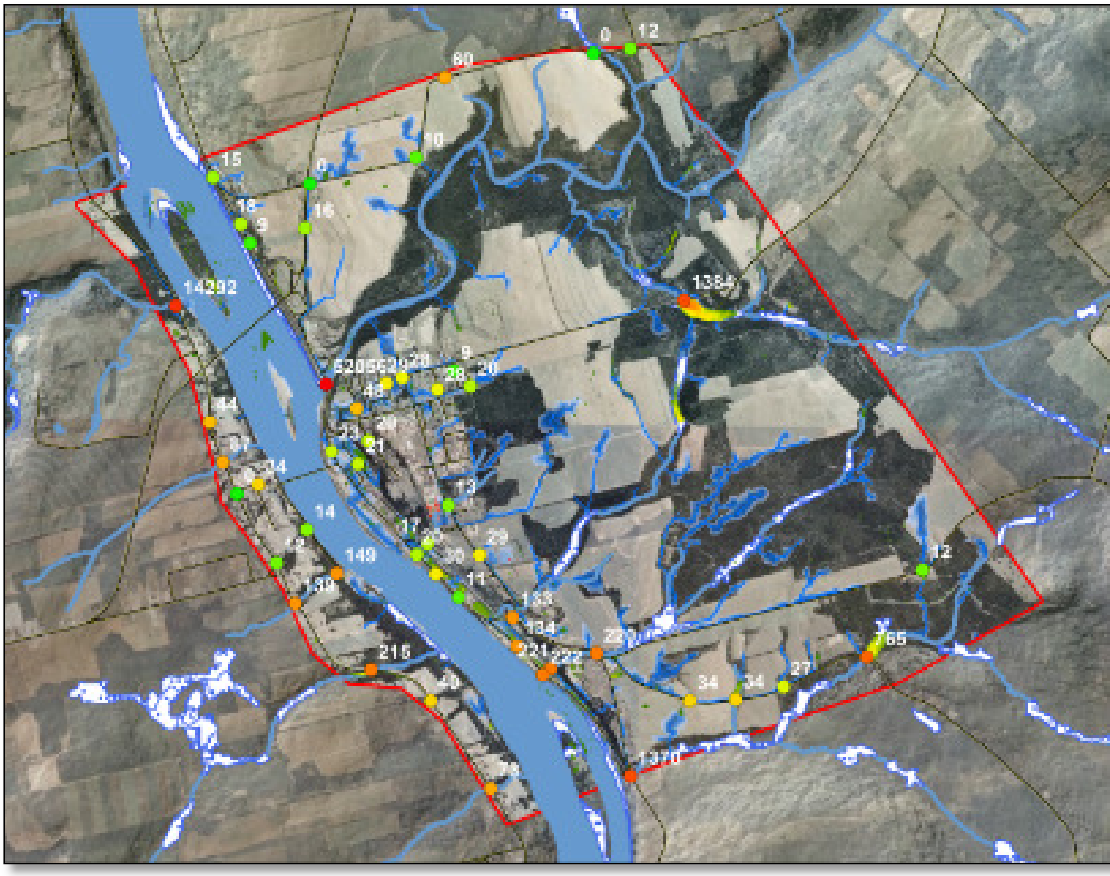

Figure 30. Hartland, NB, LiDAR based mapping with the addition of Department of Transportation culvert location data and analysis (numeric value) indicating drainage area for each culvert. The white areas are wet areas identified by the province on mapping http://geonb.snb.ca/geonb/ Source :Arp, Castonguay 2015

Culvert data, such as pictured above may be helpful in land use planning, the prioritization of culvert maintenance and clearing, or potential hazard situations and impact areas. Accurate culvert information reflects also, in the accuracy of flows in mapping products.

Wet-areas maps have been very helpful in other communities specifically as a tool for the Town Works department, in providing the ability to trace inland flooding issues back to their source, enabling attempts to slow and/or detain water between the source and the impact. The presenters explained flow rate initiation and referred to the Woodstock area is shown below with a 4 ha flow initiation (Figure 31) and a 1 ha flow initiation (Figure 32) indicating the impacts of seasonality. Issues and exercises related to socio-economics were tabled until the next meeting.

Figure 31. Woodstock, 4 ha flow initiation. Source: Arp, Castonguay 2015

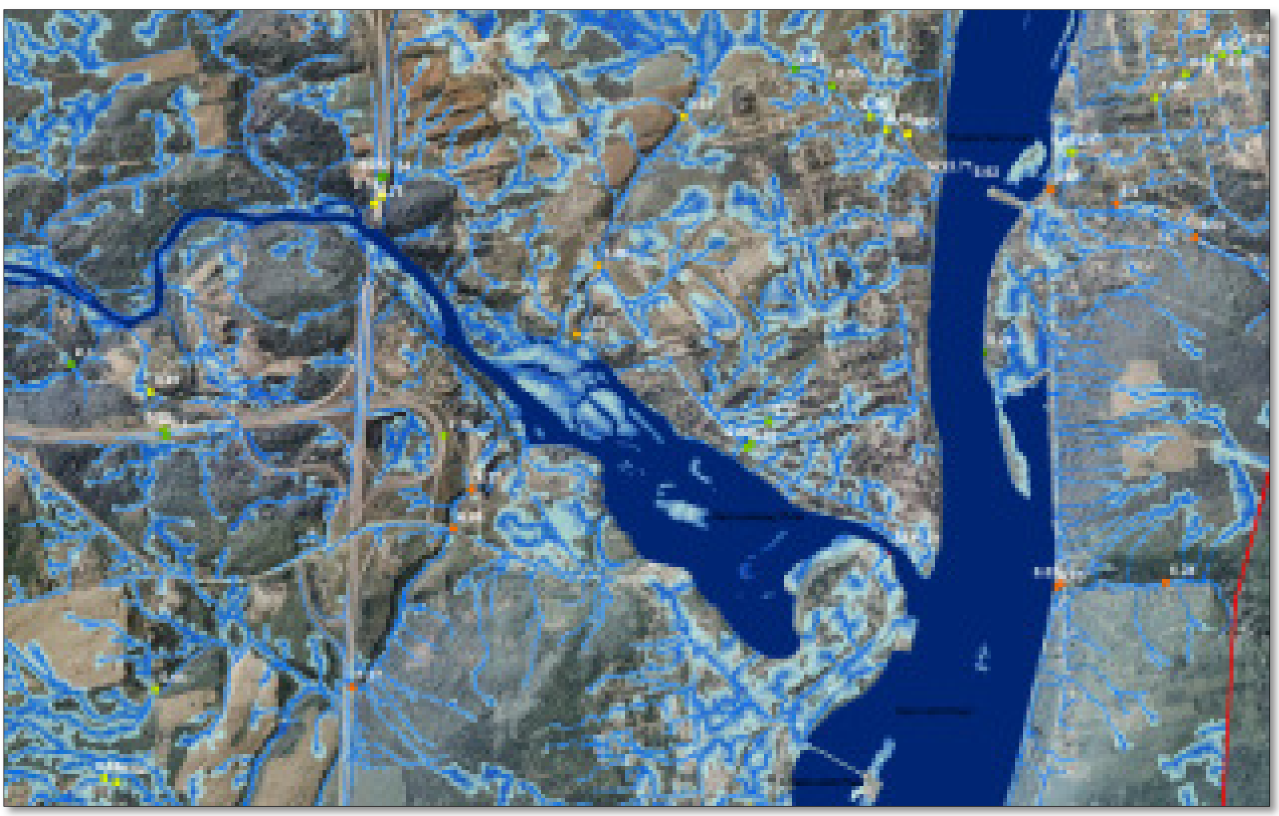

Figure 32. Woodstock, 1 ha flow initiation. Source: Arp, Castonguay 2015

4.3.2.3 Meeting 3 – May 22, 2015

Meeting 3 was held on May 22, in Woodstock (agenda can be viewed in Appendix G). Similar to meeting 2, Professor Arp and Mark Castonguay presented a review of the analysis process and provided information regarding Florenceville and Woodstock. This presentation also addressed flood risk and the presenters provided various flood scenarios of the past and future.

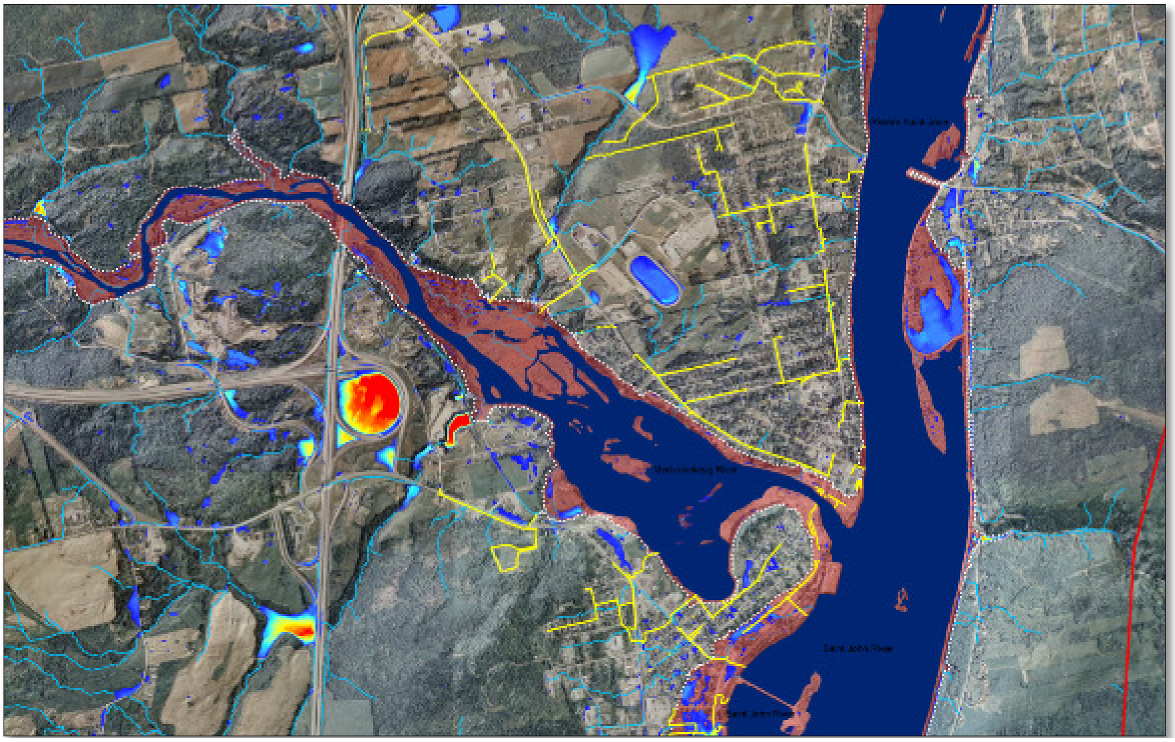

Figure 33. Woodstock flooding of 1987. Source: Arp and Castonguay 2015

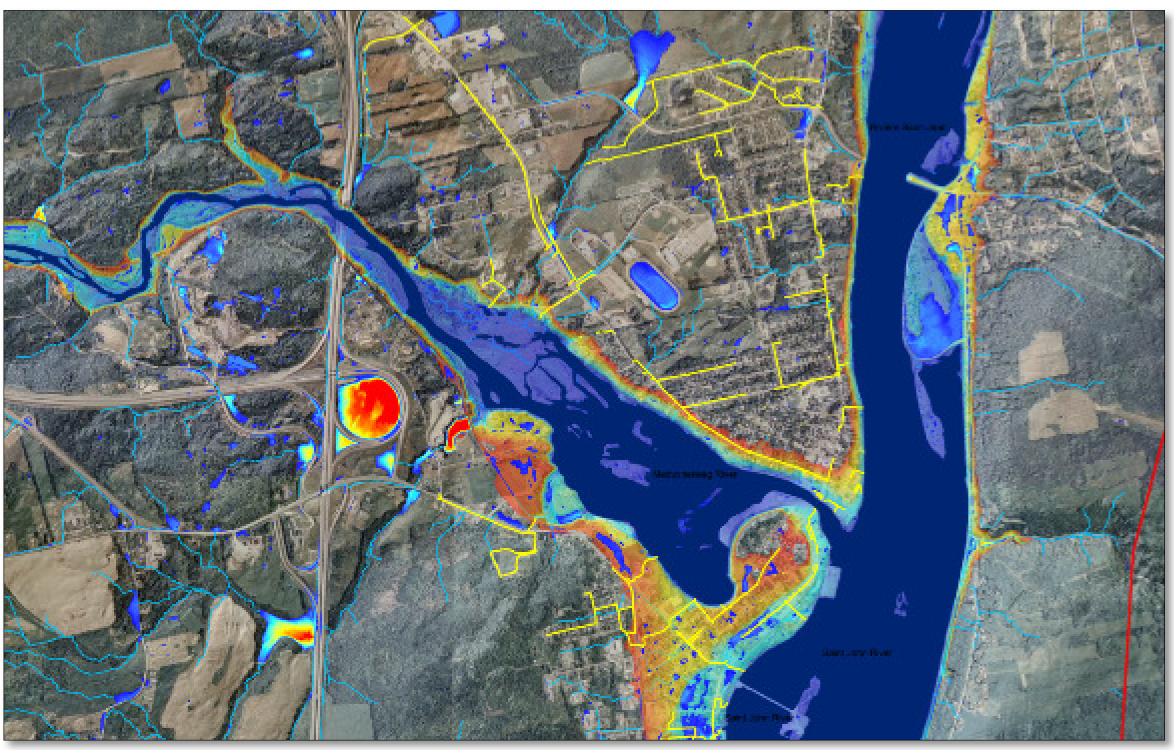

Figure 34. Woodstock LiDAR DEM – 4ha Flow, Sinks, Drainage Infra. – P. Flooding @ 15m. Source: Arp and Castonguay 2015

4.3.2.4 Forms of community capital

Following the presentation, the group started to discuss community capacity and socio-economic impacts of climate change. Discourse was held regarding the meaning of economic, natural, human and social capital and how they impact capacity to adapt. As in, *Assessing Community Capacity to Adapt to a Changing Climate: A "how to" Guide for communities,* Louise A. Comeau and Thomas M. Beckley, University of New Brunswick, March 2015, the four capitals are described;

4.3.2.4.1 Economic Capital

Community economic capital comprises two types of assets physical (Figures 35 and 36) and financial: 1) Physical capital or infrastructure sometimes referred to as fixed assets such as municipal, provincial and/or federal infrastructure, including roads, light rail and other public transit structures, bridges, piers/wharfs, potable water and wastewater treatment facilities, buildings and vehicles (city hall, police, ambulance, fire), and the physical capital associated with the fixed assets of the business community (stores, factories, tractors, boats, productive machinery, etc.); 2) Financial capital or liquid assets consists of the financial assets of the community (both public and private), covering municipal budgets (including municipal bond ratings, value of real estate and associated property tax revenue), individual and household savings, business cash flow and operating funds (Beckley, et al., 2008).

Figure 35. Florenceville-Bristol area

4.3.2.4.2 Natural Capital

Natural capital refers to the ecological assets that a community has, such as forests, arable land, minerals, wildlife, clean air and water, etc. Historically, the only natural capital assets that really counted were those which were exploited in order to create commodities. Today, wealth is also generated by capitalizing on the amenity dimensions of natural resources, for example through recreation and tourism. Two forms of natural capital are differentiated as well: 1) natural resource endowments or stocks (that are often used for creating commodities), and 2) environmental services or processes such as the hydrologic cycle, the nitrogen cycle, etc. that provide us with clean water, air, oxygen, and other natural elements critical to our survival (Beckley, et al., 2008). Changes to a community's natural capital resulting from a changing climate can affect tourism, fisheries, agriculture, forestry and water and air quality.

4.3.2.4.3 Social Capital

Social capital refers to "social networks, norms of reciprocity, mutual assistance, and trustworthiness" (Putnam & Feldstein, 2004, p. 2) within and between groups. There are three dimensions to social capital (Marin, Gelcich, Castilla, & Berkes, 2012; Woolcock, 2001). Bonding social capital refers to the strong ties we have between family members, our ethnic group, close friends, and neighbours. Think of bonding social capital as referring to our in-group and who we turn to in times of trouble, our safety net (who we rely on to get by).

Bridging social capital, on the other hand, is more outward looking and refers to the weaker, more distant and diverse ties that we have with friends, associations, and colleagues in different communities and groups. We use our bridging social capital when reach out to colleagues to help us find a job or when our local government reaches out to a near-by community to solve cross-boundary transportation problem (how we get ahead; trade favours). Putnam calls bonding social capital "a kind of sociological superglue, whereas bridging social capital provides a sociological WD-40" (1995, p. 23) or social lubricant. Bonding and bridging social capital are 'horizontal' resources because they deal at the same level (friends to friends, groups to groups). The capacity to 'go up' to leverage resources, ideas and information beyond the community, to forge alliances with sympathetic individuals in positions of power is called 'linking' social capital. When the local mayor builds a relationship with the provincial ministers of local government, infrastructure and transportation, linking capital is being built. Communities rich in bridging and linking social capital are known to be more resilient, better able to manage resources and to solve problems and create opportunities (Marin, et al., 2012; Putnam & Feldstein, 2004). Importantly, to the consideration of the community effects of a changing climate is consideration of sense of place as a component of a community's social capital (Moore, Severn, & Millar, 2006).

Figure 36. Hartland area, April 7, 2009. Source: Government of New Brunswick

4.3.2.4.4 Human Capital

Human capital refers to the knowledge, skills and experience of individuals (Johnson & Stallman, 1994; Schuller, 2001). Unlike social capital, here we are talking about the individuals rather than groups or the collective. Human capital is developed through formal education, trade and technical training, life and self-provisioning, entrepreneurial, and leadership skills, and informal learning that occur within families, communities or work places (Beckley, et al., 2008). Important to the capacity to adapt to climate change is the need to determine which skills and talents need to be nurtured or re-introduced to meet community and economic opportunities emerging from the transition to a clean energy system and climate safe communities (Hopkins, 2011). Human capital as it relates to self-reliance is best exemplified by the old adage, "Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime." The knowledge of how to fish is human capital.

4.3.2.5 Condition of Community Capital

Following the work of Comeau and Beckly, the group was lead through an exercise where participants subjectively assessed the state of community assets. Together, workshop participants were asked to think about what they believed the state of the four capitals is compared to the condition they wished it would be (Figure 37). They rated these evaluations from the possible set of indicators, using a scale where 1 is poor and 5 is excellent (Figure 38).

Figure 37. Working Group members (L-R) Regional Service Commission's Katie Hayden, Town of Hartland's Deputy Mayor Travis Dickinson with WWF's Simon J. Mitchell

In the context of adapting to climate change and its impacts, the lowest rated indicator of community assets, Quantity of Leadership Pool (Figure 38, Table 3), is concerning and may be a place to focus energies. Though the next lowest rated indicator was a four-way tie between Property Tax Values, Amenity Values, Wildlife Resources/Habitat as well as Municipal Infrastructure, it is the last two that should be heavily considered during regional adaptation planning in response to climate change. Property Tax Values may change as a result of adaptation planning and implementation. Similarly, the Value of Real Estate will likely be responsive to of adaptation planning and implementation.

Alongside Value of Real Estate, Entrepreneurship and Bridging Social Capital received scores of 3.14, while Bonding Social Capital received a score of 3.29 which may indicate a perception of a relatively stable and successful community and outreach relationships. Of course, results of this exercise are not statistically significant and can only be used to gain perspective on the reality of the situation as participant numbers were limited to eight, the participants did not delve into the indicators deeply and they were only given a short amount of time and group discussion within which to work.

