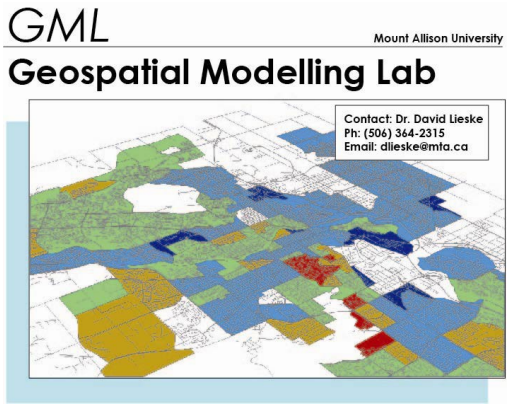
Tantramar Community Adaptation Viewer Project

(ETF Project #: 130278)

Final Report

February 28, 2014

(Available for download):
http://arcgis.mta.ca/toolkit/reports/FinalReport_TCAV.pdf



"Your Environmental Trust Fund at Work"

David J. Lieske, Lori Ann Roness, Emily Phillips, James Bornemann

Department of Geography and Environment

Mount Allison University

Tantramar Community Adaptation Viewer Project

Final Report

Table of Contents

Tantramar Community Adaptation Viewer Project

Final Report

1. Executive Summary

New Brunswick coastal communities face significant threats from coastal flooding. To better understand how software can be used to assist the identification of flood risk vulnerabilities while stimulating proactive adaptation planning, Dr. David Lieske and the Geospatial Modelling Lab of Mount Allison University developed a web-based decision support software tool called the "Tantramar Community Adaptation Viewer" (TCAV). Over the course of three phases of facilitated sessions, expert stakeholders from the Town of Sackville, New Brunswick (members of Town council, engineers and emergency measures personnel, town planners, dyke managers, NGOs, and community service providers) used the software to identify locations of concern (LOCs), delineate special adaptation planning zones (APZs), and brainstorm possible risk reduction strategies.

The first phase of consultations involved exploration of the concept of 'vulnerability', resulting in many important insights. Chief amongst the issues raised was the need for ongoing dialogue about flood risk vulnerability in order to maintain awareness of the problem and facilitate community cohesion. Also highlighted was a need for political leadership, proactive action planning, and effective emergency response.

The results of the second phase of consultations involved the identification of locations with special flood risk vulnerabilities, including: vulnerable sections of dykes and aboiteaux; need for maintenance of drainage ditches; agricultural impacts; commercial and industrial impacts; interruption to community and emergency services; flooded neighbourhoods and neighbourhoods temporarily isolated as a result of road flooding; concerns about land use decisions; questions about the resilience of lift stations and the sewage network; vulnerable historic sites; and, vulnerable populations such as children and elderly. Focus groups identified five main adaptation planning zones, with a total economic exposure of $6,470,000 under the current 10% chance per year, 8.9 metre flood scenario. This estimated damage cost more than doubles to $13,475,000 under a 10 metre flood depth (4% chance per year by 2100), for parcels with a current tax assessed value of about $21.6 million.

The final phase of consultations took the form of a single plenary session on February 18, 2014. The chief findings from this session involved new information about flood-risk tolerance and a set of key recommendations for lowering community vulnerability. With regards to flood-risk tolerance, research findings indicated that even a moderate 1% chance (1 in 100 year) flood event deters slightly over an estimated 70% of respondents. By the time one considers flood events of 1 in 50 years (2% chance), approximately 90% of respondents indicate a willingness to relocate. This suggests that 1-in-10 year flood maps under represent people's true sensitivity to risk, and for this reason we recommend that a 1-in-100 year flood extent or greater be adopted for land use planning purposes.

The project concludes with a number of key recommendations:

1. **The Member of the Legislative Assembly for Tantramar, Electoral District 18, Mike Olscamp should be engaged in flood discussions**.

2. **The provincial and federal governments are exposed to a minimum of $6-13 million dollars worth of residential disaster relief in the wake of a Tantramar flood, and need to weigh the relative costs of proactive relocation versus post-flood disaster relief.**

3. **Dyke maintenance should continue, and requires renewed investment.**

4. **The municipal government (Town of Sackville) should issue a policy statement regarding flood adaptation and develop a long term flood mitigation plan**.

5. **The reality of Sackville's flood risk should be integrated into municipal planning and activities**.

6. **Municipal by-laws and land use zoning should restrict development in areas known to be especially vulnerable to flooding.**

7. **A dedicated manager at the municipal level should be designated to spearhead flood mitigation and adaptation.**

8. **The 8.9 metre flood map should be amended to better reflect the community's true flood risk aversion.**

9. **Flood mitigation plans should be developed or continue to be developed**.

10. **Consideration should be given to converting areas in the flood zone to less vulnerable recreational or agricultural uses.**

11. **Surveys are a useful way to assess the willingness of the public to tolerate periodic flooding, or to pay for particular flood risk reduction strategies.**

12. **An education and awareness campaign and communications strategy should be developed to inform residents and business owners about flood risk and the actions they can take to reduce their risk**.

13. **Public communication should be ongoing**.

14. **Risk-reduction activities currently underway should be regularly promoted.**

15. **Communication should be enhanced among the municipal, provincial, and federal governments and others like CN rail that have joint responsibility for the maintenance of transportation systems.**

16. **Dialogue should begin with service providers who serve vulnerable populations.**

17. **Children and youth should be engaged.**

18. **Information should be available in multiple formats, including on paper and via the Internet**.

19. **Freshwater flooding scenarios should be incorporated into general flood risk communication**.

20. **The drainage/sewage/lift station/lagoon system should be reassessed**.

21. **The municipal government should bulk purchase items, such as emergency preparedness kits, backflow valves, or crank radios and sell them to the public at cost**.

22. **The municipality should actively promote lower-cost risk-reduction strategies, such as rain barrels or maintenance of green space to reduce overland water flow and help alleviate the strain on municipal storm water systems.**

23. **The Tantramar Community Adaptation Viewer should be supported, extended, and made available to other New Brunswick communities.**

2. Introduction and Purpose

Climate change adaptation is a complex, multi-faceted process that shares all the properties of so-called "ill defined" problems (Andrienko et al. 2007, Sugumaran and DeGroote 2011); it:

(1) Involves criteria, which are multidimensional (social, environmental, and economic);
(2) Involves goals and objectives that may not be completely defined, and stakeholders may have competing goals;
(3) Presents a large number of competing solutions;
(4) Is plagued by high levels of decision uncertainty.

In order for communities to make meaningful progress in planning for and implementing necessary short- and long-term changes, there is a need for information systems which allow community stakeholders to visualize climate change risk information together with various aspects of community vulnerability. Furthermore, such systems should help users to discern critically vulnerable locations, better understand the risks and vulnerabilities involved, and create plausible scenarios representing multiple courses of action. By assisting in the computation and visualization of the impacts of various adaptation measures, it should help users to articulate goals and priorities, thereby identifying the right course of action for the community. Software has tremendous potential to provide the information framework necessary to support all aspects of adaptation planning.

The Tantramar Community Adaptation Viewer Project is a project funded by the New Brunswick Environmental Trust Fund (2013-14, Project #130278), and involves the Town of Sackville, New Brunswick, as a test case. This project is an extension to earlier work funded by the Atlantic Climate Change Adaptation Solutions organization, SSHRC, and Mount Allison University (Mount A REB 2011-042 "Is geovisualization an effective tool for public communication of climate threats?" and Mount A REB 2012-071 "New Brunswick Climate Change Communication Needs Assessment: Expanding the Tantramar Map Viewer").

This project developed new spatial decision support software: the "Tantramar Community Adaptation Viewer" (Appendix 1). Physical infrastructure data (e.g., roads, schools, high density housing) were combined with social vulnerability and environmental information to allow an assessment of the potential impact of various climate-change related, coastal flood-risk scenarios. The toolkit supports the creation of hypothetical planning zones, allows for the exploration of the costs and benefits of each, and facilitates ranking of their relative priority.

Once developed, the prototype was applied to the community of Sackville, in southeast New Brunswick, Canada to evaluate its effectiveness. Through the use of facilitated, group-decision making workshops, small groups of stakeholders were brought together to use the toolkit. Through a progression from problem identification and characterization, to adaptation planning zone delineation, stakeholders brainstormed possible mitigation measures for each zone and suggested many possible adaptation actions.

Project participants were brought together for a plenary session on February 18, 2014 to view the results of their independent workshops. During the plenary, participants brainstormed a range of adaptation measures, and the relative costs and benefits of each were openly discussed.

This project illustrates that high levels of information integration are practical to achieve, and that software-aided decision making is a powerful means to augment awareness of climate change risks, support information exchange amongst stakeholders, allow interactive and dynamic exploration of the costs and benefits of alternative strategies, and stimulate creative problem solving.

3. Research Questions

The research questions focused on the implications of coastal flooding, as revealed by use of the software toolkit, impacting the Town of Sackville, New Brunswick:

1. What locations do expert stakeholders consider to be the most vulnerable to flooding?
2. What makes these locations vulnerable?
3. What areas do expert stakeholders identify to be adaptation "priority zones" (e.g., particular neighbourhoods or sections of dyke)?
4. What are potential adaptation strategies for lowering vulnerability in these zones?

4. Methodology

The project components involved the following:

Phase 1

1. User-informed development of the software toolkit (Appendix 1).

Phase 2

2. Holding preliminary meeting with constituent groups to discuss spatial information requirements (one meeting per group).
3. Amending the project database and Tantramar Community Adaptation Viewer (as necessary and feasible) to reflect the spatial information requirements identified in step #1.

Phase 3

4. Having a second meeting with individual constituent groups (one meeting per group) to present draft Tantramar Community Adaptation Viewer, identify core areas of community vulnerability, create priority zones, and propose adaptation plans to lower vulnerability in those priority zones.

Phase 4

5. The project team developing a summary of the constituent-identified adaptation plans, with a preliminary assessment of the barriers to implementation, and a proposed implementation strategy.
6. Hosting a final plenary meeting with all constituent groups) to present preliminary results of project, as well as facilitate revised priority setting by the entire group.

Phase 5

7. Completing a final report summarizing project findings.

5. Results of Phase 2

This phase involved consulting with seven constituent groups in Sackville: (1) Town Council, (2) dyke managers, (3) infrastructure and emergency response, (4) planners, (5) environmental groups, (6) community service providers (previously referred to as socio-health organizations and government departments), and (7) the public-private sector.

5.1 The Meaning of Community Vulnerability

Focus group attendees were asked to indicate what the word 'vulnerability' meant to them in order to identify notions of vulnerability. The results of the discussions are presented in Figure 1.

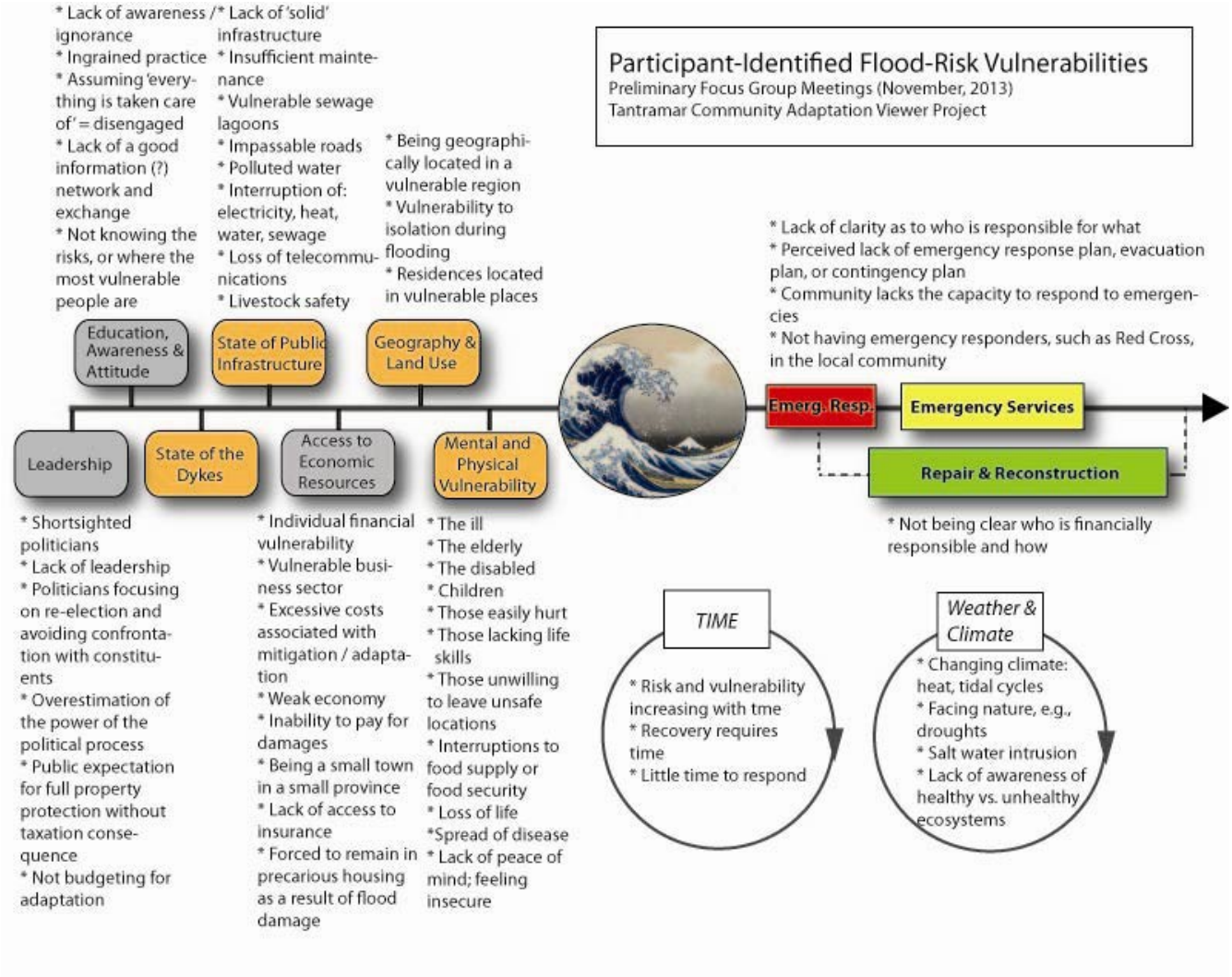


Figure 1. Participant-identified flood-risk vulnerabilities, as volunteered during phase two focus group discussions.

The left side of Fig.1 lists the main elements of vulnerability that could be pro-actively addressed prior to an actual flood event. These are grouped by main theme (see orange and gray boxes). Orange boxes indicate aspects of community vulnerability that are amenable to exploration within a software toolkit. The right side of Fig.1 presents concerns surrounding post-flood response that can contribute to vulnerability during or after a flood event. Against this backdrop are larger global issues such as time, and ongoing changes in weather and climate.

5.2. The Meaning of Community Vulnerability in Relation to Coastal Flooding in Sackville

Focus group participants where asked to indicate which aspects of the term 'vulnerability' applied when they thought specifically about coastal flooding impacting the Town of Sackville. A range of meanings were identified, including: not being prepared and lacking plans; the risk of personal or property damage; a lack of infrastructure; denial; physical and/or social isolation; a lack of information; a lack of economic and social resources; a lack of political will to take mitigative action; and a lack of personal control over the situation.

5.3. Factors that Contribute to Community Vulnerability

When probed further, participants identified numerous factors that they thought have the potential to make communities more vulnerable. These included a lack of leadership, and a reluctance or inability to make use of action planning, emergency response, resources, and/or community supports. Other factors included having insufficient food and water; being geographically isolated; being unable to manage flood waters; having a diverse population with a range of needs; challenges with communication and information management; an attitude of denial or lack of will; a lack of knowledge about what assets to protect; poor housing and infrastructure; transportation disruptions; and a lack of by-laws or policies to govern flood prevention and mitigation.

5.4. Factors that Contribute to Community Resilience

Similarly, participants also identified numerous factors that they thought have the potential to make communities more resilient (Table 1). Many participants felt that the solutions rested in structural changes, such as new planning and government by-laws, management realignments, and so forth. Furthermore, a number of other factors can contribute to community resilience: strong and proactive leadership; proactive action planning; emergency response measures; financial and human resources; community cohesion and support; a sustainable community with access to local food; local power generation; community-based services; water management; understanding the locations of risk; good communications and information management; creating a broad understanding of the issues and risks; identifying community assets and formulating a plan to protect them; improving housing and infrastructure; and creating regulations and by-laws to lead the development and utilization of new tools and planning policies.

Table 1. Participant-volunteered options for enhancing community resilience in the face of climate-change related coastal flood risk

Leadership

- Political will
- Strong leadership that makes adaptation a priority
- Leaders that are prepared to lead and drive forward in the face of opposition
- A leadership that takes responsibility
- Inspirational leadership
- Create a community government that works with all sectors
- Seek government support and awareness at the provincial and federal level

Action Planning

- Identifying risks, including different risk levels
- Assess risk factors
- Have well thought out action plans (e.g., flood plans, contingency plans, emergency plans, evacuation plans, etc.)
- Create strategies that reduce and address risk
- Plan better
- Focus on long term well-being
- Engage in long term planning
- Map the assets and vulnerabilities and create a visual representation of where the strong areas are, where weak spots are, and how the weak spots can be made stronger
- Invest in science/data
- Engage in inter-provincial planning because of a shared region
- Take timely and proactive actions
- Be realistic
- Knowing of and taking advantage of the resources at hand
- Being open to create ideas and solutions
- Being open to compromise and being able to let go of some things in favour of others
- Pre- and post-event planning
- Actively working on adaptation
- Planning for mayhem, such as panic, chaos and looting

Table 1. Continued.

Emergency Response

- Ensure emergency measures staff (and others) are well trained and ready to respond
- Engage the public in policing the dykes
- Ensure people know how to call in case of emergency
- Conduct emergency drills and simulations
- Availability of machinery for repair and emergency response
- Create a community government that works with all sectors
- Seek government support and awareness at the provincial and federal level

Resources

- Identify revenue streams
- Ensure that part of the annual budget is devoted to proactive flood prevention measures; have financial stability
- Have a contingency fund set aside for flood emergencies
- Develop expertise (or engage those that do)
- Plan for eventual retirement of experienced personnel
- Take advantage of the knowledge base at Mount Allison University
- Take advantage of technology, e.g., LiDAR mapping, GIS, web-based information

Community Cohesion

- Encourage the community to take ownership of the problem/issue
- Bring stakeholders together
- Foster community mindedness
- Foster community cooperation and working together towards common goals and objectives
- Being willing to help each other

Requirements of Life

- Ensure that the community is sustainable (e.g., access to local food, local power generation, and the use of local services to adapt)
- Ensure there are community-based services

Location/Geography

- Knowledge about local risks and the effects of climate change/flooding
- Distance from the water

Water Management

- Create buffer zones
- Identify wooded areas
- Identify marsh areas
- Create resiliency of natural areas and respecting their role in decreasing impacts from flooding

- Understanding the importance of healthy ecosystems in protecting communities and people

Table 1. Continued.

Population

- Understand where the people at risk are located
- Engage in community-based work
- Tapping into the natural adaptation power of human beings and demonstrating that adaptation is possible

Communications and Information Management

- Communicate
- Educate the public/community about the risks
- Create strong community awareness
- Engage the community
- Ensure mitigation/prevention activities are visible or promoted so the community sees/understands what is going on
- Gain more access to accurate information
- Have an open and welcoming discussion about risk, vulnerability, and action
- Demonstrate that it can be done
- Learn from others
- Engage in inter-agency communication
- Ensure people have access to information and support
- Understanding the cost of doing nothing

Attitude

- Help people realize that there is a problem; create a broad understanding of the risks
- Take a positive approach to solving issues that make the community vulnerable
- Empower people to make changes
- Create a collective belief that change is possible and that 'we can make it'
- Be forward thinking

Community Assets

- Identify at-risk physical assets and protect them

Housing and Infrastructure

- Have a good understanding of where the infrastructure is located and its state
- Maintain the infrastructure
- Repair the infrastructure
- Increase the level of dyke protection

Regulations and By-Laws (Planning)

- Legislation to lead the development and utilization of new tools
- Develop good planning policies and by-laws
- Discontinue development or expansions into the flood zone

- Effective land use planning
- Zoning for future infrastructure
- Plan ahead, both municipally and on a household to household basis (e.g., emergency preparedness kit)
- A common planning exercise that brings stakeholders together

5.5. Personal Concerns

Focus group participants were asked which vulnerabilities they were particularly concerned about. Responses included leadership; action planning; emergency response; resourcing; community cohesion and social supports; ensuring clean water, food and heat; safety for those in low lying areas; water management; citizen preparedness and safety; communications and information management; attitude about whether or not flooding is a possibility; protecting community assets; safe housing and infrastructure; transportation; regulations and by-laws, such as town planning initiatives and building zones; and pet safety.

5.6. Additional Factors or Questions

Additionally, several factors or questions arose that participants suggested should be contemplated when planning adaptation or mitigation strategies.

1. How does one empower a community to think differently about an issue such as flooding?
2. There are elements of climate change that one does not have to believe but the consequences should not be dismissed.
3. Focus on the facts that are indisputable and avoid getting into the nuances of the climate change debate.
4. The larger issues are perhaps more frightening because they are beyond any one person' personal control.
5. Adaptation often comes down to a question of economics and the amount of money one is willing to pay to adapt, prepare, or mitigate.
6. Flood issues and mitigation are community-wide or global issues so reliance on individual responses will likely not be effective or sufficient.
7. A meaningful public discourse about what should and should not happen while staying on topic will be key to engagement.
8. The pros and cons of adaptation measures will have to be assessed and a reasonable compromise will have to be reached.
9. Community-wide planning is required.
10. Legislative support will be required regardless of the types of adaptation measures that are adopted.
11. It is also important to create institutional memory that will outlive the government of the day.
12. If one adopts an adaptation solution that requires a constant infusion of cash, one will ultimately create a new vulnerability because now one faces a vulnerability of requiring ongoing cash flow that will never be guaranteed.
13. Adaptation planning should consider larger global issues, such as global financial instability, food insecurity, etc.
14. Adaptation does not mean that something has to be torn down or abandoned. However, the community does need a long term plan and decisions and actions that ensue should be part of this long term vision.

6. Results of Phase 3

This phase involved bringing the focus group participants back together to present the Tantramar Community Adaptation Viewer and providing them with an opportunity to interact with the tool. Participants were engaged in identifying locations of concern, identifying districts/zones of concern, assessing the value and vulnerability of zones, and, when possible, ranking the zones. They also completed a short software evaluation to provide additional feedback on the software.

6.1. Core Areas of Community Vulnerability

The participants identified core areas of community vulnerability in the Sackville area. These core areas fell into four categories, as follows:

1. State of the dykes – Several concerns or core segments of dykes were identified along with the Crescent Street sewage lagoon and the railway (particularly the section of rail that is built upon a section of dyke as one leaves Sackville towards Aulac, NB.
2. State of public infrastructure – Numerous concerns regarding the state of public infrastructure were raised including:
    a. The location of the Town of Sackville Public Works department being located in a low lying area;
    b. Emergency measures services, such as ambulance dispatch, being cut off from the rest of town in the event of a flood;
    c. Businesses being located in the industrial park or other low lying areas that may either experience direct flooding and possibly inventory and/or building damage or which may be cut off for the duration of a flood;
    d. Dyke and river infrastructure whose functioning may be affected in the case of an interruption in electrical power;
    e. Health services, such as extramural programs what may be impacted because of transportation disruptions and the inability of service providers to access some parts of town because of road flooding;
    f. Low lying zones that experience frequent flooding;
    g. Mount Allison University's heating plant whose location makes it vulnerable to fresh water flooding;
    h. Natural gas lines that are in the flood zone;
    i. Sewage infrastructure that will be flooded and which may experience a service interruption, and;
    j. Transportation routes that may experience an inundation of water or which may be cut off.

