The Water Utility Risk Integration Matrix: Demonstrating Potential for an Integrated Approach to Municipal Water Management

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Abstract

Municipal water utilities traditionally have been managed in isolation with little consideration of common factors affecting risk. An integrated approach to municipal water management has great potential for increasing the resilience of these systems under future uncertainties. In a recent survey conducted by the University of Guelph, respondents from various Canadian municipalities identified aging infrastructure, climate change and urbanization as the top three drivers of risk to water infrastructure. To demonstrate the potential for an integrated approach to risk management of water infrastructure, the *Water Utility Risk Integration Matrix* document was developed. This interactive document emphasizes commonalities across municipal water sectors and allows users to quickly access relevant information on the previously identified drivers of risk. Each chapter provides an overview of the impact each driver has on water treatment and distribution, sewage conveyance and treatment, combined sewer systems, and stormwater conveyance. The document provides direct access to additional details and external webpages containing statistics and examples for any implications of interest to the user. Relevant guidance and case studies are also incorporated into the document with links to external data sources. This document facilitates information gathering to assist in the widespread adoption of an integrated approach to risk management of municipal water utilities and provides a framework for further development of risk management initiatives.

1 Introduction

A recent research project carried out at the University of Guelph is aimed at addressing the challenges faced by Canadian municipalities related to risk management in municipal water infrastructure. Research goals of this project include the identification and analysis of potential drivers of risk associated with continued growth and development, climate change, aging infrastructure and the decreased capacity for sormwater infiltration in urban environments. A driver of risk, as used in the context of this paper, is defined as an external element that increases the probability of failure of a system to perform its intended function. In municipal water infrastructure, these drivers of risk must be managed effectively to ensure reliable water services are provided to residents. With these issues in mind, municipalities across Canada are realizing the benefits of an integrated approach to the management of water utilities in order to ensure the resilience of these systems in the light of future uncertainties (CWN 2014).

The merits of an integrated approach to water management can be highlighted through a case study of strategies adapted in the island city–state of Singapore located in Southeast Asia. This densely populated island with few water resources found within its borders relies on imported, recycled, stormflows and desalinated water to supply its population with potable water. Through the use of alternative water sources, this approach also decreases the management requirements for wastewater and stormwater flows (Irvine et al. 2014). A very strictly regulated water budgeting system, including demand management and regular auditing, results in 100% of the population receiving water services (Ong 2010). This approach demonstrates how the successful allocation of limited water resources to serve a large population can be achieved through the integrated management of various aspects of municipal water.

Before a similar integrated approach to municipal management can be adapted in Canada, an understanding of the full range of risks faced by municipal water systems must be understood to allow for effective risk management. An interactive PDF document, *The Water Utility Risk Integration Matrix* (WURIM), was developed to identify and discuss the full scope of risks to water management across municipal water infrastructure, including their interrelations, to demonstrate the potential for an efficient integrated approach to risk management. In addition to demonstrating integrative capacity, a series of case studies was developed, presenting positive outcomes of an integrated approach as well as the negative effects of traditional *business as usual* risk management strategies.

The WURIM is available for free download from the CVCA website (CVCA n.d.). Instructions for accessing information both

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within the document and on external websites can be found on page three of the WURIM, and will be discussed in detail in the following sections.

This objective of this paper is to familiarize readers with WURIM, its applications and the methods used in the development of this document. Through a discussion of risks and their implications to the various categories of water infrastructure, a risk management framework can be developed to support integrated water management in Canadian municipalities.

2 Background

Effective risk management in regard to municipal water infrastructure is essential to protect people, property and the environment in the most cost effective manner. While there are many definitions of risk, the general idea centres on evaluating the likelihood of outcomes and the magnitude of resulting effects. Risks can never be driven to zero however, so risk management is used to decrease the probability of occurrence to acceptable levels.

The risk management methodology as applied to municipal water infrastructure involves, first, identifying all potential pathways for risk to enter a system. Following this, resources can be devoted to reduce the likelihood of *unfavourable* occurring to *acceptable* levels (McBean and Rovers 1998). WURIM is aimed at completing the first stage of this risk management process: identifying all sources of risk. Through an analysis of these risks, and highlighting common factors that affect risk across the various categories of municipal water infrastructure, an integrated approach to the management of risks can be developed.

