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Analysis of a brownfield management conflict in Canada

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Abstract:

A strategic analysis of an ongoing brownfield management conflict in Elmira, Ontario, Canada is conducted using the Graph Model for Conflict Resolution. This investigation of the situation as it existed in late 2016 constitutes an expansion of an earlier analysis of the dispute which focused on cleansing the groundwater aquifer, polluted by a chemical company in Elmira, to a controversy over the management of the pollution impacts on an adjacent creek. Besides the chemical plant, the other decision-makers involved in the 2016 dispute are the Ministry of Environment and Climate Change of the Province of Ontario, local government, and a citizens' advisory group. The connections of the 2016 conflict to the earlier study which took place in 1991 are discussed and the evolution of the previous situation to the current one is explored in depth, along with strategic insights.

KEYWORDS graph model; conflict analysis; water resources; brownfields

INTRODUCTION

Brownfield sites are unfit for most development activities due to environmental contamination that can threaten surrounding areas if not contained (Hipel and Walker, 2012; Hipel *et al.*, 2010; Walker *et al.*, 2010). Industrialization is fueling the global creation of such sites, even as urban populations are growing, thus placing cities under increasing pressure to develop on or near contaminated lands (DeSousa, 2002; Hipel *et al.*, 2010).

The challenges of managing brownfields can lead to conflicts regarding site remediation and the distribution of management burdens (Hipel and Walker, 2012; Kilgour *et al.*, 2010; Walker *et al.*, 2010). Greater understanding of management decision impacts is needed to generate socially acceptable processes and outcomes. In this study, the authors examine a brownfield management dispute in Elmira, Ontario, Canada. Aspects of this conflict were previously analyzed using the Graph Model for Conflict Resolution (GMCR) (Hipel *et al.*, 1993, 1997; Kilgour *et al.*, 2001). The GMCR is used once again, to integrate emerging site issues and provide insights into the evolution of the Elmira conflict.

HISTORY OF WATER CONTAMINATION IN ELMIRA, ONTARIO, CANADA

Located in southern Ontario, Elmira was once known for its high quality and plentiful water. This resource attracted industry, bringing employment, as well as significant environmental and social costs (Baetz and Tanguay, 1998; Burtt, 2014a, 2014b). Of particular concern is a 35 hectares property in eastern Elmira that has been used for chemical operations for over a century. Notably, the pesticide dichloro-diphenyl-trichloroethane (DDT) was produced between 1948 and 1956, and continues to be a byproduct of manufacturing at the site. In the 1960s, the toxic herbicide Agent Orange was manufactured, producing a range of hazardous chemicals. The resulting waste materials were improperly disposed of and stored, thereby contaminating the land and aquifer underlying the property, as well as sediments in the nearby Canagagigue creek (Baetz and Tanguay, 1998; Dabrowska *et al.*, 2012; Burtt, 2014a, 2014b).

The site gained notoriety in 1989 when the discovery of N-Nirosodimethylamine (NDMA) at levels reaching 40 parts per billion (ppb) prompted the Ministry of Environment (MOE) to shut down two of Elmira's five municipal wells (Baetz and Tanguay, 1998). NDMA has a current maximum acceptable concentration (MAC) in drinking water of 0.04 ppb (Health Canada, 2011).

The owner of the land, Uniroyal Ltd. (UR) (now Chemtura), was identified as the source of this waste material (Hipel *et al.*, 1993; Kilgour *et al.*, 2001). Attention to environmental issues thus became galvanized around the site's impacts on the municipal drinking water supply. Under the Environmental Protection Act of Ontario (RSO, 1990), the MOE issued a control order (CO) to UR in August, 1990. Parts of the control order were then appealed by UR. In October, 1991, the appeal process ended when the MOE and UR negotiated a management agreement that restricted UR's responsibilities only to restoring the municipal wells and protecting land off of the site from further impacts. Contamination of the Canagagigue Creek was not addressed. Local government and citizen groups objected to the agreement as they had been excluded from the negotiations, and it weakened the original control order (Hipel *et al.*, 1993; Baetz and Tanguay, 1998).

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Beginning in 1992, Citizen Advisory Groups were formed by the Provincial and Municipal governments to provide public oversight and input into the full spectrum of UR activities in Elmira (Baetz and Tanguay, 1998; Township of Woolwich, 2013, 2015b). Participatory processes ultimately failed to build trust between the stakeholders, and the citizen advisory groups have since been restructured several times throughout the conflict (Baetz and Tanguay, 1998; Township of Woolwich, 2015a). Nonetheless, many early members of advisory groups remain involved in monitoring the clean-up and management activities of the present owner of the land, Chemtura Ltd. (Baetz and Tanguay, 1998; Burtt, 2014b).