3. Geography and land use – Several residential areas were identified as locations of concern, including Bridge Street, Devon Avenue, Lorne Street and Tantramar Place. In addition, non-residential areas of concern were also identified. This latter group consisted of social clubs like the Legion, naturally wet areas, heritage and museum sites, the industrial park, and several businesses and farms.
4. Mental and physical vulnerability – Several locations of concern were identified where people who may be mentally or physically vulnerable reside or frequent. These included childcare centres, low income housing, residences for the elderly, residential, special care and day treatment programs for those with cognitive delays, and the food bank.

The maps that depict the core areas of vulnerability identified as a result of this project can be found in Appendix 2.

6.2. Tertiary Issues

Numerous tertiary issues were also raised during the course of identifying vulnerable areas/zones. These included:

1. Agricultural Land
2. Awareness
3. Availability of Information
4. Bulk Purchases
5. By-Laws, Policies, and Laws
6. Contamination
7. Depth and Amount
8. Drainage
9. Dykes
10. Education and Communication
11. Electricity
12. Ethics
13. Evacuation Procedures and Routes
14. Flood Extent
15. Hazard Risk Vulnerability Assessment
16. Homeowner Responsibilities
17. Individual Planning
18. Information Dissemination
19. Insurance
20. Islanded Streets
21. Land Use
22. Lift Stations
23. Lorne Street
24. Mount Allison University
25. Multiple Flood Zones
26. Outgoing Water
27. Predictive Capacity
28. Private Service Providers
29. Population
30. Property Values
31. Province of New Brunswick
32. Railroad
33. Renters
34. Residential and Commercial Buildings
35. Roads
36. Run Off Mitigation
37. Sewage
38. Social Vulnerability
39. Storm Water Management
40. Stranding
41. Terminology
42. Time
43. Town Planning
44. Transportation
45. Type and Duration of Flooding
46. Water Mains
47. Weather and Seasons
48. Highway Traffic Overview

6.3. Tantramar Community Adaptation Viewer (TCAV)

Workshop participants were presented with a short questionnaire regarding the Tantramar Community Adaptation Viewer (TCAV). Twenty-eight surveys were completed, with results plotted in Figure 2. It was noted that the TCAV is very useful because it can be used for both problem identification (i.e., identifying points of concern, drawing zones of concern) and solution identification (i.e., adding information about risk mitigating measures in points of concern, or even drawing out potential solutions). Other positive aspects of the viewer included that it seemed to use a wide variety of available data, appeared fairly straight forward to learn and use, was highly visual, clearly depicted problem areas, could be use to demonstrate the potential impacts of different flood scenarios, had powerful features, such as the cost analysis feature, and was 'real', not theoretical.

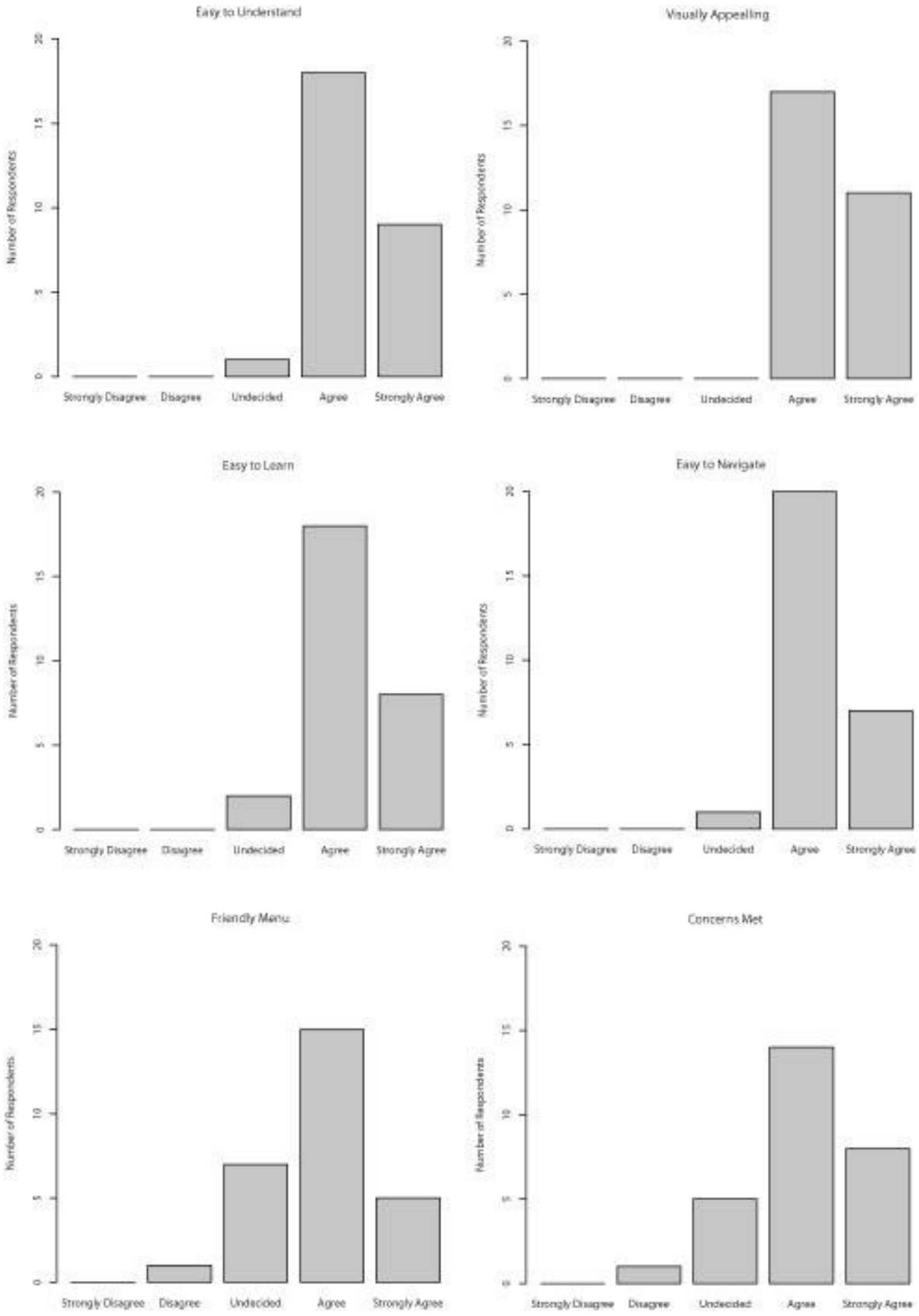

Easy to Understand
Visually Appealing
Easy to Learn
Easy to Navigate
Friendly Menu
Concerns Met
Number of Respondents
0
5
10
15
20
Strongly Disagree
Disagree
Undecided
Agree
Strongly Agree

Figure 2.

A number of modifications were recommended: adjusting the TCAV to include inland flooding areas, wetlands, finer topographical information, the sanitary collection system, population information, zoning information, photographs, and roadway elevations.

It was also suggested that the TCAV might contain additional features, such as being compatible with AutoCAD, portraying depth of water indications, adding a transparency setting to allow users to see multiple layers, superimposed adaptations (such as dyke realignments) to evaluate how they may affect potential flooding,

Participants noted that the TCAV was highly adaptable. It has the potential to be used in other jurisdictions as a land use and emergency planning tool as well as an educational and public awareness stool. To that end, it was suggested that the viewer could be used by private citizens to better understand Town decisions, identify areas for potential rehabilitation, outreach to vulnerable populations, adaptation planning, and calculating and understanding risk.

7. Results of Phase 4

This phase involved bringing the focus group participants back together as a plenary to present the phase 3 results, and to engage participants in identifying potential adaptation/mitigation activities. Participants were also asked to complete a survey to explore their willingness to tolerate flood risk, as well as willingness to pay for particular risk reduction strategies.

7.1. Willingness to Relocate

Participants completed a survey that asked participants a variety of questions regarding their level of acceptance of a flood event and their willingness to pay for adaptation measures. Questions revolved around the following issues:

1. Experience with a major flood event;
2. The type of information most compelling with regards to Sackville's vulnerability to a flood;
3. The level of damage to their home as a result of spring, summer, fall or winter flooding that would be acceptable;
4. The extent of household preparedness for a flood;
5. Acceptance of flood occurrence;
6. The acceptable frequency of flooding affecting their homes;
7. Under what frequency of flooding affecting their homes would compel respondents to relocate;
8. The amount respondents would be willing to pay every year if the Town of Sackville opted to build a municipal dyke, and;
9. The amount respondents would be willing to pay every year to contribute to the raising and maintenance of the dyke system by the New Brunswick Department of Agriculture, Aquaculture, and Fisheries.

16 surveys were completed. It is important to note that the results of this survey are not representative. Nonetheless, they do show some interesting and important tendencies.

7.1.1. Experience with a Major Flood Event

Most respondents did not have direct prior experience with a major flood event. Those that did indicated their experience stemmed from their professional activities (e.g., flood risk mapping, inundation scenarios, water depth mapping, effects on dune/beach systems, repairing dykes), fresh water flooding on roads, coastal erosion due to storm surges on property, and basement flooding. One participant experienced damage as a result of a hurricane.

7.1.2. Compelling Information

Participants were asked, what type of information they find most compelling when thinking about Sackville's vulnerability to a flood (from a personal perspective:

Most Compelling Factor	Frequency of Response
A picture of people affected by a serious, recent flood (e.g., people being rescued in Calgary)	1
An archival photo of a past flood in Sackville (e.g., the flood of 1962)	7
An animation of the estimated flood depth in the Town of Sackville (e.g., the walking man, which is a flood animation that shows water depth in relation to a man walking downtown during a flood)	5
An economic figure (e.g., from a 1:10 flood event, Squire Street will sustain approximately $1.8 million in damages (9.1m flood depth))	0
An estimated flood map for Sackville	5

As one can see, the most poignant information seems to be that which depicts local images, i.e., pictures of one's town during past floods, animations that are situated locally, and a local flood map.

7.1.3. Level of Damage

Participants indicated that, during a spring, summer or fall flood, they would be willing to accept the following levels of damage:

Acceptable Levels of Damage During the Spring, Summer or Fall	Frequency of Response
Home temporarily cut off from town on a neighbourhood 'island'	10
Temporary loss of electrical power	13
Temporary loss of plumbing/sewage services	8
Sewage back-up in the basement	0
Flooding in the basement	1
Water reaching the first floor of home	0
Other (no details provided)	1

Respondents seemed fairly tolerant of being cut off from town or being 'islanded', of losing electrical power, and of losing plumbing or sewage services temporarily. However, there was zero tolerance for sewage back up in the basement and water reaching the first level of one's home. Only one respondent (out of 16) was willing to accept flooding in the basement.

During a winter flood, participants indicated that they would be willing to accept the following levels of damage:

Acceptable Levels of Damage During the Winter	Frequency of Response
Home temporarily cut off from town on a neighbourhood 'island'	10
Temporary loss of electrical power	10
Temporary loss of plumbing/sewage services	5
Flooding in the basement	2
Water reaching the first floor of home	0
Other – comment: • "All of the above would be a major problem for me in the winter and I would not stay."	2

Overall, respondents seemed slightly less tolerant in the winter but overall, respondents seemed fairly tolerant of being cut off from town or being 'islanded', of losing electrical power, and of losing plumbing or sewage services temporarily. However, there was zero tolerance for sewage back up in the basement and water reaching the first level of one's home. Only one respondent was willing to accept flooding in the basement during a spring, summer or fall flood event.

7.1.4. Household Preparedness

When asked what their household was doing to prepare for a flood event, respondents indicated:

Household Preparedness Activities	Frequency of Response
Doing nothing	3
Installing a back flow valve	1
Creating a family flood plan	3
Putting together a 72 hour survival kit	5
Gaining familiarity with the flood map	8
Signing up for the Sentinel emergency warning service	5
Moving out of the flood plain	0
Talking to friends and neighbours	5
Other – comment: • I have installed eaves troughs to help control basement flooding during heavy rain events	1

Of note is the fact that no respondent indicated that they had a plan to move out of the flood plain to higher ground, suggesting that either the the risk of a flood is not compelling enough to cause people to think about moving. Though, in previous questions, the tolerance for flooding in the basement was extremely low and no respondent was willing to tolerate water reaching the first level of their home.

7.1.5. Acceptance of Flood Occurrence

Respondents were asked what they thought about flood occurrence.

Acceptance of Flood Occurrence	Frequency of Response
Although I live in a flood prone area, I consider absolutely no flood occurrence acceptable	0
Because I live in a flood prone area, I have no choice but to accept flood occurrence to some extent	11
I don't know.	1
Other	3

Responses show that the majority of respondents indicated they accept flood occurrence to some extent by virtue of living in a flood prone area. However, as noted above, tolerance seems to focus on a temporary loss of power and plumbing/sewage services. Respondents were far less tolerant of having their basements or first floor flooded.

7.1.6. Acceptable Frequency of Flooding

Respondents indicated that they would accept the following frequency of a flood affecting their home:

Acceptance of Frequency of Flooding	Frequency of Response
None	5
Every year	0
Every other year	0
Once every 5 years	2
Once every 10 years	1
Once every 20 years	0
Once every 50 years	4
Once every 100 years	2
Once every 200 years	0
Other – comment: • I am not willing to accept flooding in my home but may affect road flooding, electrical, etc. • N/A because I don't live in Sackville.	2

Despite respondents unwillingness to relocate in order to avoid flooding (assuming they live in a low lying area), no respondent was willing to accept a flood affecting their flood annually or bi-annually. There was some tolerance for more infrequent occurrences affecting their home, such as once every 5 years (2 respondents), once every 50 years (4 respondents), or once every 100 years (2 respondents).

7.1.7. Acceptable Frequency of Flooding that Compels Relocation

Respondents were also asked at what frequency of flooding accepting their homes would they be willing to relocate.

Acceptance of Frequency of Flooding Leading to Relocation	Frequency of Response
None	2
Every year	1
Every other year	1
Once every 5 years	2
Once every 10 years	1
Once every 20 years	1
Once every 50 years	5
Once every 100 years	1
Once every 200 years	0
Other – comment: • I am not in the flood plain but I would seriously think about it if I were going to be directly affected. • N/A because I don't live in Sackville.	2

The answers to this question were quite varied. However, even moderate flood risk (e.g., once every 50 years, or 2% chance per year) was sufficient to motivate a large proportion of respondents to consider relocating. Two respondents had a zero tolerance for flooding but the remainder of respondents seemed to accept flood risk to some degree, as indicated by their lack of willingness to relocate under scenarios of more frequent flood events.

7.1.8. Willingness to Pay

Respondents were asked what amount they would be willing to pay every year if the Town of Sackville opted to build a municipal dyke across the neck of the Dixon marsh, adding protection to the Town of Sackville from flood by reducing the kilometres of dyke that must be maintained.

Payment Threshold for a Municipal Dyke	Frequency of Response
$0	4
$10	0
$20	1
$30	0
$40	0
$50	5
$60	0
$70	1
$80	0
$90	0
$100	2
$150	0
$200	1
$250	0
$300	1

While a few respondents were willing to pay a $100 or more per year to build and then maintain a municipal dyke, the majority of respondents indicated that they would be willing to pay $50 or less. 4 indicated that they would not be willing to pay for a municipal dyke at all.

Respondents were then asked how much would they would be willing to pay every year to contribute to the raising and maintenance of the dyke system in general.

Payment Threshold for a Dyke Maintenance	Frequency of Response
$0	3
$10	0
$20	3
$30	0
$40	0
$50	4
$100	2
$150	0
$200	1
$250	0
$300	1
$350	0
$400	0
$450	0
$500	1

Once again, responses demonstrate that respondents were willing to pay more than $50 to maintain the dykes in general.

8. Discussion

The research project demonstrated that the Tantramar Community Adaptation Viewer (TCAV) successfully assisted expert stakeholders identify locations of concern (LOCs), as well as delineate zones of vulnerability (APZs) within the Town of Sackville. Key issues of concern involved the state of the dykes, the state of public infrastructure, and geography and land use. Factors that were considered to increase the vulnerability of APZs included low topography, proximity to the dykes, and tendency to be 'islanded' by temporary flood waters.

In addition to physical location, social elements of vulnerability were considered for the first time. Thus, low levels of education and awareness, an attitude of acceptance versus denial, the type of leadership (e.g., proactive or passive), access to economic resources, and mental and physical vulnerability were discussed in relation to contributing to (or conversely, alleviating) vulnerability.

During focus group session, information was brought to light revealing that local emergency measures organizations have been actively drafting an emergency plan for the Town of Sackville. Sackville Fire and Rescue is actively engaging with Ambulance NB, the Red Cross and other agencies to ensure that citizens will be able to get to safety in the event of a flood.

As a result of this project, CN Rail has become more engaged and a dialogue around flood safety and mitigation has begun between Sackville Fire and Rescue and CN rail. Similarly, agencies that have traditionally not been engaged in the flood dialogue have now become more engaged. These include the Horizon Health Network, which the Sackville Memorial Hospital is a part of, the Drew Nursing Home, Daybreak Activity Centre, Mount Allison University, and Playschool Inc. Likewise, representatives from several private businesses in the local Sackville areas were engaged during this research.

Overall, the TCAV was extremely well received. Participants felt that the Viewer was an excellent tool that could be used by expert stakeholders to explore climate change vulnerabilities. It was also considered to be a potentially useful educational tool and an important outreach tools for communicating with the general public or with targeted populations. Respondents felt that the tool seemed easy to use, used visualizations well, and assisted in portraying potential flood extents well. Suggestions for a second generation TCAV included adding flood depths, and the location of the sanitary system. It was also suggested that other types of visualizations, such as photographs, could enhance the effectiveness of the tool in terms of localizing abstract 'facts and figures' in a more tangible and personal way. Importantly, the potential for using the Viewer in other jurisdictions was identified as an important strength of the tool. Thus, the TCAV was received as a powerful visualization system with a wide range of applications.

In interpreting the results from a survey administered at the end of the plenary, 'zero tolerance' of flooding was treated as equivalent to intolerance for a 1-in-500 year flood return period (Fig.3). The '50%' break point (indicated by a broken line in Fig.3), beyond which a majority of respondents indicate an intolerance for flood risk, coincided with an approximately ~ 1-in-180 year flood event. By the 1-in-100 year flood return frequency, ~ 75% of respondents indicated a willingness to relocate.

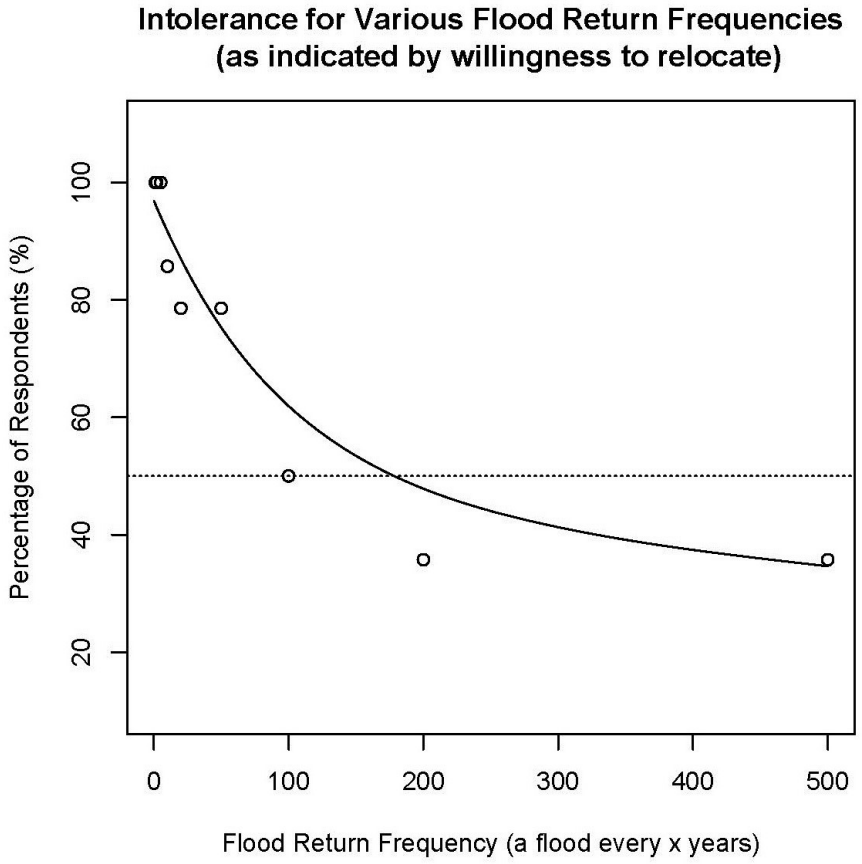


Figure 3.

While the results of survey, which are based on a small number of informed experts, are not representative of the full range of community opinion, one can observe that a 1% chance (1 in 100 year flood event) deters slightly over an estimated 70% of people. By the time one considers flood events of 1 in 50 (2% chance), approximately 90% of respondents indicate a willingness to relocate. This suggests that a 1-in-10 year flood map may under represent people's true sensitivity to risk. Perhaps a 1-in-100 year flood extent for 2100 should be used because as it better captures true risk perception and risk aversion. It would be interesting to see how this compares to non-expert members of the community who are expected to be less well informed about coastal flooding.

The results of the willingness to pay for either a municipal dyke (Fig.4) or raising of the Tantramar dyke (Fig.5, Section 7.1.8) reveal that about 50% respondents were willing to contribute slightly over $40 per year towards these projects. Also noteworthy, however, are the relatively large percentage unwilling to contribute anything: about 27% and 20% of respondents. These numbers need to be interpreted cautiously given the small sample underlying the estimates, but it does suggest that a significant number of people either do not perceive dyke maintenance as a municipal responsibility, or lack confidence in the ability of dyke infrastructure to adequately protect the town.