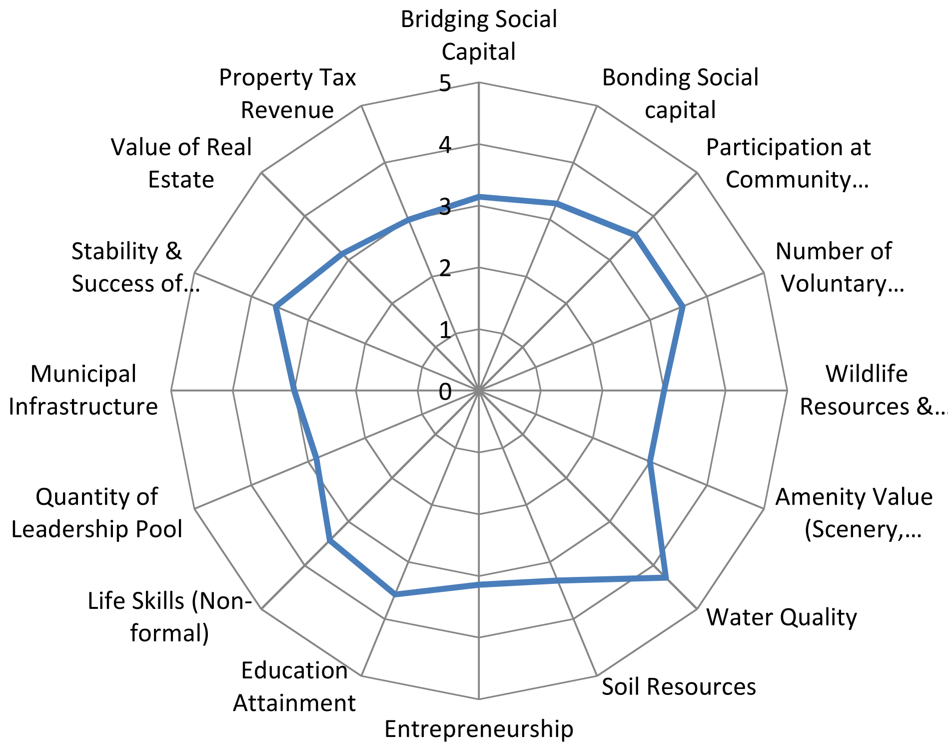

Figure 38. Representation of the working group's perception and evaluation regarding the current state of community asset indicators.

Soil Resources were rated highly, but not perceived as excellent. This provides some insight and prompted some discussion regarding how the quality of soils in the area have changed as well as what types of actions are being undertaken to improve or at the very least protect current soil quality. As an agricultural region, and one of the life-bloods of the local economy, this community asset has high relevance, especially in the face of climate change.

Life Skills (Non-formal), Stability & Success of Business, Education Attainment, Number of Voluntary Organizations, and Participation at Community Events were all rated highly by participants. These assets will be able to be nurtured and built upon for community resilience building.

Water Quality topped the asset list as very close to the desired state, however, for a community like Woodstock which is searching for new water sources, it will take much effort to maintain this assets status.

Table 3. Representation of the working group's perception and evaluation regarding the current state of community asset indicators.

Quantity of Leadership Pool	2.86
Wildlife Resources & Habitat (Marine & Terrestrial)	3.00
Amenity Value (Scenery, Aesthetics)	3.00
Municipal Infrastructure	3.00
Property Tax Revenue	3.00
Bridging Social Capital	3.14
Entrepreneurship	3.14
Value of Real Estate	3.14
Bonding Social capital	3.29
Soil Resources	3.33
Life Skills (Non-formal)	3.43
Participation at Community Events	3.57
Number of Voluntary Organizations	3.57
Education Attainment	3.57
Stability & Success of Business	3.57
Water Quality	4.29
Education Attainment	3.57
Stability & Success of Business	3.57
Water Quality	4.29

4.4 ENVIRONMENTAL CONSIDERATIONS

Meeting 3 was wrapped up when the working group identified locations on their large community maps of locations they considered significant for environmental reasons, either positive or negative.

Figure 39. Florenceville – Bristol map - physical impacts (indicated in white) and environmental areas (green).

1 – 9168 Main Street – Erosion of parking lot
2 – 9158 Main Street – Buried tanks at one point
3 – Across from post office - Buried tanks at one point
4 – Hitchcock Place - Buried tanks at one point
5 – McCains – Methane Lagoon, LNG
6 – Irving – Modern facility
7 – McCain Produce – Chemical storage
8 – Fertilizer Plant – Fertilizer and fuel (cleaned up?)
9 – Lagoon
10 - Lagoon

Figure 40. Hartland map - physical impacts (indicated in white) and environmental areas (green).

1 – Old gas station – fenced in, but tanks possibly still in ground
2 – Old Craig Manufacturing Lot – contaminated soils
3 – Greenbelts – environmental buffer
4 – Island – maintains river habitat
5 – Valley Equipment b>Hartland Agromart – hazardous materials storage
6 – Irving Gas Station – fuel storage
7 – NB Power Flood Zone – buffers flooding from residents on Main Street
8 – Wet area all residents

Figure 41. Woodstock map - physical impacts (indicated in white) and environmental areas (green).

1 – FMR Irving Plant – possible oil contamination
2 – FMR – Imperial Oil - possible oil contamination
3 – FMR – CP Rail - possible oil contamination
4 – Mortgage Pro's FMR Wilson Equip - possible oil contamination
5 – Cement Plant - possible oil contamination
6 – Maintenance Shop FMR DOT Depot – oil/fuel contamination
7 – Dry Cleaner – chemical storage
8 – Sustainable Community Design Subdivision
9 & 10 – Nature Preserve
11 – Connell Brook Watershed
12 – Fuel Storage – Marina
13 – Scrap Yard
14 – Outdoor tire storage

5 ASSESSMENT OF VULNERABILITY AND RISK

5.1 MEETING 4 – JUNE 25, 2015

During Meeting 4, June 25, held at the Hartland Town Hall, vulnerability and risk were assessed based on the ICLEI Canada methodology. While the vulnerability assessment is the study of sensitivity and adaptive capacity, the risk assessment gauges the consequence and likelihood of impacts, which provides a numerical score to assist with prioritization.

5.1.1 Sensitivity

The list of municipal service areas were first evaluated for sensitivity to changes in climate using the sensitivity scale developed by ICLEI Table 4 and 5.

Table 4. ICLEI scale used to assess sensitivity

If the impact occurs, will it affect the functionality of the service area?				
No – Functionality will stay the same (S1)	Unlikely - Functionality will likely stay the same (S2)	Yes - Functionality is likely to get worse (S3)	Yes - Functionality will get worse (S4)	Yes - Functionality will become unmanageable (S5)

Figure 42. Shiktehawk trail, Florenceville – Bristol. Source: www.hikingnb.ca

Table 5. Next page, list of municipal service areas were evaluated for sensitivity to changes in climate.

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Municipal Concerns			If the impact occurs, will it affect the functionality of the service area?				
Municipal Concerns (Outcome of the change - finite, measurable)	IMPACTS OF THE CHANGE long-term, deeper changes	SERVICE AREAS IMPACTED	No – Functionality will stay the same (S1)	Unlikely - Functionality will likely stay the same (S2)	Yes - Functionality is likely to get worse (S3)	Yes - Functionality will get worse (S4)	Yes - Functionality will become unmanageable (S5)
Access to well house cut off	Less sustainable community	Drinking Water Delivery		HARTLAND			WOODSTOCK
Water delivery lines impacted	Less sustainable community	Drinking Water Delivery			HARTLAND	WOODSTOCK	
Possible well field contamination	Less sustainable community	Drinking Water Quality			HARTLAND		WOODSTOCK
Possible overflows into river	Staff, infra & budgetary impacts	Sewerage	WOODSTOCK		HARTLAND	FLORENCEVILLE-BRISTOL	
Basement Back-ups		Sewerage	WOODSTOCK			HARTLAND	
Flooded routes - Delayed pick up	Staff, infra & budgetary impacts	Waste Collection	WOODSTOCK		HARTLAND	FLORENCEVILLE-BRISTOL	
Flooded routes - Immediate fixes necessary	Staff, infra & budgetary impacts	Road Integrity			HARTLAND	FLORENCEVILLE-BRISTOL & WOODSTOCK	
Flooded routes - Change in travel routes	Increased accidents	Road Integrity	WOODSTOCK		HARTLAND	FLORENCEVILLE-BRISTOL	
Flooded routes - Longer travel time	Impacts to individual budgets and social cohesion, risk for isolated seniors	Road Integrity		WOODSTOCK	HARTLAND	FLORENCEVILLE-BRISTOL	
Municipal Concerns			If the impact occurs, will it affect the functionality of the service area?				

OUTCOME OF THE CHANGE finite, measurable	IMPACTS OF THE CHANGE long-term, deeper changes	SERVICE AREAS IMPACTED	No – Functionality will stay the same (S1)	Unlikely - Functionality will likely stay the same (S2)	Yes - Functionality is likely to get worse (S3)	Yes - Functionality will get worse (S4)	Yes - Functionality will become unmanageable (S5)
Land saturated	Less usable land	Land Use Planning			HARTLAND		
Homes flooded	Less sustainable community	Land Use Planning				HARTLAND & WOODSTOCK	
Delayed response	Staff, infra & budgetary impacts	Emergency Services				FLORENCEVILLE-BRISTOL & HARTLAND	
Power outages		Emergency Services			HARTLAND	FLORENCEVILLE-BRISTOL – if 3 days +	WOODSTOCK
Telecommunications down		Emergency Services			FB & HARTLAND	WOODSTOCK	
Usage of staff outside of mandate	Unsafe situations may develop	Emergency Services		HARTLAND & WOODSTOCK		FLORENCEVILLE-BRISTOL	
Delayed emergency response	Citizens adopt riskier behaviour	Public Safety		WOODSTOCK	HARTLAND	FLORENCEVILLE-BRISTOL	
Assets damaged or lost	Less sustainable community	Culture & Tourism		WOODSTOCK	FLORENCEVILLE-BRISTOL & HARTLAND		
Delays in seasonal activities	Less sustainable community	Parks & Rec		FLORENCEVILLE-BRISTOL & WOODSTOCK	HARTLAND		
Businesses impacted by flooding	Less sustainable community	Economic Development			HARTLAND & WOODSTOCK	FLORENCEVILLE-BRISTOL	
Municipal Concerns			If the impact occurs, will it affect the functionality of the service area?				

OUTCOME OF THE CHANGE finite, measurable	IMPACTS OF THE CHANGE long-term, deeper changes	SERVICE AREAS IMPACTED	No – Functionality will stay the same (S1	Unlikely - Functionality will likely stay the same (S2	Yes - Functionality is likely to get worse (S3)	Yes - Functionality will get worse (S4	Yes - Functionality will become unmanageable (S5)
Increases in ice jam flooding				FLORENCEVILLE-BRISTOL	HARTLAND & WOODSTOCK		
Planting/Harvesting season impacted		Eco Development - Agriculture			FLORENCEVILLE-BRISTOL & HARTLAND & WOODSTOCK		
Forestry operations impacted		Eco Development - Agriculture			FB & HARTLAND		

After completing the sensitivity assessment, the municipality's adaptive capacity to the climate change hazards and impacts was evaluated using the adaptive capacity scale developed by ICLEI (Table 6 and 7).

5.1.2 Municipal Adaptive Capacity

Table 6. ICLEI Adaptive Capacity scale

Can the service area adjust to the projected impact with minimal cost and disruption?				
No – Will require substantial costs($$$$$) and staff intervention (AC1)	No – Will require significant costs($$$$) and staff intervention (AC2)	Maybe - Will require some costs($$$) and staff intervention (AC3)	Yes – But will require some slight costs ($$) and staff intervention (AC4)	Yes – Little to no costs ($) and staff intervention are necessary (AC5)

Figure 43. Working group Florenceville – Bristol members Daniel Guest and Andrew Cougle.

Table 7. Evaluation of adaptive capacity to climate c

Municipal Concerns	Can the service area adjust to the projected impact with minimal cost and disruption?

	No – Will require substantial costs($$$$$) and staff intervention (AC1)	No – Will require significant costs($$$$) and staff intervention AC2	Maybe - Will require some costs($$$) and staff intervention AC3	Yes – But will require some slight costs ($$) and staff intervention AC4	Yes – Little to no costs ($) and staff intervention are necessary AC5
Access to well house cut off			WOODSTOCK		HARTLAND
Water delivery lines impacted			HARTLAND & WOODSTOCK		
Possible well field contamination		HARTLAND	WOODSTOCK		
Possible overflows into river	HARTLAND	WOODSTOCK	FB		
Basement Back-ups		HARTLAND			
Flooded routes - Delayed pick up				FB & HARTLAND	
Flooded routes - Immediate fixes necessary		WOODSTOCK	FLORENCEVILLE-BRISTOL	HARTLAND	
Flooded routes - Change in travel routes				HARTLAND	FLORENCEVILLE-BRISTOL & WOODSTOCK
Flooded routes - Longer travel time				FLORENCEVILLE-BRISTOL & HARTLAND	WOODSTOCK
Land saturated					HARTLAND
Homes flooded	HARTLAND & WOODSTOCK				
Delayed response		HARTLAND		FLORENCEVILLE-BRISTOL	
Power outages		WOODSTOCK	FLORENCEVILLE-BRISTOL & HARTLAND		
Telecommunications down		WOODSTOCK	FLORENCEVILLE-BRISTOL	HARTLAND	
Usage of staff outside of mandate		HARTLAND	FLORENCEVILLE-BRISTOL		WOODSTOCK
Delayed emergency response			HARTLAND	FLORENCEVILLE-BRISTOL	WOODSTOCK
Assets damaged or lost	HARTLAND	WOODSTOCK	FLORENCEVILLE-BRISTOL		
Delays in seasonal activities		FLORENCEVILLE-BRISTOL		HARTLAND	WOODSTOCK
Businesses impacted by flooding	FLORENCEVILLE-BRISTOL	WOODSTOCK	HARTLAND		
Increases in ice jam flooding		HARTLAND & WOODSTOCK		FLORENCEVILLE-BRISTOL	
Planting/Harvesting season impacted	FLORENCEVILLE-BRISTOL				HARTLAND & WOODSTOCK
Forestry operations impacted			FLORENCEVILLE-BRISTOL		HARTLAND

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5.1.3 Vulnerability Scores

The values for sensitivity and adaptive capacity were then combined using the matrix in Table 8. Results in Table 9 provide the vulnerability score. Figure 44 provides a view into the working group process.

Table 8. ICLEI Vulnerability Matrix

	S1	S2	S3	S4	S5
AC1	V2	V2	V4	V5	V5
AC2	V2	V2	V3	V4	V5
AC3	V2	V2	V3	V4	V4
AC4	V1	V2	V2	V3	V3
AC5	V1	V1	V2	V3	V3

Figure 44. Woodstock working group members Andrew Garnett, Ken Harding and Catherine Cummings

Table 9. Evaluation of vulnerability to climate change hazards and impacts.

Municipal Concerns			
	FLORENCEVILLE - BRISTOL	HARTLAND	WOODSTOCK
	Vulnerability Index	Vulnerability Index	Vulnerability Index
Access to well house cut off	N/A	V1	V4
Water delivery lines impacted	N/A	V3	V4
Possible well field contamination	N/A	V3	V4
Possible overflows into river	V4	V4	V2
Basement Back-ups	N/A	V4	N/A
Flooded routes - Delayed pick up	V3	V2	N/A
Flooded routes - Immediate fixes necessary	V4	V2	V4
Flooded routes - Change in travel routes	V3	V2	V1
Flooded routes - Longer travel time	V3	V3	V1
Land saturated	N/A	V2	N/A
Homes flooded	N/A	V5	V5
Delayed response	V3	V4	N/A
Power outages	V4	V3	V5
Telecommunications down	V3	V2	V4
Usage of staff outside of mandate	V4	V2	V1

Delayed emergency response	V3	V3	V1
Assets damaged or lost	V3	V4	V2
Delays in seasonal activities	V2	V2	V1
Businesses impacted by flooding	V5	V3	V3
Increases in ice jam flooding	V2	V3	V3
Planting/Harvesting season impacted	V4	V2	V2
Forestry operations impacted	V3	V2	N/A

5.1.4 Likelihood Scores

Those municipal concerns with a vulnerability score of 3 or higher were then assessed for risk using the likelihood rating index developed by ICLEI (Table 10). The results of this assessment can be found in Table 11.

Table 10. ICLEI Likelihood Rating

Likelihood Rating	Recurrent Impact	Single event
Almost Certain 5	Could occur several times per year	More likely than not – probability greater than 50%
Likely 4	May arise about once per year	As likely as not – 50/50
Possible 3	May arise once in 10 years	Less likely than not but still appreciable – probably less than 50% but still quite high
Unlikely 2	May arise once every 10 to 25 years	Unlikely but not negligible, probability low but greater than zero
Rare 1	Unlikely during the next 25 years	Negligible, probability very small, close to zero

Table 11. Municipal Likelihood scores

Municipal Concerns			
	FLORENCEVILLE-BRISTOL	HARTLAND	WOODSTOCK
	Likelihood	Likelihood	Likelihood
Access to well house cut off	N/A	<V2	3
Water delivery lines impacted	N/A	4	3
Possible well field contamination	N/A	4	3
Possible overflows into river	3	4	>V2
Basement Back-ups	N/A	5	N/A
Flooded routes - Delayed pick up	3	<V2	N/A
Flooded routes - Immediate fixes necessary	3	<V2	3
Flooded routes - Change in travel routes	3	<V2	>V2
Flooded routes - Longer travel time	3	4	>V2
Land saturated	N/A	<V2	N/A
Homes flooded	N/A	4	2
Delayed response	3	4	N/A
Power outages	4	5	5

Telecommunications down	4	<V2	5
Usage of staff outside of mandate	4	<V2	>V2
Delayed emergency response	4	3	>V2
Assets damaged or lost	3	3	>V2
Delays in seasonal activities	<V2	<V2	>V2
Businesses impacted by flooding	3	2	4
Increases in ice jam flooding	<V2	4	4
Planting/Harvesting season impacted	3	<V2	>V2
Forestry operations impacted	3	<V2	N/A

5.1.5 Consequence Scores

The results from the vulnerability assessment (those impacts labeled as having high vulnerability), along with research on projected climatic changes were used to estimate the consequence of specific impacts. The likelihood assessment, (Table 11) together with the consequence evaluation (Table 13) constitutes the risk score for each impact (Table 14 and 15.) Below, (Table 12) the municipal concerns were assessed against five consequence criteria: public safety, local economy and growth, community and lifestyle, environment and sustainability, and public administration.

Table 12. ICLEI Consequence scale

Consequence Rating	Criteria				
	Public Health and Safety (H)	Local Economy and growth ($)	Community and lifestyle (C)	Environment and sustainability (E)	Public Administration (A)
Catastrophic	Large number of serious injuries or loss of life	Regional decline leading to widespread business failure, loss of employment and hardship	The region would be seen as very unattractive, moribund and unable to support community	Major widespread loss of environmental amenity and progressive irrecoverable environmental damage	Public Administration would fall into decay and cease to be effective
	5	5	5	5	5
Major	Isolated instances of serious injuries or loss of life	Regional stagnation such that businesses are unable to thrive and employment does not keep pace with population growth	Severe and widespread decline in services and quality of life within the community	Severe loss of environmental amenity and a danger of continuing environmental damage	Public Administration would struggle to remain effective and would be seen to be in danger of failing completely
	4	4	4	4	4
Moderate	Small number of injuries	Significant general reduction in economic performance relative to current forecasts	General appreciable decline in services	Isolated but significant instances of environmental damage that might be reversed with intensive efforts	Public Administration would be under severe pressure on several fronts
	3	3	3	3	3
Minor	Serious near misses or minor injuries	Individually significant but indicated areas of reduction in	Isolated but noticeable examples of decline in services	Minor instances of environmental damage that could be reversed	Isolated instances of public administration

		economic performance relative to current forecasts			being under severe pressure
	2	2	2	2	2
Negligible	Appearance of threat but no actual harm	Minor shortfall relative to current forecasts	There would be minor areas in which the region was unable to maintain its current services	No environmental damage	There would be minor instances of public administration being under more than usual stress but it could be managed
	1	1	1	1	1

Table 13 below, H refers to Public Health and Safety, $ to Local Economy and Growth, C to Community and Lifestyle, E to Environment and Sustainability, A to Public Administration while = refers to the total numerical value of all consequence ratings.

