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A VISION OF PREPAREDNESS FOR RESPONDING TO CULVERT FAILURES FOLLOWING SEVERE WEATHER EVENTS: A NEW BRUNSWICK DEPARTMENT OF TRANSPORTATION AND INFRASTRUCTURE CASE STUDY

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Abstract: Infrastructure that was built in the 1970s is now approaching the end of its service life and significant investments will be required to avoid service disruptions. Age-based deterioration, combined with an increase in the frequency of severe weather events, has caused numerous culvert washouts in rural Atlantic Canada, leaving residents isolated from essential services. The magnitude of damage caused by severe weather events in the past five years is exacerbated by the scarcity of human resources within the New Brunswick Department of Transportation and Infrastructure (DTI). The University of New Brunswick Construction and Engineering Management Group (UNB) assessed the capacity of DTI to respond to severe weather events. A framework for assessing capacity was developed from the National Institute of Standards and Technology, and the American Planning Association disaster preparedness guides. The framework includes the identification of people and processes that should be in place prior to a severe weather event. These form a "vision" of a severe weather response scenario. The "vision" was refined during twelve interviews with key DTI representatives. Opportunities for improvement in capacity were generated by comparing the "vision" to the people and processes that are currently in place for severe weather response. The comparison also identified policies and protocols that the DTI either has in place or would benefit from implementing. Seventeen recommendations were made to improve the DTIs efficiency in responding to severe weather events. The common characteristic of the recommendations is the lack of formality in the DTIs current response to severe weather events. This paper is of value to infrastructure managers who are interested in formal processes to prepare for severe weather events.

1 Introduction

The province of New Brunswick (NB) has a dispersed population and a network of rural roads connecting them to city centers. During the 1970's, the New Brunswick Department of Transportation and Infrastructure (DTI) made a significant investment in infrastructure, which is now nearing 50 years in service. DTI has observed an increase in rural road washouts as a result of culvert failures over the past five years and attributes them in part to ageing infrastructure, but also more frequent severe weather events precipitated by climate change.

A severe weather event on September 30, 2015 caused numerous culvert failures throughout NB that resulted in road washouts that left residents isolated from essential services. DTI requested the assistance of the University of New Brunswick's (UNB) Construction Engineering and Management group

(CEM) in collecting reconnaissance data at several of the sites. Reconnaissance data consisted of aerial images captured from a Unoccupied Ariel Vehicle (UAV), as well as panorama images captured from the ground. The purpose of the reconnaissance data was to assist DTI with assessing the sites and developing a remediation plan. Discussions between CEM and DTI following the September 30, 2015 severe weather event concluded that there was an opportunity for DTI to improve their response to such events. Assessing DTIs capacity to respond to severe weather events, in particular culvert washouts, was identified as an initial step in improving their current response capacity.

1.1 Literature Review

A literature review was completed to investigate the state of the art in disaster preparedness planning. Two key documents were identified:

- "Community Resilience Planning Guide for Building and Infrastructure Systems" published by the United States National Institute of Standards (NIST) in 2015.
- "Planning for Post-Disaster Recovery: Next Generation" published by the American Planning Association (APA) in 2014.

These planning guides focus on resilience, which is more holistic than assessing response capacity. NIST (2015) defines resilience as "… the ability to prepare for anticipated hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions. Activities, such as disaster preparedness – which includes prevention, protection, mitigation, response, and recovery – are key steps to resilience." Assessing the capacity of DTI is one component of a resiliency plan, which falls within the response phase of disaster preparedness. Figure 1 presents these components of resilience in sequence. The guides nonetheless provide an initial framework for the assessment.