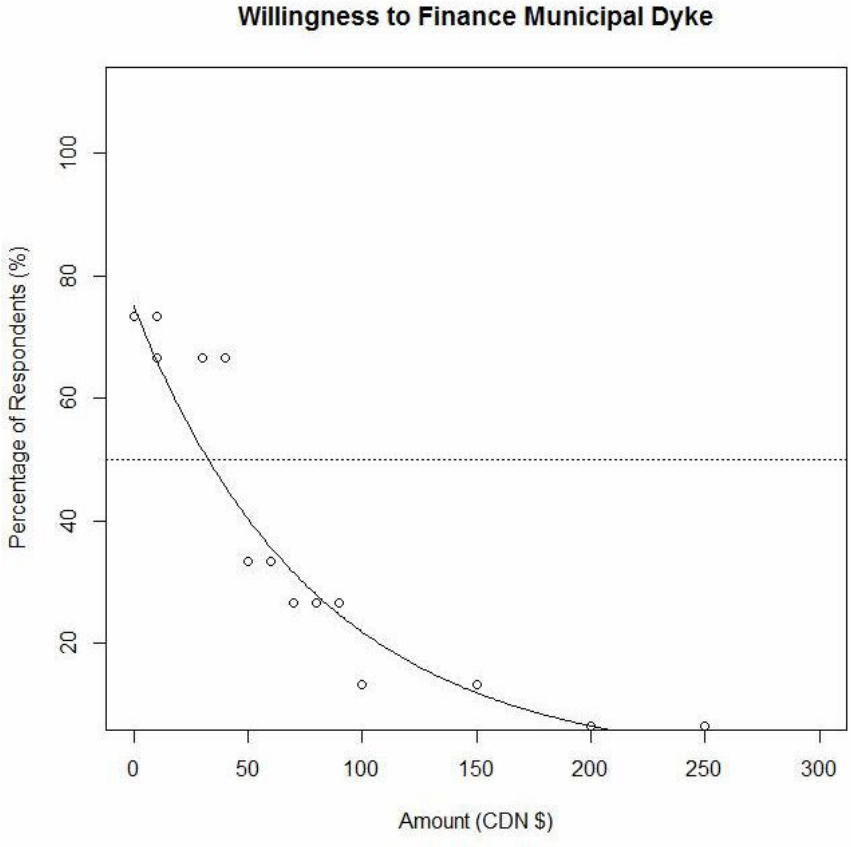


Figure 4.

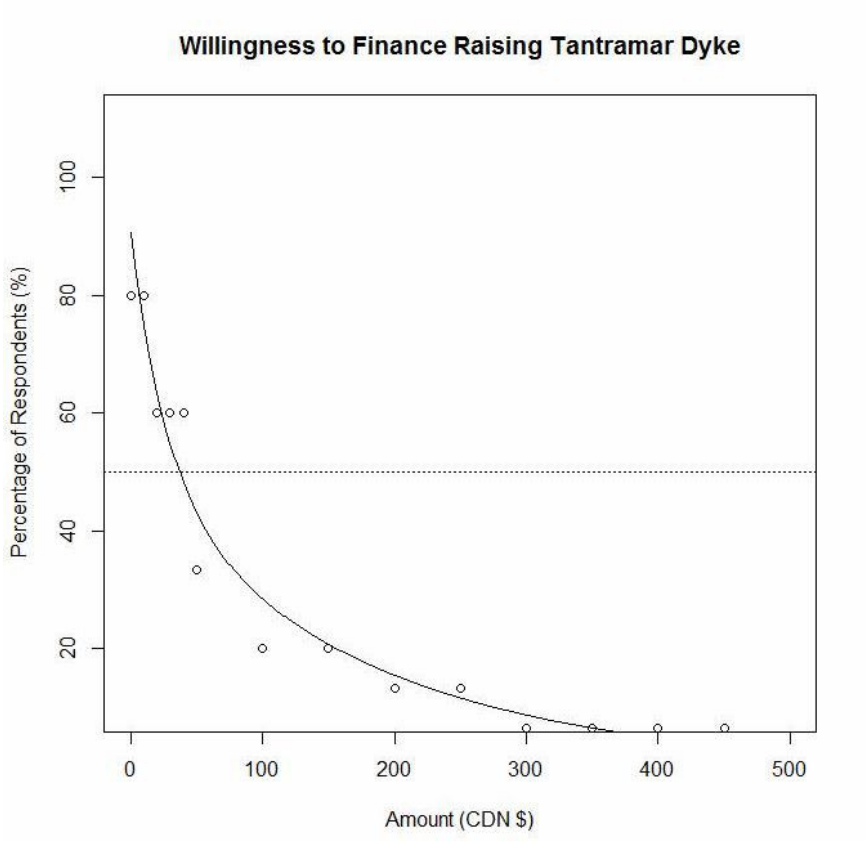


Figure 5.

9. Recommendations

A number of recommendations emerge from this research project and from the plenary session, where participants were asked to comment on potential adaptation/mitigation activities.

1. **The Member of the Legislative Assembly for Tantramar, Electoral District 18, Mike Olscamp should be engaged in flood discussions**. Mr. Olscamp is the Minister of Agriculture, Aquaculture and Fisheries and therefore is ultimately responsible for the department under which dyke maintenance falls. In addition to that, Mr. Olscamp is a resident of Sackville.

2. **The provincial and federal governments are exposed to a minimum of $6-13 million dollars worth of potential residential disaster relief in the wake of a Tantramar flood, and need to weigh the relative costs of proactive relocation versus post-flood disaster relief.** Focus groups identified five main adaptation zones (Appendix 2, Table 3) with a total exposure of $6,470,000 under the current 10% per year, 8.9 metre flood scenario. This estimated damage cost more than doubles to $ 13,475,000 under a 10 metre flood depth (4% chance per year by 2100), for parcels with a current tax assessed value of about $21.6 million.

3. **Dyke maintenance should continue, and requires renewed investment.** In recognition of budget limitations, an ongoing review of the placement of aboiteaux and dykes should continue along with a prioritization of maintenance and upgrades.

4. **The municipal government (Town of Sackville) should issue a policy statement regarding flood adaptation and develop a long term flood mitigation plan** that articulates a municipal commitment to (a) accepting flood risk (b) taking proactive steps to educate citizens about risks and adaptations, and (c) integrates flood risk mitigation into budgets, plans and activities.

5. **The reality of Sackville's flood risk should be integrated into municipal planning and activities**. The flood potential is a reality in this area and should be accepted as such. Accordingly, flood mitigation and adaptation measures should be integrated into municipal government and planning activities to gradually, over time, make Sackville more resilient to flooding and to ensure citizens are engaged and prepared, in as much as is possible. For instance, commercial and residential development should be limited to areas outside the flood zone using a combination of incentives and restrictions. Such a planning approach will ensure that (1) future development is encouraged without adding to the community's flood risk vulnerability, and (2) help to ensure that emergency measures agencies and personnel involved in flood mitigation activities (such as the engineering department) are adequately resourced.

6. **Municipal by-laws and land use zoning should restrict development in areas known to be especially vulnerable to flooding.** Municipalities, on their own, lack access to financial resources to implement expensive adaptation strategies, e.g., relocation of neighbourhoods, but they do have control over present and future land use decisions. Municipalities which fail to adequately manage current and future land use decisions will witness an increase in their community's vulnerability to climate-change related disasters.

7. **A dedicated manager at the municipal level should be designated to spearhead flood mitigation and adaptation.** Someone has to lead the process and be responsible for coordinating activities not only within the municipal government but also among agencies, service providers, and citizen groups to ensure ongoing communication, collaboration, and progress.

8. **The 8.9 metre flood map should be amended to better reflect the community's true flood risk aversion**. The 8.9 metre flood map is based on data from the year 2000 and is therefore too conservative. Given the findings regarding willingness to relocate (Section 8, Figure 3), study participants also revealed a significant risk aversion to even a 1 % chance per year flood event. For this reason, a 1-in-100 year (1 % chance per year) flood event for the year 2100 (10.1 metre flood depth) should be adopted by Town Council

9. **Flood mitigation plans should be developed or continue to be developed** that include an emergency measures plan, storm water management plan, vulnerable populations plan, etc. Such plans should cover various scenarios, such as evacuation and recovery, equipment and human resources, housing/shelter requirements, food and water requirement, first aid and health care. A vulnerable populations plan could involve identifying where vulnerable populations reside or receive services so that a plan can be devised to ensure their safety and to ensure that emergency measures agencies are aware of their presence.

10. **Consideration should be given to converting areas in the flood zone to less vulnerable recreational or agricultural uses.** Creating more green spaces in particular would have the added benefit of further beautifying Sackville and providing additional recreational spaces to the community at large.

11. **Surveys are a useful way to assess the willingness of the public to tolerate periodic flooding, or to pay for particular flood risk reduction strategies**. Such surveys should be distributed to residents and business owners in the Town of Sackville to determine the public's tolerance to potential flooding and willingness to pay for flood adaptation measures. This information could, in addition, be used by decision makers like Town Council to shape responsive and proactive policy.

12. **An education and awareness campaign and communications strategy should be developed to inform residents and business owners about flood risk and the actions they can take to reduce their risk.** This campaign and strategy could draw and build on the toolkit contained in the report entitled *Tantramar Dyke Risk Project: The Use of Visualizations to Inspire Action* (Roness and Lieske 2012) which inventories a range of visualizations that could be used to communicate information and engage various audiences and proposed content for a toolkit that could be both in paper format and available online. The report also discusses the nature of risk communication and communicating for action. Elements of an education and awareness campaign could include:
    α. Explaining what is a dyke and what are they for, not only in a historical sense but contemporarily as well. (Tours of the dykes could be part of an education/communications campaign).
    β. How to prepare a household and/or business evacuation plan, including escape options and the identification of a 'safe' house (e.g., that of a friend or family on higher ground).
    χ. How to make one's house/business less vulnerable to flooding.
    δ. How to formulate 'neighbourhood flood committees' to ensure community support during an emergency.
    ε. Engagement of farmers and others in the agricultural sector who may have operations in flood-prone areas.

13. **Communication should be ongoing**. A one-time centre-spread piece appeared in the Sackville Tribune Post in the Spring of 2013 that informed about the Town Council's adoption of the 8.9 metre flood map. However, such information should appear regularly to maintain the issue in the public consciousness and increase the level of preparedness.

14. **Activities currently underway should be regularly promoted**. There are several initiatives currently under way. For example, emergency measures providers are currently engaged in developing an emergency measures plan for the town. The Town is also implementing an emergency alert (sentinel) system. However, this type of information may not be as widely known as it should be. Promoting ongoing work would educate the public on what is already being undertaken and would demonstrate how the municipality is taking steps to being proactive.

15. **Communication should be enhanced among the municipal, provincial, and federal governments and others like CN rail that have joint responsibility for the maintenance of transportation systems**.

16. **Dialogue should begin with service providers who serve vulnerable populations.** This would include schools and childcare centres (both licensed and non-licensed as well as private, in-home childcares), organizations that deliver services to people with cognitive delays, the hospital, the nursing home, etc.

17. **Children and youth should be engaged.** This could be through formal school programs and the design and implementation of curricula, through summer camps, etc. Information exchange often begins

through the schools where children will often discuss what they learned with the parents. Thus, the schools are powerful mechanisms by which to not only teach children and youth but to reach parents as well.

18. **Information should be available in multiple formats, including on paper and via the Internet**. The Internet is a powerful communication medium that could be harnessed in addition to more conventional communication avenues.

19. **Freshwater flooding scenarios should be incorporated into general flood risk cmmunication.** Many points in Sackville are vulnerable to freshwater flooding in addition to coastal inundation.

20. **The drainage/sewage/lift station/lagoon system should be reassessed** in terms of their maintenance requirements, possible protection measures, etc. On that same vein, one should consider the drainage capability in low lying areas and how lift stations are affected by power failures, for example.

21. **The municipal government should bulk purchase items, such as emergency preparedness kits, backflow valves, or crank radios and sell them to the public at cost**. Bulk buying would increase buying power and lower per unit costs to the consumer. The sale of items could also consider income level such that those with a lower income level could receive the items at no cost or at a subsidized cost.

22. **The municipality should actively promote lower-cost risk-reduction strategies, such as rain barrels or maintenance of green space to reduce overland water flow and help alleviate the strain on municipal storm water systems.**

23. **The Tantramar Community Adaptation Viewer should be supported, extended, and made available to other New Brunswick communities.**

10. Conclusion

This research project built on earlier work looking at the effectiveness of visualizations for public communication of climate change-related flood risks. This was done through a two-pronged approach. First, various stakeholders who are involved in flood mitigation or emergency measures or serving vulnerable populations were engaged in a dialogue about the meaning of vulnerability, particularly within the context of flood risk. Second, new spatial decision support software was developed that combined information about infrastructure vulnerable to coastal flooding with new information about community vulnerability (based on Statistics Canada census data). The software, called the Tantramar Community Adaptation Viewer (TCAV), can ultimately be used by planners to support the creation of hypothetical planning zones, allow governments to explore other costs and benefits of each, and facilitate policy and program planners in ranking their relative priority.

The resulting recommendations offer a framework for developing a comprehensive flood mitigation strategy. The recommendations highlight the need for (a) a strong municipal government to take the lead in developing a municipal adaptation plan, (b) a designated staff or department to spearhead coordination, (c) ongoing and regular communication and education to inform citizens and foster active community engagement, (d) individual responsibility and action, and (e) infrastructure planning, including ongoing maintenance of the dykes and drainage system.

While the discussion and focus of this project centred specifically on Sackville, New Brunswick, the results of this project and the TCAV are inherently flexible and there can be adapted to any location, given access to the required geospatial data.

11. References

Andrienko, G., N. Andrienko, P. Jankowski, D. Keim, M.-J. Kraak, A. MacEachren, and S. Wrobel. 2007. Geovisual analytics for spatial decision support: setting the research agenda. International Journal of Geographical Information Science 21: 839-857.

Hopfer, S. and A.M. MacEachren. 2007. Leveraging the potential of geospatial annotations for collaboration: a communication theory perspective. International Journal of Geographical Information Science 21: 921-934.

Roness, L.A. and D.J. Lieske. 2012. Tantramar dyke risk project: the use of visualizations to inspire action. http://arcgis.mta.ca/docs/Tantramar%20Dyke%20Risk%20Project%20-%20Risk%20Communication%20Report%20-%20FINAL.pdf

Sugumaran, R. and J. DeGroote. 2011. Spatial decision support systems: principles and practices. CRC Press, New York.

Wilson, J., R. Trenholm, J. Bornemann, and D. Lieske. 2012. Forecasting economic damages from storm surge flooding: a case study in the Tantramar region of New Brunswick. http://arcgis.mta.ca/docs/ForecastingEconomicDamagesfromTantramarStormSurgeFlooding.pdf

Appendix 1: Overview of the Tantramar Community Adaptation Viewer (TCAV)

This section outlines the design and implementation of the Tantramar Community Adaptation Viewer (TCAV), a web-based spatial decision support system (web-SDSS) for assisting adaptation planning. The web-SDSS is implemented using a thin-client, Javascript enabled user interface combined with an ArcGIS Server back-end, and can be run in any web browser by a distributed body of users.

It allows for the visualization and analysis of overlapping "risk" and "sensitivity" layers, the creation of locations of concern (LOCs), and the interactive development of adaptation planning zones (APZs). In a Web 2.0 fashion, users upload their knowledge of community vulnerabilities, and rank their perceived importance. The prototype web-SDSS was applied to a community in south-east New Brunswick, Canada to evaluate its effectiveness.

Figure 1 illustrates the main viewer screen, with the bulk of the display occupied by the central map viewer. Feature creation tools (#1, Figure 6) are continually accessible from the lower horizontal pane, and are classified as either "locations of concern" (LOCs), "adaptation planning zones" (APZs), or "dyke improvement zones" (DIZs).

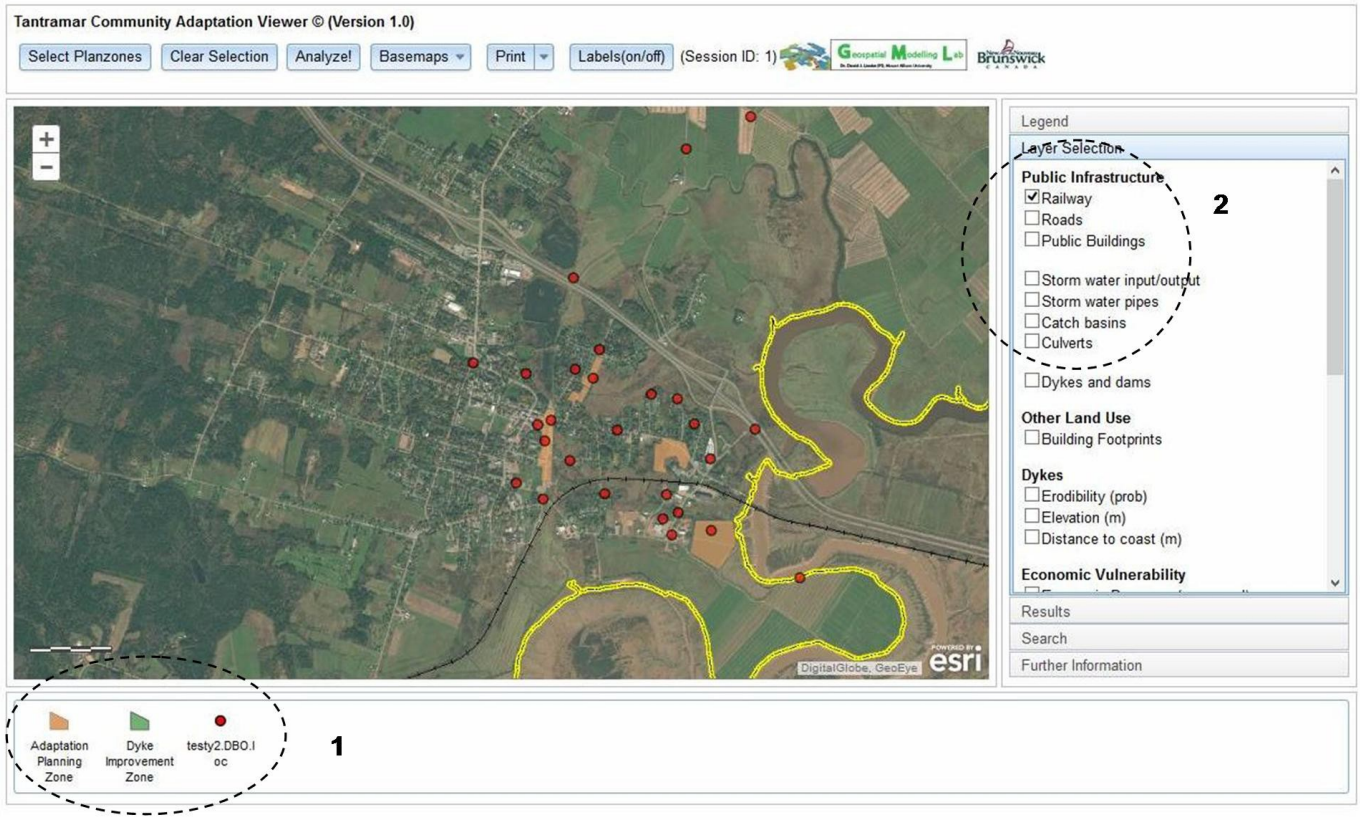


Figure 6.

Features are created as part of an interactive session (in Fig.6., using an example session id number of 1), which are invisible to users outside of that session. This allowed for large and diverse groups of stakeholders

to be subdivided into smaller working groups for the purposes of adaptation prioritization. In this way, "collective information sharing" bias (Hopfer and MacEachren 2007), or the tendency for people to self-censor themselves when in a public setting, could be minimized. Individual data layers (summarized in Table 2) can be hidden or exposed using check box controls (#2, Figure 7).

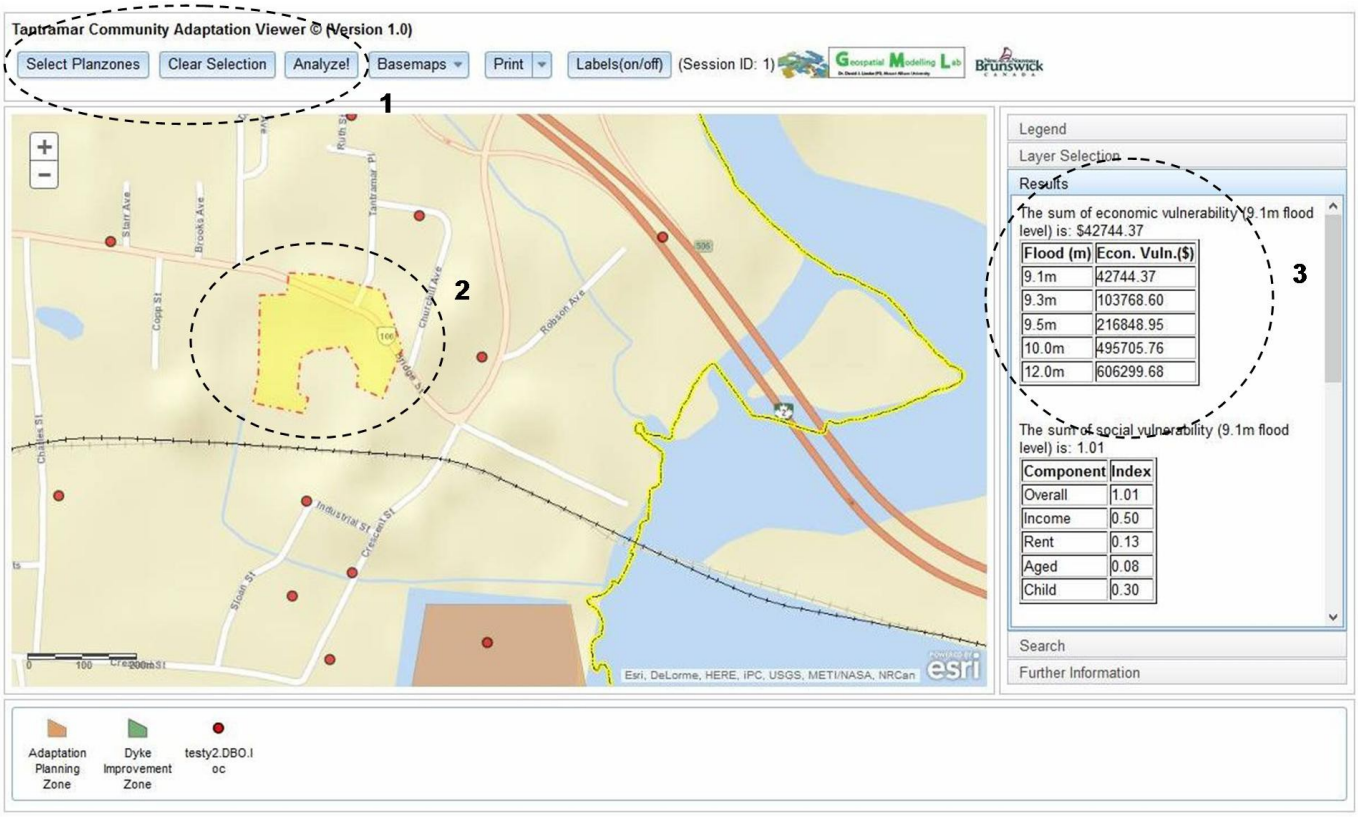


Figure 7.

Figure 7 illustrates the dynamic query tools available in the TCAV. Using the button controls in the top pane (#1, Fig. 7), APZs can be selected (#2, Fig.7), and economic and social vulnerability summarized in the results pane (#3, Fig.7).