Table 13. Consequence Evaluation

Municipal Concerns																		
	Florenceville-Bristol						Hartland						Woodstock					
	H	$	C	E	A	=	H	$	C	E	A	=	H	$	C	E	A	=
Access to well house cut off													1	4	4	1	4	14
Water delivery lines impacted							1	2	3	2	3	11	1	2	3	2	3	11
Possible well field contamination							4	3	4	3	4	18	4	3	4	3	4	18
Possible overflows into river	2	1	1	2	1	7	2	1	1	2	1	7						
Basement Back-ups							2	2	2	2	3	11						
Flooded routes - Delayed pick up	1	1	1	1	1	5												
Flooded routes - Immediate fixes necessary	2	2	3	2	2	11							2	2	3	2	2	11
Flooded routes - Change in travel routes	2	2	3	1	1	9												
Flooded routes - Longer travel time	2	2	2	1	1	8	3	2	1	1	1	8						
Land saturated																		
Homes flooded							2	1	1	2	3	9	2	1	1	2	3	9
Delayed response	4	1	2	1	1	9	4	1	2	1	1	9						
Power outages	4	3	2	1	3	13	4	3	3	1	3	14	4	3	3	1	3	13
Telecommunications down	3	2	2	1	3	11							2	2	3	1	3	10
Usage of staff outside of mandate	2	1	2	1	2	8												
Delayed emergency response	4	1	2	1	2	10	4	1	2	1	2	10						
Assets damaged or lost	2	2	2	2	2	10	2	2	2	2	2	10						
Delays in seasonal activities																		
Businesses impacted by flooding	1	2	3	3	1	10	1	2	3	1	1	8	2	2	2	3	2	11
Increases in ice jam flooding							2	2	2	3	3	12	2	2	2	3	3	12
Planting/Harvesting season impacted	1	3	2	2	1	9												
Forestry operations impacted	1	3	2	2	1	9												

5.1.6 Risk Scores

Risk is the combination of an event's likelihood and its consequences – risk therefore equals the probability of a climate hazard multiplied by the consequence of that event. By assigning each municipal concern a rating for each consequence criteria, and then multiplying that score by the likelihood, each concern was then given a risk score on a scale of 1-100. Those scores fell in ICLEI – defined general risk categories (Table 9) and were ranked accordingly (Table 9a.).

Table 14. ICLEI-defined general risk categories

Very Low	Low	Med. Low	Medium	Med. High	High	Very High	Extreme
5 - 20	21 - 35	36 - 50	51 - 65	66 - 80	81 - 96	96 - 110	111 - 125

Table 15. Assignment of ICLEI Risk value by multiplying Likelihood x Consequence

	FLORENCEVILLE - BRISTOL			HARTLAND			WOODSTOCK		
	Likelihood	Conseq	Risk	Likelihood	Conseq	Risk	Likelihood	Conseq	Risk
Access to well house cut off							3	14	42
Water delivery lines impacted				4	11	44	3	11	33
Possible well field contamination				4	18	72	3	18	54
Possible overflows into river	3	7	21	4	7	28			
Basement Back-ups				5	11	55			
Flooded routes - Delayed pick up	3	5	15						
Flooded routes - Immediate fixes necessary	3	11	33				3	11	33
Flooded routes - Change in travel routes	3	9	27						
Flooded routes - Longer travel time	3	8	24	4	8	32			
Homes flooded				4	9	36	2	9	18
Delayed response	3	9	27	4	9	36			
Power outages	4	13	49	5	14	70	5	13	65
Telecomms down	4	11	44				5	10	50
Usage of staff outside of mandate	4	8	32						
Delayed emergency response	4	10	40	3	10	30			
Assets damaged or lost	3	10	30	3	10	30			
Businesses impacted by flooding	3	10	30	2	8	19	4	11	44
Increases in ice jam flooding				4	12	48	4	12	48
Planting/Harvesting season impacted	3	9	27						
Forestry operations impacted	3	9	27						

Based on the ICLEI methodology, risk is prioritized across the municipalities as follows:

Florenceville – Bristol's

11. Power Outages
12. Telecommunications down
13. Delayed emergency response
14. Flooded routes – immediate fixes necessary
15. Use of staff outside of mandate
16. Assets damaged or lost and businesses impacted by flooding
17. Flooded routes – change in travel routes and Planting\harvesting season impacted and Forestry operations impacted
18. Flooded routes – longer travel times
19. Possible sewage overflows into river
20. Flooded routes – delayed pick up of solid waste

In Hartland, prioritization is as follows;

10. Possible contamination of well field
11. Power outages
12. Basement back ups
13. Increases in ice jam flooding
14. Water delivery lines impacted
15. Homes flooded and Delayed response in emergency management
16. Delayed emergency response and Assets lost or damaged
17. Possible sewage overflows into river
18. Businesses impacted by flooding

In Woodstock, prioritization is as follows;

8. Power Outages
9. Possible well field contamination
10. Telecommunications down
11. Increases in ice jam flooding
12. Businesses impacted by flooding
13. Access to well-house cut off
14. Water delivery lines impacted and Flooded routes – immediate fixes necessary

Following the assessment of risk, a conversation was started about who lost and gained in the community during these incidents. Topics included what resources, skills and social elements helped to reduce the community's vulnerability as well as how these resources, skills and elements might be improved upon to reduce risk.

In these communities no specific vulnerable groups were identified, recognizing that the communities as a whole experience hardships during impacts, various groups, in various ways, for example seniors may experience stress related to safety and travel and experience social isolation; while families may experience stress related to extra expenses because of childcare and or increased fuel bills.

Local public works departments and their skilled labour have aided the regions in reducing potential impacts, as well as mitigating those that do indeed take place. The fire departments as well as the province's

Department of Transportation workers have also been on the front lines, contributing to the reduction of harm.

Increased coordination with NB Power and the province's Emergency Measures were identified as actions which could contribute to the improvement of risk categories as well as preventative actions such as:

- Municipal infrastructure
    - locating new water sources – Woodstock.
    - relocation of lagoon - Hartland (reinforcement has already been completed in Florenceville-Bristol in a few instances).
    - dredging – specific suggestion by Hartland, although could be useful throughout the communities.
    - building flood barriers/berms – specific suggestions by Woodstock, although could be useful throughout the communities.
- Municipalities ensuring they have back up power as well as provision of community charging stations.
- Further developing the Quantity of Leadership Pool.
- Nurturing Voluntary Organizations, and participation at Community Events as they are current assets that can be built upon for increased community resilience building, and improvement regarding neighbours knowing/helping neighbours.
- Considering wildlife resources/habitat – including soils in all land use planning decisions. Arrangements that can benefit the wildlife habitat may also benefit the community and the economy.
- Further developing bridging and linking social capital to aid in:
    - the coordination and timing of mediation actions,
    - awareness regarding provincial action on its newly developing flood strategy,
    - the awareness regarding financial aid,
    - awareness regarding the province, non-profit organizations and/or academia's involvement in forecasting and analyzing ice jam-related flood events, and anticipating the potential for increased risks as a result of a changing climate.

6 NEXT STEPS

Next steps for this region include the presentation of this review to the communities. With the original working group, and the participation of the Regional Service Commission, the group should work to further expand the climate change adaptation team and prepare and encourage the involved communities to further engage, possibly through the passing of a council resolution and community charter on climate change. The group should also work to establish an adaptation vision and objectives and set goals to identify options and actions, possible drivers and constraints of actions, while determining appropriate baseline and indicator data. ICLEI milestone 3 then encourages examining financing and budget options to implement the actions as well as the development of an implementation schedule, followed by the creation and launch of an action plan. This effort has allowed the region to leap forward on the adaptation front and brought new science and understanding to climate adaptation within a freshwater context in New Brunswick. Maintaining this momentum and the community involvement and support for it is imperative to long-term success on climate change at the local level. WWF Canada and other partners are keen to continue to encourage and support these efforts and looks forward to continued involvement in this region and elsewhere, in support of a healthy and resilient St. John River.

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8 APPENDIX A

Flood History as Derived from Government of New Brunswick's Flood History Database, Summarized and Specific to the Study Area					
Start Date	End Date	Cause		Magnitude	Description
3/20/1846	4/5/1846	Heavy Rain, Snowmelt	Melting of a heavy snow accumulation plus heavy rain for a week beginning March 13. There may have been some ice jams. The event has been referred to as the "Great Freshet" of 1846.	Ice began running at Grand Falls on March 25. At Presque Isle, the water level rose 20 feet in a short time. Keswick Island was under 12 feet of water.	On the tributaries between Woodstock and Fredericton, all bridges were taken out except those at Eel River and Sullivan's Creek.
4/25/1887	5/14/1887	Ice Jam, Heavy Rain, Snowmelt	Ice jams, melting of a heavy snow accumulation, heavy rain from April 29 to April 30 in the upper and middle portions of the Saint John River Basin	Upstream of Woodstock, the main railway line was washed out and railway communications with the west were suspended from May 2 to May 13. Lowlands in the Woodstock area were flooded. Nearly all bridges along the Saint John River were either damaged or carried away. At Woodstock, buildings on low lying land were carried away by flood waters.	On April 26, the ice began running above Andover. A serious jam formed six mile upstream of Woodstock. The jam released the same day and caused water to rise five feet [approximately 1.5m] that afternoon but no serious damage occurred. At Woodstock, the river peaked around May 6 or 7th. It then subsided about two feet [0.6m] between May 7th and 8th, and then rose a foot [0.3m] by May 10th before finally receding.
4/7/1901	4/12/1901	Ice Jam, Heavy Rain		At Woodstock, the damage to the sawmill was estimated to be about $15,000 while the loss of logs was estimated to be in the order of $25,000.	The ice began running on April 7. This was reported to be the earliest since 1846. A mill on the Meduxnekeag River was swept away. The Meduxnekeag River also took out a mill dam and swept away one span of the railway bridge at Woodstock.
3/17/1902	3/23/1902	Ice Jam, Mild Weather, Heavy Rain	Unusually early break up due to high temperatures, heavy rains in the southern portion of the Province lasting about 40 hours, and ice jams.	An ice jam at Hartland caused water to reach the highest point recorded in 37 years.	This was reported to be one of the earliest spring breakups in history. Opening of the Saint John River for navigation was the earliest on record, exceeding the previous record set on April 2, 1862. A severe ice jam at Hartland lasted two days. The water rose to a height at which it covered the walkway of the bridge. The lower street was completely under water and the basements of stores along Main Street were inundated. The contents, mainly general merchandise, were ruined. The Keith and Plumber Cheese Factory was swept off its foundation. The Shaw and Estys Mill [about 1.6km], a mile below Hartland, was also moved from its foundation. Ice jams occurred at Newburg Junction (north of Woodstock) at Hawkshaw and from Bear Island to Springhill. These ice jams backed up water flooding the Barony and the road to Woodstock Crossing, destroying the Norton Dale Bridge.

8/8/1912	8/14/1912	Heavy Rain	The Dominion Meteorological Bureau at the University of New Brunswick reported that during the month of July there were 15 rainy days. A total precipitation of 4.43 inches [113 mm] was recorded during this period as compared with 3.52 inches [89 mm] in July, 1911. During the month of August, there had been eight rainy days to date and a total precipitation of 2.77 inches [70 mm]. The heaviest rainfall occurred on Saturday, August 10, which measured 1.33 inches [33 mm].		Saint John River Basin: Bridges, culverts and railroads were washed out in the vicinity of Perth, Hartland, Woodstock and Blissville. C.P.R. freight trains north were cancelled and all passenger trains were running late. Considerable damage resulted to crops in various parts of the Province. The C.P.R. railway bridge, across the Shikatehawk Stream, was badly damaged. The dam at Lockhart's Mill, Bristol, had broken. A large quantity of lumber was lost. About 200 rafts belonging to the Peel Lumber Company and B. S. Smith had also gone adrift. Another C.P.R. washout had occurred between Newburg Junction and Hartland. At Woodstock, the Meduxnekeag Creek had risen to flood the interval destroying the hay crops. The Lake Company's Power Plant was threatened and the Meduxnekeag Bridge was in danger. A large warehouse used by the Frost and Wood Machinery Company, at the south end of the bridge, was being undermined. About 0.5 million feet [1 177 m3] of logs were jammed in the Meduxnekeag Creek.
4/6/1920	4/10/1920	Ice Jam, Mild Weather, Heavy Rain	Rain, melting snow and some ice jams	The ice in the Saint John River at Hartland was reported to be in the order of two feet thick. Local residents stated that "a greater depth of snow than had been known for years" was on the ground prior to the thaw. The ice run was said "to be the heaviest ever witnessed at Hartland". When the ice jammed downstream of the town, water levels were stated "to have risen six feet in less than 10 minutes". The ice run which followed was reported to be moving at 15 miles [24 km] per hour.	At Hartland, the rain was reported to have begun during the evening of April 5, and continued throughout the night. The river was said to have risen rapidly and by 9:30 a.m. on April 6, the ice began to move and jammed a short distance below the town. The rapid rise in water levels resulted in several families being forced from their homes, the evacuation of livestock and damaged stock in the basements of some stores. These flood conditions were reported to have lasted a very short period of time as the jam broke under its own pressure. The ice run pounded the piers of the new bridge for a three hour period, destroying the two western-most spans. As a result of the bridge loss, a steam ferry was put into operation at Simonds. It was anticipated that temporary spans would be installed and traffic would resume on the structure by May 15. Another ice jam was reported to have formed at the Hawkshaw Bridge. The debris from the Hartland Bridge was also reported to be piled up on this jam.
4/1/1921	4/30/1921	Ice jam, Freshet	Spring freshet with some ice jams		The covered bridge at Hartland was lifted from its piers by rising water and ice.

6/17/1922	6/25/1922	Heavy Rain	Heavy rainfall continued for nearly six days in northern New Brunswick. Logs released from broken booms and dams increased the damage somewhat.	On the main stem of the Saint John River, the level rose about 10 feet [3.0 m] from June 18 to June 24 at Fredericton. It was reported to have peaked at 19 feet [5.8 m] above summer level. The damage was confined almost entirely to the northern portion of the Province. Lumber was swept from booms and bridges and houses were swept away by the force of the current. Along the lower reach of the river, crops of hay and other produce were destroyed. Newspapers reported damage totalling $1 000 000 (most of the damage within New Brunswick was in the Saint John River Basin). This included losses to bridges, highways, railways, crops and agricultural lands. The New Brunswick Minister of Public Works estimated losses of $150 000 to $200 000 to the provincial highway system, and, in another account, $75 000 damage to provincial bridges. The Hayden Lumber Company at Woodstock lost logs valued at $4 000.	Water covered railway lines throughout most of the Province, mainly the lines belonging to the C.P.R. The flood was particularly high on the Tobique and Becaguimec rivers. Bridges were taken out on the Becaguimec, on the Little Shikatehawk near Bristol, along Coldstream, a tributary of the Becaguimec River, and at Hartland. Highway and railway damage was reported to be extensive between Hartland and Woodstock. Sawmills were destroyed on the Becaguimec River. Strawberry crops and gardens were lost in the Woodstock area. The flood conditions on the Meduxnekeag River forced the mills and power plant to close down their operations.
4/29/1923	5/9/1923	Ice jam, Heavy Rain, Snowmelt, Mild Weather	Snowmelt combined with heavy rain and warm temperatures from April 28 to April 30. Some ice jams as well as log jams were reported.	A rainfall of 3.39 inches [86.1 mm] was recorded at Fredericton. The flood rose rapidly on the tributaries and the Upper Saint John River to peak on or about April 30. At Hartland, the level was reported to be seven inches [178 mm] higher than in 1887. At the time of the flood, the provincial Public Works Department estimated $450 000 damage to roads and bridges within the Province. The public accounts for 1923 and 1924 show expenditures on bridges, as a result of the 1923 freshet, totalling about $380 000 ($252 000 ordinary bridge expenditures and about $128 000 permanent bridge expenditures). About one-half of these expenditures were incurred in the Saint John River Basin. The Provincial Bridge Department records indicate 57 bridges were damaged or destroyed in the Province. The railways sustained heavy damages during this flood. Most lines in the Province were impassible for periods varying from two days to a week.	This flood was significant in all parts of the Province. In the Saint John River Basin, small dams were lost on the Oromocto, Meduxnekeag, Allagash and Kennebecasis rivers. Bridges, mills and logs were lost all along the Saint John River and its tributaries. A railway bridge was partially destroyed at Florenceville. Bridges at Shikatehawk near Bristol and Florenceville were destroyed. A bridge, grist mill and planing mill at Boundary Line were swept down the Presque Isle River to Centreville. At Hartland, one house was completely turned over and other buildings were carried away. The town was without water or lights for about six days. Bridges were lost in the Meduxnekeag River basin: one on the North Branch, one on the South Branch and a third at Woodstock. At Woodstock, a portion of the power dam went out and all buildings along the river bank were more or less damaged. At Grafton, opposite Woodstock on the Saint John River, the main road was inundated and several buildings were partially submerged.
5/5/1926	5/7/1926	Heavy Rain, Mild Weather, Snowmelt	Snowmelt (due to warm weather) accompanied by rain		At Woodstock, riverfront properties were inundated to some extent.

4/7/1932	4/11/1932	Ice Jam, Mild Weather, Snowmelt	Snowmelt (due to mild temperature), ice breakup and ice jams.	According to records taken at the Fredericton Pumping Station, the Saint John River rose some 16 feet [4.9 m] following the ice jamming.	As a result of the spring thaw, several ice jams caused minor flooding throughout the Saint John River Basin. Most of the resultant damage was reported from the Fredericton area. An ice jam had formed at Bath during the winter, and the spring freshet caused some flooding in this area until it was breached. Another jam was reported at the bridge in Florenceville. This ice jam broke under its own pressure shortly after being formed. A huge ice jam was also reported below Hartland. At Woodstock, ice damaged some timber supports and carried others away on the approaches to Island Park.
10/17/1932	10/30/1932	Heavy Rain	Severe fall rainstorms lasting three days.	The flood damage reported to have occurred was to roads and railways.	At Woodstock, the Saint John and Meduxnekeag rivers were running at peak freshet height. The Fredericton to Woodstock highway was inundated at several points. Damage occurred principally at Pokiok, Meductic and the Barony.
5/4/1933	5/6/1933	Ice jam, Snowmelt, Heavy Rain	Heavy rains and melting snow throughout New Brunswick and Eastern Quebec, and possibly ice jams	A new freshet level was set at Woodstock, which apparently was the highest since 1923.	Flood conditions on the Saint John River existed at Fort Kent, Edmundston, Hartland and Woodstock. High flows were recorded in the upper portion of the Saint John River Basin. At Hartland, the lower flats were badly inundated, surrounding a home and several outbuildings. The mill was closed when it became inundated. At Woodstock, the road to Island Park was inundated.
4/16/1934	4/24/1934	Ice jam, Snowmelt, Heavy Rain	Continuous rainfall for several days, with snowmelt and ice jams.	At Woodstock, water levels were the highest since 1923. At least a million feet of lumber was lost in the Grand Falls and Woodstock areas. Railway schedules were disrupted in several areas.	In the Saint John River Basin, the areas most affected by this flood were in Sunbury and York counties. Washouts and inundated sections of railway lines and highways disrupted rail and highway traffic throughout the Saint John River Valley. At Woodstock, the Island Park Road was damaged by floating ice and debris. The Exhibition Building was partially submerged. The highway at Grafton was inundated.
1/9/1935	1/12/1935	Ice Jam, Mild Weather, Heavy Rain	Two days of snow, sleet and rain. The rainfall totaled about five inches [125 mm] at Saint John. Some ice jams were created by the record breaking thaw		Woodstock was impacted
3/16/1936	3/25/1936	Ice jam, Heavy Rain, Mild Weather	High temperatures with some rainfall for two days caused the unusually early spring breakup. Ice jams resulted in most parts of the Province	In the Saint John River Valley, significant damage was caused by the ice jams and floating blocks of ice, which were reported to be 16 to 18 inches [0.41 m to 0.46 m] thick and 50 feet2 [approx. 15 m] long. Stages at Indiantown and Woodstock were reported to have reached those of 1934.	Two dams went out on the Meduxnekeag River. At Woodstock, houses on the interval had cellars flooded and in some cases the water was over the lower floor. At Grafton, the main road was inundated and the small bridge over Wright's Brook was submerged.