Figure 1: Components of resilience

The framework developed to assess DTI's capacity to respond to severe weather events includes identification of the people and processes that DTI should have in place prior to a severe weather event. These form a "vision" of a severe weather response scenario, which was developed by CEM and refined during twelve interviews with key DTI representatives. The "vision" is communicated using two documents: (1) a resource table that identifies key groups, their area of expertise, physical and information resources required, and the their roles and deliverables and (2) a swim lane diagram identifying the sequence of events and decisions to be made during a severe weather event. Opportunities for improvement in capacity were generated by comparing the "vision" to the people and processes that DTI currently has in place for severe weather response. The comparison also identified policies and protocols that DTI either has in place or would benefit from implementing. The following terms are themes that are used as a subheadings for subsequent sections of this paper:

- Policies – high-level standards that govern organizational operations,
- Protocols – the flow and storage of information,
- Processes – activities and their sequencing, and
- People – allocated to respond to severe weather events.

The final version of the "vision" after refinement following the interviews is presented in Table 2 and Figure 2 in Section 4.

2 Interview Process

The purpose of the interviews was (a) to refine the "vision" and (b) to identify current response deficiencies. Twelve DTI personnel were identified with each contributing a unique area of expertise. Table 1 is a summary of the roles of the interviewees and highlights the diversity in their areas of expertise.

Table 1: Interviewee roles

Interviewee Role
Three district engineers
Communications officer
Environmental manager
Bridge maintenance program manager
Geotechnical engineer
Highway maintenance engineer
Hydraulics engineer
Ordinary Programs & Consulting Assistant Director
Structures assistant director
Engineering surveys manager

2.1 Steps Followed

The interviews were designed to refine the draft "vision" and identify deficiencies in the current response capacity within the area of expertise of the interviewee. Each interview was scheduled for a one-hour period, although several interviews extended an additional 15-30 minutes. The interviews were completed in five days between August 4 and August 22, 2016. Interviewees were not provided with the draft "vision" prior to the interview. All interviews were completed at DTI's head office in Fredericton, N.B., except for two, which were conference calls originating from UNB.

Each interview began by providing the interviewee background information on the project and the purpose of the interview. This created an atmosphere that invited the interviewee to contribute to the project and clarified that we were there to obtain their advice. The interviewee was then provided a copy of the "vision" (resource table and swim lane diagram) followed by a verbal overview of the two documents. A detailed explanation of the resource table and swim lane diagram was provided and discussion in the interviewee's area of expertise ensued; inevitably resulting in refinement of the "vision." The resource table and swim lane diagram were updated at the end of each day of interviews to incorporate feedback received that day and to prepare for the following interviews. The final "vision" that incorporates feedback from all of the interviewees is presented in the following sections.

No specific questions were asked, but information was presented in a similar manner for each interview and each interviewee was asked for feedback. Responses were captured by taking notes of the discussion as it ensued.

3 Interview Commentary

Analysis of the interview notes identified twelve themes within the categories of response policies, response protocols, response procedures, and people allocated. The following interview commentary is our summary of the interview notes and the identified themes.

3.1 Response Policies

The four response policy themes are:

- formalization of teams,
- on-going education,
- financial planning, and

- use of temporary structures during remediation.

The teams outlined in the “vision” (Table 2) do not have terms of reference, although DTI has and does create similar ad hoc teams as required. The formalization of other teams should be completed by the Resource Appropriation Team. The Resource Appropriation Team should consist of senior level management that have strong organizational awareness and know the expertise and availability of existing personnel. The Resource Appropriation Team should also include a district representative that has the authority to assign district staff.

Continuing education is required for all staff to ensure that the response phase as well as the subsequent recovery phase is executed efficiently. Lessons learned from previous severe weather events should be documented and made available to all involved to continuously improve infrastructure resiliency.

Financial policies were identified that affect processes both before and after a severe weather event. An annual budget should be established for severe weather events given their frequency in recent years. The Resource Appropriation Team should secure and manage this annual budget.

A trigger to implement temporary spending authority is needed to expedite large purchases during the response phase. The timeline for district exemptions should also be lengthened during the response phase.

Guidance is required to establish when the tender process is followed and when remediation is completed using the district’s own forces. Although tendered work has a greater reimbursement rate, interviewees highlighted the fact that some work during the recovery phase is more rapidly completed by the district’s own forces which thereby speeds the reinstatement of services.

The fourth policy theme is with respect to the temporary infrastructure that is used to restore services as quickly as possible. It is essential to revisit temporary infrastructure after the response phase is complete, to implement permanent solutions that are viable over the long-term.