Drinking water systems have the most detailed risk management framework currently in place to ensure consumers are provided a continuous supply of water, free of microbiological and chemical contamination, while also considering aesthetics aspects such as while taste, colour and odour. Effective risk management in drinking water systems is achieved through the implementation of detailed water safety plans. Through these plans, a *hazard analysis and critical control points* (HACCP) methodology is employed to identify and mitigate potential hazards from water source all the way to the consumer (Pollard et al. 2004).

The greatest contributors to increased risk in Canadian water infrastructure were identified as the aging of existing infrastructure, climate change and increased occurrence of extreme weather events, and continued urban growth. Most municipal infrastructure currently in service in North America was built during the period of rapid economic growth following the Second World War. As these assets approach the end of their design life, significant investment will be required to maintain existing levels of service; a recent estimate states $87 billion will be required, an average of $6 488 per household (FCM 2012). Climate change is another significant contributor to increased risk, potentially having significant effects related to variation in precipitation, evaporation and runoff trends. This results in considerable uncertainty about future water supply, drinking water quality, flood management, and ecosystem health (CWN 2014). In regards to flood management, recent projections state that in light of climate change, 500 y floods could occur as frequently as every 25 y to 240 y (MIT 2012). A final driver of risk to existing infrastructure is urbanization and increased population growth. Eighty percent of North Americans live in urban centers, and between 1970 and 2000 urban surface cover grew at a rate of 3.31% (Seto et al. 2011). These changes in land use alter the natural water balance (Konrad 2003), while increased population increases water and wastewater treatment requirements (Environment Canada 2013).

3 Methods

3.1 Information Gathering Through Contact with Industry Professionals

In order to identify the top drivers of increased risk in municipal water infrastructure, or at least those that are perceived to be of greatest concern, a series of surveys was conducted in which experts in municipal water management were asked to identify the top three drivers of risk to municipal systems. Respondents were asked to identify the top drivers in descending order when presented with a list of nine drivers. The original list of drivers was developed by researchers at the University of Guelph based on areas that had been identified as of concern in previous research and individual experience of risk assessment. The list of nine drivers included:

- climate change and increased extreme weather levels;
- increased urbanization (population growth and development);
- sprawl (increased area of urban land);
- increased demands on aging infrastructure;
- evolving financial mechanisms;
- legislation;
- combined sewer overflows;
- health and safety issues; and
- protection of people and property.

Participants at the Canadian Water Resources Association (CWRA) conference held in July 2014 were asked to identify the top drivers of risk to municipal stormwater, wastewater and drinking water systems. Polls were conducted using *Data on the Spot* (DOTS) technology in order to survey a large group in a single session. In total 38 participants with extensive knowledge of various types of municipal water systems responded to the questionnaire.

A similar survey was conducted by polling the stakeholder committee for the *Development of Integrated Risk Management Framework for Municipal Water Systems* research project. Survey respondents were again asked to identify the top the drivers of risk to municipal water systems in descending order through an online survey. The stakeholder committee consisted of a total of 23 participants from across Canada. In total 48% of individuals

worked for a municipality, while 26% worked in academia. The remainder of individuals on the committee either worked in the private sector or other non-governmental organizations.

3.2 Assembly of Applicable Literature

Following the identification of the top drivers of risk to municipal systems, applicable literature relating to the areas of concern was collected. This was achieved through an extensive review of technical documents, published scientific research, news articles and guidance tools. These documents were located through extensive keyword searches using search engines, while sorting through content by age and relevance to risk management in Canada. Additional guidance was provided through communication with experts in various municipalities across the United States and Canada, who assisted in locating applicable literature.

3.3 Information Organization

WURIM was developed to efficiently communicate the wide range of risks to municipal water systems while focusing primarily on the areas of concern identified through the surveys discussed above. This PDF document was created using Microsoft Visio. This software allowed for hyperlinks to be incorporated into the document to allow internal links within the document and external links to literature on the Internet. Internal links are employed to lead the user from general information to details at other points in the document, while external links are used to show further details including scientific publications, consulting reports, news articles and other literature. Through use of links to online data sources, the extent of information contained within the document could be minimalized, while still allowing the user to link to the internet if more information is desired on a specific driver of risk.