5/10/1939	5/14/1939	Freshet	General spring freshet.	At Woodstock, the river reached the highest level since the flood years of 1923 and 1936.	In the Saint John River Basin, the highways were inundated, the trains were halted and the mills ceased operation due to the high water. The main highway between Hartland and Florenceville was inundated at Buckwheat Bridge. In Hartland, several cellars were flooded and one family was forced to evacuate their home.
4/30/1947	5/10/1947	Heavy Rain, Snowmelt, Mild Weather	Heavy rains, mild temperatures and snowmelt.	The stage was reported to be the highest since 1923 at Grand Falls, Hartland and Woodstock. Two men were killed in a train wreck near Bristol as a result of the track being undermined by the Saint John River.	Highway #2 was washed out at Muniac and between Florenceville and Andover. Near Bristol, a C.P.R. freight train was wrecked when the roadbed caved in as a result of undermining by the Saint John River. At Buckwheat Bridge, three miles [4.8 km] south of Florenceville, about 18 inches [0.46 m] of water was reported to be over the highway. Several other sections of Highway #2 were inundated. At Hartland, a few homes were surrounded by water and in the business section, water lapped the rear of the blocks on the west side of Main Street. At Woodstock, the Meduxnekeag River overflowed its banks, inundating the surrounding interval land. The upper end of River Street was flooded. Cellars of houses on the interval were full of water and in some cases the freshet had invaded the main floor of others. The front access to houses on Bridge Street was cut off by the floodwaters. The approach road to Island Park was inundated. At Grafton, the main road to Southampton was submerged at the mouth of Wright's Brook.
4/20/1950	4/24/1950	Ice Jam, Freshet, Heavy Rain	Heavy rains coinciding with spring breakup while the frost was still in the ground. Some ice jams	The rain was caused by a low pressure area which moved in from the Great Lakes region. Heavy ice runs occurred, with ice cakes reported to be two feet [0.6 m] thick. Bridges were damaged at Florenceville. : At the Dominion Experimental Station, Fredericton, a rainfall of 3.11 inches [79.0 mm] was recorded. At Fredericton, the river reached an elevation of 22.1 feet [6.74 m], which was estimated 20.8 feet [6.34 m] above the summer low.	Heavy rain fell during the period from April 20 to April 21. Bridges, rail lines and roads sustained the greatest damage. Newspaper reports assessed the damage at one million dollars or more in New Brunswick. Probably one-half of the overall damage was in the Saint John River Basin.
9/11/1954	9/13/1954	Heavy Rain, Wind	Heavy rainfall associated with Hurricane Edna.	At the Tobique Power Plant, a rainfall of four inches [approx. 100mm] was recorded. The flood on the Meduxnekeag and Nashwaak rivers was said "to be the highest since 1923".	In Woodstock, the Meduxnekeag River was on the rampage, flooding homes, business establishments and streets. A covered bridge at Weston, on the North Branch Meduxnedeag, was carried out; another span was damaged at Brigg's Mill when the dam broke. Two sawmills were swept away by the Meduxnekeag River and many logs were lost. Some cattle were marooned and had to be rescued by boat and barge. The business establishments located on Main Street sustained minor damage. River Street was completely inundated and many cellars were flooded in the community. One

					family was forced to move their belongings to the upper floor of their home. A bridge across the Becaguimec River, on Highway #24 at Cloverdale, was carried away.
4/24/1958	4/30/1958	Heavy Rain, Snowmelt		The flood level at Fredericton reached 24.95 feet [7.605m] on April 25. Peak (daily mean) discharge at Pokiok was 277 000 cfs [7 844m3/s]. Discharge at Beechwood was reported to be 234 000 cfs [6 626m3/s]as compared to the previous record of 232 000 [6 569m3/s] set in 1923.	Flood conditions prevailed over most of the Saint John, Restigouche and Miramichi River basins. Most transportation was severely disrupted because of the submerged highways and railways. The C.P.R. line was submerged at three points between Perth and Plaster Rock to a depth of 12 to 18 inches [approx. 0.3m to 0.45m]. Basement flooding also occurred at Perth and Andover. A bridge across the Becaguimec River, at Coverdale east of Hartland, was submerged. At Woodstock, the approach to Island Park and the Park itself were submerged, and buildings were moved from their foundation. Some people were evacuated from their homes in Woodstock. The Grafton area, near Woodstock, was also severely affected by the flooding.
5/8/1961	5/20/1961	Snowmelt, Mild Weather		On the Allagash and Fish rivers and on the Saint John River at Fort Kent, the highest levels in 30 years were recorded. At Pokiok, the maximum daily mean discharge was 241 000 cfs [6 824m3/s], and the stage at Fredericton reached a peak elevation of about 23.9 feet [7.29m] on May 16.	The most serious flooding conditions existed in the upper part of the Saint John River Basin, the Nashwaak Valley and the Miramichi River Basin where snow accumulations were the heaviest. In the Saint John River Basin, proceeding downstream, the relative magnitude of the flood gradually decreased as snow accumulation in the lower part of the basin was closer to normal.]. Two thousand cords of pulpwood escaped from a log boom at Upper Kent and were spread over the low lying area below Fredericton. Highway 2 was closed due to flooding between Florenceville and Hartland. At Hartland, families were evacuated from their homes. On Main Street, one house was totally isolated and the water lapped the rear of all remaining buildings on the street. At Woodstock, minor damage occurred at Island Park.
5/25/1961	5/31/1961	Heavy Rain	A severe extra-tropical storm caused rainfall of approximately four inches [102mm] over most of the Saint John River Basin below Grand Falls.	The Tobique River was reported to be at its highest level since 1922. The Shikatehawk Stream at Bristol was said to be at its highest level in 15 years. No information is available on losses by the C.N.R. However, newspapers reported a considerable washout of track in Carleton County, along the Nashwaak River and in the Miramichi River Basin.	Because of the pattern of rainfall produced by the storm, serious flooding conditions occurred on the Nashwaak and Miramichi rivers. In Carleton, Victoria and Madawaska counties, the damage was restricted to highways and farms. In Woodstock, Water Street was inundated and closed to traffic.

3/1/1968	3/31/1968	Ice Jam, Snow Melt, Heavy Rain		At Hartland, it was reported that similar flood levels had occurred in 1953. One store in Hartland was said to have sustained about $7 000 worth of damage. At Hartland, flood damages totalling $17 000 to $18 000 were reported by the Town Clerk.	In the Saint John River Basin, an ice jam near Florenceville caused water to back up over the highway near Buckwheat Bridge. The water intake to the McCains Food Processing Plant was blocked by ice, forcing the cancellation of production. In Hartland, an ice jam caused flooding of homes and business establishments. The pumping station was put out of commission when ice destroyed the main transformer there. Telephone and electrical services were disrupted in other areas due to the destruction of lines. The southern highway approach to the town was blocked by water for a period of time. Several homes had flooded basements and two families were evacuated from their homes by boat when water reached a depth of 14 inches [approx. 355mm] over the main floor. The business establishments were hard hit.
5/11/1969	5/13/1969	Freshet		At Hartland, a level two feet [0.6m] below that of 1968 was reached. At Woodstock, the Mactaquac headpond peaked at 133 feet [40.5m].	Saint John River Basin: Flood conditions prevailed over the upper portion of the Saint John River Basin. In New Brunswick, at Edmundston, the river reached a level which was 16 feet [4.9m] above normal. Floodwater also caused damage at Ste. Anne-de-Madawaska, Bristol and at Grand Falls.

2/2/1970	2/6/1970	Ice jam, Heavy Rain, Mild Weather	Very low temperatures and abnormally low snowfall caused thick and hard ice cover on the rivers and lakes during the winter of 1969/70. From February 2 to the 4th, precipitation upwards of four inches, and unseasonably high temperatures occurred. About 3.7 inches [93.43mm] of rain fell on central New Brunswick, followed by two inches of snow. The storm was accompanied by winds gusting as high as 70 miles per hour [113.4km/h]. Following the precipitation, the ice-packed streams started to break up on February 3 or 4th and by the morning of the 5th, ice flows were rushing down the Meduxnekeag, Nashwaak, Oromocto, Keswick, Miramichi and Magaguadavic rivers.	The maximum daily mean discharge of 179 000 cfs at Mactaquac and maximum stage of 20.6 feet reached at Fredericton are both around the average levels reached during spring freshet.	Highways sustained considerable damages as well as being impassable for several days at many points. Telephone and power services were also disrupted in several areas. Farmers reported excessive losses of livestock, barns and equipment. Homes and cottages along the rivers were either damaged or lifted from their foundations. The C.N.R. and C.P.R. were plagued with water and ice damage. According to the Department of Public Works, Supplementary Report, 32 major structures were completely destroyed. An additional 124 structures received varying amounts of damage. Saint John River Basin: In the Saint John River Basin, damage occurred at the fish hatchery at Florenceville when a portion of the storage dam was washed out. A small stream near Bristol overflowed and demolished six cabins at a church summer camp. On the Meduxnekeag River, eight miles above Woodstock, floodwaters and ice destroyed two homes and a bridge.
7/3/1973	7/4/1973	Heavy Rain		About two inches [51mm] of rains was reported to have fallen in about a one-half hour period.	Along the Trans Canada Highway from Woodstock north, cultivated potato fields were eroded, and in several places, culverts were blocked allowing water to run over the road. During the storm, traffic was reported to be at a standstill on the Trans Canada Highway. Northern Carleton County was reported to be the hardest hit area. In West Florenceville, damage was extensive as culverts could not cope with the heavy runoff. Two houses and a mobile home were reported as being inundated. The west end of the Florenceville bridge was cut off by water and another road in the area was washed out. Electrical service was disrupted in the area for several hours as a pole had been washed out and other shortages occurred.

3/31/1976	4/5/1976	Ice jam, Heavy Rain, Snowmelt, Mild Weather		At Woodstock, the flood levels were reported to have reached 142.6 feet [43.46 m] and this was said to be higher than that of 1923. In Hartland, the floodwaters were reported to have peaked late on April 1. Local residents were reported as saying "that the situation was much worse than in 1967 when a similar ice jam had developed". The river levels were reported to have raised 10 feet to 12 feet [approx. 3.0 m to 3.7 m] in a matter of a few hours as the ice jammed at Sproule Island. The estimated flood damages on the Saint John River, from just south of Woodstock to Green River, was expected to total more than $4 million. In Woodstock, about "a dozen homes and businesses had actual flood damages". The C.P.R. bridge was destroyed on April 2 and reconstruction was estimated to cost $700 000. The new structure was built four feet [1.2 m] higher than the old one, and five of the seven washed out spans from the old bridge were reused. In Hartland, a new well for the water supply was begun in February 1977, to prevent a recurrence of the contamination due to flooding. The total claim for flood damages was $28 000, which included $25 000 for the ice damage to the town's pumphouse. The town end of the covered bridge was reported to have dropped 12 inches [0.3 m].	Widespread flooding was reported along the Saint John River and its tributaries from just south of Woodstock north to Madawaska County, and in the Restigouche River Basin. The New Brunswick Electric Power Commission reported widespread damage to poles and transformer installations along many of the Province's rivers. In the Grafton area, a 12 000 volt line crossing the river was lost and their Branch Office suffered ice and water damage. At Woodstock, the railway bridge at the mouth of the Meduxnekeag River was destroyed by high water and ice. Near Bath, a freight train was derailed as a result of a washout, killing the brakeman. Rail lines were also inundated at other locations and some structures were threatened. At Bull's Creek south of Woodstock, the junction of the River Road and the Trans Canada Highway was inundated. A nearby home and business were said to be inundated, destroying thousand of dollars’ worth of antiques, 12 snowmobiles, a truck and accessories. At Woodstock, the high water and ice were reported to have taken their toll. Along Water Street, utility poles were smashed, leaving the power and phone lines in a tangled state, houses and businesses were inundated and damaged by ice. Heavy losses to goods and furnaces were reported. Basement flooding was reported at Feere's, Newnham and Slipp's pharmacies, the Regional Library office on King Street, the Coffee Shop, Monteith Motors and the provincial government offices in the Feldman Building. At Centennial Park, the boathouse and light poles were destroyed, and the pool and its buildings were inundated. The Centennial Fountain was swept away along with playground equipment. The old General Daries body shop was surrounded by water, the frozen Food Lockers and Stewart’s warehouse were heavily damaged by water and ice. The Curling Club was inundated and/or damaged by water and ice. A 10-inch water main on the underside of the highway bridge was destroyed by ice. The army and local residents supplied water to those who were without. An ice jam at the Grafton Bridge, just north of Woodstock, caused a seven foot difference in river level between there and one mile downstream. Several houses in the Grafton area were surrounded by water, and ice was reported over a portion of Route 105. A mud slide was reported to have partially blocked Highway #105 near Northampton. At Pembroke, a quarter mile section of railway was inundated and rail cars were set on the bridge for weight. At Hartland, a state of emergency was declared as high water and ice damaged the pumping station and

					polluted the drinking water. The problems began with an ice jam occurring on March 31, about a mile downstream of the town, and extending upstream of the Hugh John Flemming Bridge. The ice jam broke on April 1 leaving extensive water and ice damage. Approximately 20 properties received flood damages, which included businesses and residences along Main Street. About 12 persons were evacuated to a nearby motel. As a result of the water supply problems, the schools were forced to close. The Simmonds Road between Florenceville and Hartland was covered with water and ice for a while during the night of March 31. The Hartland Clothing and Hartland Furniture stores reported extensive damage to stock in the basements, and the United Baptist Church was inundated. The town engineer was reported as having evacuated his home and his garage was said to have been overturned by ice and water. Ice also piled up under the rail and highway bridges crossing the Becaguimec River.
4/29/1979	5/7/1979	During the latter part of April and the early part of May, extreme flood conditions occurred in most parts of the Province. These conditions were caused by rainfall combined with heavy snowmelt.		Saint John River Basin: Discharges for this event exceeded maximum of record, for four of the five hydrometric stations on the main stem of the Saint John River, above and including the gauge at Grand Falls. At hydrometric stations on a number of tributaries to the Saint John River above the Beechwood Dam, including the St. Francis, Green, Grand and Aroostook rivers also exceeded record discharges. Below the Beechwood Dam, steamflow on tributaries to the Saint John River peaked prior to the end of March. Despite this, streamflow as recorded at hydrometric stations on the main stem of the Saint John River below Beechwood Dam peaked on April 30.	During the winter of 1978-79, snowfall was about average throughout New Brunswick and in adjacent areas of Maine. However, above average snowfall was observed in northeastern New Brunswick and Quebec. The water equivalent of the snow pack at the end of April was slightly above normal in northern New Brunswick, and about 50% of normal in the southern portion of the Province. During the period of April 24 to May 7, mean temperatures were well above 0oC. On April 29, a storm system moved into Maine, Quebec and western New Brunswick resulting in precipitation varying from 10 to 22 millimetres in the northern part of the Saint John River Basin. Several major highways throughout the Province and, in particular, the Saint John River Basin, were closed as a result of the flooding for varying periods of time. At Hartland, reports of minor flooding were documented.
3/17/1980	3/18/1980	Heavy Rain			The provincial Emergency Measures Organization received reports of flooding from Woodstock, Boiestown, Pennfield, Burton, McAdam, Saint John and Fairvale.

2/2/1981	2/2/1981	Heavy Rain, Mild Weather, Snowmelt			Various sections of Route #105, between Grafton and Hartland, were covered with water and ice, and one section was washed out at Deep Brook. The washout at Deep Brook was reported to be approximately 25 feet [7.6 m] wide and 30 feet [9.1 m] deep. The C.P.R. rail line between the road and the river was blocked with earth in this area as well.
2/24/1981	2/27/1981	Ice Jam. Mild Weather, Heavy Rain		The breakup of the river was reported to be "one of the earliest on record". The main jam in the Hartland area was reported to consist of ice cakes 0.6 metres thick which were piled up to six metres high. One of the homes, evacuated at East Florenceville, was reported to have about four inches [approx. 100 mm] of water over the main floor. Two spans of the covered bridge were destroyed in 1920 when ice jammed and ripped out the old wooden piers. The piers were then replaced with concrete piers.	An ice jam was reported to be located near Aroostook, about 50 kilometres west of Florenceville. The ice jam was reported to be about three miles [approx.4.8 km] in length. In the Hartland area, three ice jams resulted in rising river levels and flooding in the low-lying areas. One ice jam was located west of the town, above the Hugh John Flemming Bridge, causing flooding in the area of Buckwheat Creek. The highway (Route 105) was closed to traffic when the road was inundated with 0.6 metres of water and ice. A portion of the road was washed out in this area. At least four East Florenceville families were forces to evacuate their homes due to floodwaters. Another jam occurred at the Hugh John Flemming Bridge, while the third jam had formed at the lower end of Sproll's Island (near Nixon Siding). The old McMullin Flat at the south end of Hartland was flooded with ice lying on the back lawns of houses in that area. The ice jams at Buckwheat Creek and the Hugh John Flemming Bridge had broke on their own.
1/11/1983	1/12/1983	Ice Jam, Mild Weather, Snowmelt, Heavy Rain		Temperatures reached 14 degree Celsius at Fredericton and just over 2.5 millimetres of rain was reported to have fallen. At Beechwood, 34 millimetres of rain was recorded.	Ice jams resulted in minor localized flooding on the Meduxnekeag River near Woodstock and the Saint John River near Hartland.
1/28/1986	1/29/1986	Ice Jam, Mild Weather, Snowmelt, Heavy Rain			On the Saint John River, an ice jam lodged at Lower Becaguimec Island, resulting in minor flooding in the Hartland area. Localized flooding was also reported along the Meduxnekeag River.
4/1/1986	4/4/1986	Ice Jam, Mild Weather, Snowmelt, Heavy Rain		In Simonds, some residents stated "the flood was the worst in 80 years".	A late-January thaw created antecedent conditions that were important contributing factors to floods on the Saint John and Nashwaak rivers in April 1986. Throughout much of New Brunswick, river flows increased gradually in late March as mild weather returned. Above normal daytime temperatures occurred at the end of March, causing a surge in snowmelt and runoff. Mild temperatures during the last two weeks of January, with rain on January 27, caused the breakup of the ice cover between Hartland and Florenceville. The broken ice formed an ice jam, which eventually came to rest two kilometres downstream of Hartland on Lower Becaguimec Island, on January 28. The ice jam caused a

					temporary increase in water levels, but no flooding. Temperatures dropped below freezing on and remained seasonably cool until late March. During this time the jam consolidated and solidified as the ice fragments froze together to a depth of approximately three to 3.6 metres. River flows increased gradually in late March as mild weather returned. Especially mild weather prevailed from March 26 to April 3, with rain on March 27. Discharges from the Beechwood Dam rose from 793 cubic metres per second on April 1 to 3172 cubic metres per second on April 4, in response to rapidly increasing inflows to the headpond. Early on April 2, broken ice above Stickney moved downstream, forming an ice jam that lodged temporarily at Lower Presque Isle. At noon, the jam (five kilometres in length) moved five kilometres further downstream, and came to rest with the toe [downstream end of the ice jam] at the upstream end of Upper Becaguimec Island. When the ice jam moved to Upper Becaguimec Island, located about two kilometres downstream of Simonds, the water level at Simonds increased suddenly from 47.09 metres to 48.52 metres at approximately 13:00 hrs. The water level gradually increased thereafter until 21:00 hours, then stabilized at approximately 49.7 metres until 13:00 hours, April 3. This was sufficient to cause overnight flooding of Route #103 near Simonds. On April 3, the discharge from Beechwood Dam increased gradually during the day, from 2747 cubic metres per second at 14:00 hours to 3 172 cubic metres per second at 20:00 hours. A surge of flow, which originated 38 kilometres upstream at Tinkers Dam on the Aroostook River. Although partially contained within the headpond of Beechwood Dam this surge caused further increases in the water level at Simonds where the ice jam was continuing to restrict the river's flow. At 18:22 hours, April 3, the water level peaked at 51.14 metres, causing heavy flooding in the Simonds area. It forced the evacuation of at least six families from their homes, and further flooded the highway, isolating a three to five kilometre stretch of Route #103 for a number of hours. Some of the evacuations were carried out using boats and a helicopter. On the opposite side of the river, Route #105 near Upper Brighton was flooded, and a few area residents reported water damage to their basements. Ice also damaged a number of utility poles; however interruptions to electrical and telephone services were minor. Between 21:00 hours and 22:00 hours on April 3, the ice jam at Upper Becaguimec Island released, causing the water level at Simonds to drop by

						2.3 metres in less than an hour. The water level continued to decline, and by 01:00 hours, April 4, it was near normal, at 46.58 metres. The ice jam at Lower Becaguimec Island, which had formed in late January, was still present at the end of March. As river flows increased, water levels in Hartland rose higher than normal due to the channel restrictions caused by this ice jam. On April 1, the water level at Hartland was 45.50 metres for most of the day, then began to rise at a steadily increasing rate to 47.35 metres by 24:00 hours, April 2. The water level generally continued to increase, but at a reduced rate, and peaked at 48.01 metres at 21:50 hrs, on April 3. The water reached the underside of the road and railway bridges crossing the mouth of the Becaguimec Stream, and came to within approximately one metre of the underside of the Hartland covered bridge. The ice jam at Lower Becaguimec Island broke on April 3, causing the water level at Hartland to quickly fall 1.25 metres. The Hartland water level continued to decline, reaching 45.90 metres by the morning of April 4. Subsequent analysis of this flood revealed that, although ice jams frequently lodge at Upper Becaguimec Island, they do not usually remain in place as long as in this case. It is likely that the backwater created by the ice jam at Lower Becaguimec Island extended upstream, beyond Upper Becaguimec Island. This backwater probably allowed the ice jam at Upper Becaguimec Island to stay in place longer than normal, thus requiring a greater-than-normal river flow to dislodge it, and greatly aggravating flooding in the area. Ice jams also occurred in the Perth-Andover, Hartland and Woodstock areas of the Saint John River valley, but significant flooding only occurred at Simonds and Woodstock. The Woodstock area began to flood on April 4, shortly after the ice jam at Lower Becaguimec Island let go, causing ice to pile and jam from Newburg downstream to Lower Woodstock. The water level peaked during the early morning of April 4, closing Water Street in Woodstock. Ice caused slight damage to the fence behind the sewage treatment plant, and Centennial Park flooded.