The integration of economic and social vulnerability information is a major innovation incorporated into the TCAV. Such information is normally scattered or unavailable. Flood damage information, based on the work of Wilson et al. (2012), was calculated for current (2000) and projected (2025, 2055, 2085 and 2100) 1:100 year sea levels. Economic damages, which depend on the extent and depth of flooding, were calculated for property parcels by summing the value of exposed building structures, building contents, vehicle values, and (where relevant) agricultural crop values. Agricultural damages considered the value of the crop type at different times of year, and the percentage of active agricultural land flooded. It was assumed that damages to residential, commercial, and public parcels are tied to the structures on the parcels. Damage depth curves relate the depth of floodwater to the expected severity of damage to building structural, content and vehicle damages, and were obtained from the U.S. Army Corps of Engineers. The damage costs are based on flood depth, property value, and are weighted by the percentage of the building footprint flooded on any given parcel. Vehicle costs were only calculated for residential buildings that were flooded and number of vehicles

was determined from NRCAN assessment of NB households, and market values assessed from a review of local used vehicle prices.

Social vulnerability was assessed using a social vulnerability index (SVI) to reflect residents' relative ability to prepare, respond and recover from flooding. When creating the SVI, care was taken to ensure that the range of social vulnerabilities to flooding were reflected, that the vulnerability types were equally weighted, and that the index was easily interpretable. Literature was initially reviewed to identify the types of social vulnerabilities that can make it difficult for neighbourhoods to prepare, respond and recover from flooding. Measures of these indicators were obtained from the 2006 Canada Census (Statistics Canada), and Principal Component Analysis (PCA) was used to group similar, or correlated, indicators together. Interpretation of the PCA shows that there 4 social vulnerability groups exist in NB: socioeconomic status (wealth, knowledge and employment status), minorities and renters, elderly, and youth. When creating the SVI, a single representative measure was selected from each of the 4 vulnerability groups: median income, percentage of dwellings that are rented, aged dependency (the ratio of persons over 65 to the population aged 15 to 65) and youth dependency (the ratio of persons under 15 to the population aged 15 to 65). Renters were selected instead of minorities because in the Tantramar region renters were deemed to be more vulnerable. Each vulnerability measure was scaled out of 1 (by dividing by the provincial maximum value), and the sum of the 4 scaled measures was calculated to create the SVI. A SVI score of near to 0 means that communities are less vulnerable to flooding while a SVI score approaching 4 are more vulnerable.

Table 2. Data layers accessible for display and interaction within the TCAV.

Layer Group	Data	Resolution / Scale	Source	Description
Dyke Vulnerability	Distance to coast	1 m horz., 0.15 vert.	MTA GML	GIS derived data layer
	Height	10 m	MTA GML	Maximum height and elevation profile at each 10 m section of dyke. Derived from LiDAR.
	Erodibility	10 m	MTA GML	Modelled from NDVI, proximity to coast, historic erosion
Social Vulnerability	Social Vulnerability Index (SVI)	Dissemination Area (area containing ~500 persons)	http://www.statcan.gc.ca/	Social vulnerability obtained using Stats Canada Census Dissemination Areas
Infrastructure Vulnerability	Roads	1:10,000	RSC7 planning	Digitized from 2013 satellite

Layer Group	Data	Resolution / Scale	Source	Description
				imagery and SNB DPM
	Hospitals	0.05-10 m	SNB real property attribute data	
	Seniors residences	0.05-10 m		
	High density residences	0.05-10 m	SNB	
	Building Footprints	1:5000	MTA GML	Digitzed from 2009 orthophotos
	Historic sites		Parks Canada	
	Waste treatment facility	0.05-10 m	SNB	
	Lift Station	0.05-10 m	SNB	
	School		SNB	
	Church	0.05-10 m	SNB	
	Storm water system	0.5-10 m	Town of Sackville/MTA GML	
	Rail Line	0.05-10 m	SNB	
Economic Vulnerability	Depth-damage costs based on different flood depths	0.05-10 m	Wilson et al. (2012)	Privacy concerns require that individual properties can-not be displayed
Land Allocation	AgUse	1:10,000	NB Dept. Aquaculture Agriculture and Fisheries	
	Zoning	0.05-10 m	RSC7 planning	
Adaptation Planning	Location of Concern (LOC)			User-created during workshops
	Adaptation Planning Zone (APZ)			User-created during workshops
	Dyke Improvement Zone (DIZ)			User-created during workshops
Risk Layers	Maximum extent of inland flooding	1 m	MTA GML	Derived using a "bathtub" model for 8.9m to 10.2m flood depths

Appendix 2: Core Areas of Vulnerability

The maps contained herein are a result of the phase 3 discussions whereby working sessions were held with various stakeholder groups to identify core areas of vulnerability in Sackville. The red dots or 'pins' represent vulnerable locations of concern (LOCs), the orange polygons represent adaptation planning zones (APZs), and the green polygons represent dyke improvement zones (DIZs). All three feature types were identified by project participants and created during the small-group sessions of phase 3.

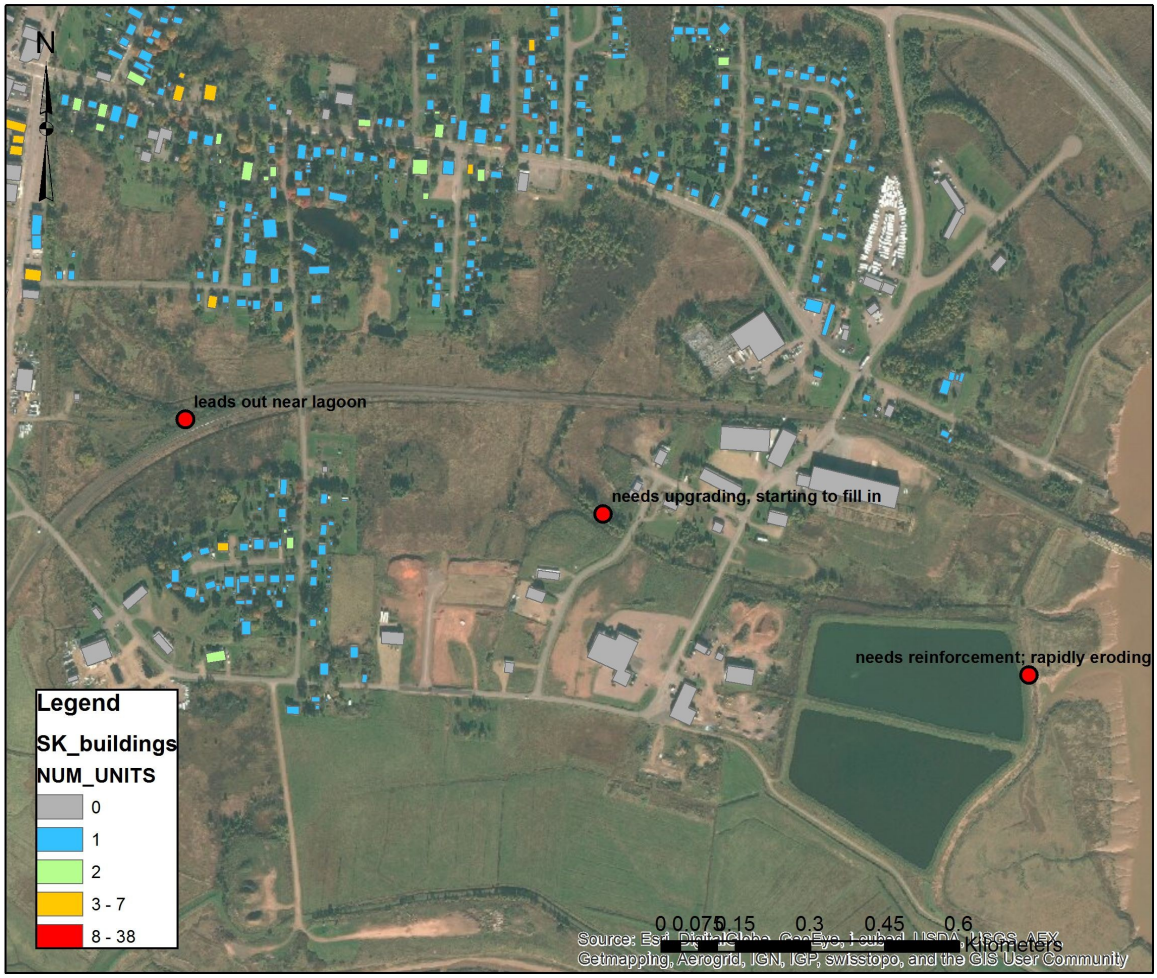
1. Aboiteaux

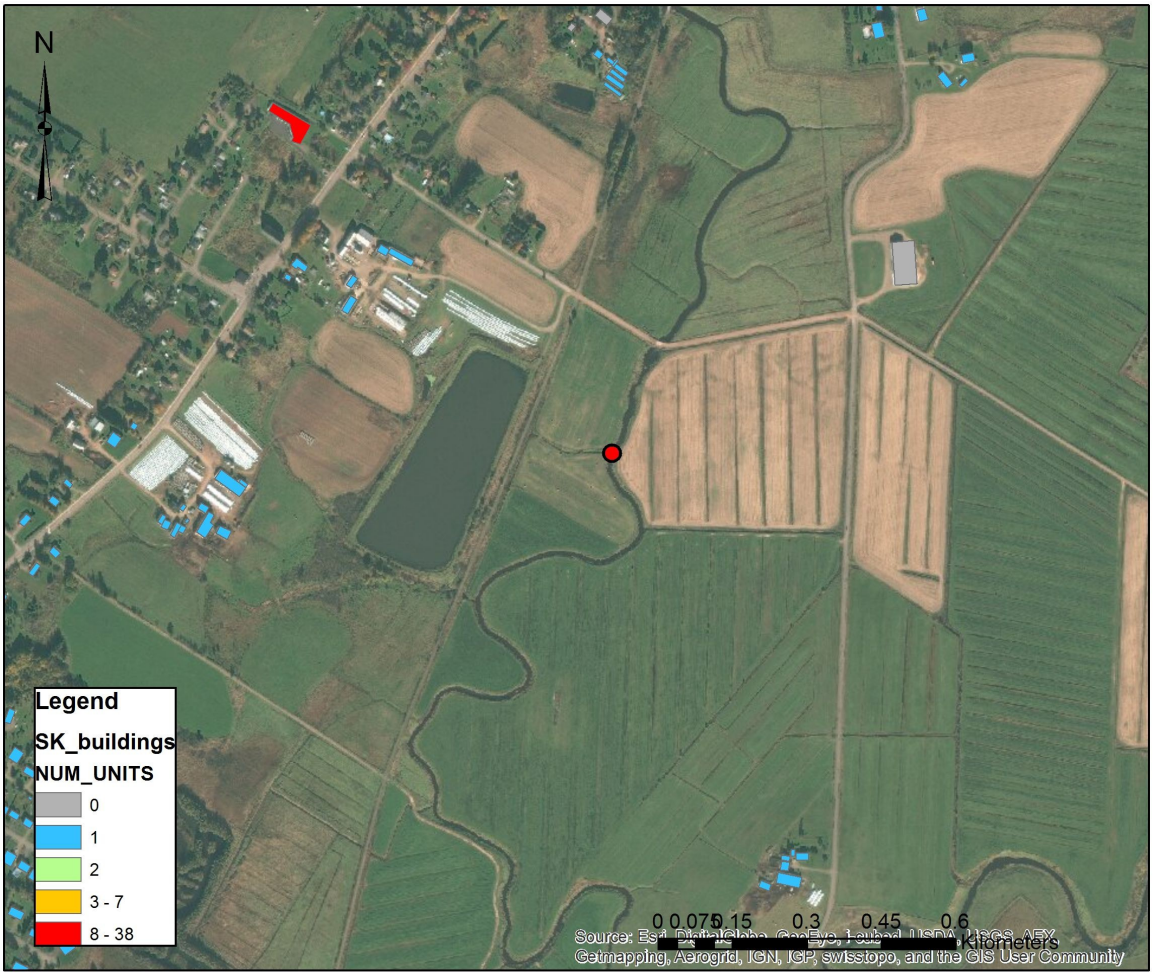
This map depicts aboiteaux considered to be vulnerable to stresses associated with sea level rise. The need to maintain the aboiteaux, along with the associated drainage ditches leading to these features, was repeatedly raised. These points and the ditches leading to them are the means by which accumulated water can drain away from the land and exit the bay. In order to fulfill this function, they need to be cleaned of leaves and organic matter to avoid back up.

2. Drainage Maintenance

The following maps depict various points along the drainage system that are vulnerable. As noted above, if proper drainage is not maintained, water will be more likely to accumulate. It was noted that drainage vulnerabilities are relatively low cost activities that should be addressed immediately and routinely.

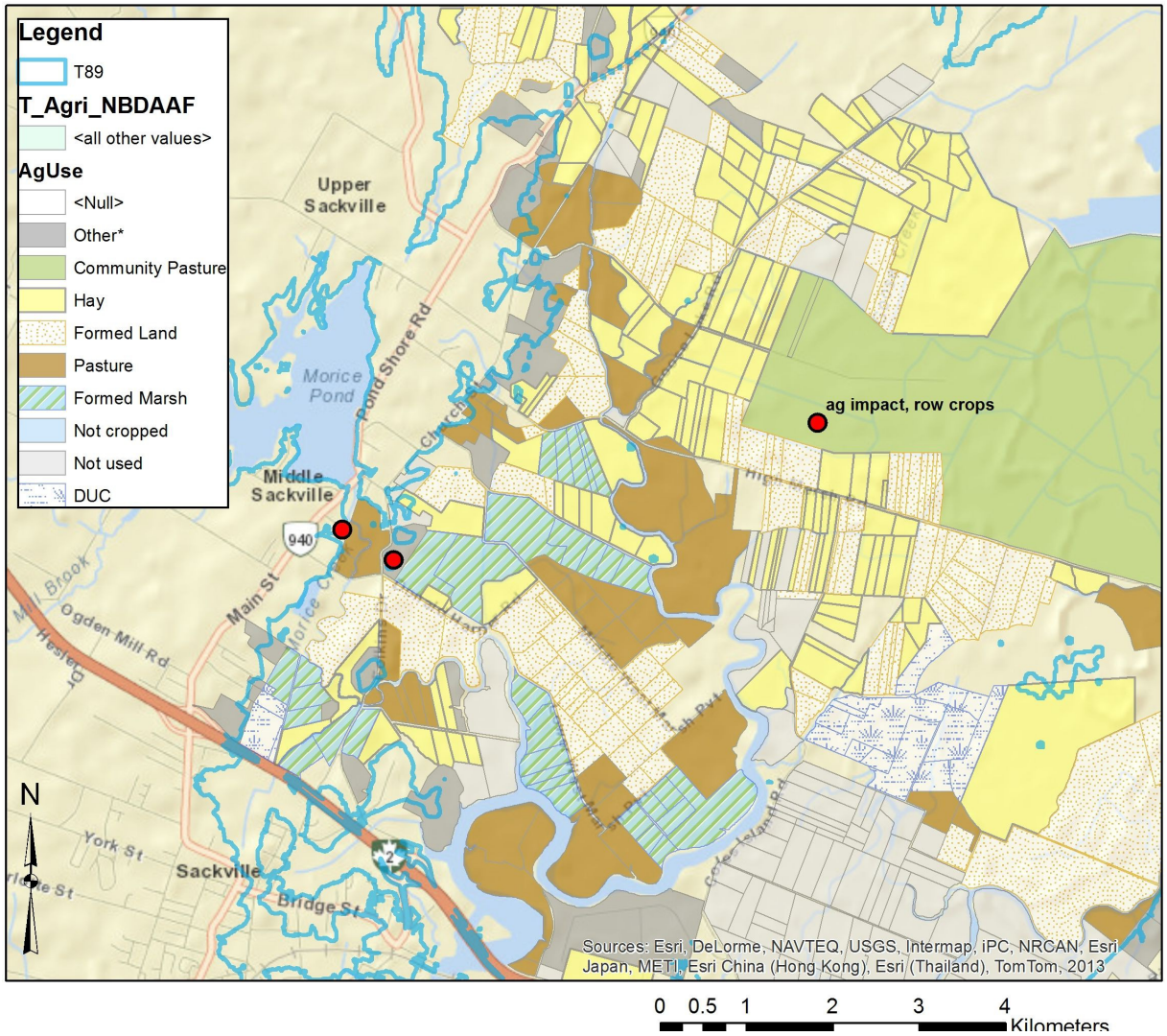
The outlet for the sewage lagoon was also flagged as a LOC on account of its design. Participants reported that water exiting the outlet is causing river bank erosion, and it was suggested that a conduit be installed to convey water further away from the bank..




N
Legend
SK_buildings
NUM_UNITS
0
1
2
3 - 7
8 - 38
0 0.075 0.15 0.3 0.45 0.6
Kilometers
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

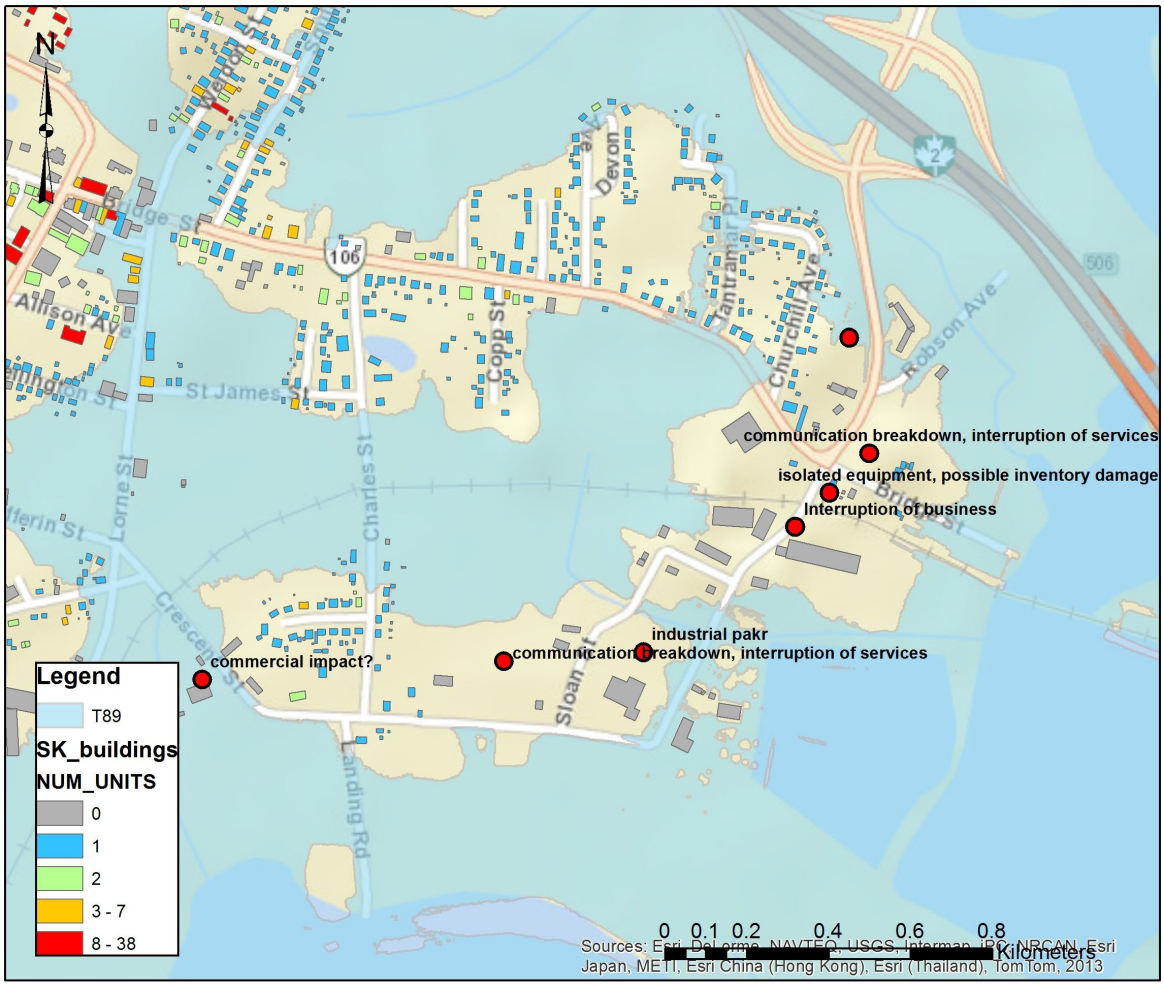
3. Agricultural Impact

The following map classifies the types of production occurring in the Sackville area. The yellow shaded areas represent hay crops, the brown is pasture land, the green is common pasture, etc. (see the legend inset on the map). Rural areas are a lot more resilient in general. There may be a temporary deposition of sediment and salinity as a result of a flood but eventually conditions will be renewed.



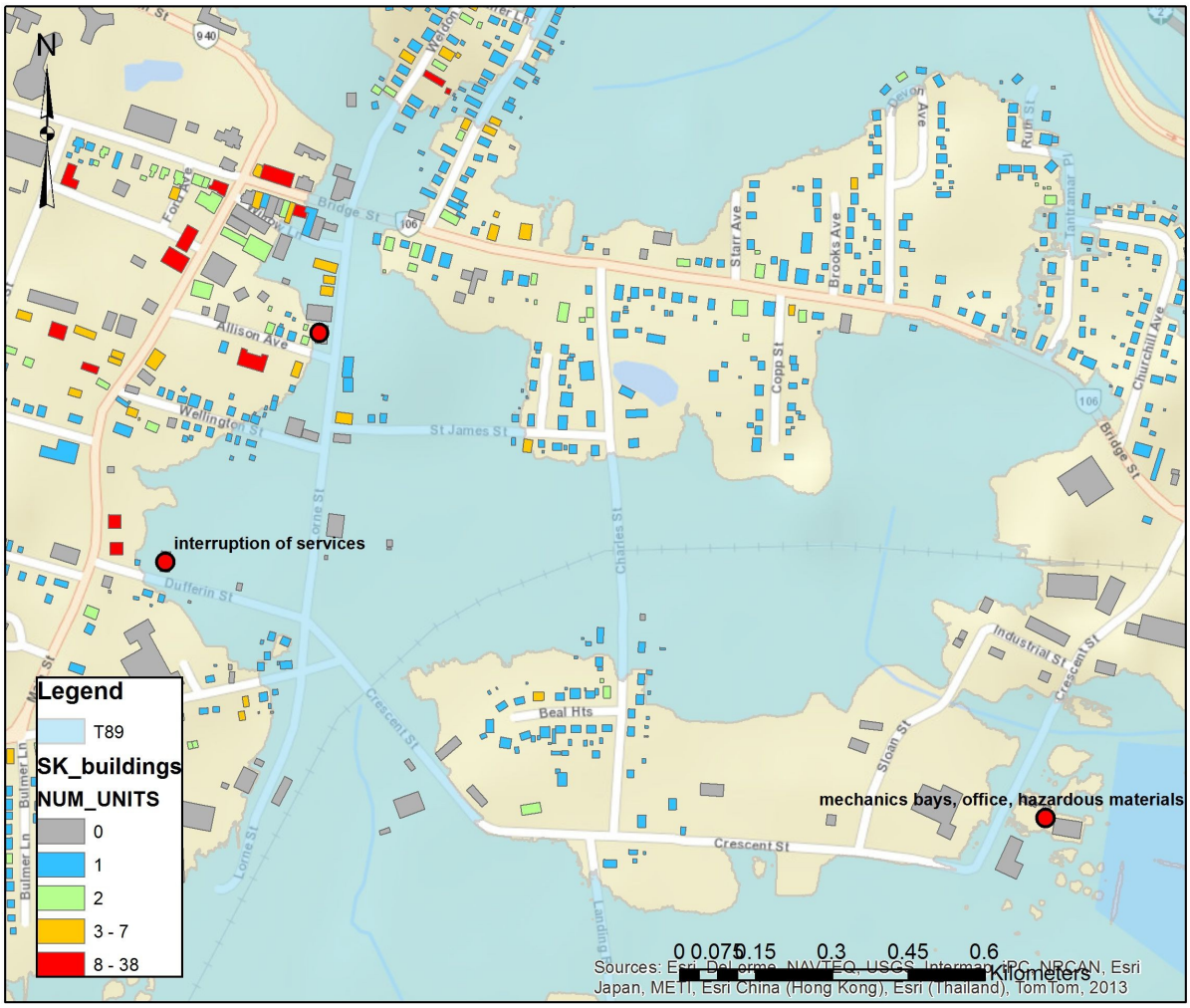
4. Commercial and Industrial Impact

Businesses located in the industrial park may not necessarily flood directly but as the map below shows, islands may be formed, temporarily cutting off the industrial area. Employees may not be able to get to or from work and inventory may be damaged while in storage. If there is an electrical outage, operations requiring electricity or materials/supplies requiring refrigeration, could be interrupted or damaged.