3.2 Response Protocols

Two themes within response protocols were identified and include:

- internal communication, and
- external communication.

IT protocols are required for design reconnaissance and reimbursement documentation. Protocols need to provide details on file size limitations, storage location, archiving, privacy, and data backup. These protocols need to be tested and participants trained on their use.

To facilitate the use of reconnaissance data it should be delivered in a convenient interface, and possibly integrated into a current DTI database such as BRDG. IT personnel should be dedicated to manage this integration.

A liaison within DTI should manage information on all sites that can be easily shared between the district and head office. This information should be automatically updated for all parties when one party adds information. Some districts have found it necessary to plot sites on a map and maintain a spreadsheet indicating site status.

External protocols are needed to focus on communication with the public. Typically the public does not have high expectations during the first 48 hours of the response phase. Thereafter they expect roads to be accessible. Effective communication with the public is therefore critical. There are two main communication lines with the public: NB511 and incoming calls. NB511 should be updated to be more user friendly, and to the extent possible, provide the public with real time information. Alternate traffic routes could also be displayed on NB511. Incoming calls from the public could be handled more efficiently with standardized forms and allocation of additional personnel.

3.3 Response Processes

The swim lane diagram provides a high level view of the entire response process. The interview commentary below provides additional discussion on key items. Response processes were categorized into four themes:

- site reconnaissance,
- site triage,
- the response phase, and
- financial reimbursement.

Reconnaissance is completed by several entities, although the type of reconnaissance they complete differs. The district completes the initial reconnaissance to identify sites requiring remediation and triages sites accordingly. Sites that require specialized design work are directed to the head office. Reconnaissance is also completed by head office personnel on sites that require their design expertise. Head office can initiate two forms of reconnaissance: (a) a reconnaissance team to generally document the site with land and aerial imagery for visualization and possibly the development of a physical model, and (b) specialized reconnaissance for discipline-specific design purposes.

As context, a typical duration of the response phase is assumed to be approximately 1-6 weeks. During the response phase, the district hires contractors with the goal of restoring services as quickly as possible. A more routine contractor selection process is followed after this phase.

The New Brunswick Emergency Measures Organization (EMO) is a critical component to the district during the response phase and provides the district with central office space to work directly with other entities such as fire departments, the RCMP, Natural Resources, Environment, etc. EMO also provides on-site support once the district completes their initial reconnaissance.

There are several processes critical to financial reimbursement that occur before, during and after the response phase. Setting up event activity tracking codes before remediation work is completed, is necessary to avoid extra effort with journal entries and ensure that reimbursable work is captured. Sites requiring remediation need documented costs as well as photographs, both before and after remediation. Environmental documentation is also required before and after remediation. Documentation needs to be completed in a timely manner to ensure successful reimbursement. Events typically occur during spring, late summer, or fall and documentation needs to be completed before the next fiscal year-end in March. A formal timeline of the documentation requirements and when they are required would facilitate the completion of the documentation. It was suggested that either the district engineer or their designate be responsible for this documentation.

Three sub themes related to financial reimbursement were noted: (a) the need for proper documentation to ensure that all required documentation is completed at the appropriate times, (b) the need for an electronic repository that facilitates the use and archival of documentation, and (c) the need to complete reporting to a high degree of quality.

3.4 People Allocated

Two main themes were evident with respect to people allocated for severe weather events:

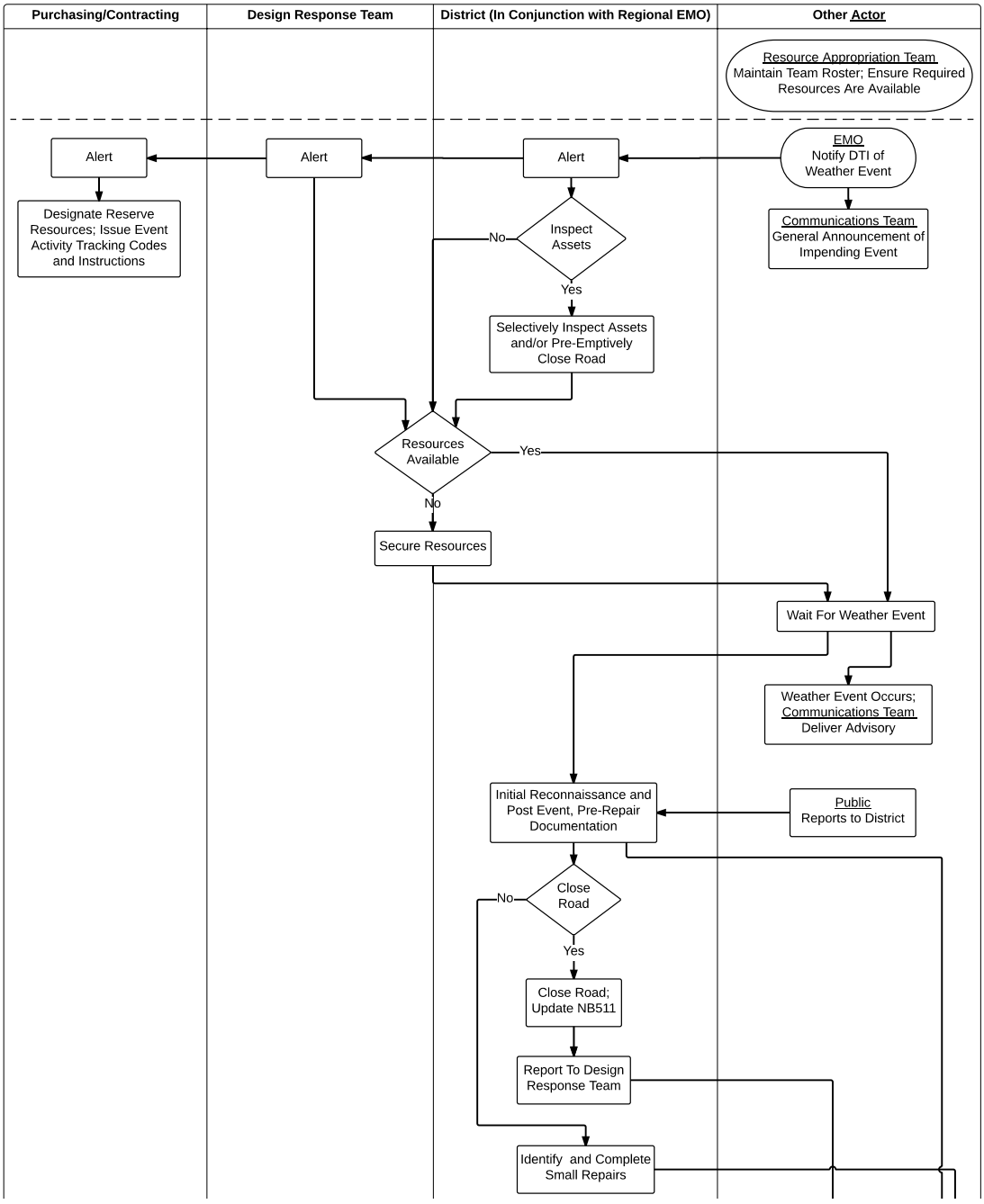
- a roster detailing the availability of people with appropriate skills, and
- additional personnel to handle the increase in workload.