4/1/1987	4/13/1987	Ice Jam, Mild Weather, Snowmelt, Heavy Rain		The effect of high spring flows was greatly magnified in many locations by the large backwaters created by the ice jams. Since much of the flooding was caused by ice jams, it is difficult to relate the magnitude of the flooding to river discharge and their return periods. Subsequent failure of the ice jams occasionally created very high instantaneous flows. Saint John River Basin: In Perth-Andover, water levels peaked at 79.3 metres on April 2, the highest on record. On April 2, following release of the ice jam at Upper Guisiguit Brook, the water level at Beechwood Dam increased by over three metres in less than 20 minutes, causing the dam to spill ice for the first time since the plant began operation in 1957. This surge at Beechwood resulted in discharges from the dam of approximately 5 300 cubic metres per second to 8 800 cubic metres per second between 09:00 hours and 10:30 hours. This represented a 65% increase in discharge in 90 minutes. The water level at Woodstock peaked at 43.9 metres on April 3, the highest on record.	During the winter of 1986-87, the total snowfall was significantly below normal in the north, and near normal in the south. However, early-March snowfalls and the absence of any mid-winter thaws contributed to an above normal snowpack in the southern parts of the basin by mid-March. High soil moisture and below normal temperatures in the late fall of 1986 limited infiltration of meltwater into the frozen soil, and no significant thaws occurred prior to March 17. Warm temperatures preceded the flood, with light to moderate rain falling on a heavy snowpack. The resulting floods peaked early in April. Though the rainfall and snowmelt were the primary causes of the high flows, much of the flooding and damages were caused by ice. Snowmelt was the major source of runoff for this event as compared to the 1979 flood, in which rainfall and snowmelt were almost equal contributors. The Saint John River Basin sustained the majority of the damage. Serious structural damage occurred in the Woodstock area. Above the Mactaquac Dam most damage was ice related. Saint John River, Beechwood to Mactaquac: Ice runs between Beechwood and Mactaquac began on March 30 with the formation of small ice jams at the TransCanada Highway bridge in Florenceville, and then later at Buckwheat Bridge. On March 31, the Beechwood Dam outflow increased, resulting in the dislodgement of the Buckwheat Bridge jam during the afternoon of March 31. At 15:45 hours, ice moved through Simonds and lodged at a location upstream of the Town of Hartland, causing the water level to gradually increase at Simonds. At 16:40 hours, the ice at Hartland started to move and stopped at Lower Becaguimec Island. By 17:00 hours, the water level at Hartland was reported to have risen 1.5 metres in 20 minutes. At 18:40 hours, the head of the Lower Becaguimec Island jam was observed at Simonds. Water levels continued to increase at Simonds, resulting in the flooding of Route #103 by 19:20 hours. Following the earlier movement of the Hartland jam, which stopped at Lower Becaguimec Island, the water level at Hartland continued to increase until 21:35 hours on March 31. Then the ice at Lower Becaguimec Island moved again, and the water level dropped. As the Hartland water level dropped, the water level at Simonds did not change, suggesting the existence of a secondary jam above Hartland, but below the Simonds gauge. Local consolidation of the jam at Lower Becaguimec Island then took place and the Hartland water level showed no significant change until 23:00 hours, when the water

					level started rising again, reaching a peak of 47.7 metres at 01:00 hours, April 1. At 01:20 hours, April 1, the water level at Simonds started to subside when the jams below Simonds and at Lower Becaguimec Island released. The water level at Woodstock rose rapidly while the level at Hartland dropped as the Lower Becaguimec Island jam moved. The jam stopped in the west (main) channel at the Sharps Island railroad bridge. By 11:00 hours, the water level at Hartland was rising again because of that jam. The jam in the west channel at Indian Island diverted a large amount of the river flow to the east (secondary) channel causing the undermining of one pier and the west abutment, and as a consequence, the collapse of two bridge spans occurred at about 11:15 hours. After the bridge failure, banks in the east channel eroded, and some ice from the jam in the west channel moved to the east channel. At noon on April 1, ice was lodged at the Woodstock pumping station and the water level behind the jam was rising. At 13:00 hours, the jam moved to lower Woodstock. As the ice released from the Beechwood headpond reached Simonds and Hartland, the water level in these areas increased to reach secondary peaks, at approximately 13:00 hours. When that ice arrived at the Bulls Creek jam, the Trans Canada Highway near Bulls Creek was innundated. At 13:45 hours, the jam at Bulls Creek released. At 16:35 hours, the ice was observed moving near Temple before it stopped at its final lodgement point at Sullivan Creek. When the Bulls Creek jam released, the water level at Woodstock dropped. At 22:00 hours, the Woodstock water level rose again because of the Sullivan Brook jam. On April 3, the water level continued to increase at Woodstock, forcing the closure of the Trans Canada Highway at Bulls Creek at 02:00 hours. Because of the Sullivan Brook jam, water levels rose once again until 11:00 hours. At 19:00 hours, the rising water level at Woodstock reached its maximum level of 43.9 metres, which was the highest on record. After 21:00 hours, it started to drop gradually.
4/6/1989	4/10/1989	Ice jam, Freshet			On April 7 the river ice cover began to break up and move in the Hartland - Woodstock area, causing ice jams to develop between Simonds and Peel, and near Hartland. An ice jam developed at the bridge between Woodstock and Grafton which flooded about 50 metres of the Canadian Pacific Railway line at Newburg Junction with 0.1 m to 0.2 m of water from April 8 to the 10th. High water levels were reported at Hartland and Simonds, but no flooding resulted. Some flooding

					occurred near Cloverdale on the North Becaguimec River on April 7 when an ice jam lodged at the Adair covered bridge. Water and ice floes overflowed on to the road, making it impassable, but no serious damage occurred. The Meduxnekeag River was reported to be near flood stage on April 1.
8/11/1990	8/12/1990	Heavy Rain		The Fredericton Daily Gleaner reported that 130 mm of rain fell during the rainstorm. Earlier estimates ranged from 100 mm to 200 mm of rainfall over time spans of four to twelve hours. In Houlton, Maine, the weather office recorded rainfalls of 42 mm and 43 mm on August 11 and 12, respectively.	Heavy rains caused severe flooding overnight in the Hartland and Woodstock areas. Local roads were badly damaged in many locations, forcing the closure of Routes 103, 104, 570 and several other smaller roads. Some road sections were restricted to one lane travel until washouts were repaired. Near Woodstock, there was a major washout of a Route 103 bridge over Lanes Creek. The bridge abutments at Bannon on Route 570 were severely eroded by high flows on Cold Stream. Middle Saint John River Basin: Hartland Area: In Hartland, some basements flooded at the lower end of town, and driveways on Rosedale Avenue were eroded. The Hartland covered bridge was closed for one hour after a washout occurred at the west entrance to the bridge. Some nearby sections of riverbank along the Saint John River were eroded. Some potato fields were damaged by the runoff, which washed potatoes into and down roadside ditches next to the fields.
4/6/1991	4/18/1991	Ice Jam, Freshet			Ice-jam-related flooding first occurred in the Florenceville area on April 6 and occurred at several locations until April 18. Grand Falls to Beechwood: On April 9, small ice jams were developing around Morrell, and ice cover was disappearing at the confluences of the Tobique and Aroostook rivers, located 11 km and six kilometres downstream of Morrell respectively. On April 10, there were major ice movements in the area which lead to the formation of an ice jam at the upstream end of Perth-Andover, causing increasing water levels on the Tobique, and Aroostook rivers. On April 11, the jam moved intermittently as the downstream ice cover broke up, eventually forming a five kilometre long ice jam lodged two kilometres above the Beechwood Dam. This jam caused no further problems, and eroded to two kilometres in length by April 18. Water levels in Perth-Andover peaked at 77.41metres at 20:30 hours, April 11. Beechwood to Mactaquac: The first significant ice jam began to develop in the Florenceville area on April 4 when ice on the Saint John River moved from the mouth of Shikatehawk Stream down to Florenceville. Further ice movements on April 5 created a one kilometre long ice jam, with the head [upstream] located about two

					kilometres below Florenceville bridge. By the morning of April 6, water levels had risen to within 1.0 m to1.2 m of the road. The jam moved approximately two kilometres further downstream at noon that day and stopped just upstream of the mouth of Big Presque Isle Stream. By the morning of April 7, water levels rose to within 0.6 metres of the road, and guard rails were preventing blocks of ice from spilling onto the road. From April 6 to the 7th, some ice had run out of the river downstream of the ice jam near the mouth of Big Presque Isle Stream, creating a 4.5 km "narrow" strip of open water extending from Upper Stickney (three kilometres downstream of the jam) to Lower Peel Island. Large open areas in the ice were also developing downstream in the Simonds and Hartland areas. At 21:00 hours, April 7, the ice jam by the mouth of Big Presque Isle Stream broke, and moved to the upstream end of Upper Becaguimec Island to form a jam 4.5 km in length, extending upstream to Peel Island. The water level at the Simonds gauge peaked overnight at 49.51 metres and was receding by the morning of April 8. Route 103 was flooded to a depth of 0.3 to 0.4 metres, over a section six to nine metres long on the morning of April 8. Floodwaters also inundated an aircraft hangar located next to the jam to a depth of 0.5 metres, and aircraft were removed from the hanger. Ice cover continued to deteriorate, forming numerous open areas downstream of the jam. By evening of April 8, there was only 0.8 km of ice separating two major open water stretches, one located immediately downstream of the jam, and the other in the Hartland area. At 02:50 hours, April 9, the ice jam moved down to Lower Becaguimec Island, and extended upstream five kilometres to a point 1.5 km above the Hugh John Flemming Bridge. The head of the jam was now located close to Upper Becaguimec Island, where the tail of the jam was previously lodged. Water levels in Hartland rose, and by 11:30 hours, April 9, the ice jam was six kilometres in length, with broken ice one to 2.4 metres below the bottom chord of the Hartland covered bridge. The water levels at 07:00 hours on April 10 were 47.78 metres and 48.84 metres at Hartland and Simonds respectively. Minor flooding was occurring, with water over sections of highway at Hartland and Simonds. By the morning of April 10, a three-kilometre open channel existed downstream of the jam at Lower Becaguimec Island. Later that day, the ice jam moved 12 km downstream to Sharpes Island near Woodstock, where the Grafton railroad bridge is located. The jam extended upstream 11 km, and was causing flooding

					over the road at Lower Hartland and Newburg. Ice was reported to be on the rails of the railroad bridge. The water level at Hartland quickly dropped to approximately 47.0 metres after the jam moved to Sharpes Island. On April 11, the jam moved six kilometres. It stopped two kilometres downstream of the mouth of the Meduxnekeag River, and extended upstream five kilometres. Water levels at Woodstock peaked at 42.84 m at 22:55 hours on April 11. By the morning of April 12, the water level had dropped to 41.77 m, and Front Street was flooded up to 0.15 m deep over a distance of about 100 m. Approximately 0.05 m of water was over the road at Newburg, and blocks of ice were scattered over a road at Grafton. The jam consolidated during the day, causing the water level to rise again to a maximum of 42.76 m at 16:44 hours. By 23:50 hours on April 12, the water level was 42.35 m, and the ice jam extended upriver only two kilometres. Water levels by Woodstock continued to drop gradually over the next few days, and on April 14 the remnants of the jam moved four kilometres downstream to Bulls Creek. No further flooding resulted from this ice jam.
11/11/1991	11/11/1991	Heavy Rain			The storm severely affected Nova Scotia, but caused almost no damage in New Brunswick. Over much of New Brunswick, rainfall approached 100 mm in 24 hours. More than six centimetres of snow fell in areas north of Woodstock and Miramichi.
4/11/1993	4/28/1993	Ice Jam, Freshet, Heavy Rain	Spring freshet and ice jams. Rain fell over the upper Saint John River Basin on April 11 and April 12. A reduced snow cover in December and January produced thicker and stronger ice cover on many rivers. On the Saint John River, ice was an average of 25 mm thicker than normal, and contained a higher proportion of blue ice.	By Woodstock, some ice chunks were two to three metres wide, and 0.5 metres thick. The town of Woodstock sustained damages in the order of $150 000. Flooding cut off the fresh water supply, shut down the sewage treatment plant, and closed schools and roads. Floods damaged playground equipment and metal guard rails. Woodstock council considered replacing metal guard rails with concrete traffic barriers along the banks of the Meduxnekeag River, as the concrete barriers would not be as prone to flood damage. Removable playground equipment was also considered as a way of reducing flood damages in future.	The major flooding was caused primarily by ice jams which occurred on the Saint John River between Edmundston and Woodstock, and its tributaries in the northwest area of New Brunswick. On April 11 the ice began to move and jam below Florenceville. An ice jam, initially two kilometres in length, moved intermittently throughout the day, causing high water levels and minor flooding at various locations on the river as it passed by. It stopped briefly at Buckwheat Brook, Stickney, and Hartland. At Simonds, the water level peaked at 47.23 metres at 16:30 hours. At 17:45 hours the ice jam lodged 2.5 km downstream of Deep Creek, causing some flooding of roads in the Hartland area. The Hartland water level rose until the jam released at 19:30 hours, reaching a maximum level of 45.79 metres. At 21:20 hours the jam lodged at Pine Island by Newburg Junction, and was five kilometres in length. Shortly after midnight on April 12, the ice jam moved 4.6 km, lodging at Grafton at 01:00 hours, where it remained until 05:20 hours. Then the jam passed by Woodstock, before lodging two kilometres downstream of the pumping

					station at 08:00 hours. After the jam dislodged from Grafton, the Woodstock water level increased approximately 4.5 metres, to a peak of 42.39 metres at 10:15 hours. A minor movement of the jam occurred at 09:10 hours, and a large channel opened below the jam, which extended two kilometres downstream by 11:00 hours. Centennial Park, Water Street in Woodstock and the Shore Road in Grafton were closed due to flooding. Ice was also clearing from the Meduxnekeag River, causing flooding of the New Brunswick Community College lower parking lot, near the river's mouth. Chunks of thick, blue ice were piled on either side of the moving channel. Some ice chunks were two to three metres wide, and 0.5 metres thick. Water levels declined little until 16:30 hours when the jam moved 1.8 km downstream, close to the settlement of Bulls Creek. Subsequently, water levels gradually increased again to about 42.3 metres. At 00:10 hours, April 13, the ice jam moved 0.6 km and lodged at the island by Bulls Creek. Subsequently, the Woodstock water level increased to the flood maximum of 43.13 metres at 07:30 hours. By 08:30 hours several channels were observed opening up below the ice jam, and the Woodstock water level began to drop slightly. At 14:00 hours April 13, the jam moved 8.5 km, stopping at Hillman from 15:30 hours to 20:09 hours, before moving another 7.6 km to its final resting point about two kilometres downstream of Meductic. At Woodstock water levels dropped substantially after the jam dislodged from the island at Bulls Creek at 14:00 hours. At 01:00 hours April 14, the water level had dropped to 41.5 metres.

4/14/1994	4/26/1994	Ice Jam, Freshet, Heavy Rain	Spring freshet and ice jams. An unusually cold winter formed thicker and stronger ice cover on most rivers. Ice jams and runs during the spring breakup were more severe and widespread than usual. Heavy rains on night of April 16 raised flows in the Saint John River to exceptionally high levels.	Flows in the upper Saint John River Basin began to surge on April 14, and peaked on April 17 after a heavy rain on the night of April 16. During the night of April 17, the water level at Bristol reached the top of the railway bridge spanning the Shikatehawk Stream. In Woodstock on April 16, the ice jam at the mouth of the Meduxnekeag River raised blocks of ice as high as the sides of the railroad bridge. Water Street, Centennial Park, and the New Brunswick Community College parking lot were flooded. The flooding associated with the spring freshet occurred over a shorter time span than normal. Ice jam related floods in the different river basins occurred over a span of about five days. Throughout Victoria County, road shoulders were damaged and there were several washouts. In Bristol, the basements of several homes and one business were flooded The ground floor of one house was flooded. In Hartland, the basements of several homes were flooded, and telephone poles were damaged along flooded sections of Route #105. In Woodstock and Perth-Andover, damages were relatively minor. In Woodstock, floods destroyed a section of fence in Centennial Park.	On the afternoon of April 14, an ice jam formed just upstream of Stickney. It broke without incident at 17:00 hours, then lodged at Lower Becaguimec Island until April 15. In Hartland, the ice jam caused flooding of portions of lower Main Street near the sewage lagoon. One of the town's fresh water wells was shut down. At 20:00 hours April 14, Route 105 was inundated near Lower Becaguimec Island, forcing spectators to abandon three vehicles trapped by fast rising floodwaters. The vehicles were almost completely submerged until floodwaters receded at about noon on April 15. About one metre of icy debris blocked the road until April 18. In Woodstock, ice in the Saint John River and the Meduxnekeag River began to move on April 15. By April 16, a large ice jam had formed at the mouth of Meduxnekeag River, causing the river to flood Water Street, Centennial Park, and the New Brunswick Community College parking lot. A section of fence at Centennial Park was destroyed. The jam was seven kilometres in length, and threatened the Woodstock pumping station. The ice jam broke late on the afternoon of April 16, and water levels receded. By April 18, the jam had moved downstream of Meductic, and by April 19, it was lodged at Barony, well inside the Mactaquac headpond. The jam had grown to 22 km in length, but was no longer a concern. On the afternoon of April 17, the opening of all nine spillway gates at Beechwood Dam created a surge of water and ice downstream of the dam which caused some flooding. The temporary surge of water, combined with high flows in the river, contributed to the flooding and closure of Route 105 in two locations: at Bristol, and around Buckwheat Brook about three kilometres downstream of Florenceville. The basements of several homes and one business in Bristol were flooded. The sewage lagoons at Bristol and Florenceville, located next to the Saint John River, were closely monitored for any flood related problems. During the night of April 17, the water level at Bristol reached as high as the top of the railway bridge spanning the Shikatehawk Stream. The Florenceville Village Park was flooded from the evening of April 17 to April 18.
1/16/1995	1/22/1995	Ice Jam, Mild Weather		No major flood damages were reported. A farmer in Blissville estimated he could lose 50% of his hay crop from winter kill, and that it could take two weeks to clear the driftwood from his fields.	Very mild temperatures occurred on January 15 and 16th, and rain fell on January 15 to the 17th. After January 16, temperatures declined to within a few degrees of freezing and weather remained overcast for the next week, with some precipitation continuing to fall. The mild weather allowed runoff from snowmelt and rain to continue. Flows increased greatly on many

					rivers, but only minor flooding occurred. Peak flows in the Saint John River Basin occurred between January 19 and January 22. A large ice jam formed on the Saint John River at Lower Becaguimec Island after much of the ice cover ran downstream of Beechwood Dam. The jam formed on April 18 and extended upstream of Hartland, surrounding the Hartland covered bridge with broken ice. Water levels rose to near flood level in Hartland.
1/25/1996	1/30/1996	Ice Jam, Mild Weather, Heavy Rain	Mild weather and heavy rain caused ice to run and jam at many locations in New Brunswick.	In almost all cases, the flooding caused little or no damage.	A jam lodged at Hartland, then moved to Woodstock and grew to eight kilometres in length. A four kilometre long jam formed near the mouth of the Meduxnekeag River.
2/25/1996	2/27/1996	Ice jam, Heavy Rain			On the Saint John River, ice jams occurred at Dickey (Maine), Connors, Baker Brook, Saint Basile, Morrell, Hartland, and Woodstock.
3/9/1998	3/14/1998	Ice Jam, Mild Weather, Snowmelt, Heavy Rain	An intense storm pushed a warm front through New Brunswick on March 9 causing heavy rain and rapid snowmelt.		Hartland Area: An ice jam, six kilometres in length, formed below Hartland. It caused localized flooding, closing Route #105 between Hartland and Woodstock. Total rainfall amounts reached were up to 67 mm in southern New Brunswick. Mild temperatures during the previous week had produced moderately elevated seasonal flows in many rivers. River flows and water levels increased rapidly overnight, causing wide spread flooding on March 10. By March 11, flows and water levels had peaked and were beginning to decline in most of the rivers in southern New Brunswick. However, water levels continued to rise along the lower Saint John River until about March 13.
3/29/2005	5/16/2005	Ice jam, Heavy Rain, Mild Weather	A blend of warm weather on April 16th-19th with 17-20 degrees Celsius temperatures, moderate rainfall on April 24th-25th with 12 mm (1/2") – 25 mm (1") over most of the upper basin, and heavy rainfall on April 28th-29th with 75 mm over the middle and lower basin, combined with Spring snow melt, caused flooding.		In mid-March, the Saint John River basin had above average ice thickness and a heavy snow pack in northern portions of the basin. Ice jams were in place at Hartland. Near the end of March heavy rains began breaking up ice cover in some central and southern rivers. During the first week of April, the ice jams caused flooding in parts of the Nashwaak River valley, at locations along the Meduxnekeag River and in the Miramichi River basin in the Porter Cove and Priceville areas. Ice in the Upper Saint John River and Aroostook River began to break up and caused some flooding in the Hartland, Peel and Morrell areas. During the second week of April, ice jams near Woodstock caused some minor flooding.