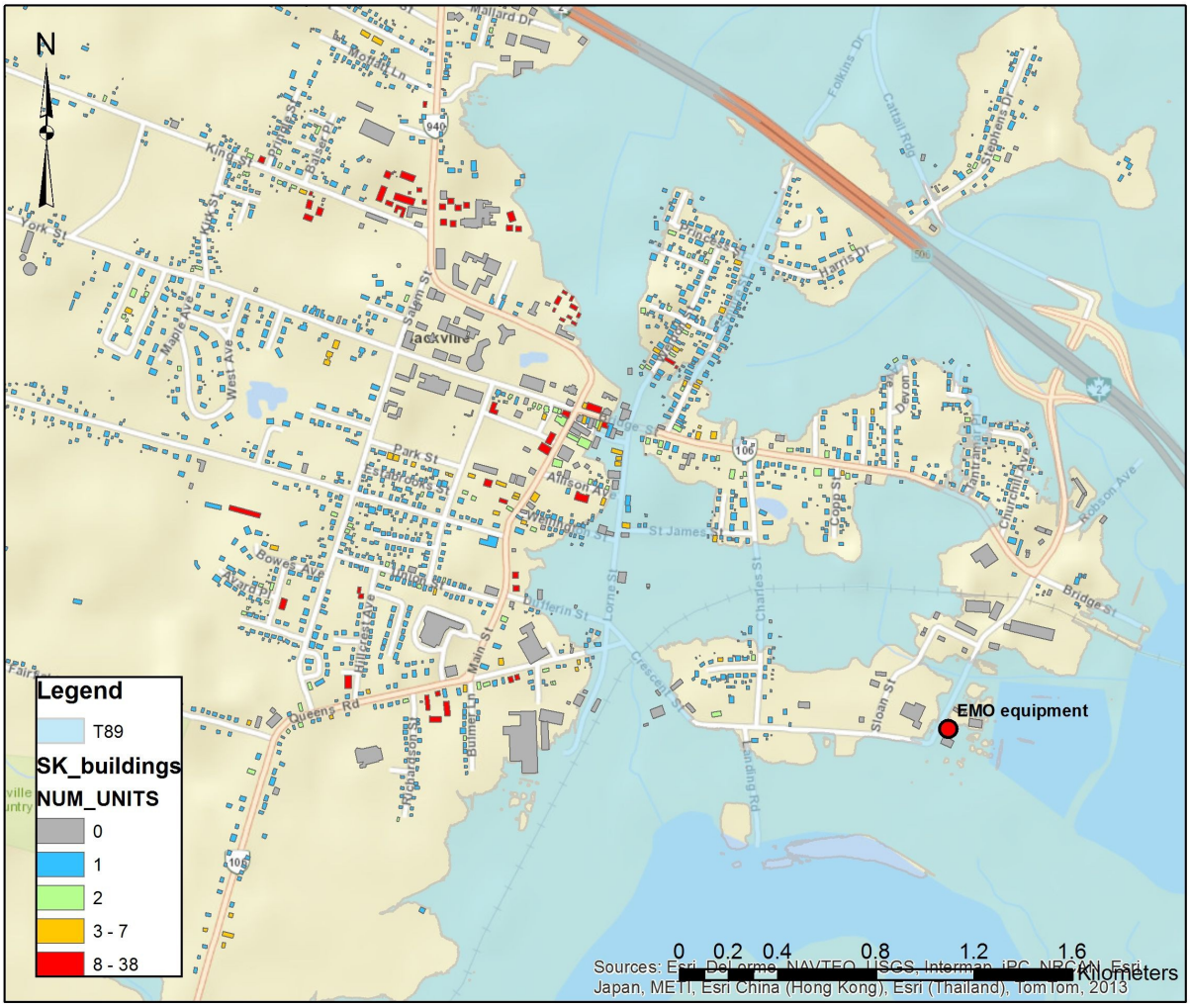
5. Community Service

Even under an 8.9 metre flood scenario, community services may potentially be affected; services will likely be halted or impeded.



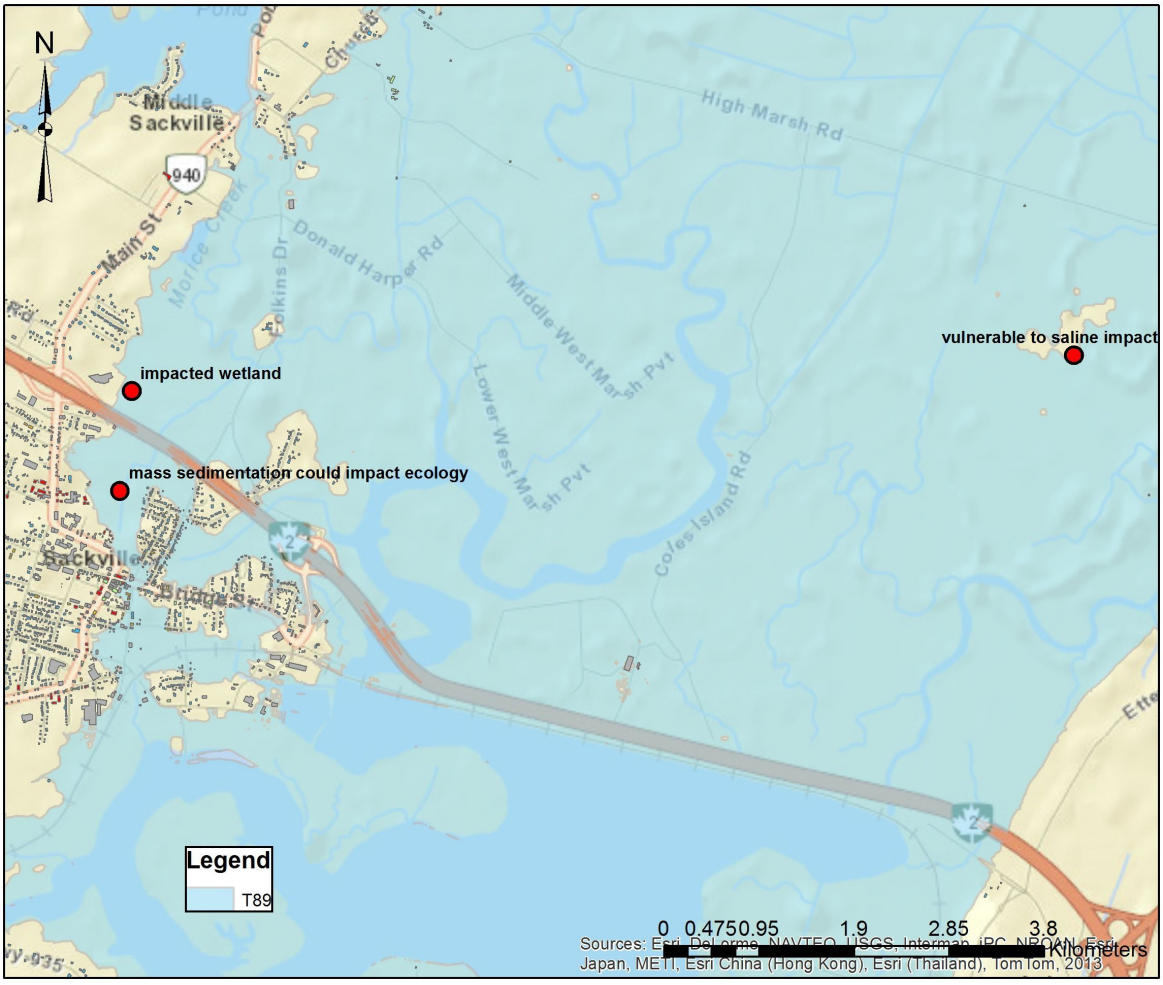
6. Emergency Measures Equipment

Similarly, because emergency measures equipment is stored in the industrial area, it will likely suffer from isolation and 'islanding' during a flood. Unless that equipment is evacuated at the first signs of a flood, accessing it could be extremely difficult.



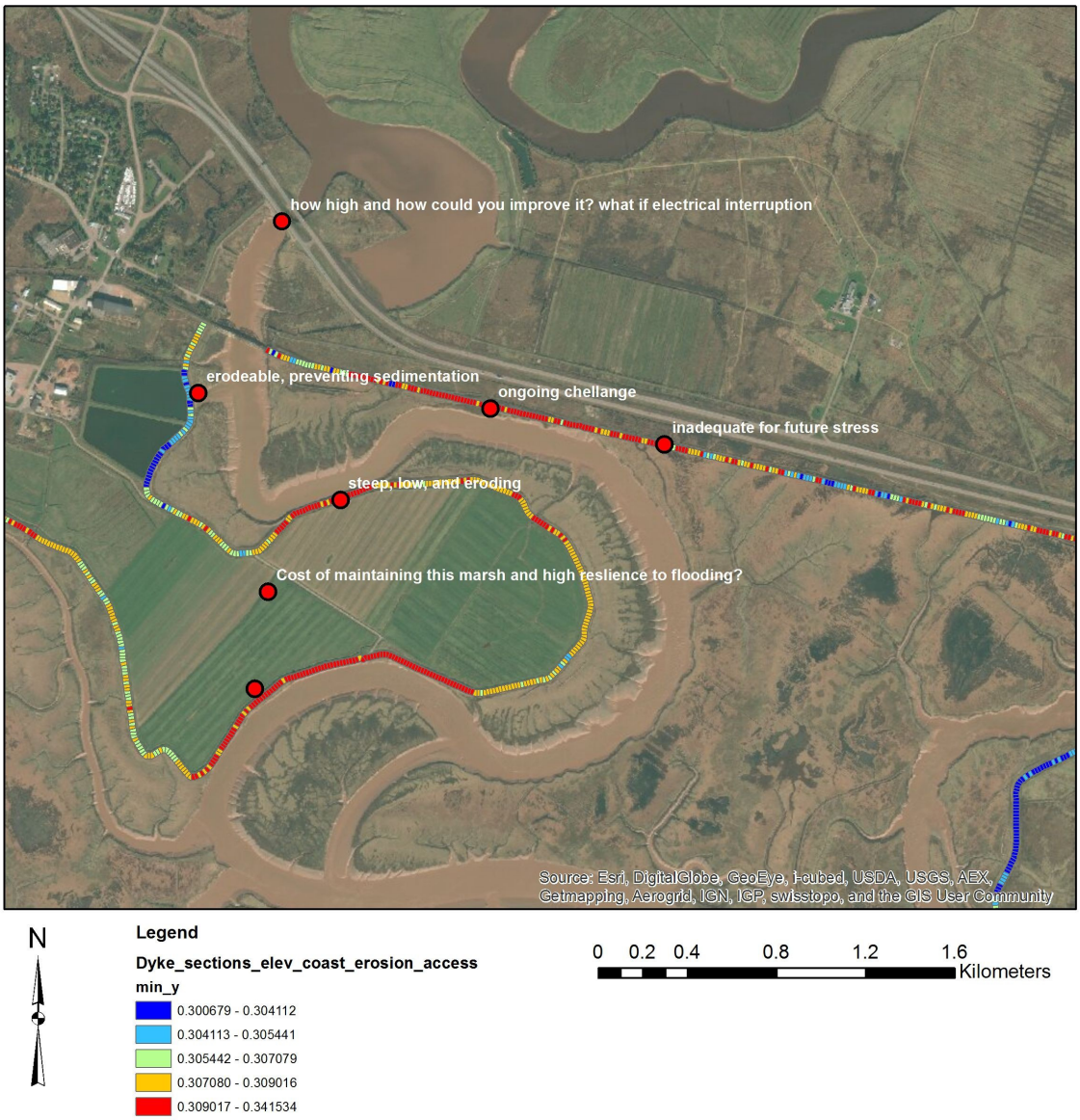
7. Ecological Impact

The map below indicates that during a flood, the Sackville Waterfowl park will likely flood. The chemistry of the wetland will be impacted and the shape of the wetland will likely be altered as well as a result of sediment loading. It may be necessary to dredge and reshape the wetland to return it to a healthier state and to its pre-flood form.



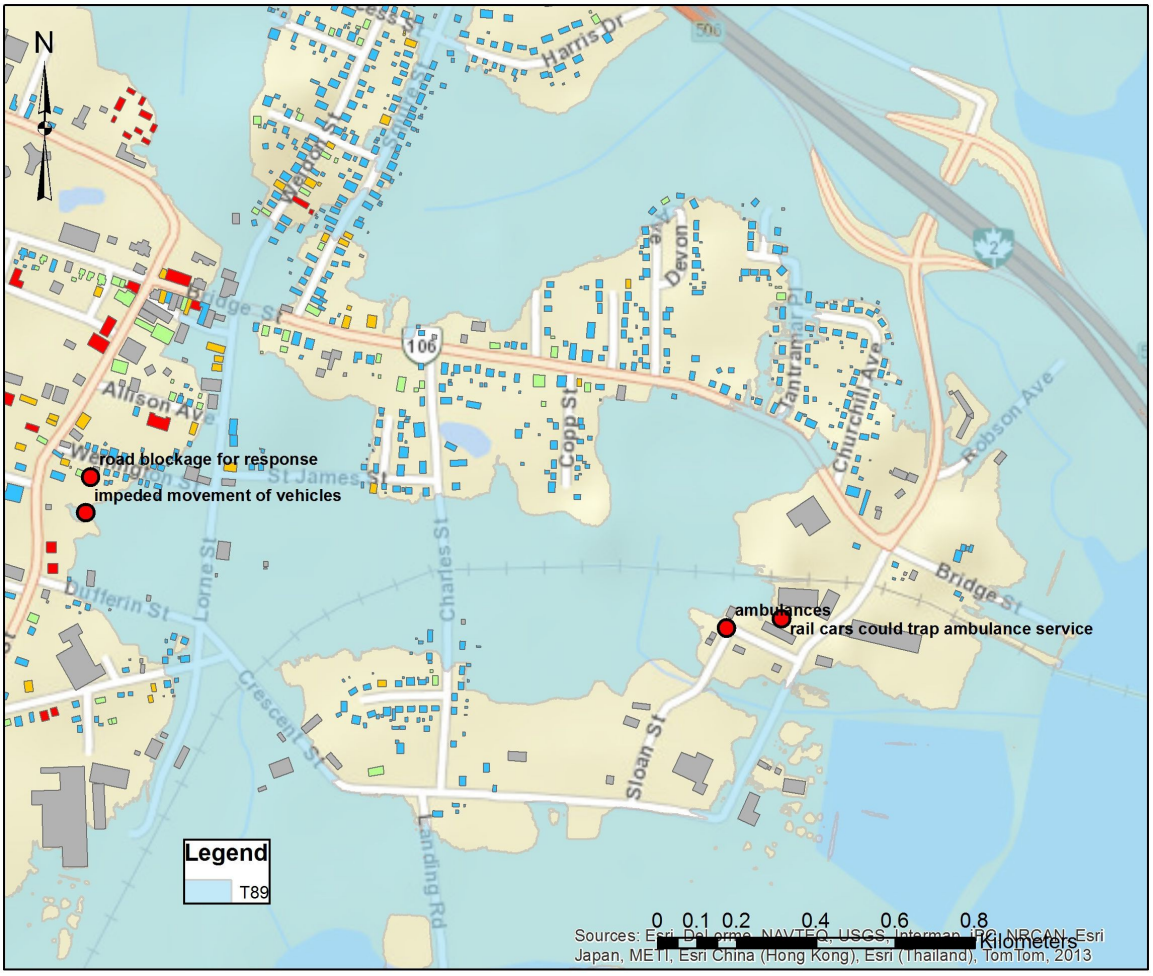
8. Vulnerable Dykes

The dykes are under constant pressure. They are literally keeping the tide waters out. The red areas shown in the map below are the most vulnerable sections of the dykes that are low or considered to be extra vulnerable to erosion. The portion of the dykes that follow the bends in the river are particularly vulnerable; they receive water that comes out of tidal dams and these sections are getting scooped away. As noted earlier, the Crescent Street sewage lagoon which abuts the dyke on one side also faces erosion. The section of the railway that is along the top of one section of the dyke (as one leaves Sackville towards Aulac) also faces ongoing damage.



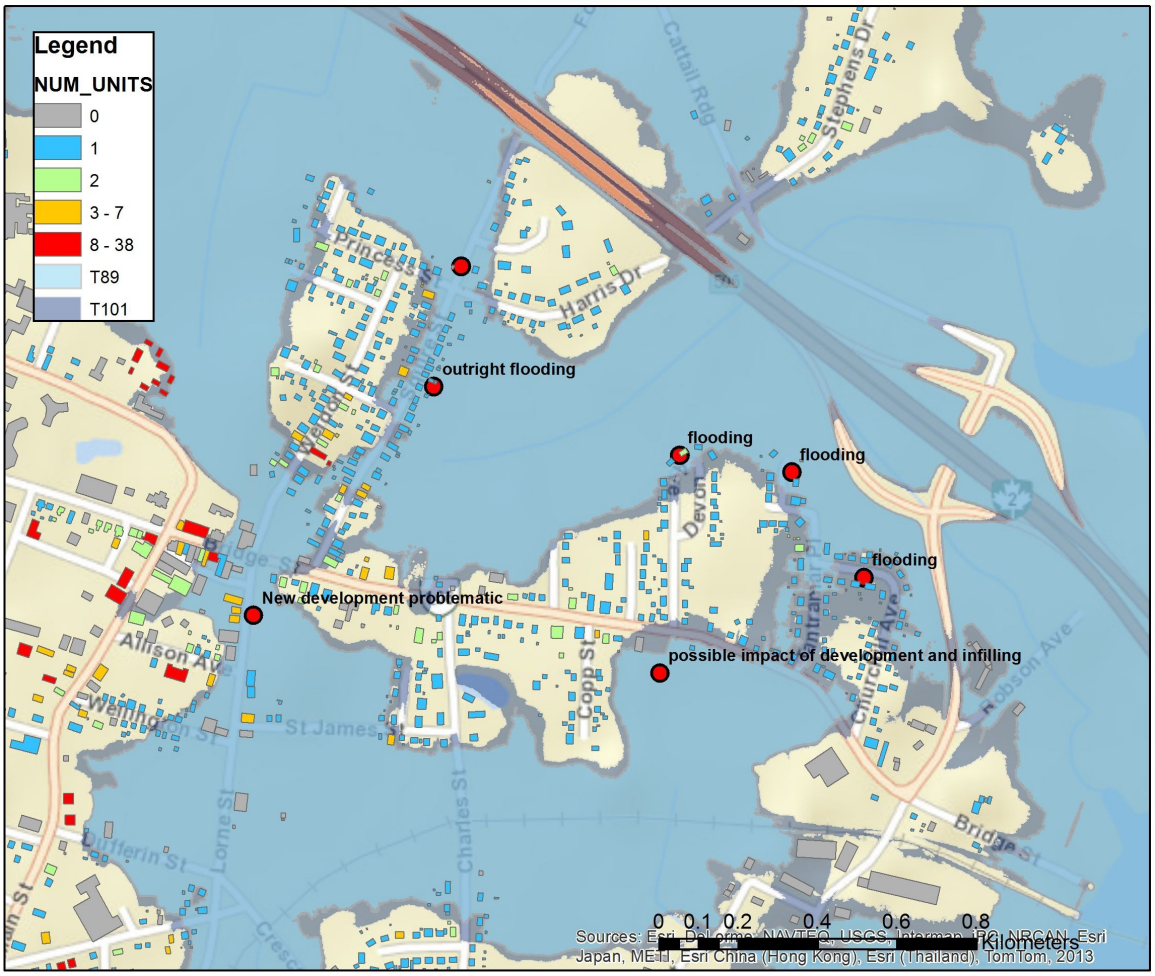
9. Emergency Services

The ambulance bay is located in the industrial park and there is potential for the ambulances and personnel to be temporarily stranded if the road access points to the industrial park are flooded without sufficient warning. In addition, the rail track cuts across both entrances to the industrial park and in the event of an immobilized train the cars would potentially block both entrances, effectively stranding everyone else in the industrial park, including the ambulance personnel and vehicles.

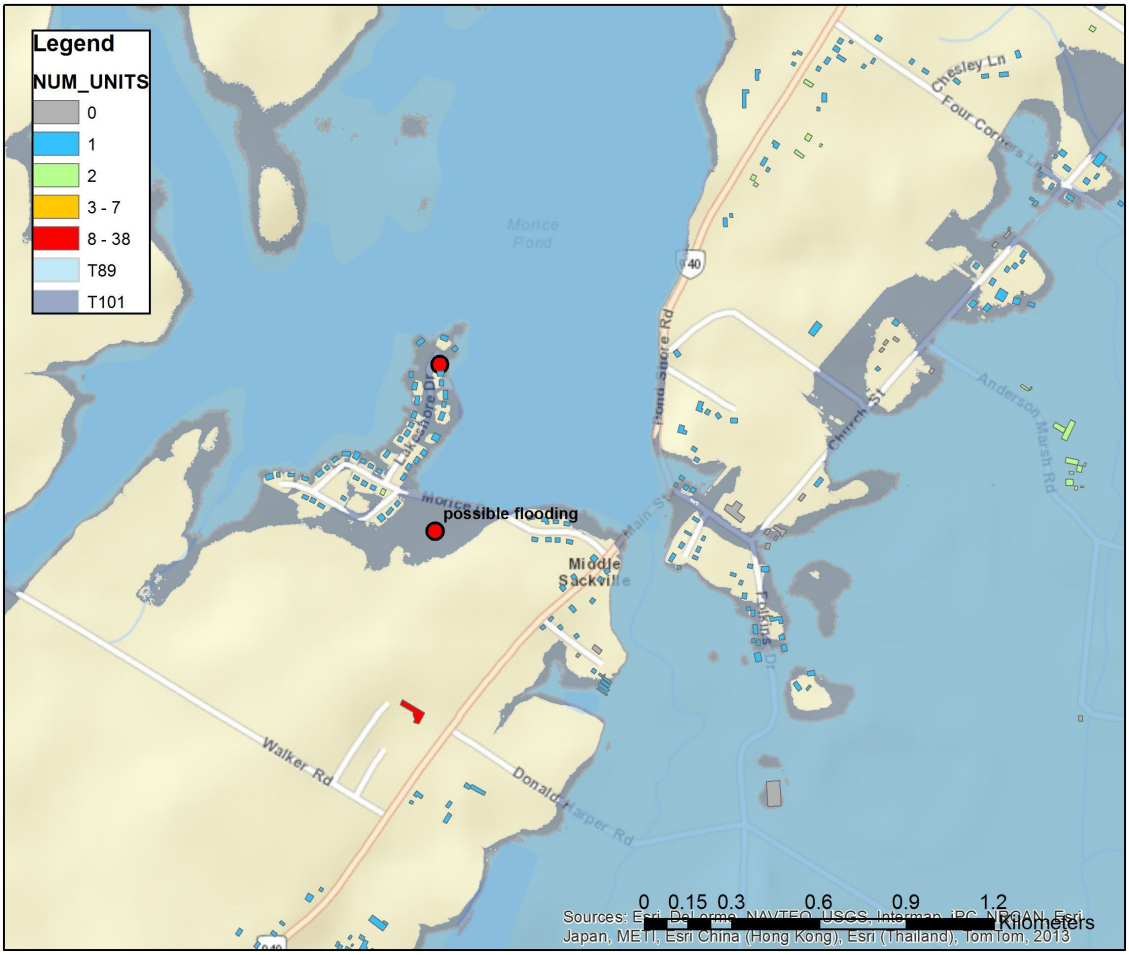


10. Flooded Neighbourhoods

These maps depict the residential areas that are particularly vulnerable to flooding and which may be 'islanded'. Not surprisingly, participants in different focus group sessions consistently identified these neighbourhoods, which included: Squire Street, Lorne Street, along its entire length, Tantramar Place, and Devon Avenue (upper end).