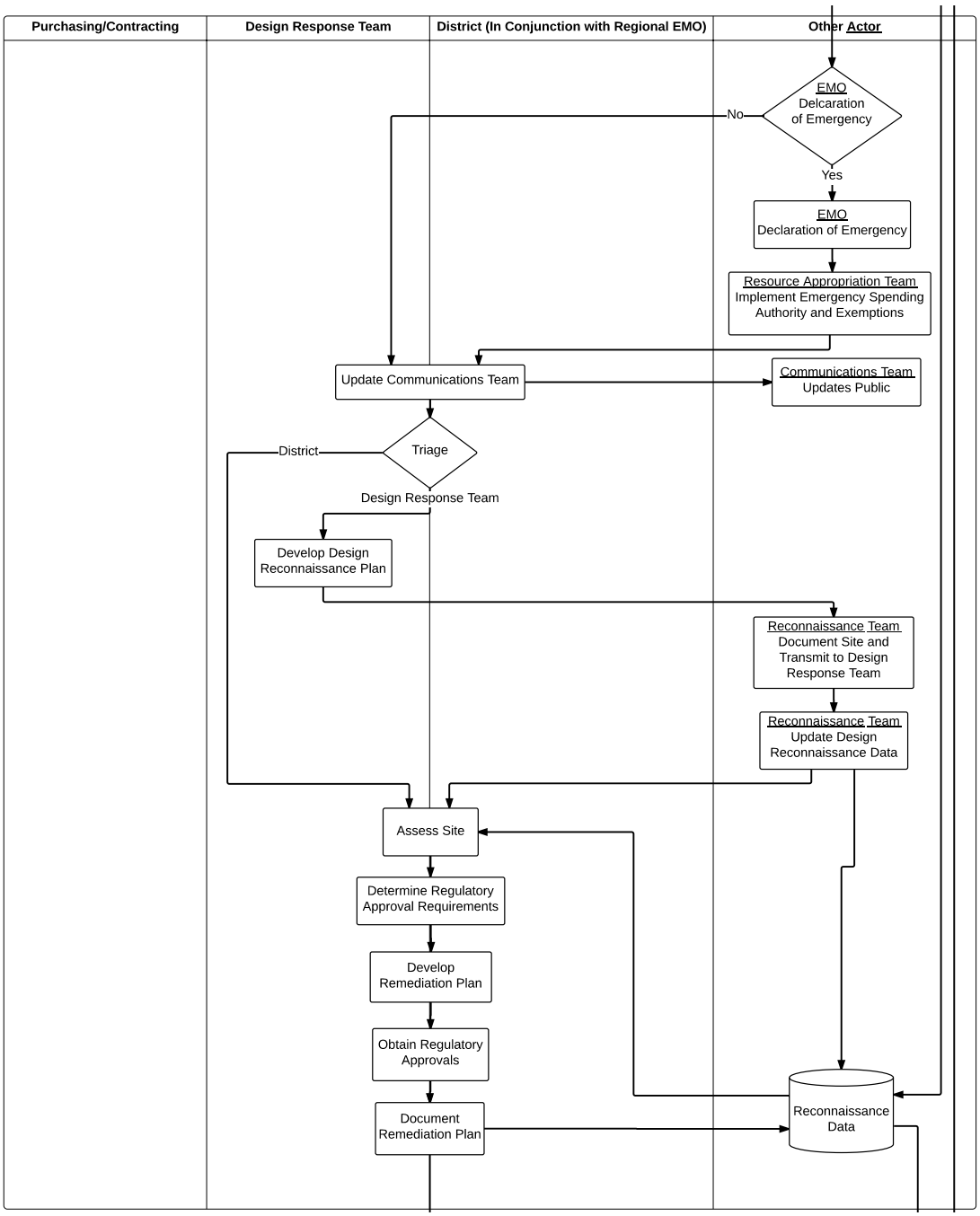
The Resource Appropriation Team should consist of the Bridge Maintenance Program Manager, the Structures Assistant Director, the Director of Engineering & Technical Services, and possibly the Executive Director of Operations, as they have the knowledge required to develop the roster. The appropriate people on the roster should be “on call” including IT, district, and head office personnel.

Additional personnel are required to backfill the regular work of those who are responding to a severe weather event. These additional personnel could consist of part-time DTI personnel, as well as personnel from the private sector.

4 Final Vision

The final vision is presented in the following swim lane diagram (Figure 2) and resource table (Table 2). The swim lane diagram includes three main entities: the purchasing and contracting team, the design response team, and the districts. Other entities that play a minor role include Emergency Management Operations (EMO), the resource appropriation team, the communications team, the public, and the reconnaissance team.