1/14/2006	1/20/2006	Ice Jam, Mild Weather, Snowmelt, Heavy Rain	Heavy rains followed by above freezing temperatures caused premature ice break-up and ice jam flooding.	A heavy rainfall with some areas receiving over 40 mm caused significant increase in water flows.	Provincial and local officials were concerned about 6 km of ice on the St. John River which was threatening the safety of the covered bridge in Hartland.
2008/04/23	5/2/2008	Heavy Rain, Freshet, Snowmelt, Mild Weather, Snowfall	Record breaking snowfalls in winter - some 50 percent above normal, a late spring thaw and heavy rain combined with warm weather caused water levels to rise rapidly along the St. John River and its tributaries.	This was the worst spring flooding in 35 years along the entire St. John River. The high runoff resulted in flooding in the northwest parts of the province, and all along the Saint John River to southern New Brunswick.	Northern areas of the province had very high runoff from heavy rainfall and snowmelt from a record winter snow pack - 50 percent above normal. Streams in the northwest had the highest runoff rates at 400% of normal. Flow in the Saint John River reached 360,0000 cubic feet per second on 1st May, more than 20 times the normal flow. On 2nd May, according to River Watch the water levels were: Hartland 47.91 m, flood stage is 45.7 m. Woodstock 41.83 m, flood stage is 41.4 m.
4/3/2009	4/7/2009	Ice jam, Heavy Rain, Snowmelt, Mild Weather	On April 8th, above-freezing temperatures, snow melt, and rainfall caused the water levels along the St. John River to increase further causing the breakup and movement of ice covers and ice-jam formation.		In Hartland, rising water spilled over the road closing a portion of Route 105. A number of homes along Hartland's Main Street had their basements flooded with water. Residents from Riverbank, 14 kilometres above Hartland were evacuated.
12/13/2010	12/14/2010	Heavy Rain	An intense low pressure system with strong deep southerly flow brought heavy rain to NB. The aftermath of the torrential rains caused more than 120 roads to be closed across southern and western parts of New Brunswick. In Florenceville-Bristol, the road leading to Shiktehawk Bible Camp was washed out, causing the bridge to sink 5-10 feet below its original location.	An extreme rain event from December 12-14 caused flooding in the south-western and mid-western regions of the province. There was a light snow cover less than 5-10 cm before the rain began. The flood was particularly damaging as the ground was already saturated from heavy rains in November.	The losses included roads, homes, barns and sheds, and valuables within the homes. More than 880 claimants were registered with the province for compensation from floods and storm surges. The total heavy rainfall damage cost was $3.98 million - Carleton, Charlotte, Queen, Sunbury, Victoria, and York Counties.

4/14/2014	4/20/2014	Ice Jam, Freshet, Snowmelt, Mild Weather	Flooding was caused from rainfall, melting snow, and ice jam	Rainfall event of 25-35 millimetres of rain was experience by several regions of the province.	April 14: In Red Bridge, a small community west of Woodstock families and neighbours helped rescue cows and calves trapped a barn when an ice jam on the Meduxnekeag River caused the waters to rise.
7/5/2014	7/6/2014	Heavy Rain, Wind	Heavy rainfall and high winds		On Saturday July 5th, Hurricane Arthur transformed into a potent Post-Tropical storm over the Maritime provinces. Hurricane Arthur passed over New Brunswick bringing heavy rain and wind across the province. Across the Province widespread road closures occurred due to fallen trees, washouts and localized flooding. Due to Arthur's interaction with an easterly moving storm front, wind speeds were greater than anticipated causing widespread power outages and road closures in all parts of the Province. At the peak approximately 140,000 NB Power customers were affected. Fredericton and Woodstock areas experienced highest numbers of power outages. Maximum wind gusts in Fredericton was 100 KM/HR.
12/9/2014	12/11/2014	Heavy rain, Snowmelt, Mild Weather, Snowfall	Heavy rain, snowfall, and snowmelt from mild temperature caused the flooding event across the province.		On December 9th and 10th, a Nor'easter brought a mix of snow and rain across the province. Precipitation fell predominantly as rain over the southern half of the province. Rainfall amounts were very significant over much of the province. Over portions of Northeastern New Brunswick very high snow accumulations were reported. Flooding occurred in low lying areas. Two residences in Woodstock were evacuated due to storm related sewage back-up. Schools were closed across central, northern and eastern regions of the province.

9 APPENDIX B

Climate Vulnerability Assessment
Meductic, Woodstock, Hartland and Florenceville-Bristol
Meeting 1 - Agenda 3/19/2015 - 6:30pm - Northern Carleton Civic Centre, 40 McCain Street, Florenceville-Bristol

Identifying hazards, impacts to infrastructure

- Introductions
- Background information
    - Project Background
    - Descriptions of meetings & process
    - Go through definitions/Brief discussion of climate change
    - Talk about climate expectations in area
    - Complete survey together
- Identify Assumptions
    - Timeline
    - Scope - Strictly Municipal Concerns? Inclusive of Economics – Ag? Forestry? Transportation?
- Identify **3** (maximum) climate hazards on which to base further discussions
    - These hazards will be used throughout the CVAT process
- Use maps & legends to identify localities of impacts
    - Risk analysis: Understand what the risks are; what could happen, where, to whom?
        - Identify on maps what has been impacted in the past, what may be at risk in the future
        - What key infrastructure would be vulnerable in the event of each hazard?
        - Is there any infrastructure that is in need of repair, replacement or upgrades?
            - Does the state of this infrastructure make damage more likely?
            - What is the condition of the culverts, bridges and dams in your community? Are they in need of upgrades, replacement or maintenance?
        - Is there other infrastructure in your community that helps divert or control the impacts from each hazard?
        - What has been the damage to buildings in your community due to the hazard?
- Summing Up
    - Determine vulnerability classes of identified impact zones: COMMUNITY & REGIONAL (rate vulnerabilities)
        - High, moderate, low
        - Based on population density, economic criterion (areas of valuable economic activities and their importance to the local economy: national, regional, local), cultural heritage (buildings, monuments, landscapes, etc.; world heritage sites, national/regional importance, local)
- Meeting Schedule
        - Day of week & Scheduling

10APPENDIX C

Background information:

Climate Change

There is now widespread scientific agreement that accelerated climate change is occurring and that human activities are the principal cause. However, measures to reduce greenhouse gas emissions are only part of the climate change challenge. Even if significant reductions in emissions were put in place tomorrow, the lag in the climate system means that past emissions will continue to affect the climate for several decades to come.

The Intergovernmental Panel on Climate Change (IPCC) and Emissions Scenarios

Intergovernmental Panel on Climate Change (IPCC) is the leading scientific body for the assessment of climate change. The IPCC reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change; they do not conduct any new research. The IPCC was established in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), and later endorsed by the United Nations General Assembly.

Every seven years, the IPCC releases a series of reports which are reviewed by representatives from all of the member governments to the United Nations and the WMO; there are currently 195 countries that are members of the IPCC. The series of reports includes three Working Group reports and one Synthesis Report; the report from Working Group I of the Fifth Assessment Report (AR5) was released on September 26, 2013, outlining the physical science basis of the climate system and climate change.

Widely used emissions scenarios for the analysis of possible climate change, its impacts and options for potential mitigation have been developed by the IPCC. A revised report was prepared and published in 2000; titled the IPCC Special Report on Emissions Scenarios (SRES). This report was developed to better represent the enhanced understanding of the driving forces of emissions. This increased knowledge was specific to the carbon intensity of energy supply, the economic gap between developed and developing countries and sulphur emissions. The scenarios are based on various predicted realities of our future world, specific to demographic, economic and technological driving forces that contribute to greenhouse gas (GHG) and sulphur emissions. Successively, the AR5 has updated scenarios.

The scenarios are used to describe reasonable trajectories of varying aspects of the future that are constructed to investigate the potential consequences of human-induced climate change. The scenario representing the ‘worst case’ is usually the most fossil fuel intensive and represents a world of rapid economic growth. The ‘best case’ scenario characterizes a world that is more integrated and ecologically friendly with reductions in fossil fuel intensity and the introduction of clean and resource efficient technologies.

Vulnerability Assessment Process

Vulnerability Assessments at the community level requires a good understanding of historical weather trends as well as scenarios for future conditions of climate and sea level and guidance on how to interpret and use them.

One way this can be done at the community level is through the Vulnerability Assessment process which will be used in the Charlotte County Region. A basic outline of this process includes;

- Define the issue;
- Understand hazards and risks - identification of the types of climate and weather-related issues that have or will affect the community;
- Identify the physical consequences - location of where these issues have occurred or could occur in the community and an assessment of what infrastructure has been or may be impacted, identification of how the natural environment has been or will be affected;
- Identify the socio-economic consequences - identification of the residents who have been or will be most affected as well as those who can provide assistance in the community, assessment of which economic sectors have been or will be most impacted by the issues;
- Identify the governance and policy consequences - governance means how things were handled and by whom, are the current policies in place in your community helping to reduce vulnerability?
- Integrating and defining the options - analyze the options: pros and cons and prioritize

Definitions

Adaptation: Adaptation to climate change refers to any adjustments or activity in natural or human systems in response to actual or expected climatic changes or their effects, which reduces harm/impacts or takes advantage of new opportunities that may be presented (IPCC 2001) (Moncton 2013).

Adaptive capacity: The collective capabilities, skills, assets, networks, resources and policies that enable a community/region/country to continually asses and improve their ability to respond to changing conditions over time (Vasseur 2012) (Moncton 2013).

Anthropogenic: "Resulting from or produced by human beings" (IPCC 2001).

Capacity building: "In the context of climate change, capacity building is a process of developing … technical skills and institutional capability in … [communities] and economies … to enable them to participate in all aspects of adaptation to, mitigation of, and research on climate change" and the implementation of mechanisms to address it (IPCC 2001).

Climate Change: "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods," generally periods of 30 years or more (UNFCCC).

Climate Scenario: A plausible and often simplified representation of the future climate, based on a consistent set of climatological relationships and assumptions, that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change and serving as input to impact models (IPCC 2001) (Moncton 2013).

Climate Variability: Climate variability refers to variations above or below long-term averages of the climate on all temporal and spatial scales beyond that of individual weather events. "Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability)" (IPCC 2001).

Governance: The process of regulating behavior or coordination action between the actors in accordance with shared objectives, missions or interests. It recognizes the contributions of various levels of government (global, international, regional, local) and the roles of the private sector, non-governmental actors and civil society to a situation.

Hazards: Possible events that can have a negative impact on people, infrastructure, ecosystems, communities, etc.

(Climate) Impacts: Consequences of climate change on natural and/or human systems.

Mitigation: "An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (IPCC 2001)

Resilience: The ability of a social, ecological or economic system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change (Moncton 2013). *A resilient system can withstand shocks and rebuild itself when necessary. Resilience in social systems has the added capacity of humans to anticipate and plan for the future (Resilience Alliance).*

Risks: A combination of the likelihood (probability of occurrence) and the consequences of an adverse event or to hazards where there is potential for loss (Moncton 2013) Degrees of exposure.

Scenario: "A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces" (IPCC 2001).

Socioeconomic Used to describe something that relates to or is concerned with the interaction of social and economic factors.

Vulnerability: "The risk of exposure to hazards (e.g., settlements in flood plains), as a capability for social response (e.g., exit road systems and insurance) and as an attribute of places (e.g., vulnerability of coastlines to sea level rise)(Malone 2009).

"The degree to which a system is susceptible to, or unable to cope with, [the] adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2001).

Flood (flooding, flood event) – An event that occurs when ditches, streams, lakes or rivers overflow their banks or channels as a result of one or more of the following: a) prolonged or intense precipitation; b) melting snow, or c) blockage of flow (e.g. by an **Ice jam**).

Flood adaptation – Measures taken to reduce **flood vulnerability** (e.g. **flood-proofing**, avoiding the creation of living space in basements, moving structures out of flood hazard areas, flood forecasting, emergency planning, etc.). Individuals, businesses, communities and the Province all have a role to play in flood adaptation.

Flood hazard (flood hazard area) – A description of the threat of a flood at a given location, based on the flood's anticipated magnitude (e.g. its depth, horizontal extent, and flow velocity) and its **probability of occurrence**. This information is typically shown on a flood hazard map.

Flood proofing – site grading techniques and temporary or permanent structural features (e.g. raised foundations, higher doors and windows, one-way valves on drainage pipes, raised electrical panels, etc.) that can be employed to reduce or avoid flood damage to buildings or facilities that are located in **flood hazard areas**.

Flood resilience – The capacity of a community, business or individual that is exposed to a **flood hazard** to prepare for, respond to, recover from, and reduce the potential consequences of a flood. Identifying flood hazards is the first step toward resilience. The next step is **flood adaptation**.

Flood risk – The combination of **flood hazard** and **flood vulnerability**. Floods that have a high **probability of occurrence** and have significant consequences for life and property are floods that present the highest risk. A flood that happens frequently but has little or no potential to affect human life and property presents a low flood risk.

Flood risk reduction (prevention, mitigation) – Flood risk can be reduced by reducing the **flood hazard** or reducing **flood vulnerability**, or both. Reducing a flood hazard typically means employing structural measures (dikes, dams, sea walls, drainage controls, etc.) to reduce the severity and/or probability of a flood. Reducing flood vulnerability means implementing **flood adaptation** measures.

Flood vulnerability (flood exposure) – The consequences (e.g. impacts on human life, health and property) that would result from a flood at a given location; in other words, the potential for harm to occur as a result of a **flood**.

Ice jam (ice dam) - An accumulation of floating or grounded, ice causing full or partial blockage of flow, resulting in elevated water levels and potential damage due to moving ice.

LiDAR – An acronym for "light detection and ranging." This technology allows researchers and map makers to accurately measure and record land elevations and other topographic features. LiDAR involves the emission of laser pulses towards the earth's surface from an aircraft and measuring the return time of the pulse, and is a useful technology to assist in creating accurate **flood hazard** maps.

Probability of occurrence (return period, recurrence interval) – An estimate of the average interval of time between flood events of the same magnitude, based on historical records and predictions about future climatic variability. For example a 1:100 year event is expected to occur on average once every 100 years. In other words, it has a 1% chance of occurring in any given year. The longer the return period, the larger the flood.

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11APPENDIX D

Questions for St John River Working Group

WWF

Please identify which recent events you have had impacts from and please circle which event you feel the community endured the worst impacts.

Spring freshet April 17, 2014 x x x x   Tropical Storm Arthur in July 2014 xxxx   Winter storm on Nov 4, 2014 xxx

Severe storm Sept 11, 2013 xxx   Perth Andover flooding Spring of 2012 helped

May 1, 2008 (excessive rain and rising waters in the St John River - ice damming) x

How many times in the last 10 years has the Provincial Emergency Management Organization had to come to help manage the emergency? Zero – but on their radar

What type of infrastructure or plans are currently in place regarding flooding other than River Watch (have these met your needs? What else do you need?

EMO plans, mutual aid, these inform needs

Have you done anything since the event that would help you get through the next one better? What? How much did it cost? How much time did it take?

EMO plan reviews – identify at risk pop'n,

built better causeway, brought generators to assist SCADA system

generator for town hall, looking for new water source

causeway reinforcement, major water system change – F/B

Did you lose power? For how many days/hours? How did this impact operations?

Couple days diesel back up at well house, lift station overflows

Day

2 days – 1 wk –F/B

Did you receive financial compensation for damage? From whom? Disaster Financial Assistance?

Yes – Hartland, yes - road to pump house – Woodstock, yes – Florenceville - Bristol

Is your Town still suffering repercussions?

Yes – Hartland, no – F/B & Woodstock

Is your storm water system hindering the draining of large rain events?

Yes

Climate change impacts the environment in many ways. Please rank the importance of the following local issues related to projected changes;

Drinking water quality & quantity, Power outages, Flooding – Homes, Flooding – Businesses, then Flooding – Streets & Stormwater Management & Road maintenance and snow removal, then erosion, then ag - Woodstock

Drinking water quality & quantity, Power outages, Flooding – Homes, Flooding – Businesses, Road maintenance and snow removal, Stormwater Management, Agricultural impacts, erosion - Hartland

F/B – no problems with drink water/water quality, everyone on wells

Please indicate with a check mark

	Yes, we are experiencing	Not yet, but we are concerned	Not concerned
Our buildings cannot stand up to the changes we are seeing	Old school library, Old buildings – Hartland		X - Woodstock X – F/B
Our roads cannot stand up to the changes we are seeing		X – Hartland X - Woodstock X – F/B	
It has become more difficult and expensive to respond to large rain events, storms and flooding	X - Woodsock X – budgets increasing – Hartland Servicing citizens & snow removal budgets – F/B		
We have experienced increases in sewer back-ups in combined sewer areas due to high rainfall volume in sewer system.	X - Hartland	X - Woodstock	
We have experienced increases in the number of combined sewer overflows	Lagoons at risk X - Hartland	X - Woodstock	NOT for F/B
We feel we have had instances of increased public safety risk on streets due to damage to infrastructure & trees	X - Hartland	X – F/B X - WOODSTOCK	
We have experienced water supply shortages due to extended dry periods in the summer months.	Came close during Arthur - Hartland	X - Woodstock	X – F/B

12 APPENDIX E

Florenceville-Bristol

DOT #	SPECIFIC ADDRESS OR BOUNDS	ISSUE
11	HOME HARDWARE	FLOODING – LOST FACILITY, REINFORCED BANK & REBUILT WATER MAIN FLOOR 1.5’
14	SHITEHAWK TRAILHEAD	UNUSABLE LAND – TOWN TOOK OVER, ADDED PICNIC TABLE
12	ICE JAM	LOST LAGOON IN 2008, HAS HAPPENED AT LEAST 4 TIMES
EAST OF DOT 11 ON 105	6-7 HOUSES EVACUATED (NOT MANDATORY)	
13	BRIDGE OUT AT BIG SHITEHAWK	BRIDGE ACROSS 105, LOST IN ARTHUR, OUT 6 WKS, CAUSED MAJOR SOCIO-ECO ISSUES AT FOLKS HAD TO TRAVEL WAY OUT OF THE WAY
15	GAZEBO, WHERE LITTLE SHITAHAWKE ENTERS DOWNTOWN	ERODING BUT THIS SUMMER PLANS FOR CULVERT, RIGHT BY NB TRAIL AND TURNING LANE
16	ISLAND	SEDIMENT BUILD UP, ICE BUILD UP, ANYWHWERE STREAMS EMPTY IN SJR SAME SIRUATION
17	FLORENCEVILLE LAGOON (JUST OFF MAP)	

Town F - B **Physical Impact #** 13, 12, 11

Which priority community assets, markets, property or services are affected and how?