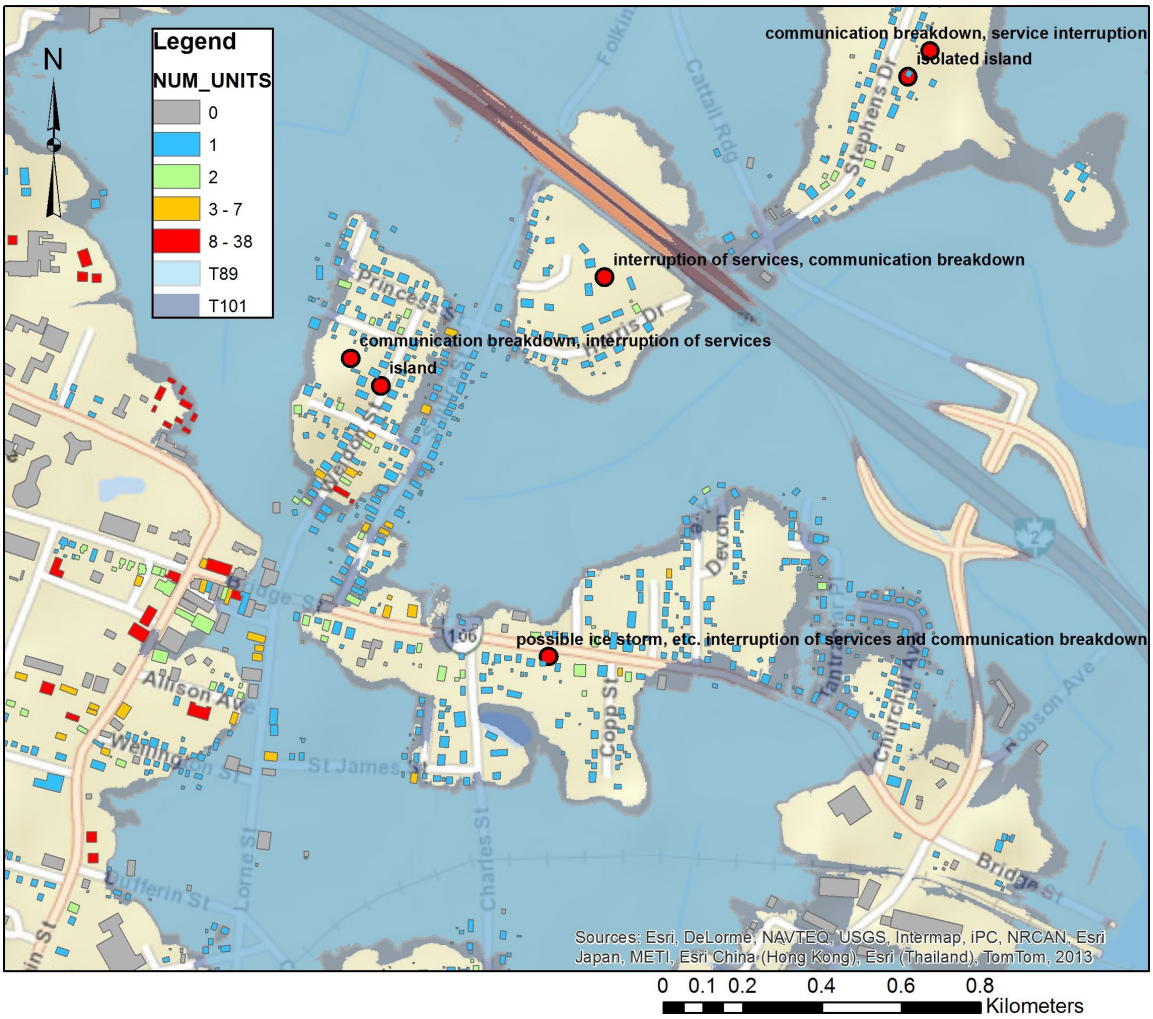


With higher flood scenarios (e.g., 10.1 metre), additional areas may be impacted including Lakeshore Drive.

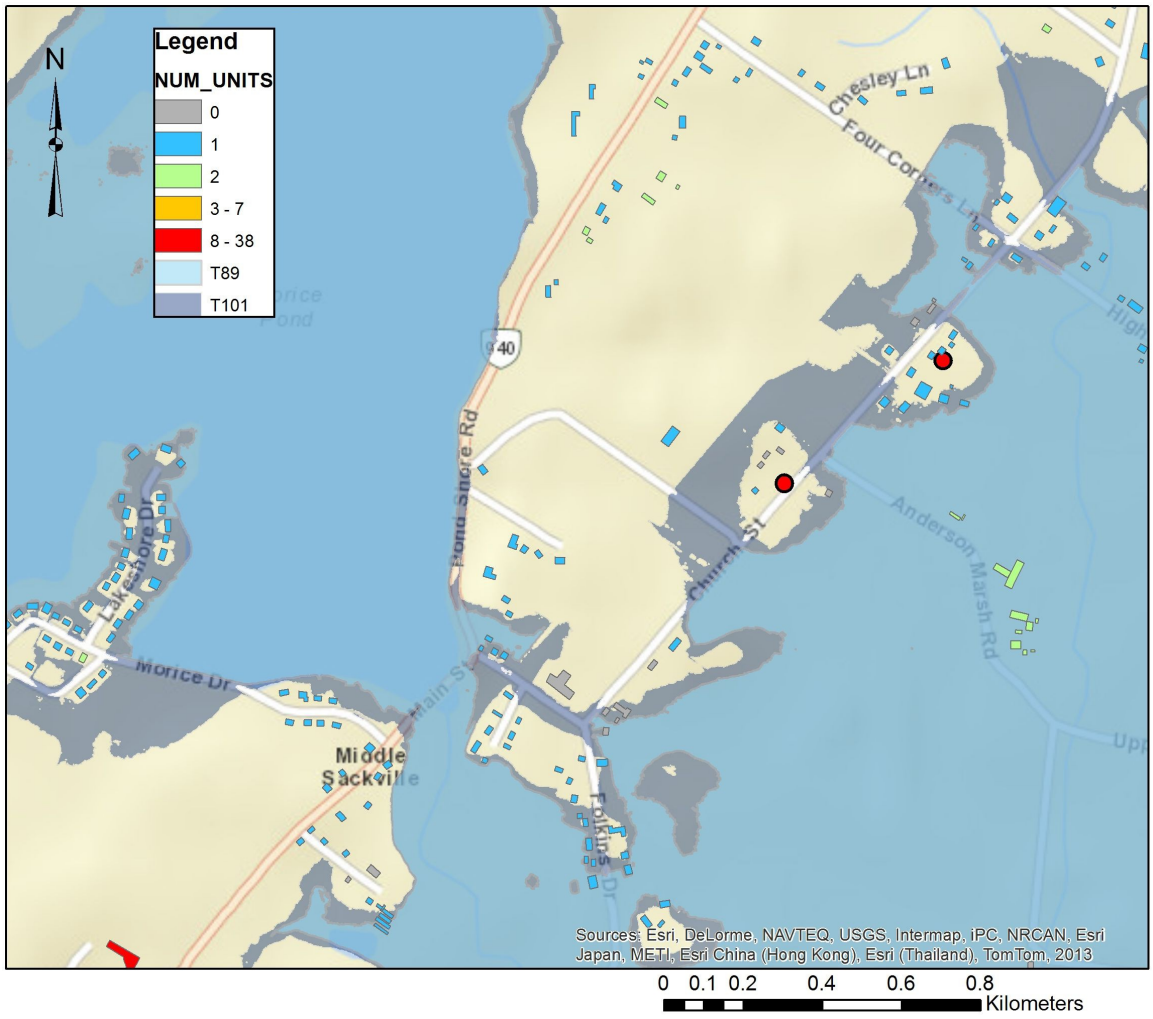

Legend
NUM_UNITS
0
1
2
3 - 7
8 - 38
T89
T101
possible flooding
Middle Sackville
Morice Pond
Chesley Ln
Four Corners Ln
Pond Shore Rd
Anderson Marsh Rd
Church St
Main St
Main Dr
Walker Rd
Donald Harper Rd
0 0.15 0.3 0.6 0.9 1.2
Kilometers
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013

11. Isolated Residences

As noted earlier, some neighbourhoods will be 'islanded' or temporary stranded until the water ebbs. Streets like Harris Drive and Stephens Drive, which form part of 'Spectacle Island' may face temporary isolation.

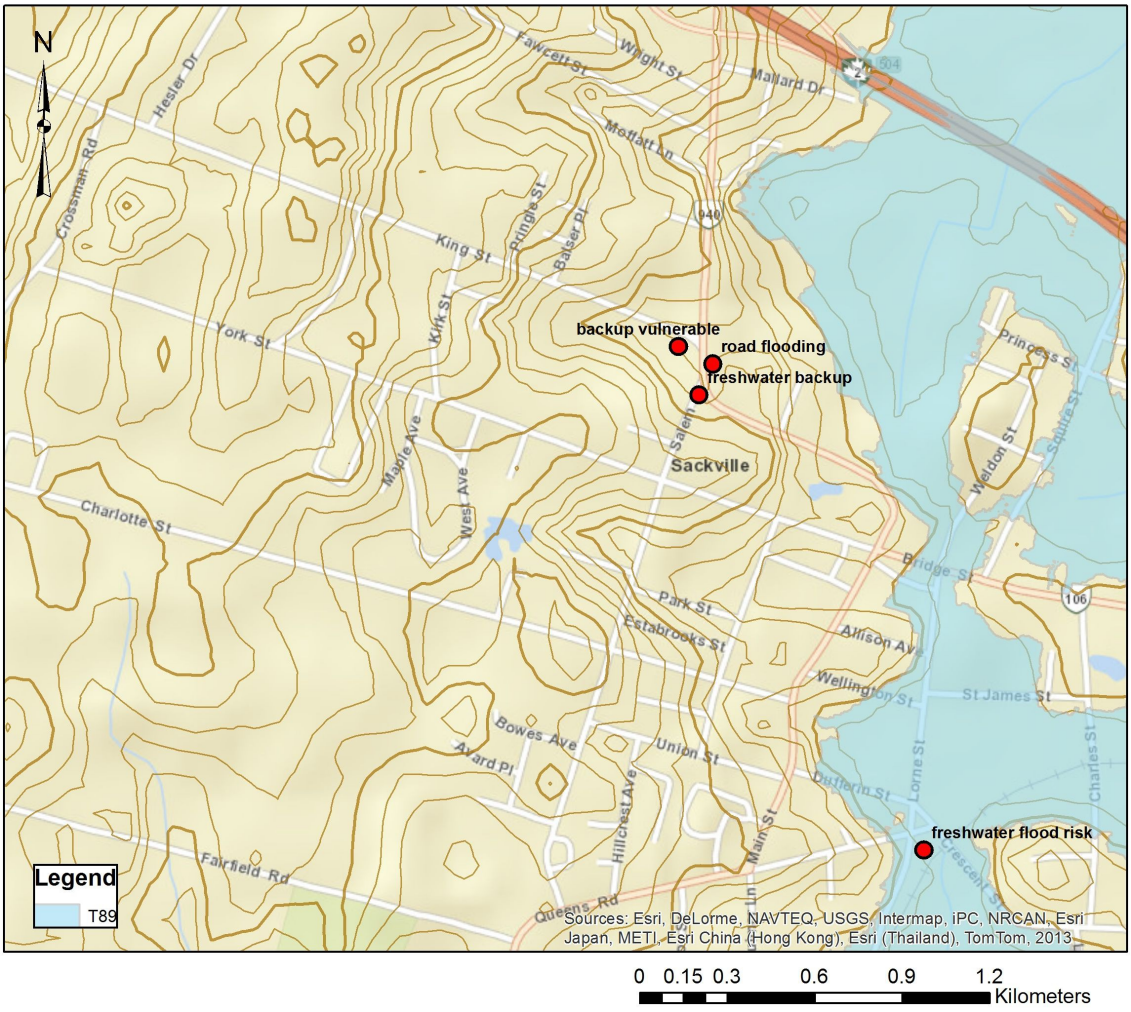


Areas towards Middle Sackville may also experience some 'islanding' but this is only likely under worse flood scenarios, such as a 10.1 metre flood.

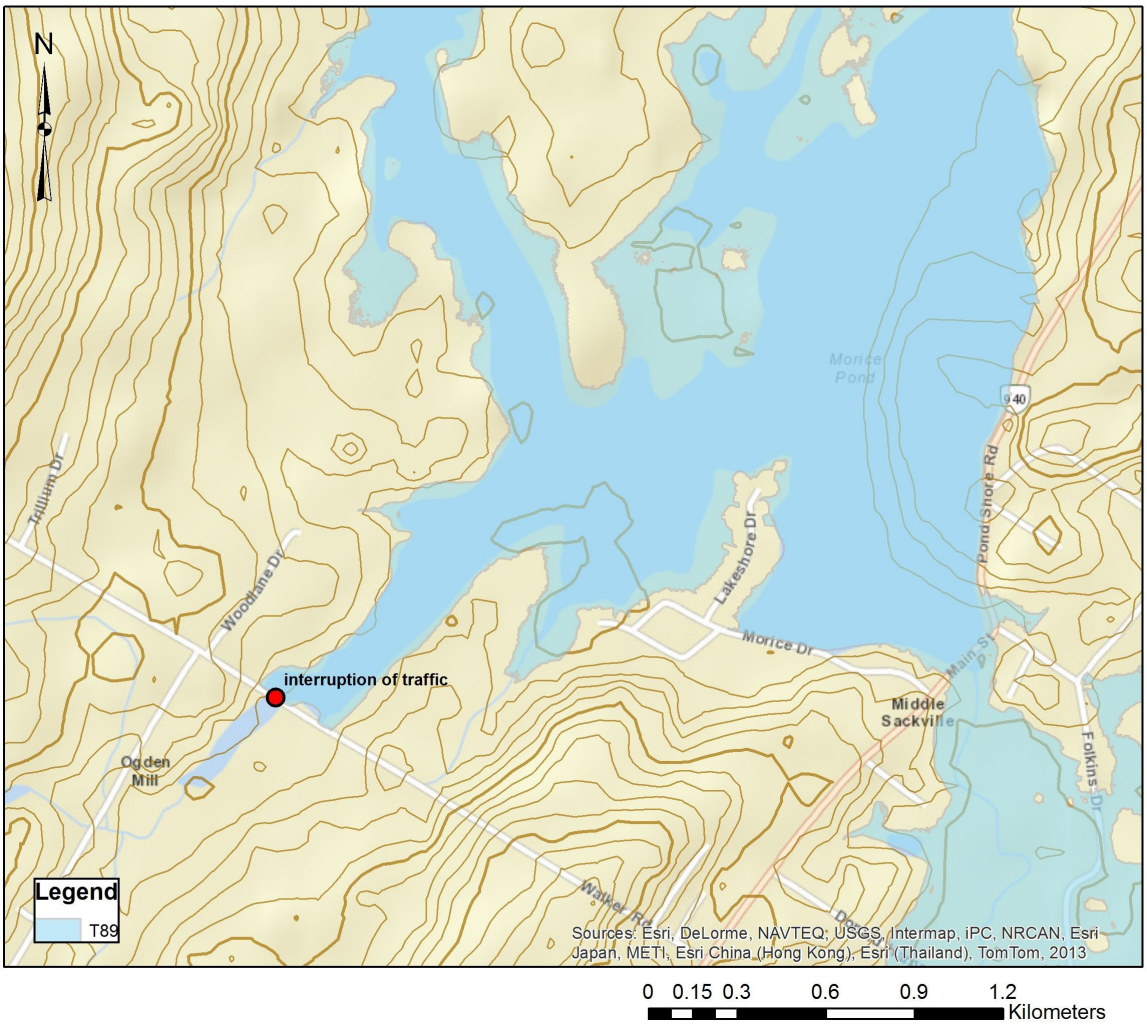


12. Freshwater Flooding

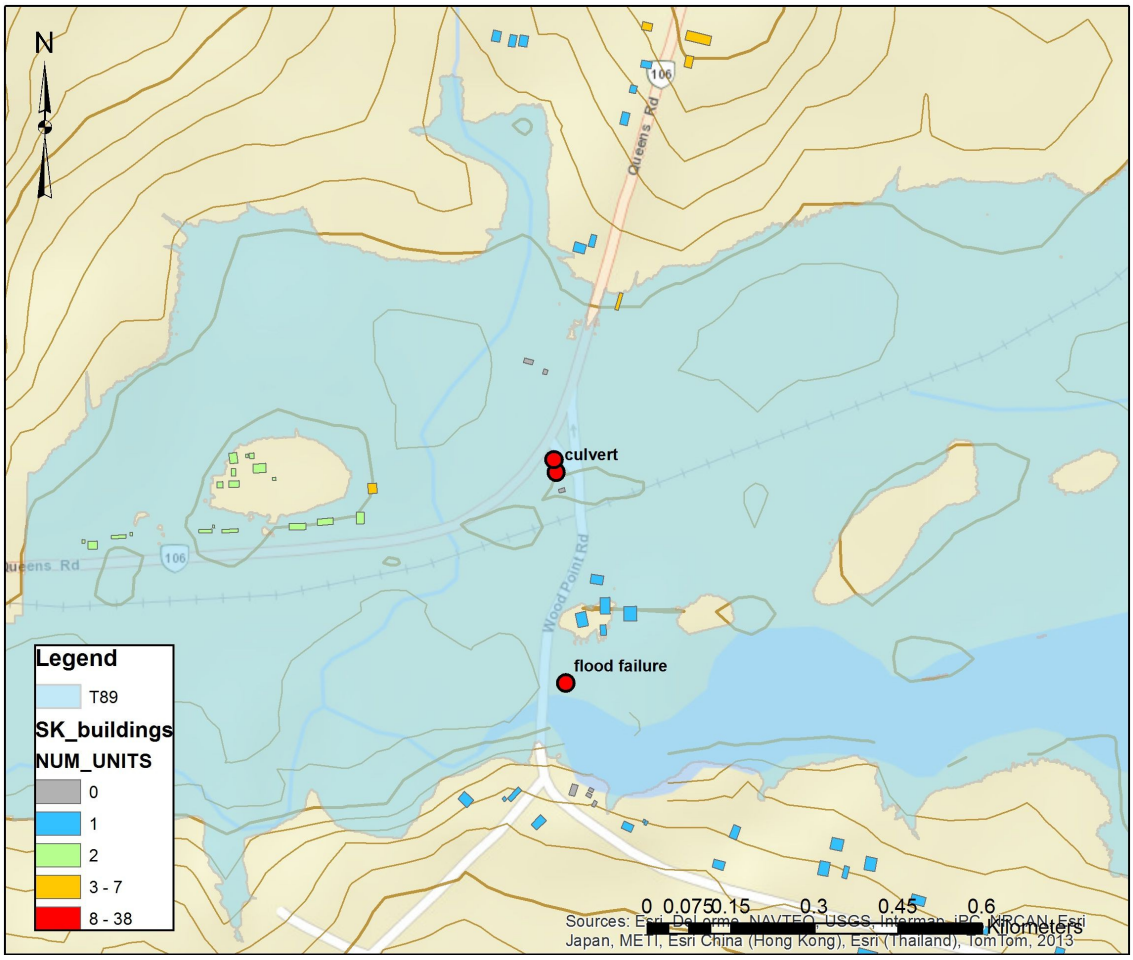
The following maps depict LOCs vulnerable to freshwater flooding. One area that was repeatedly noted was the corner of King and Main Streets near where the Mount Allison University heating plant is located. Drainage flows down King Street and is a meeting point for a significant amount of drainage. Rain barrels and other green options may be ways to reduce run off and cut down water load.



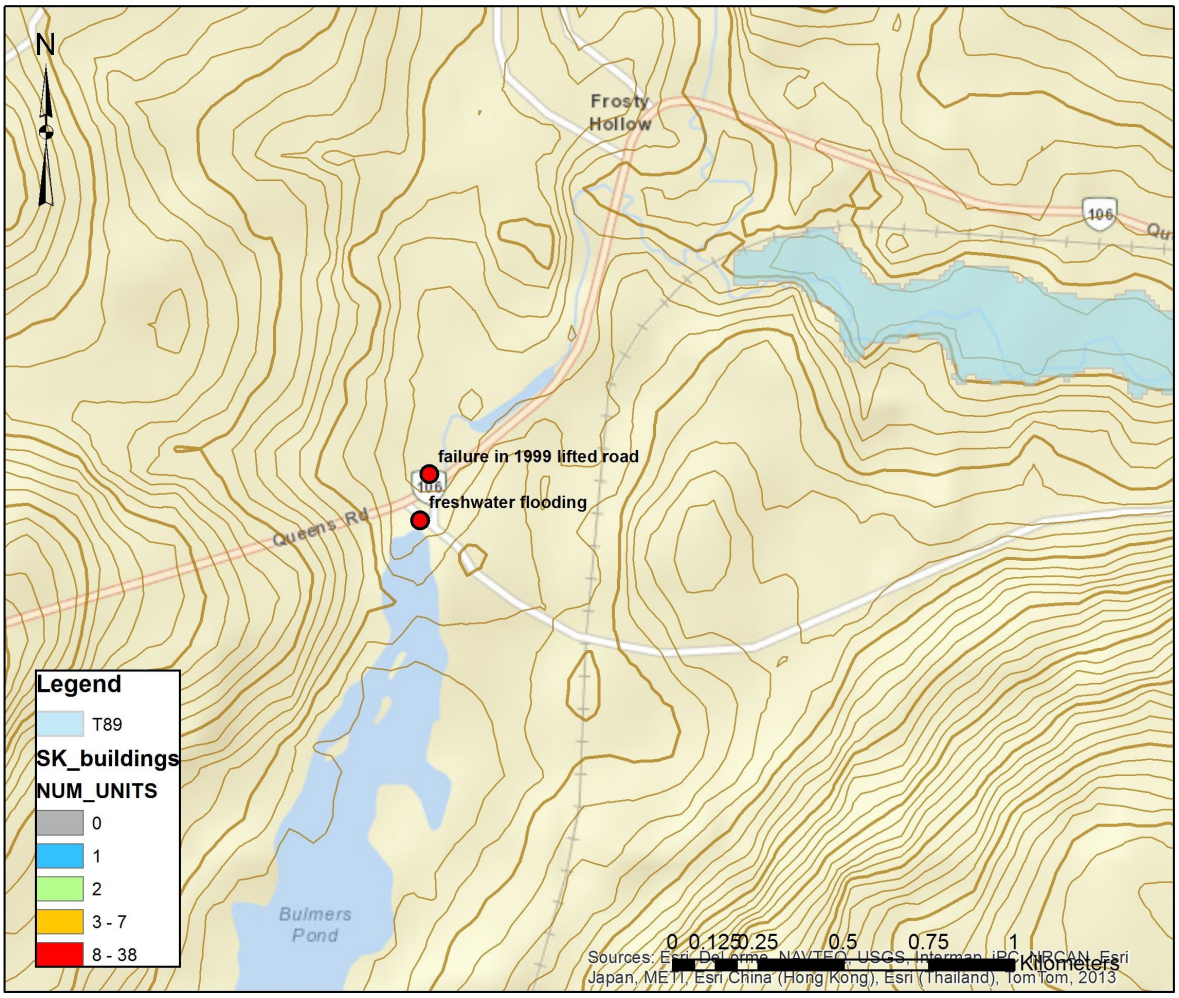
The following slide illustrates an area north of Silver Lake that experiences fresh water accumulation.



