Examples of Reactive and Proactive Strategies for Physical Security Protection of Water Systems in Canada

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Background

- Water distribution system infrastructure is typically both the biggest asset and liability of a water utility
- Water distribution infrastructure is necessarily complex
  - Redundancy is required;
  - Complex because of the manner in which the infrastructure has been built;
  - Water supply infrastructure in North America is one of its oldest infrastructures
  - Water security is a key mandate – but how to protect the integrity?

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- Overview indication of approach adopted by Canadian municipalities
  - General character of City reactive response –
    - “we can’t afford to do that very efficiently – but we have learned from it”

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Part I – Examples of a Reactive Strategy Response

- Overview of Town of Walkerton outbreak in 2000 – Evidence of a failure to provide safe water supply
- Situation -
  - Lying and failure of operators to understand the responsibility of their position
- This was a case of
  - Animal Feedlot/Farm – heavy rains – no chlorination – operators lying about activities – 7 deaths and one-half of the community became ill, many who will need kidney transplant
  - Result - a basic element – mandatory source water protection plans and the Clean Water Act 2006

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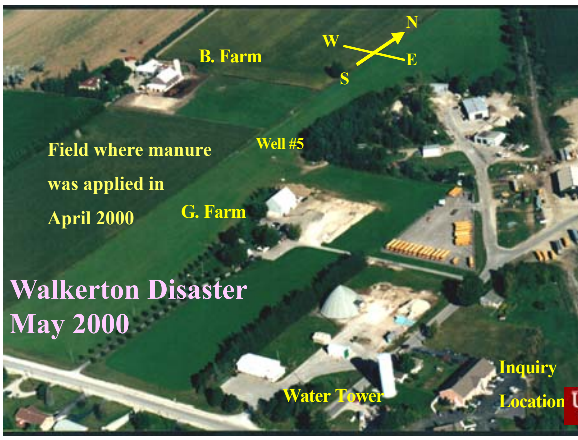

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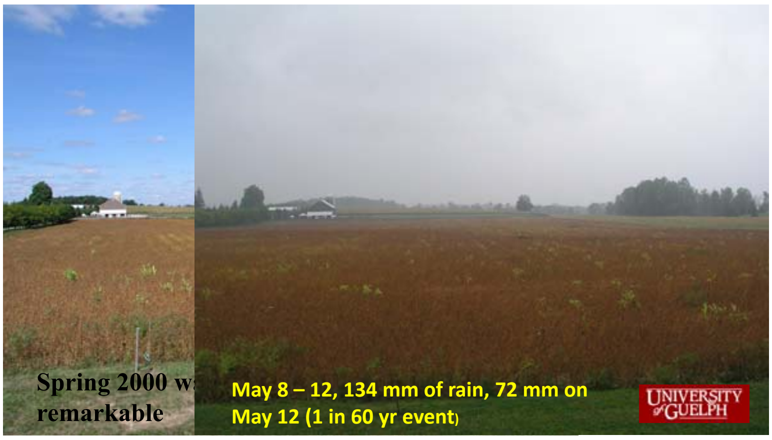


Reaction to a Disaster

- A cascade of problems
- Use of a shallow well as residents complained about hardness of water so operators relied upon a GUDI well
- Chlorination unit was turned off because people objected to the taste
- Many children became ill
- Operators continued to lie, indicating that chlorination had been ongoing
- Net result – one-half the town of 5000 became ill, **7 died**
- Resulted in the passing of the Clean Water Act of 2006 – required all municipalities to complete a **source water protection plan**
- Also forced recognition of need for a specific reporting structure

The Health Consequences in Walkerton

- 65 were hospitalized patients; 27 developed Hemolytic Uremic Syndrome (HUS)
- 52 % of HUS cases were between 1 and 4 yrs old
- One death, a four year old of a nurse, who visited the community to assist
- An estimated 2,300 individuals were ill with gastroenteritis (half the town's population)
- Many, including several children, were severely ill. Everyone knew someone who was severely ill and many knew someone who died
- Many report continuing ill health

- As a consequence – determination that a specific response system in-place, is needed
- Resulted in proactive approaches – source water protection (SWP) and water safety plans (WSP).