3.4 Feedback and Adjustments

Feedback was received at multiple stages over the development of WURIM, followed by appropriate adjustments to the document. The initial content and document setup was first presented through a webinar hosted by the University of Guelph. Participants at this session included project stakeholders and other members of the Canada wide research team. Feedback on the document was received during an open discussion period following the webinar, and was continued through follow-up email communication leading to additional guidance and recommendations to contact other individuals. Several participants commented on the document's setup, leading to a change in format to better demonstrate an integrated approach, the focus of this paper. Additional material for case studies and guidance tools was identified in the discussion period and included in the document.

A second round of feedback was received at the *Water, A Risky Business* workshop held at the London Convention Centre in London, Ontario on February 13, 2015. By the date of this presentation the document was reaching the final stages of its development. Through a series of four afternoon breakout sessions, 75 industry professionals working in municipal water management were provided small group access to hands-on time with the document. This provided very useful feedback through an open discussion between the practitioners and the document developers. This feedback included suggesting other possible implications to water systems as well as suggesting applicable guidance tools and case studies. This feedback was incorporated into the document.

4 Results from Survey of Industry Professionals

4.1 Survey Results and Analysis

Survey results from polls conducted at the CWRA conference in July of 2014 are summarized in Figure 1. In total 38 experts attending the conference responded to the survey.

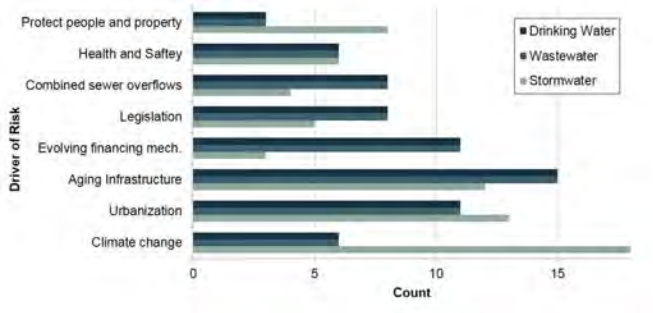

Figure 1 Survey results from CWRA conference July 2014 (38 respondents).

In regard to municipal stormwater systems, respondents identified increased urbanization as the highest driver of risk, receiving 27% of all votes. Aged infrastructure and climate change were identified as the second and third drivers of concern receiving, 24 and 21% of all votes respectively. The top driver of risk to municipal wastewater systems was identified as aging infrastructure, receiving 28% of all votes, while increased urbanization was identified as second most concerting and combined sewer overflows third (24% and 19% of total votes respectively). Finally, for drinking water systems, the top driver of risk was identified as health and safety issues, receiving 23% of votes while increased urbanization and aging infrastructure both received 20%.

Figure 2 summarizes results from the *Development of Integrated Risk Management Framework for Municipal Water Systems* project stakeholders' committee. In total 23 respondents took part in this survey. When questioned about municipal stormwater systems, survey respondents identified the top driver of risk as climate change receiving 30% of all votes. Urbanization and aging infrastructure were identified as the second and third greatest threat to stormwater systems, both receiving 15% of votes. In regard to wastewater systems, survey respondents identified aging infrastructure and urbanization as the most significant drivers

of risk, receiving 31% and 22% of votes respectively. Finally, in regard to drinking water systems, health and safety issues was identified as the top driver of risk, receiving 25% of votes, while aging infrastructure received 21% and increased urbanization received 19%.

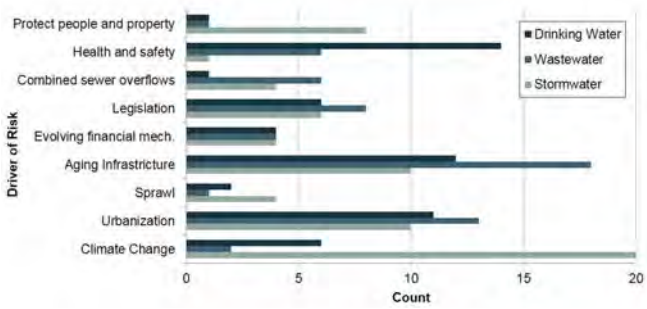

Figure 2 Survey results from *Development of Integrated Risk Management Framework for Municipal Water Systems* project stakeholders' committee (23 participants).