#13 – Travel delays, emergency response (mutual aid), stress on Lockhart Mill road

#12 – Lagoon – cost to replace (17)

#11 – Main road closed – delay in emergency response, comm traffic

Who lost or gained socially and economically from the impacts of the hazard? Who are the groups/individuals that suffer the most/are the most affected during these periods of stress? (elderly, workers at a certain location, rural, families with school-aged kids)

Everyone loses travel time, more secondary roads abused – emerg response longer

What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard?

Public works, fire dept, DOT

How could these resources, skills or other social elements be improved? What else was needed?

Timing of mediation

Is it possible this will be a recurring impact? Explain.

Main street closure impacts, emergency response – yes

Hartland

DOT #	SPECIFIC ADDRESS OR BOUNDS	ISSUE
1	SEWAGE LAGOON	POTENTIAL FOR BREAK
2,3	FLOOD AREA	AREA FLOODS ALMOST YEARLY – LOW GROUND
4	LIBRARY	BASEMENT FLOODS EVERY FEW YEARS
5	BAPTIST CHURCH	BASEMENT FLOODS
6	COVERED BRIDGE	DAMAGE TO BRIDGE DUE TO ICE OR FLOODING

7	SPROULL ISLAND	SILT AROUNF ISLAND HAS MADE THE RIVER VERY SHALLOW
8	WELL FIELD	WATER SUPPLY POTENTIAL PROBLEM
9	SCHOOL/SUMMER CAMP	FLOODING RISK
10	FIRE STATION	EMERGENCY SERVICE RISK – ACCESS PROBLEM
11	ARENA	SNOWLOAD RISK
12	GREENBELT	HELPS TO STOP EROSION OF AG AREAS

Town Hartland **Physical Impact #** 1, 7, 8 (identified on map)

Which community assets, markets, property or services are affected and how?

Sproul's Island (7)

Sewage lagoon (1)

Well Field (8)

Who lost or gained socially and economically from the impacts of the hazard? Who are the groups/individuals that suffer the most/are the most affected during these periods of stress? (elderly, workers at a certain location, rural, families with school-aged kids)

Entire population – flooding for residents on Main, environmental impact downriver from leaking sewage, possible contamination of drinking water

What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard?

Staff skills – shutting pump off on contaminated well

EMO

River Watch

Council

Dredging (preventative)

How could these resources, skills or other social elements be improved? What else was needed?

More collaboration w gov't to lobby for dredging

Work with province on finding funding to move lagoon out of flood plain

Is it possible this will be a recurring impact? Explain. Yes

Woodstock

DOT #	SPECIFIC ADDRESS OR BOUNDS	ISSUE
1	WELL HOUSE	FLOOD – ROADWAY WASH OUT 2014
2	NBCC MAIN/BROADWAY	FLOODING
3	FLOODING LOWER MAIN/UPHAM ST AREA	
4	ROSE CRT	POWER OUTGES – EXTENSION TIME BACKLOT SERVICES
5	PLEASANT ST	"
6	WATER ST	FLOODING
7	WATER ST	FLOODING – LIFT STATION
8	"SHILINGS" SUBDIVISION	FLOODING LOW AREA, WATER BACKS UP CULVERT FR SJR
9	EASTWOOD HEIGHTS	RUN OFF FLOODING
10	MAIN ST BRIDGE CROSSING MEDUXNEKEAG	FLOODING & WATER LINE RUNNING UNDERNEATH

Town Woodstock **Physical Impact #** 1, 2 & power outages

Which community assets, markets, property or services are affected and how?

#1 – can't access well house – ice & No power, no water

#2 – Flooded parking lot, street and building (home hardware)

Power outages – areas 4 & 5 (on map) lasted longer than most, but the whole community could be impacted

Who lost or gained socially and economically from the impacts of the hazard? Who are the groups/individuals that suffer the most/are the most affected during these periods of stress? (elderly, workers at a certain location, rural, families with school-aged kids)

Whole community – business and residential affected, schools shut down…cost, time, inconvenience, health

#2 – Students & downtown - Flooded parking lot, street and building (home hardware) – street lights damaged, NBCC could close

Power outages – schools could shut down, sewage overflow – can't supply water, system vulnerable

What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard?

Second source to water

Coordinate with EMO and NB Power

#2 – Nothing

Power outages – Municipal building installing generator, could provide places to charge phones

How could these resources, skills or other social elements be improved? What else was needed?

Can't improve the well-house situation, need to avoid situation – find another water source

#2 – could build berm around NBCC parking lot

Power outages – know your neighbour, know who is in trouble – i.e. seniors

Is it possible this will be a recurring impact? Explain.

Yes – with ice. Results of physical impact (not being able to get to well-house are difficult and long-term to repair)

#2 – yes, ice jams

Power outages – yes

13 APPENDIX F

Climate Vulnerability Assessment
Meductic, Woodstock, Hartland and Florenceville-Bristol
Meeting 2 - Agenda 4/23/2015 - 6:30pm - Hartland

LiDAR Results & Identifying social and economic impacts

- Introductions
    - What was discussed last month; overview of physical impacts
    - Recap climate hazards chosen

- Background Information
    - Presentation- LiDAR wet areas mapping results
    - Questions, Answers & discussion
    - Presentation - Identifying social and economic impacts

- Identifying localities of impacts & Social Capital
    - Vulnerability analysis: identify the social and economic impacts of flooding and sea level rise
        - What are the known economic and social aspects that have been affected as a result of the hazard?
        - Who lost or gained socially and economically from the impacts of the hazard?
        - What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard? How could this be improved?
        - Who are the groups/individuals that suffer the most/are the most affected during these periods of stress? (rural citizens, elderly)
        - Are these people present today?
        - Which community assets, markets, property or services are affected and how?
        - Are the impacts discussed current, past or of concern into the future?
        - Are there issues of **social equity** that are required to be addressed?
    - Determine capacity of social assets

- Meeting Schedule Review

14 APPENDIX G

Climate Vulnerability Assessment
Meductic, Woodstock, Hartland and Florenceville-Bristol
Meeting 3 - Agenda 5/21/2015 - 6:30pm - Woodstock

Further LiDAR results & identifying social and economic impacts

- Introductions 10 minutes
  - Summary of discussions
  - Overview of physical impact priorities

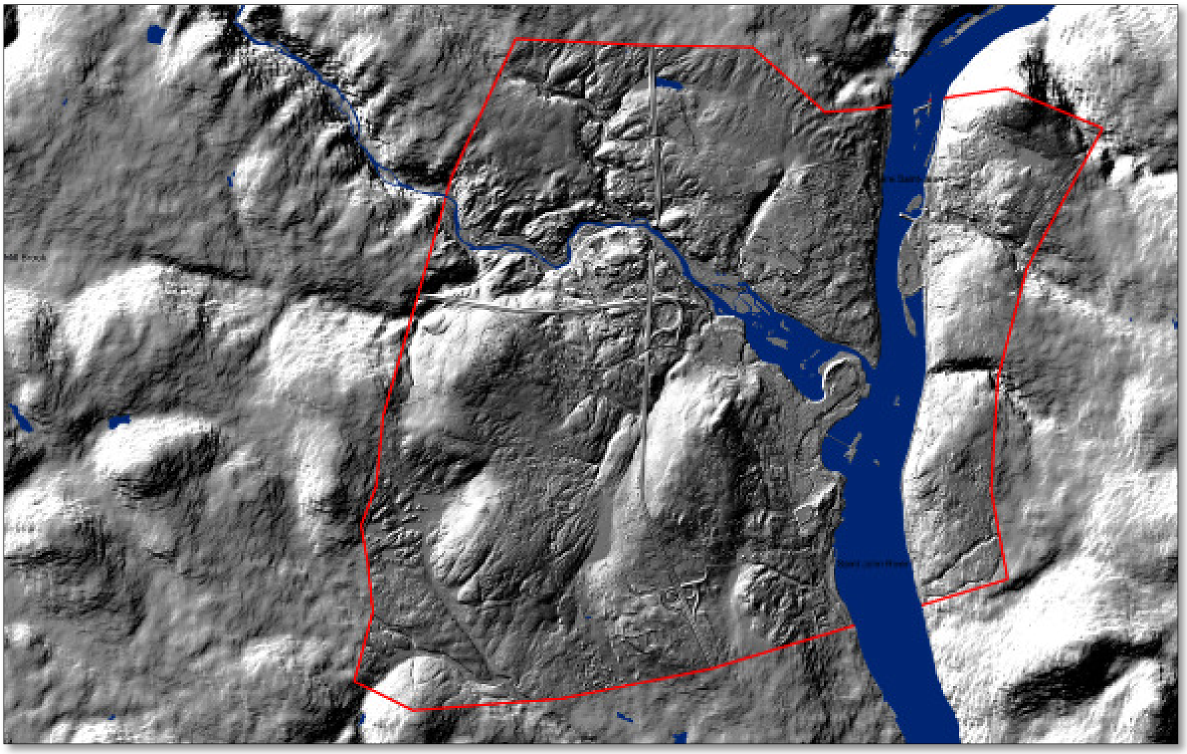
- Background Information 45 minutes
  - Presentation- LiDAR wet areas mapping results 30 minutes
  - Questions, Answers & discussion 15 minutes

- Identifying social and economic impacts 30 minutes
  Vulnerability analysis:
  - Identify the social and economic impacts of increased precipitation in all seasons and increased intensity & frequency of storms
    - What are the known economic and social aspects that have been affected as a result of the hazard? Who lost or gained socially and economically from the impacts of the hazard?
    - What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard? How could this be improved?
    - Who are the groups/individuals that suffer the most/are the most affected during these periods of stress? (rural citizens, elderly)
    - What are the resources, skills or other social elements that helped to reduce the community's vulnerability or impacts of/to the hazard?
    - How could these resources, skills or other social elements be improved? What else was needed?
  - Determining capacity of social assets 30 minutes

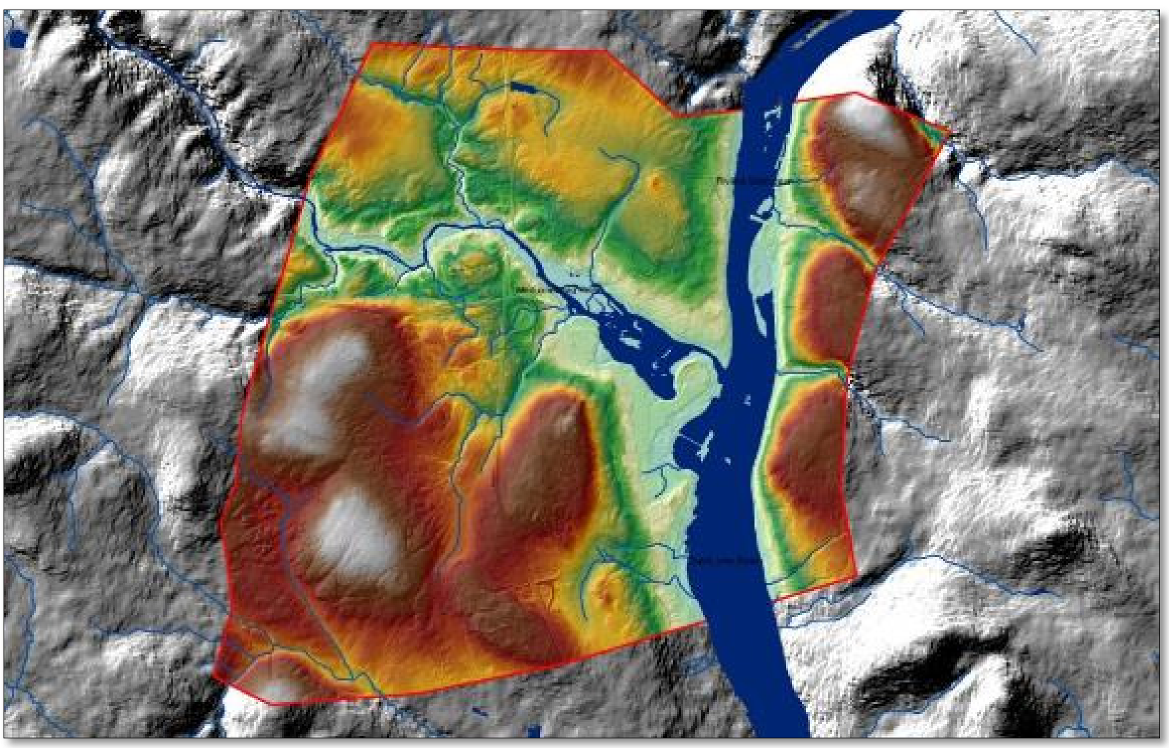
- Meeting Schedule Review

The following series of images are included so that readers may familiarize themselves with the layer names and processes related to LiDAR-based mapping

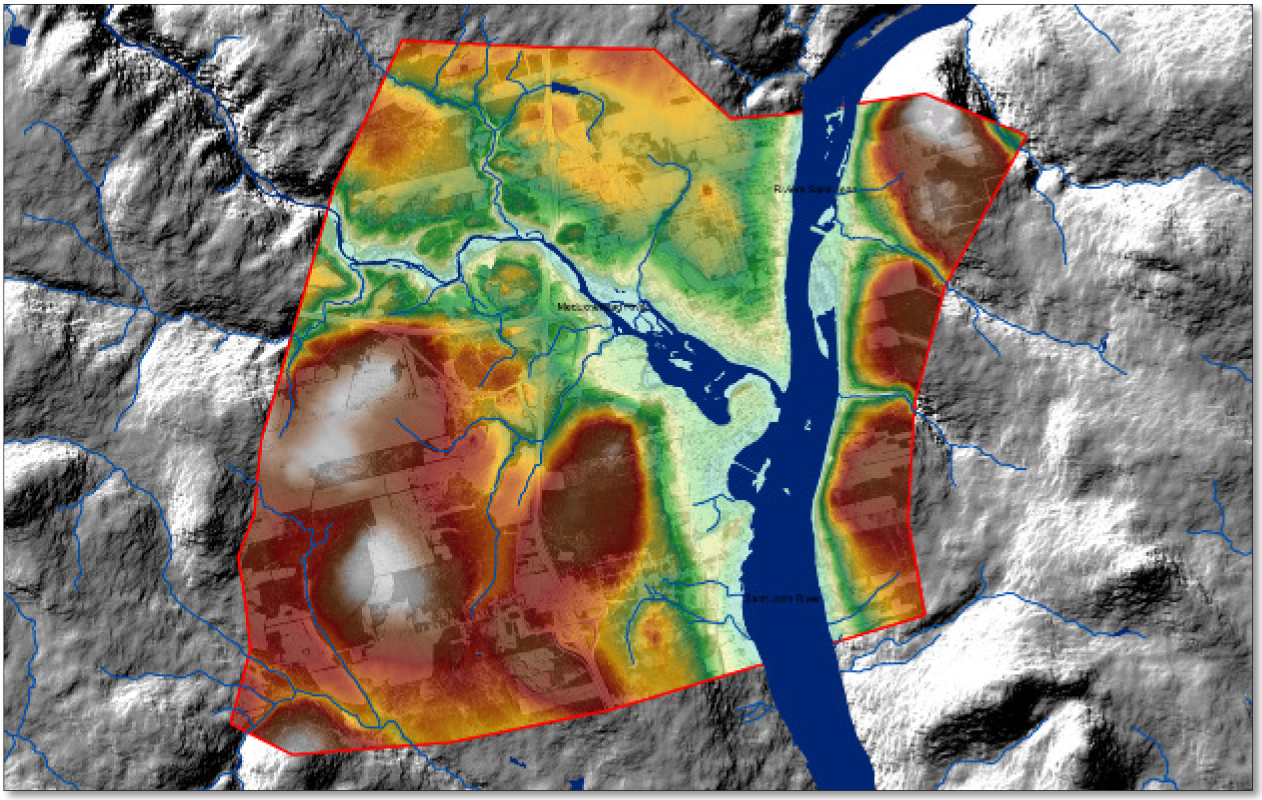
Woodstock Provincial DEM extent



Woodstock Bare Earth LiDAR DEM with Provincial DEM – Hillshade



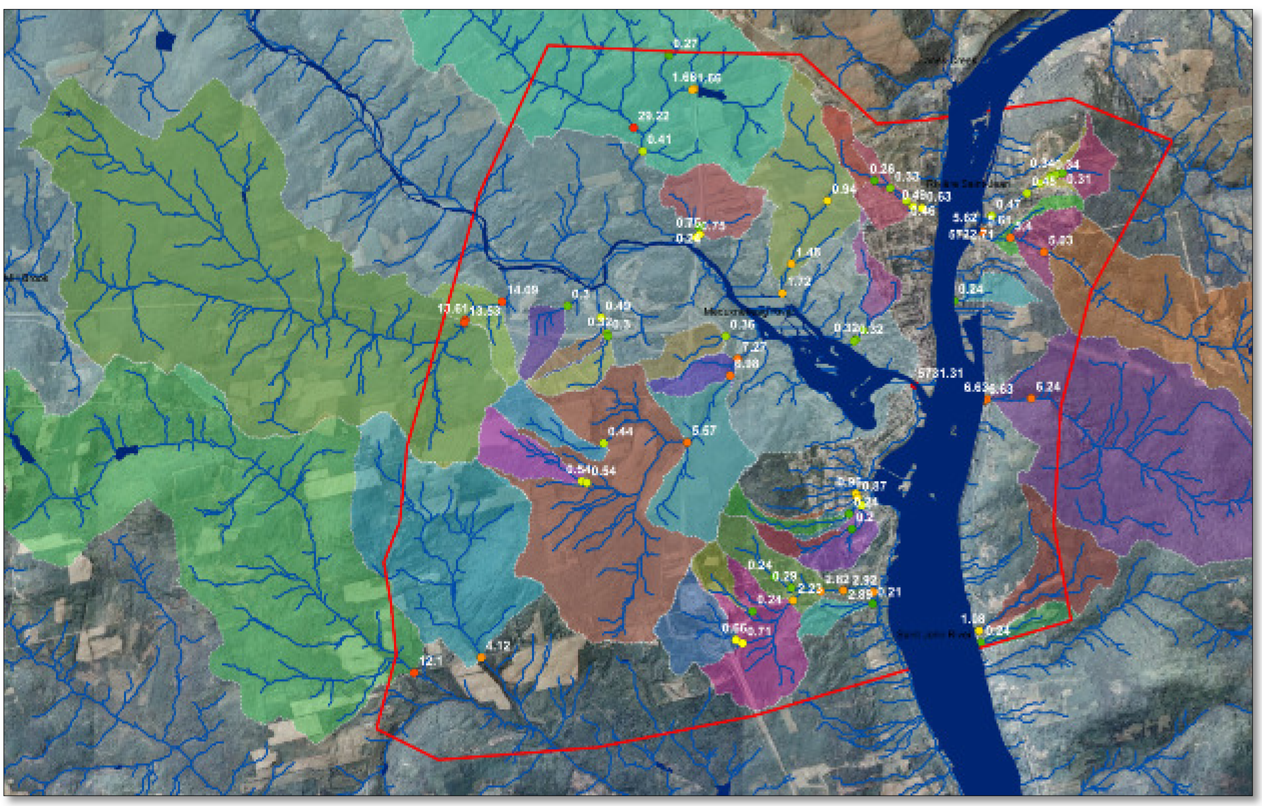
Woodstock Bare Earth LiDAR DEM with Provincial DEM Hillshade – Elevation