Participants in the Decision-making

Contract Lab

Council

MOE

Spills Action Centre

Emergency Planning Management Team

Public

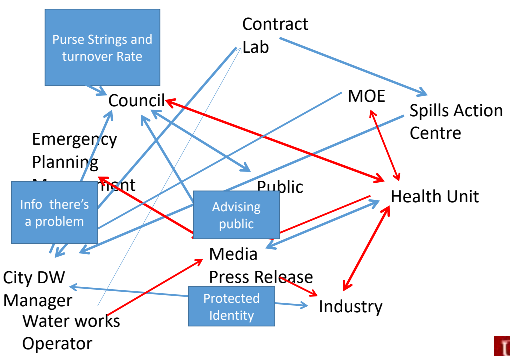
Health Unit

City DW Manager

Media Press Release

Industry

Water works Operator



Incubation Time for Waterborne Diseases

Incubation Time (days)	*E-coli*	*Giardia*	*Cryptosporidium*
Minimum	2	3	1
Average	3	7	7
Maximum	10	25	12

Source Water Protection (SWP) and Water Supply Plan (WSP)

- SWP (now enacted/**<u>Reactive</u>**) – all municipalities have to complete a source water protection plan
  - where does their water come from,
  - what sources of contamination are in the watershed, etc.
- Water Supply Plan - not uniform throughout entire country (only in 3 provinces, so far)
  - extensive set of questions to identify where the water system might be susceptible. 190 questions (challenging to complete)

Result

Transitioning from a reactive to a proactive strategy

Source Water Protection vs Multi-Barrier Risk Assessment

Source Water Protection Plan

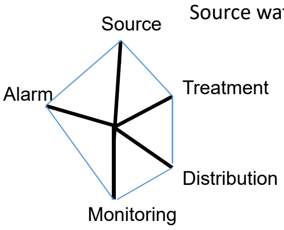
- Set of policies or actions to protect a drinking water source
- Based on identified hazards and risks in the watershed
- Only address one barrier

Multi-Barrier Risk Assessment

- Takes the source water protection plan a step further
- Addresses hazards and risks from the source all the way to consumer

Multi-Barrier Risk Assessment

Source water protection is only one dimension



Questions are asked Regarding all dimensions of spider diagram

Risk Assessment Templates

- Used in 3 provinces - British Columbia, Ontario, and Alberta
- Aim to identify hazards, assess likelihood and consequence, and calculate a risk score
- Risk scores used to prioritize hazards
- About being proactive rather than reactive
- Foster a culture of awareness

Comparison of Risk Assessments

Setup

British Columbia' Comprehensive Source to Tap Assessment (CS2TA)	Ontario's Drinking Water Quality Management Standard (DWQMS)	Alberta's Drinking Water Safety Plan (DWSP)
• Eight modules • Team identifies and evaluates hazards • Risk score calculated using Likelihood and Consequence	• One risk assessment table • Team identifies and evaluates hazards • Risk score calculated using Likelihood and Consequence, sometimes Detectability	• Excel spreadsheet • 190 hazards identified • Likelihood and Consequence scores selected from dropdown – spreadsheet calculates Risk score

Comparison of Risk Assessments

Barriers

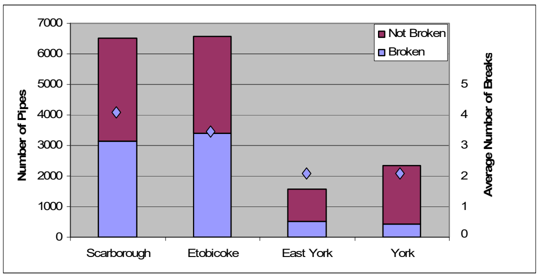
British Columbia's Comprehensive Source to Tap Assessment (CS2TA)	Ontario's Drinking Water Quality Management Standard (DWQMS)	Alberta's Drinking Water Safety Plan (DWSP)
1. Source protection 2. Treatment 3. Water system maintenance 4. Water monitoring 5. Operator training 6. Emergency response planning	1. Source protection 2. Treatment 3. Distribution 4. Monitoring programs 5. Management systems	1. Source 2. Treatment 3. Network 4. Customer