There is also freshwater accumulation where Queens Road forks to Wood Point and this area is susceptible to being overloaded.



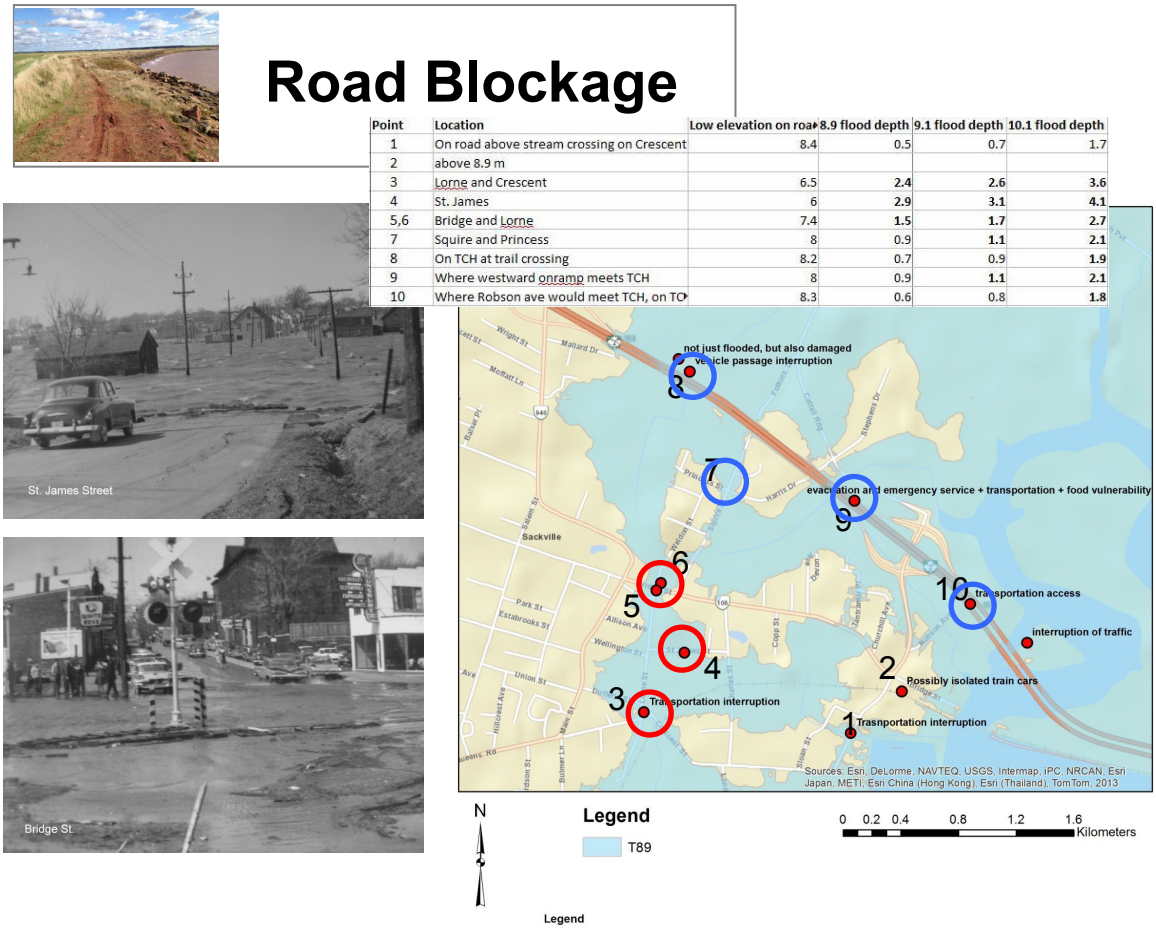
The area near Bulmer's Pond in Frosty Hollow also experiences freshwater flooding. In 1999, the road there was lifted as a result of the energy from the flood waters.



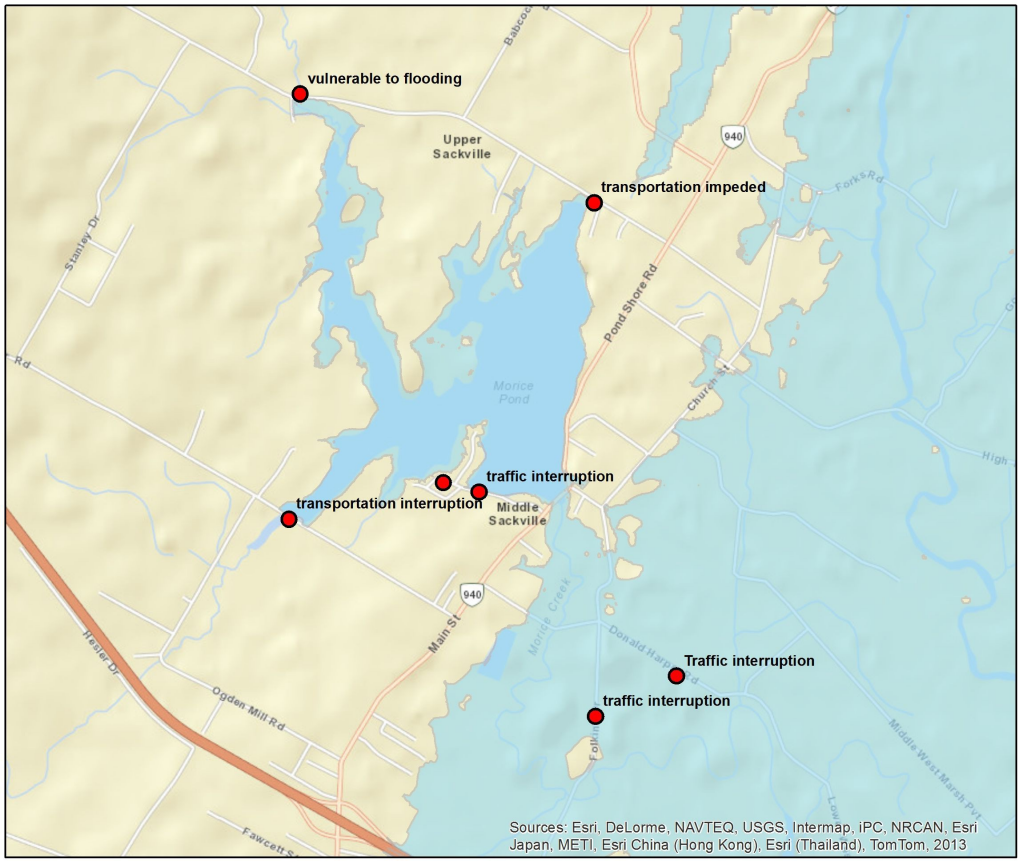
13. Road Blockage

The flood scenarios indicate that travel along some roads will be temporarily impeded, with the possibility that some sections may be permanently damaged. Water will likely flood areas at the bottom of Lorne Street (#3 on the map below) to the corner of Bridge and Lorne Streets (#5 & #6 on the map) and including St. James Street (#4 on the map), even under a 8.9 metre scenario where the water will likely be over a metre in depth.

The areas circled in blue are sections of highway that will likely be exposed to flood depths < 1 metre under an 8.9 metre (1 in 10 year) flood scenario, but will have more than 1 metre of a water at higher storm scenarios. Areas circled in red are expected to experience flood depths of > 1 metre under all flood scenarios



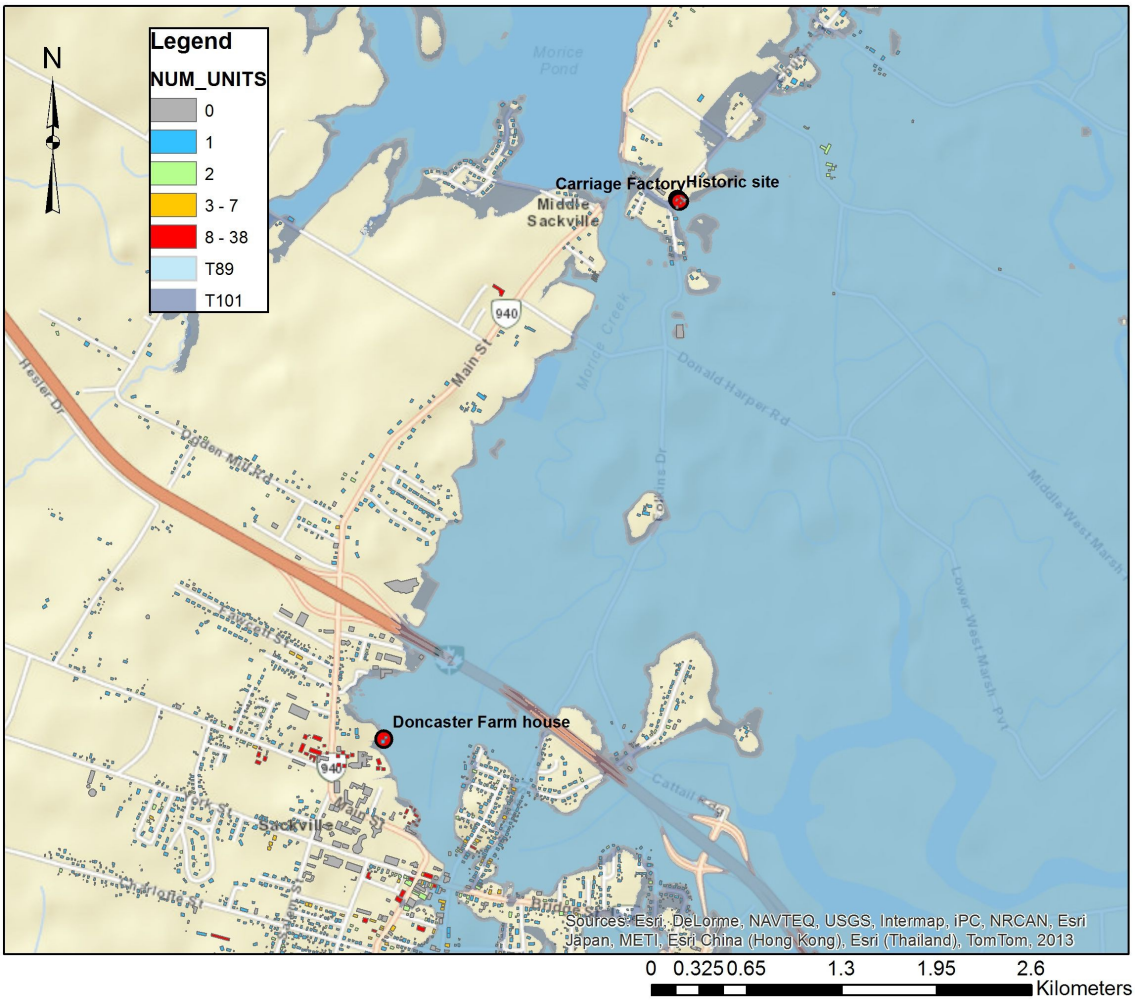
Point	Location	Low elevation on road	8.9 flood depth	9.1 flood depth	10.1 flood depth
1	On road above stream crossing on Crescent	8.4	0.5	0.7	1.7
2	above 8.9 m				
3	Lorne and Crescent	6.5	2.4	2.6	3.6
4	St. James	6	2.9	3.1	4.1
5,6	Bridge and Lorne	7.4	1.5	1.7	2.7
7	Squire and Princess	8	0.9	1.1	2.1
8	On TCH at trail crossing	8.2	0.7	0.9	1.9
9	Where westward onramp meets TCH	8	0.9	1.1	2.1
10	Where Robson ave would meet TCH, on TO	8.3	0.6	0.8	1.8


vulnerable to flooding
Upper Sackville
transportation impeded
Pond Shore Rd
Morice Pond
traffic interruption
transportation interruption
Middle Sackville
Main St
940
Traffic interruption
traffic interruption
Ogden Mill Rd
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
N
Legend
T89
0 0.35 0.7 1.4 2.1 2.8
Kilometers

Legend

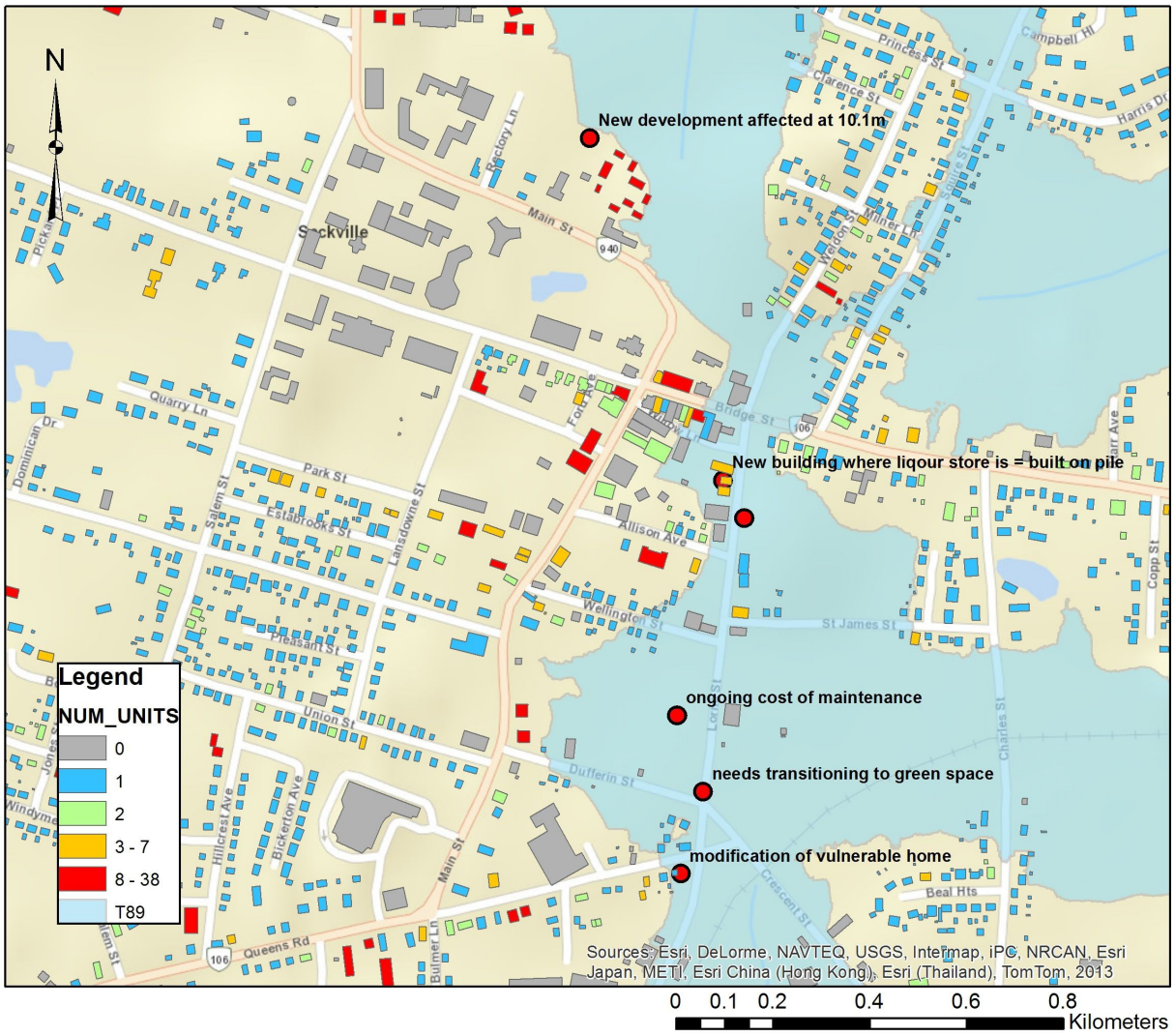
14. Historic Sites

Historic sites along Bridge Street, along Main Street and in Middle Sackville may experience flooding.



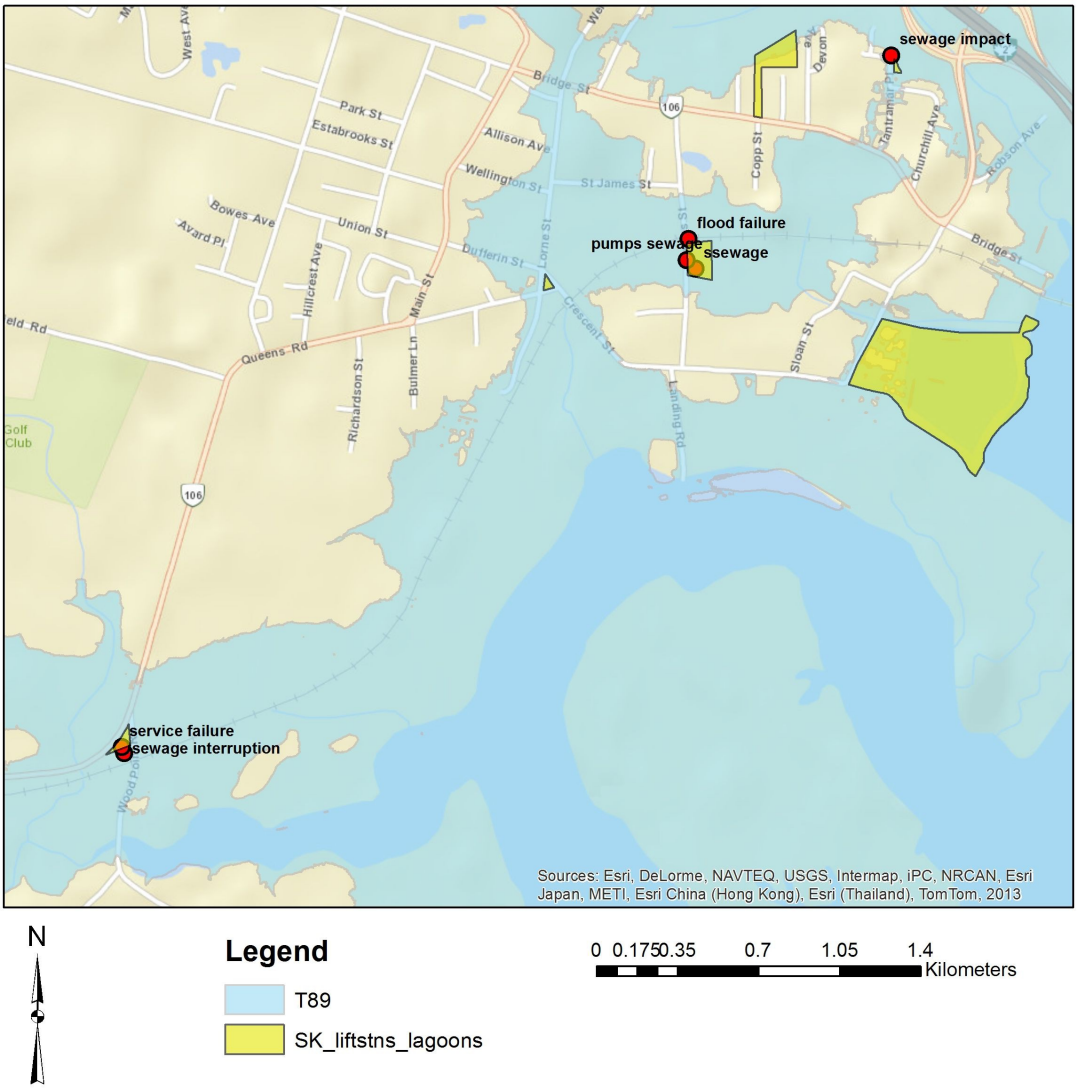
15. Land Use Concerns

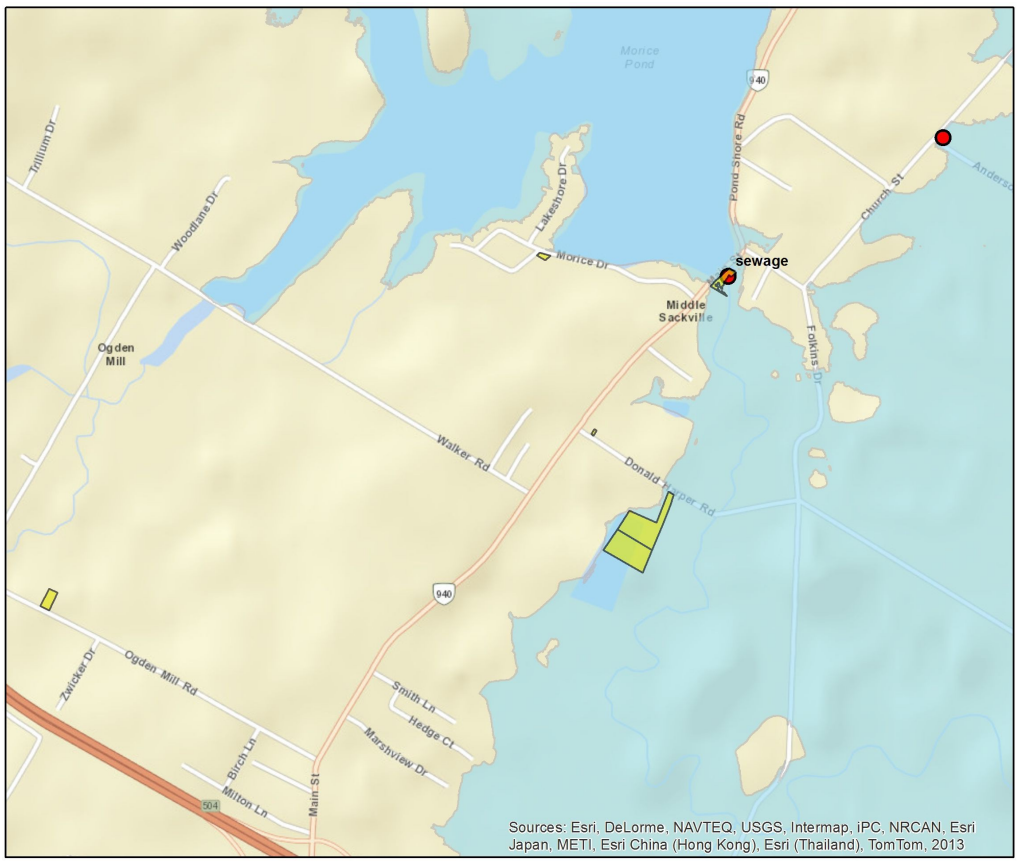
Land use concerns include the cost of maintaining baseball fields along Lorne Street and the extent to which homeowners invest in, repair or renovate homes that are in or on the edge of the flood prone areas.