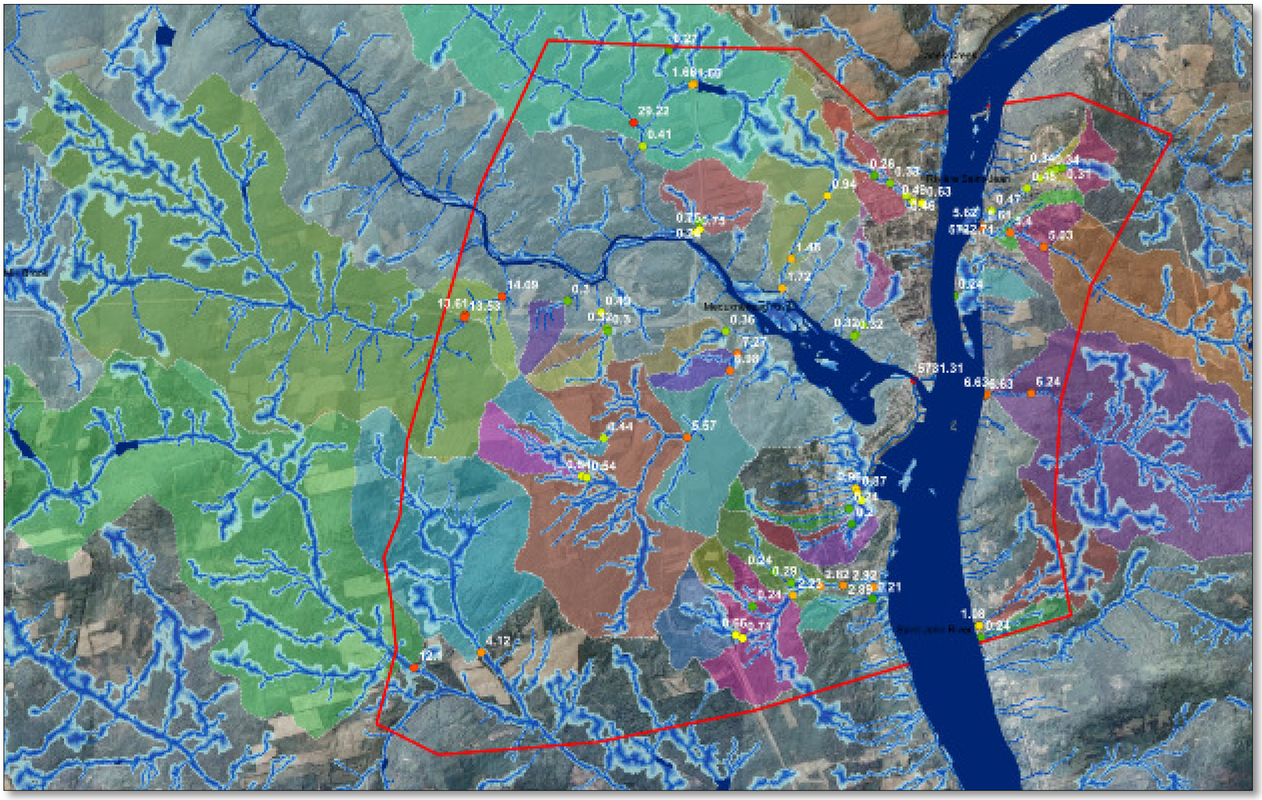
Woodstock Full Feature DEM with Provincial DEM – Elevation

Woodstock Bare Earth LiDAR DEM with Provincial DEM – Photo Imagery

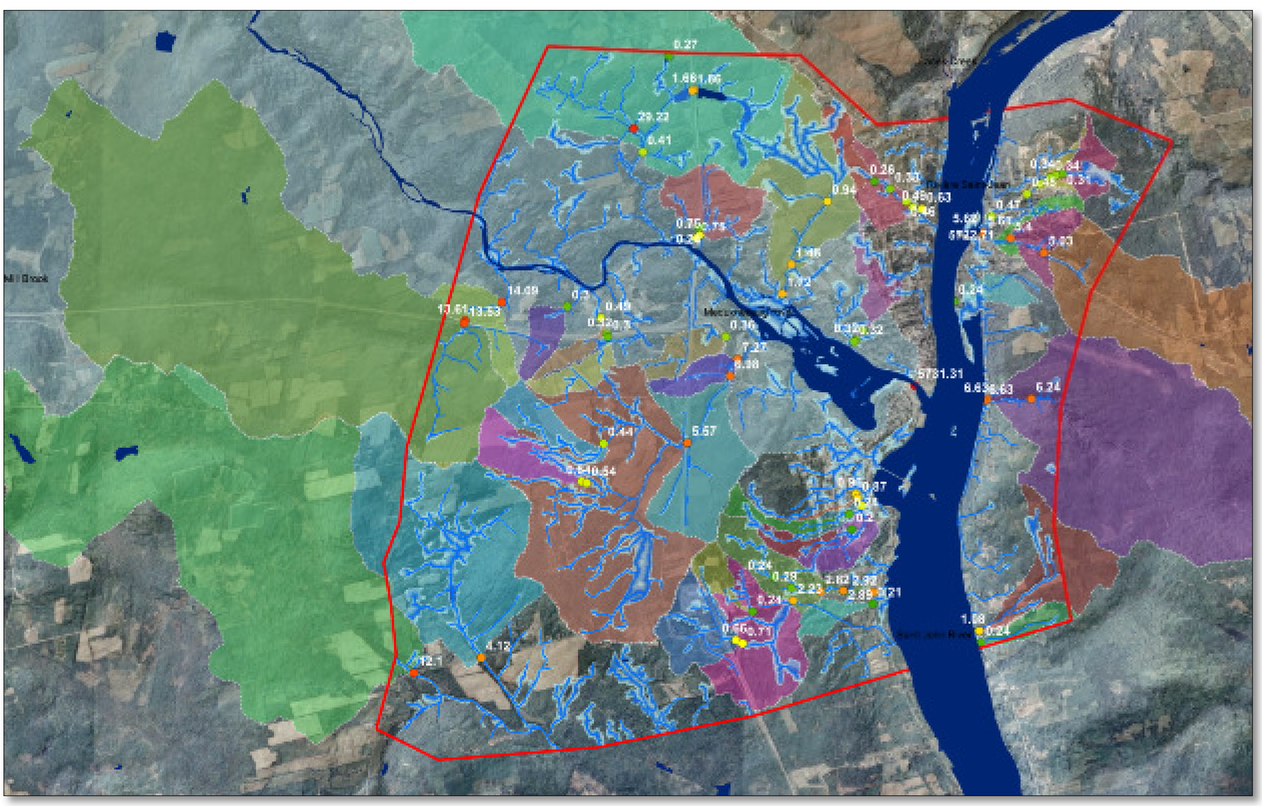
Woodstock Bare Earth LiDAR DEM with Provincial DEM - 4 ha Flow Network



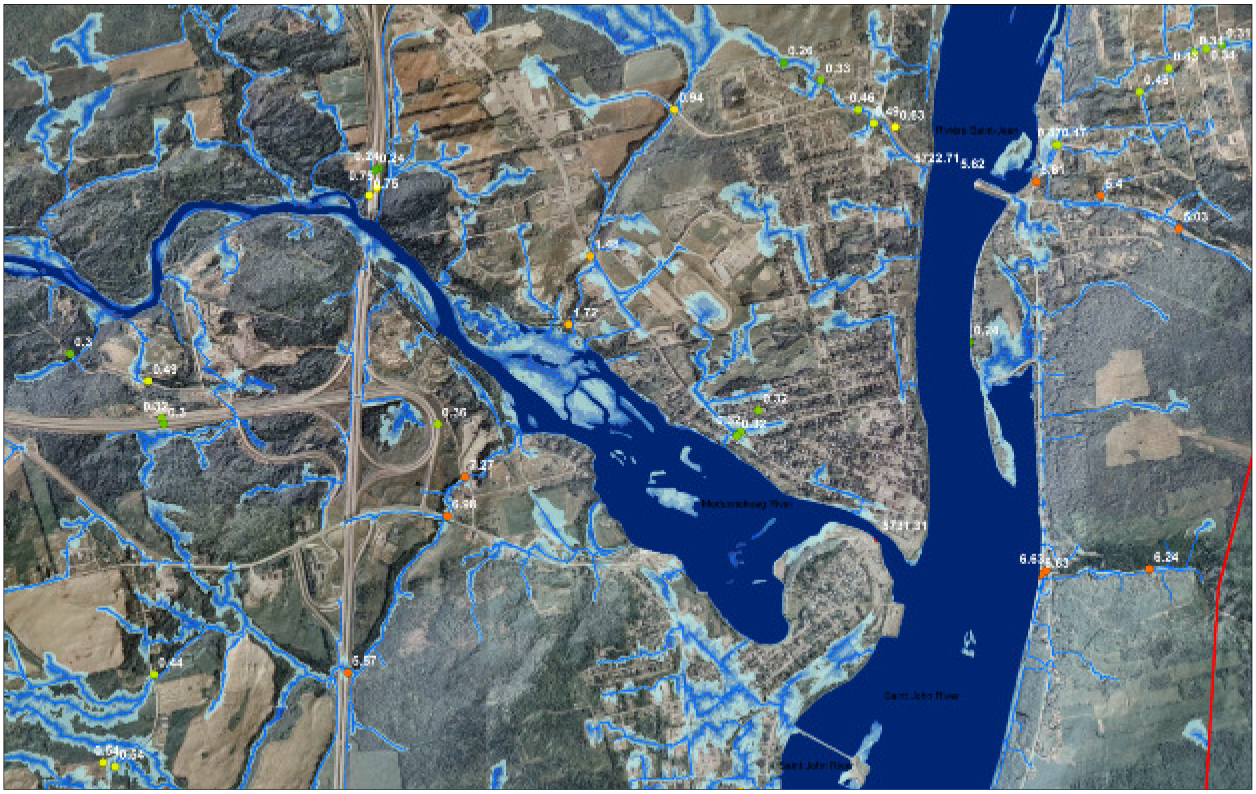
Woodstock Bare Earth LiDAR DEM with Provincial DEM - Watersheds and DOTI culverts



Woodstock Bare Earth LiDAR DEM with Provincial DEM - Provincial WAM @ 4 ha

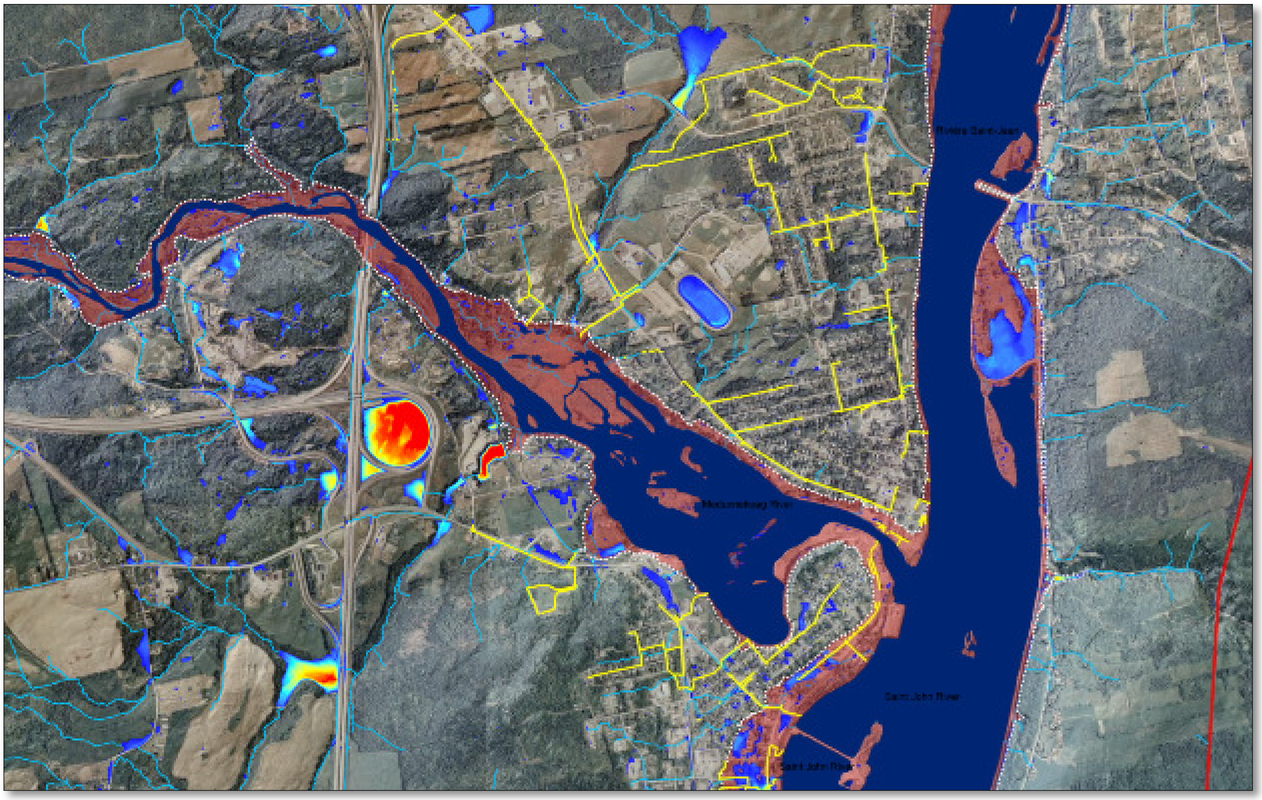


Woodstock Bare Earth LiDAR DEM with Provincial DEM - LiDAR WAM @ 4 ha

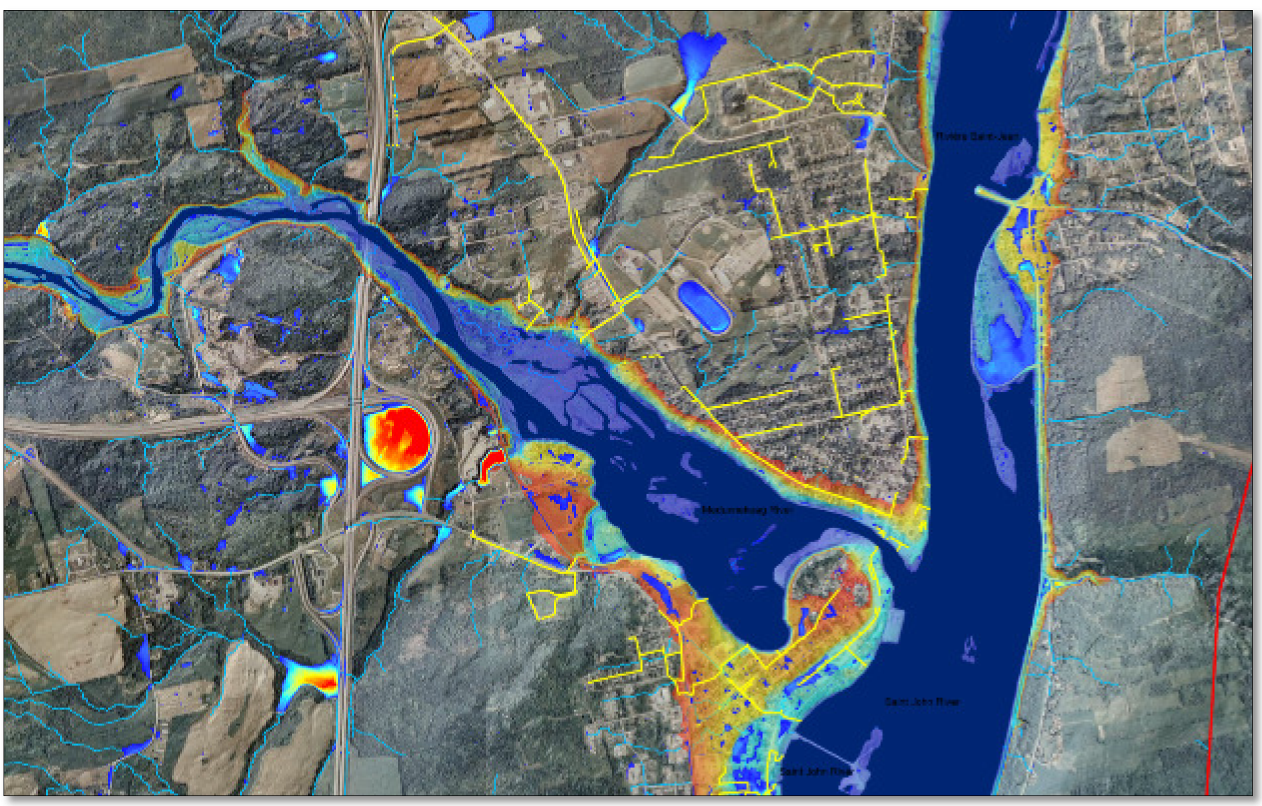


Woodstock – LiDAR WAM @ 4 ha

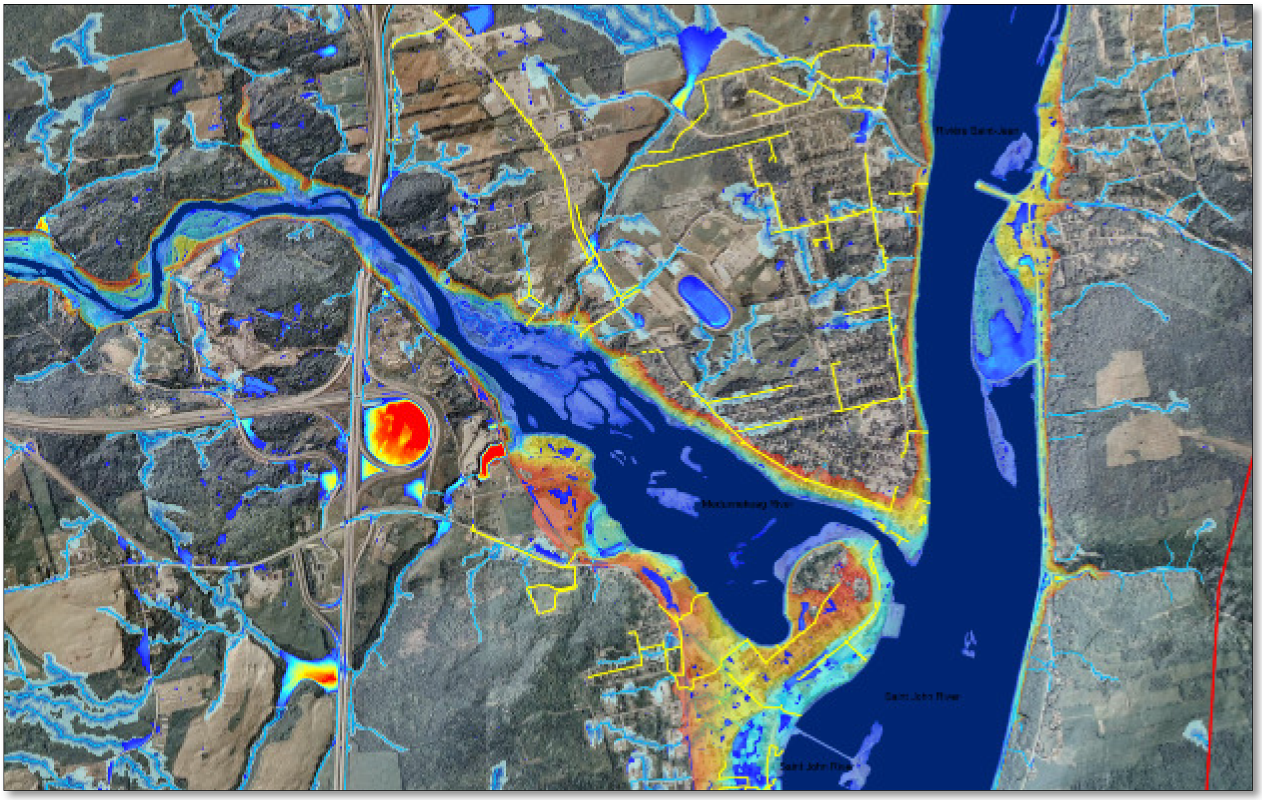
Woodstock – LiDAR WAM @ 1 ha



Woodstock - LiDAR DEM – 4ha Flow, Sinks, Drainage Infra. – 1987 Flood



Woodstock –LiDAR DEM – 4ha Flow, Sinks, Drainage Infra. – P. Flooding @ 15m


Saint John River
Saint John River

Why we are here.
We are creating solutions to the most serious conservation challenges facing our planet, helping people and nature thrive.

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