Condensed Version of the Alberta DWSP

- Evaluated in a hypothetical but representative location
- Not a single hazard was deemed to be a high risk by every technically knowledgeable person
- Respondents' feedback
  - DWSP was tedious to complete
  - Some of the hazards were similar causing them to second guess their responses
    - Condensed version grouped similar hazards together based on
      - Effect on water quality
      - Treatment technology
      - Point of contamination
    - Added in monitoring and emergency response hazards
    - We (Guelph) decreased the template down to 20 statements and a dropdown list to proceed if an area of high risk

Part II - Proactive Strategy (an indication)

Data Summary



Number of pipes broken versus not broken and the average number of breaks per broken pipe

Proactive Response

- Trying to identify sources of risk ahead of time, what might work.
- Lots of pipe failures – can be intentional disruption, industrial accident, and can be simply due to aging, severe temperatures in winter, etc.

Challenges for small systems

- Don't have the resources to operate and maintain their treatment and distribution systems
- Many (most) small water systems use chlorination to provide primary and secondary disinfection but water does not frequently undergo additional treatment

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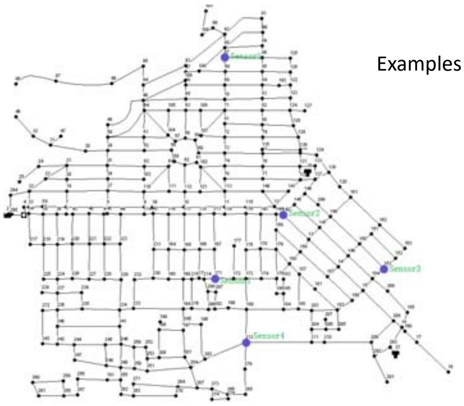
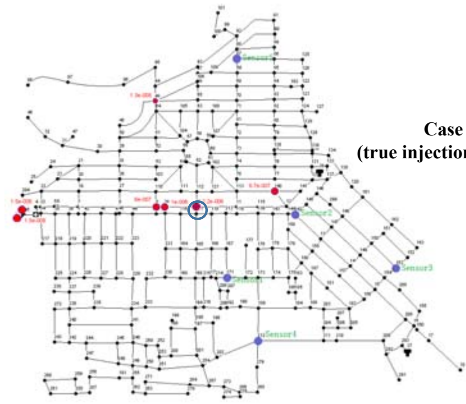
- E.g. continuous online monitoring for water quality parameters
  - Chlorine residual
  - TOC
  - Conductivity
  - pH
  - Temperature
  - Oxidation reduction potential
  - Turbidity
- Simply placing a collection of monitors and equipment throughout a water system is not sufficient to effectively detect contaminants or incidents
- Stratford – fortunate, but lucky

Examples of strategies evaluated

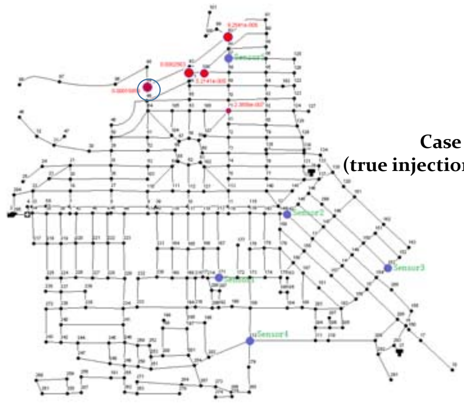




Case A
(true injection node 10)