Based on the survey results discussed above, the drivers of risk to municipal water systems of most concern were identified as the aging of existing infrastructure, climate change and increased extreme weather events, and increased urbanization. These areas of risk were identified as being of most concern, and ultimately became the focus of WURIM.

5 Organizational Approach

5.1 General Approach

The organizational approach used in developing WURIM, was adapted from the United States Environmental Protection Agency's (USEPA) publication *Climate Ready Water Utilities Adaptation Strategies Guide for Water Utilities* (USEPA 2013). Using this tool, the user is able to track through the document through a series of clickable links as well as to external websites to access guidance on how to design and operate their infrastructure in light of climate change. This organizational approach is effective as users can readily sort through large volumes of information to access applicable guidance for their own municipality's unique challenges. The USEPA chose to use this format because while there is significant guidance material on the Internet, locating information applicable to specific issues faced by a municipality can be challenging. Through this organizational approach, the user can start at high level general information and follow links to access more detailed information. WURIM takes this setup a step further by including both risks associated with aging infrastructure and urbanization, in addition to climate change. A second benefit to the organizational approach adapted in WURIM is the ability to demonstrate possibilities for integration in risk management through depicting how a specific driver of risk can impact multiple categories of water infrastructure.

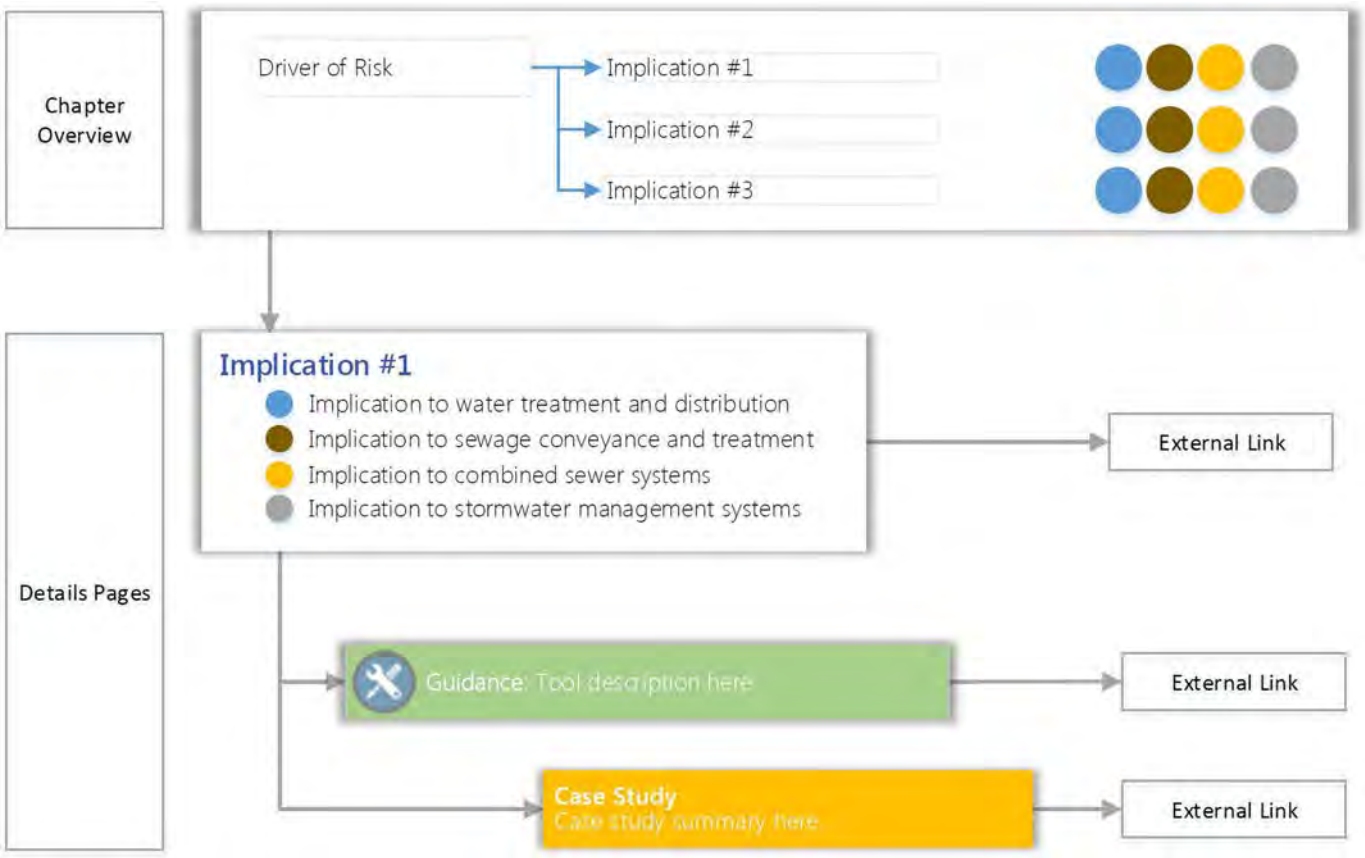

Figure 3 Schematic depicting the organizational approach used in WURIM.

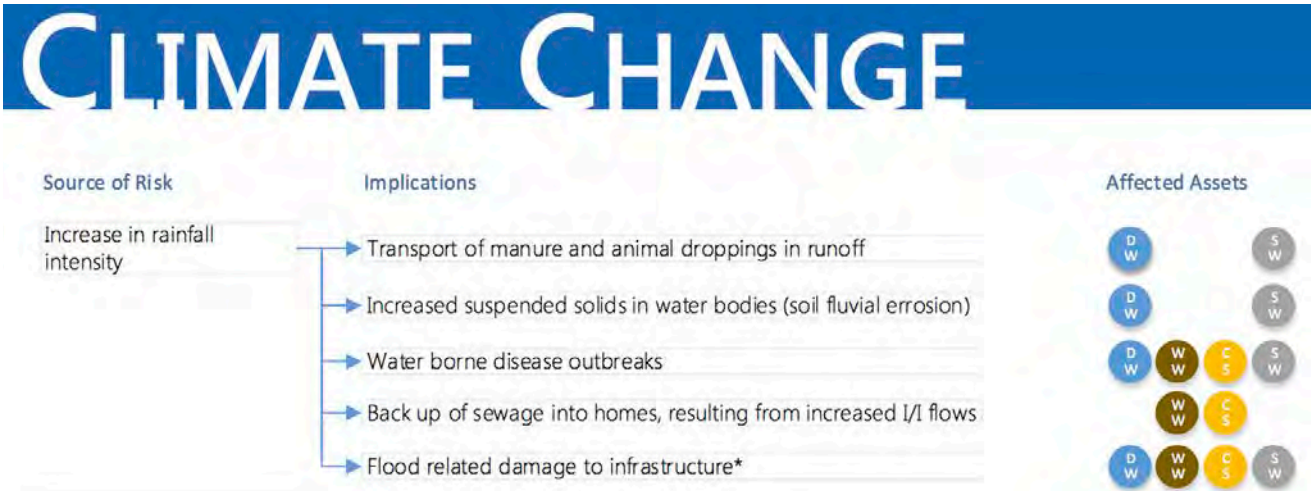

Figure 4 Excerpt from the climate change chapter overview of WURIM.

Figure 3 above demonstrates the organization of information within WURIM. Links between boxes represent a hyperlink, either within the document or to online references.

5.2 Chapter Overview

Each of the three identified drivers has a chapter overview page which through a flowchart style organization, demonstrates how the specified driver of risk can lead to a series of implications relevant to water infrastructure. Figure 4 above shows an excerpt from the climate change chapter overview in WURIM. From this page, the user first sees a driver of risk that is a direct result of climate change (*increase in rainfall intensity* in Figure 4) can lead to a series of implications. Corresponding systems that are affected by each implication are identified by an asset symbol found along the right side of the page. Assets include drinking water treatment and distribution (DW), sewage conveyance and treatment (WW), combined sewer systems (CS) and stormwater management systems (SW).