16. Lift Stations

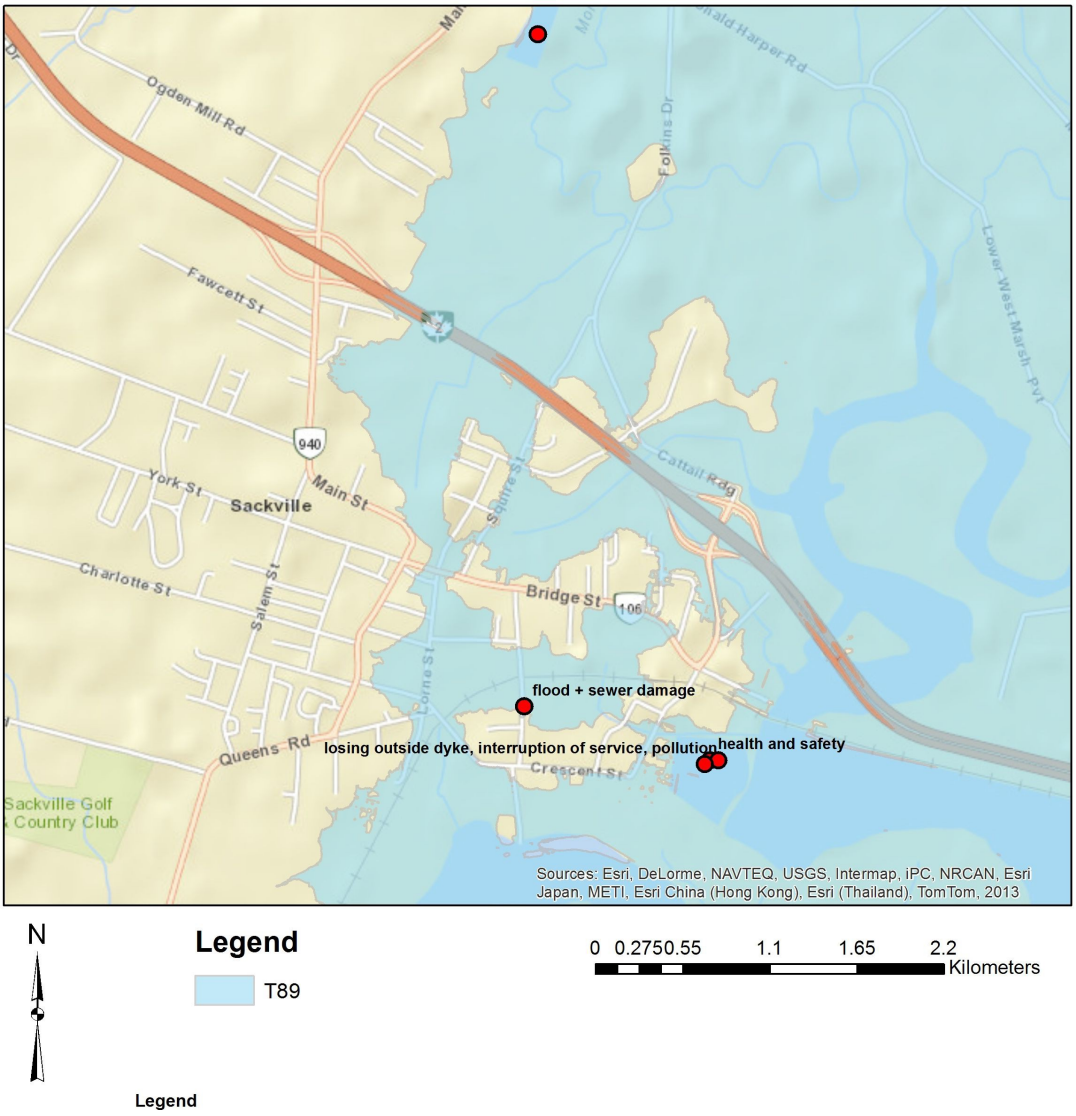
The main lift station along Charles Street is vulnerable to water infiltration. There are questions about how much a facility like that can withstand before it ceases to function. In the event of water infiltration, sewage conveyance will be affected; people will not be able to flush their toilets.




Morice Pond
940
Trillium Dr
Woodlane Dr
Lakeshore Dr
Pond Shore Rd
Church St
Morice Dr
sewage
Middle Sackville
Folkins Dr
Ogden Mill
Walker Rd
Donald Turner Rd
940
Zwicker Dr
Ogden Mill Rd
Smith Ln
Hedge Ct
Marshview Dr
Birch Ln
Milton Ln
Main St
504
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
N
Legend
T89
SK_liftstns_lagoons
0 0.175 0.35 0.7 1.05 1.4
Kilometers

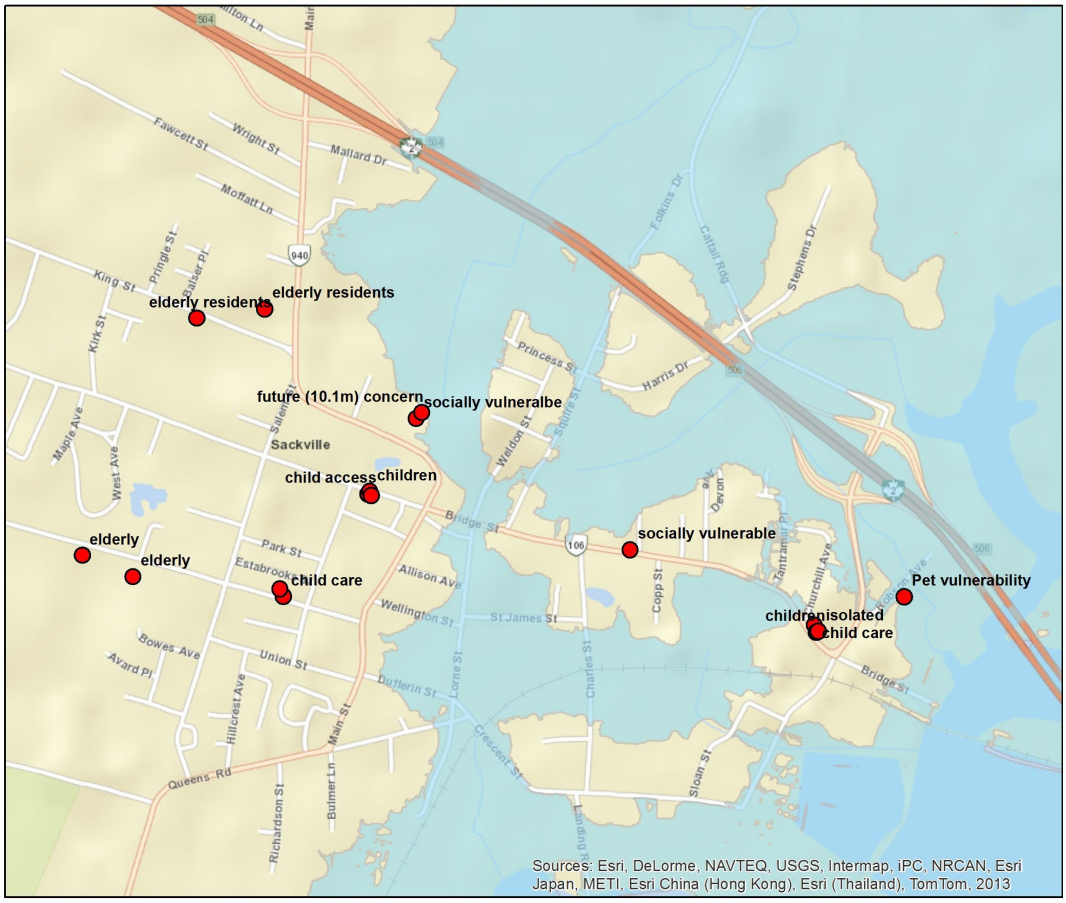
17. Sewage

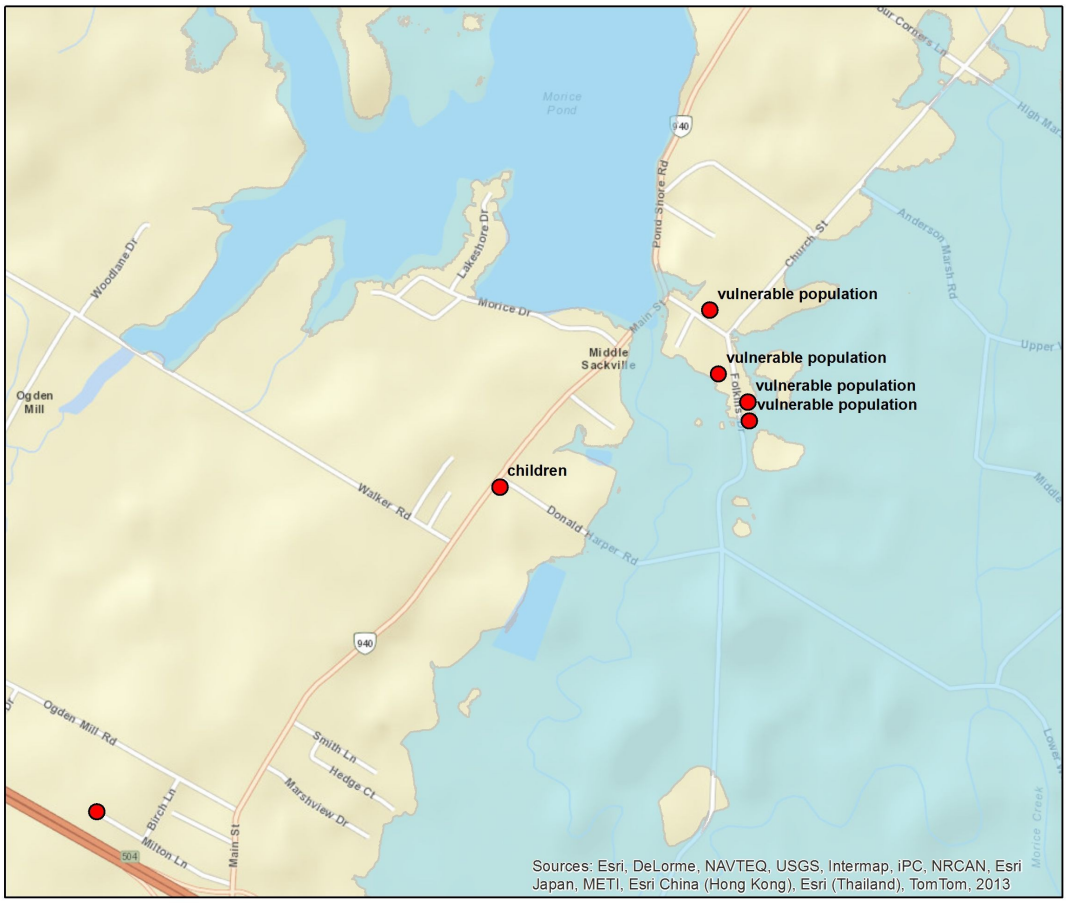
Contamination does not appear to be as major an issue as was originally believed because it will be flushed out into the Bay of Fundy as the water recedes. If the lagoon ceases to function, waste will be flushed into the bay until the lagoon is repaired.



18. Vulnerable Populations

These maps depict the location of various programs that service vulnerable populations, such as childcare centres, programs for people with cognitive delays, and residences for the elderly. These locations are mostly situated outside of the flood plain. However, it is necessary to consider that an interruption to highway traffic flow will prevent the arrival of services from Nova Scotia. Likewise, it will likely not be possible to travel to Nova Scotia (Amherst) for medical services. Though children may be physically safe, parents may not be able to pick up their children because they themselves are stranded on temporary islands or are behind flood-impassable sections of road.

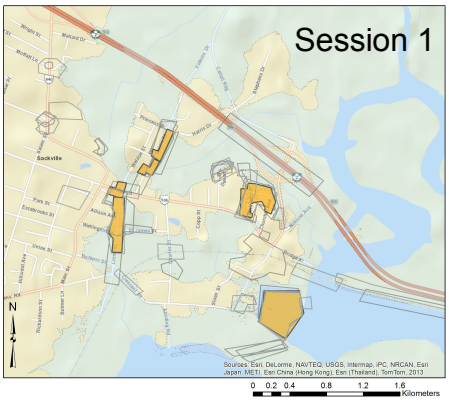


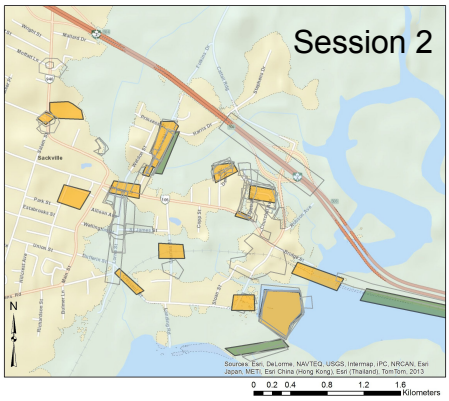

Morice Pond
Woodlane Dr
Lakeshore Dr
Morice Dr
Pond Shore Rd
Church St
Main St
Middle Sackville
Fort Beausejour
Anderson Marsh Rd
vulnerable population
vulnerable population
vulnerable population
vulnerable population
children
Ogden Mill
Walker Rd
Donald Harper Rd
940
Ogden Mill Rd
Smith Ln
Hedge Ct
Marshview Dr
Birch Ln
Milton Ln
Main St
504
Sources: Esri, DeLorme, NAVTEQ, USGS, Intermap, iPC, NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, 2013
N
Legend
T89
0 0.2 0.4 0.8 1.2 1.6
Kilometers

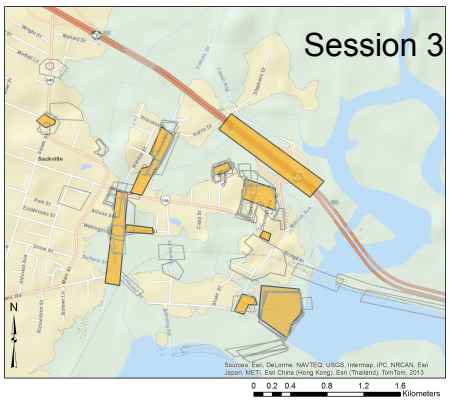
Legend

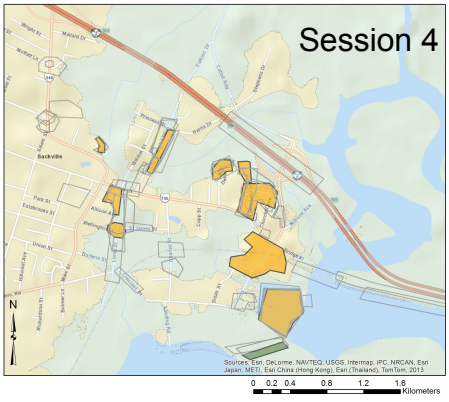
19. Adaptation Planning Zones (APZs)

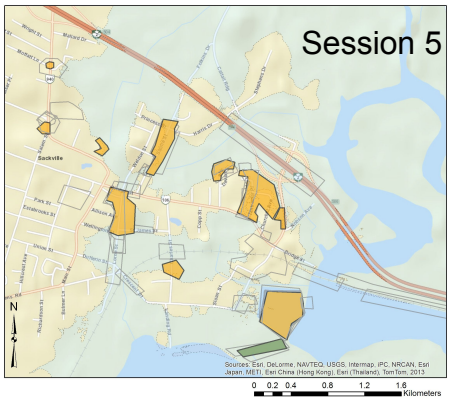
The polygons on the map below are neighbourhoods that appear to be most likely to experience risk. Each session (group) marked its own areas and each session's results are presented below. Orange polygons show the areas delineated by the participants in that particular session; hollow polygons show the results of all sessions combined. One can see that there is a fairly high level of consensus as to major APZs, but also differences as reflected by the interests, expertise, and concerns of particular combinations of participants.

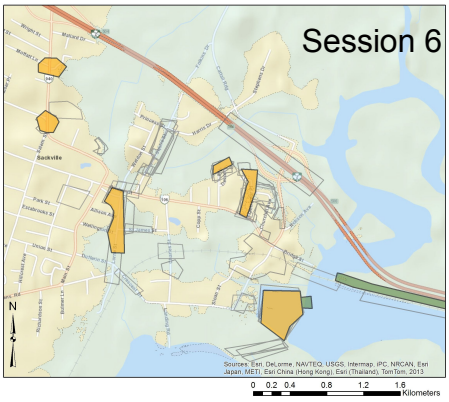




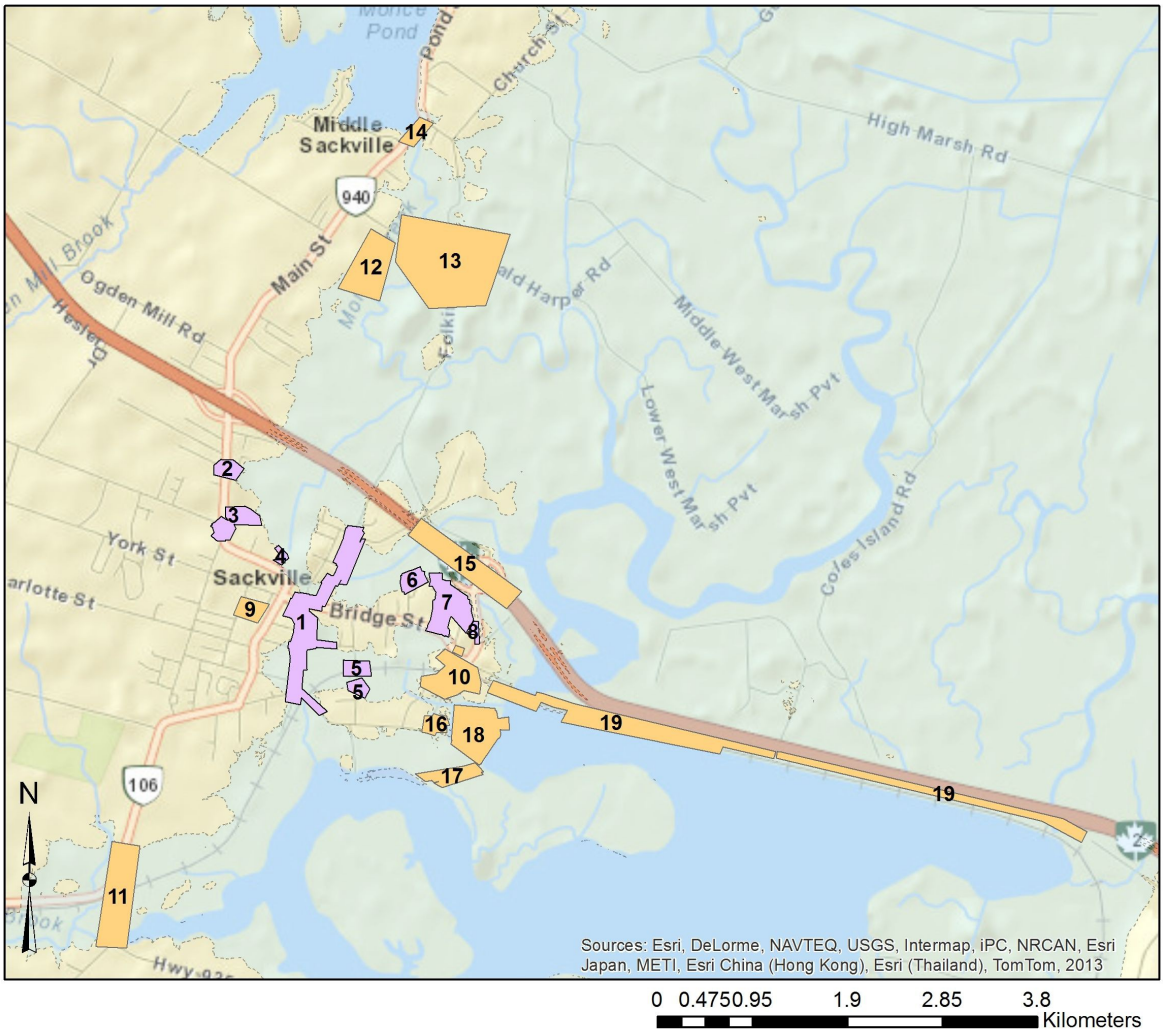






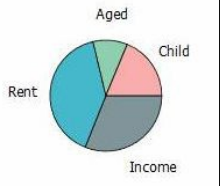
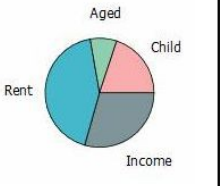
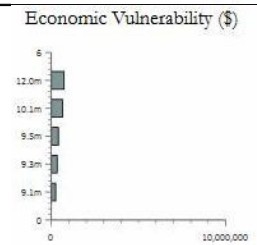
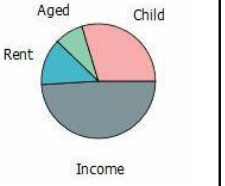
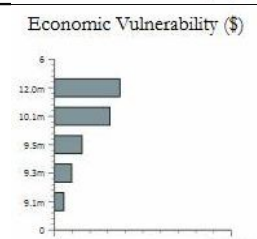
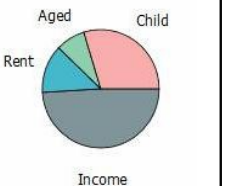


In the map below, the polygons from each of the six sessions were merged into contiguous units.



20. Economic Vulnerability

Under a 9.1 metre flood scenario, the estimated damage is over $5 million. This shifts to $10 million under a 10.1 metre flood by the end of the century. If the damage over the century is averaged out annually, it is estimated that there will be approximately $1.4 million/year in damages that will accumulate to $3 million as the frequency of storms increase and the community contends with more stress.

Table 3.									
	Economic Vulnerability (CDN $)								
Location	9.1m	9.3m	9.5m	10m	12m		**Social Vuln.**		**Current Assess.**
1 (Lorne and Squire St.)	5,319,648	5,965,677	6,542,513	8,984,669	10,209,207		1.22		$13,438,085
5 (Charles St.)	371,691	475,501	562,234	719,915	755,637		1.18		$685,151
6 (Devon)	249,223	334,094	405,905	637,202	727,947		1.01		$1,392,462
7 (Tantramar Place)	529,486	969,623	1,558,443	3,133,294	3,699,602		1.01		$6,124,829
Total	6,4700,48	7,744,895	9,069,095	13,475,080	15,392,393				21,640,527