Purchasing/Contracting
Design Response Team
District (In Conjunction with Regional EMO)
Other Actor
EMO Delcaration of Emergency
No
Yes
EMO Declaration of Emergency
Resource Appropriation Team Implement Emergency Spending Authority and Exemptions
Update Communications Team
Communications Team Updates Public
Triage
District
Design Response Team
Develop Design Reconnaissance Plan
Reconnaissance Team Document Site and Transmit to Design Response Team
Reconnaissance Team Update Design Reconnaissance Data
Assess Site
Determine Regulatory Approval Requirements
Develop Remediation Plan
Obtain Regulatory Approvals
Document Remediation Plan
Reconnaissance Data

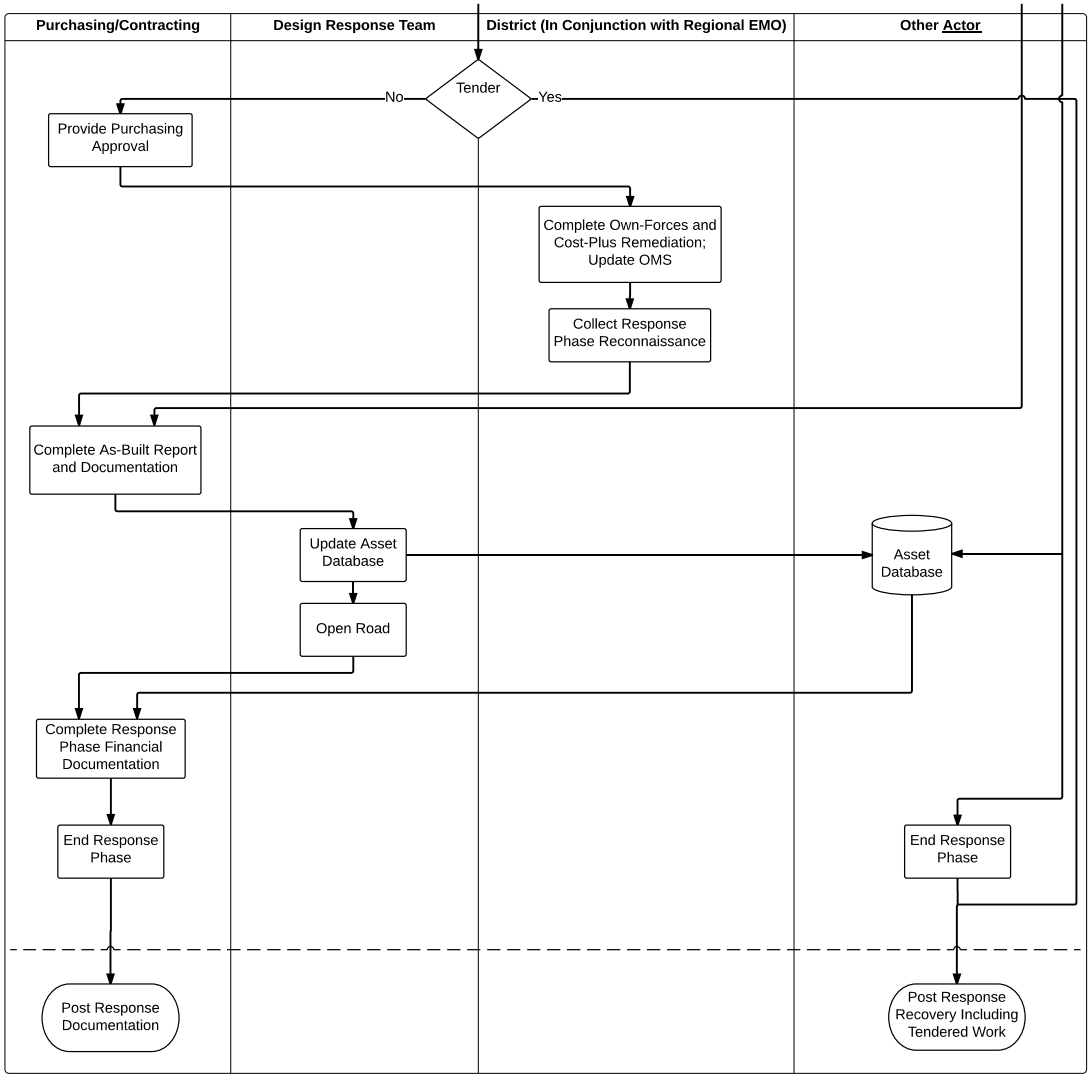


Figure 2 – Swim lane diagram

The roles and deliverables of each entity are described in the resource table (Table 2).