5.3 Details Pages

If a user wishes to view additional information on any of the identified drivers they can click on an implication from where they will jump to a details page later in the document. An excerpt from the details page from the climate change portion of WURIM can be seen in Figure 5.

On the details pages, the same asset symbols are used to identify specific implications to each category of water infrastructure. If the user wishes to view further details on a specific implication, any line of text containing an asset symbol can be clicked to access an external link. A hyperlink will lead the user to relevant literature on the Internet.

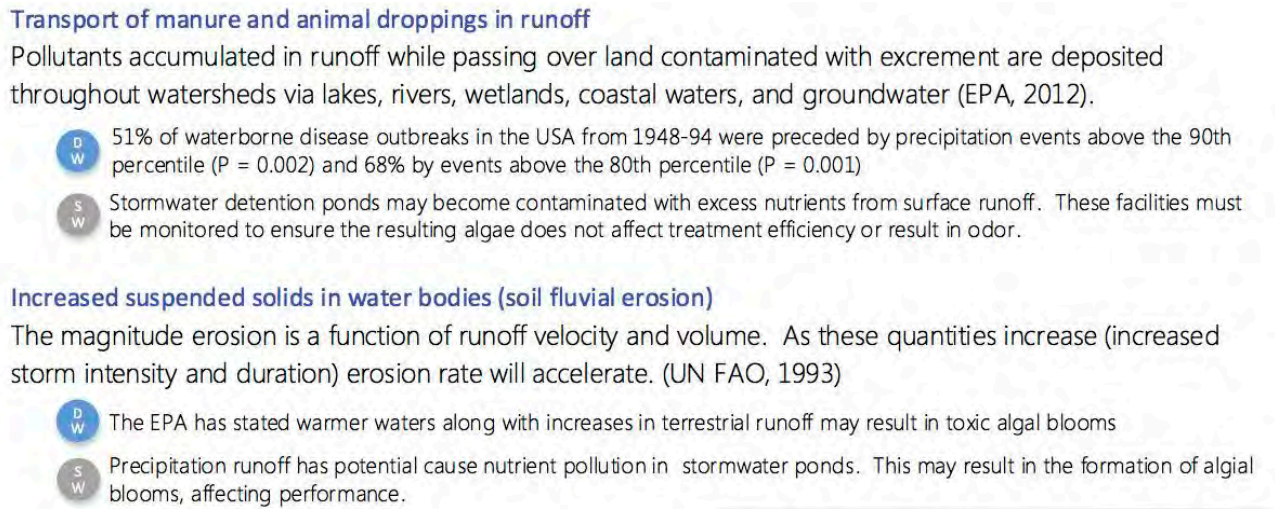

Figure 5 Excerpt from an implications details page from the climate change chapter of WURIM.

5.4 Additional Information

Additional information is also found on the details pages within WURIM in the form of case studies and a variety of guidance tools. These features are sorted by common implication. If a user wishes to see more information on a guidance tool they can click a link on the details pages from which they will be directed to a tool summary located later in the document. If the user wishes to access this tool, they can link directly from the tool summary to the guidance tools website. In a similar fashion, case studies can also be found in the details pages. If a user wishes to view details on a specific case study, they can link to a full case study in the appendix of the document as well as to online material.

6 Conclusions

Effective risk management in municipal water systems is of great concern in order to protect people, property and the environment in a cost effective manner. Through extensive consultation with practitioners, it was determined that many recognized the benefits of an integrated approach to water management at a municipal scale. The *Water Utility Risk Integration Matrix* was developed to identify the wide range of risks faced by these systems while containing information useful to municipal water managers. Areas of greatest concern which were identified through consultation with industry professionals are the aging of existing infrastructure, climate change and urbanization.

The integrated approach to water management at a municipal scale as demonstrated in WURIM shows great potential for sustainable and cost effective water utilities. Upon the identification of these risks and their interrelations a framework for an integrated approach to water management can be developed. In addition to demonstrating potential for integration, WURIM is a useful tool for municipal water managers. The document setup allows for ready access to a wide variety of guidance tools and case studies to assist practitioners across North America.

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