Table 1. The Likelihood of Possible Injection Node for Case A

Injection Node	Injection Time	Possible Node	Likelihood
10	21600	9	6.0E-7
		10	2.2E-6
		49	1.3E-8
		140	6.7E-7
		295	1.5E-6
		39	1.0E-6
		2	1.5E-6



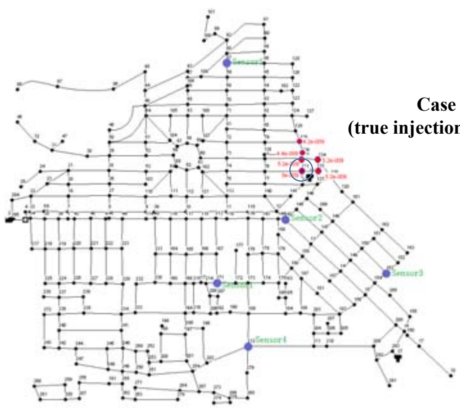
Case B
(true injection node 94)

WDSA Kruger, South Africa Aug 2008

Table 2. The Likelihood of Possible Injection Node for Case B

Injection Node	Injection Time	Possible Node	Likelihood
94	10800	67	2.85E-06
		71	2.18E-06
		92	2.49E-04
		94	2.49E-04
		109	1.74E-06

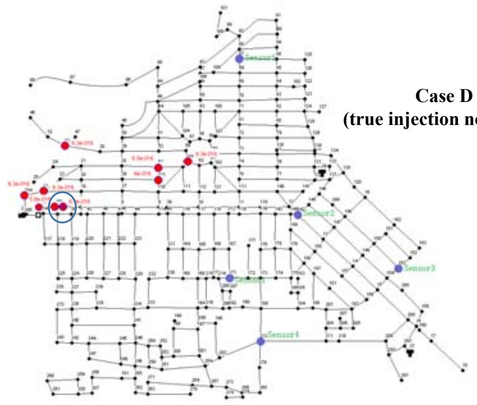
WDSA Kruger, South Africa Aug 2008



Case C
(true injection node 131)

Table 3. The Likelihood of Possible Injection Node for Case C

Injection Node	Injection Time	Possible Node	Likelihood
131	0	129	4.24E-09
		130	5.23E-09
		131	5.01E-09
		133	5.23E-09
		134	5.23E-09
		136	4.42E-09



Case D
(true injection node ID 6)

Table 4. The Likelihood of Possible Injection Node for Case D

Injection Node	Injection Time	Possible Node	Likelihood
6	0	5	6.3E-16
		6	6.3E-16
		4	5.8E-16
		294	6.3E-16
		22	6.3E-16
		31	6.3E-16
		53	6.5E-16
		103	6.0E-16
		55	6.3E-16

Table 5 Summary of the Algorithm Findings

Cases	Number of nodes identified by the algorithm	Injection node is the maximum probability?
Case A	7	Yes
Case B	5	Yes
Case C	6	No (the second highest probability)
Case D	9	No (the second highest probability)

Conclusions

- Transition in Canada, away from reactive to proactive strategies
  - A realization that we can't afford to be reactive
- Data mining procedures in conjunction with a maximum likelihood approach, provide a means to identify the most probable source nodes of contaminant ingress
  - however, has not been accepted – too expensive to implement and maintain, too many false positives
  - don't know what types of contaminants may be in the water
  - examining a set of noisy signals in order to detect a contaminant is a challenge
  - there is significant potential to enact to protect key locations (e.g. hospitals with immunocompromised individuals or government (e.g. embassies), or military facilities

Conclusions (continued)

- Robustness of data mining methodology was demonstrated – the procedure was able to identify the correct node as the first or second as the source location but many people exposed before response can be formalized
- Contamination event detection in a WDS is a case of examining a set of noisy signals in order to detect events – proving difficult
  - having a low probability of occurrence
  - only appear as very subtle deviations from typical background signals. The required sensitivity of the monitoring algorithm and overlap in the background and event signal signatures will lead to false alarms in event detection