The swim lane diagram may be separated into the following steps:

- preparation by the resource appropriation team;
- monitoring and notification the of severe weather event;
- initial reconnaissance and repairs completed by the districts;
- implementation of policies upon the declaration of an emergency;
- triage of the affected sites;
- detailed reconnaissance, planning and approvals;
- site remediation through own forces; and
- tender of post response remediation.

Table 2: Modified resource table*

Entity (number of people); - Expertise required	Role and Deliverables
Resource Appropriation Team (2 ongoing; 4 during an event) - Senior level management - Organizational awareness and capacity	1. Develop an on-call roster for other teams as well as identify team leaders. 2. Ensure required resources are available.
Design Response Task Force (3-6) - Project manager, - Hydrotechnical - Geotechnical - Environmental - Structural - IT (designated individual) - Liaison	1. Initiate Design Reconnaissance Task Force and specialized design reconnaissance on selected sites. 2. Develop remediation plan to restore road function as quickly as possible accounting for social, environmental and economic factors.
District (variable number of people) - Highway/bridge maintenance - Engineering and technical - Project management - Modular bridge assembly - Safety signage - Site documentation (designated individual) - Site supervision/inspection of contractors	1. Collect post-event pre-repair documentation, and recovery documentation (Appendix A and B). 2. Emergency traffic re-routing 3. Update NB511. 4. First response data collection 5. Prioritize site remediation 6. Remediate sites to restore road function as quickly as possible. 7. Update Operations Management System.
Design Reconnaissance Task Force (3) - Photography - UAV - Site control (benchmarks)	1. Document damaged sites and transmit data to a common interface.
Purchasing, Contracting and Recoverables Team (3) - Large purchases - Small purchases - Emergency spending authority and exemptions	1. Secure resources for sites that require remediation and document costs and scope of work for remediated sites. 2. Collect, assemble and complete reimbursement documentation.
Communications Team (2) - Communication - Liaison	1. Inform public and media of: a) road closures and openings, b) remediation progress. 2. Central and regional EMO and DPS liaison 3. Design Response Team Liaison

* Table 2 omits physical and information resources found in the original.

5 Conclusion

Much of DTI's current infrastructure was built in the 1970's and is approaching the end of its expected life. This age-based deterioration is exacerbated by the increased frequency of severe weather events and the scarcity of human resources. Historically, the infrastructure was in better condition, severe weather events were less frequent, and DTI resources were not as stretched. Due to these compounding factors, it is no longer feasible to deal with severe weather events as has been done in the past. Much more rigorous organizational planning is now essential.

All interviewees saw the draft resource table (Table 2) and the draft swim lane diagram (Figure 2) as improvements over DTI's current means of responding to severe weather events. Based on feedback from the interviewees, the vision represented by these documents was refined significantly. Although we

encourage additional time being spent on further refinement, this vision of DTI's response was accepted by the interviewees as a good approach.

As indicated in the commentary, there are significant gaps between the current mechanisms of responding to severe weather events and the vision represented by Table 2 and Figure 2. The common characteristic of these gaps is the lack of formality in DTI's response to severe weather events.

Along with focusing DTI's efforts to improve their capacity to respond to culvert failures following severe weather events in the future, the vision provides an opportunity for other departments of transportation whose infrastructure may not yet be as vulnerable as DTI's to become more proactive. As infrastructure continues to deteriorate and severe weather events become even more frequent, rigorous planning will need to be integrated into on-going operations at all departments of transportation to maintain infrastructure at its desired level of service. Should resources at departments of transportation continue to be stretched, as they have in New Brunswick, more rigorous planning will become even more critical.

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