In spite of relative stability since the agreement's implementation, this conflict continues to evolve, recently driven by two factors. Firstly, the 1991 agreement did not address citizen concerns about the creek's water quality (Township of Woolwich, 2014a). Secondly, although an indemnity clause for known contamination restricts the MOE from issuing further control orders, an exception exists for new evidence relating to the extent or impact of the contamination (Kannon, 2015; Township of Woolwich, 2014b). Current activists are motivated to leverage this exception.

The citizen advisory group (CAG) at the time of this study, the Chemtura Public Advisory Committee, initiated the collection and analysis of ten samples from the Canagagigue Creek, upstream and downstream of the site (Township of Woolwich, 2015a). Elevated levels of contaminants, including dioxins, DDT and furans were discovered. These findings are supported by evidence from Chemtura's own 2011 testing, from earlier MOE initiated studies (Jaagumagi and Bedard, 1997), and from MOE testing in 2012 and 2013 (Township of Woolwich, 2014a). From the perspective of CAG, evidence of contamination beyond the scope of the initial control order opened a new regulatory option. CAG members called for 'Action' on the part of the MOECC to protect and restore the creek (Township of Woolwich, 2014a). The authors interpret this as escalating pressure on the MOECC to issue a control order compelling Chemtura to restore the Canagagigue Creek, as control orders are the regulator's primary enforcement tool.

The Uniroyal site became Crompton Ltd. in 2001 and then Chemtura Ltd. in 2006 (CBC, 2015), with each successor required to adopt the responsibilities outlined in the control order (Township of Woolwich, 2011). The company could abandon the site, but only by declaring bankruptcy, which would require a prohibitive level of restructuring. This restriction does not, however, offer full protection to the other decision-makers (Township of Woolwich, 2014c) as evidenced by bankruptcy filings initiated by Chemtura in the United States in 2009 (United States Attorney Southern District of New York, 2010; United States Bankruptcy Court Southern District of New York, 2003a, 2003b). In 2011 CAG and LG received assurances that if Chemtura pursues Bankruptcy, the MOECC will assume responsibility for managing the site (Township of Woolwich, 2011). This necessity, combined with the alternate possibility of a lengthy appeal process in response to regulatory actions, makes the MOECC highly unlikely to issue a new control order.

From the LG perspective, the risk of Chemtura abandoning the site is a concern, as 180 local jobs would be lost (Township of Woolwich, 2014c). Further, a judgement in the case of Kawartha Lakes (City) v. Ontario (MOE) (2013), ordered a municipality to pay for property contamination that was not the city's fault.

PREVIOUS RESEARCH

The Graph Model for Conflict Resolution (GMCR) is a game-theoretic methodology used to model real-world conflicts (Fang *et al.*, 1993, 1989; Kilgour *et al.*, 1987). The method involves the identification of decision-makers (DMs), the set of options under the control of each DM, possible outcomes of the conflict, known as states, state preferences for each DM, and possible state transitions under the control of each DM. The model is analyzed for different types of stability, reflecting potential interactive human behavior under conflict. Unstable states will not endure but ones that are stable for all decision-makers will not change unless the conflict parameters are altered because the decision-makers receive no benefit from moving away from a stable state. The latter is an equilibrium and if it is reached during the dispute, may resolve the conflict. An equilibrium may be more or less desirable from the perspective of an individual decision-maker depending on their unique viewpoints. Thus, the fact that an equilibrium is likely to endure may represent a satisfactory resolution to one decision-maker but stagnation of the conflict to another.

A solution concept is a mathematically expressed description of possible human behavior under conflict that can be used to predict likely conflict outcomes (Fang *et al.*, 1989). A given decision-maker is assumed to make choices that result in outcomes more preferable from his or her own perspective; however, different viewpoints, degrees of foresight and levels of risk aversion underlay decision-maker's evaluations. Thus, GMCR integrates a range of solution concepts into its analysis. One, Nash stability (Nash, 1950; Von Neumann and Morgenstern, 1944), describes situations in which a DM cannot unilaterally move the conflict from an initial state to a more preferred one. In contrast, a Nash unstable state exists if the DM can independently move the conflict to a more preferred state, via a unilateral improvement. If, however, a unilateral improvement can result in a counter move by another DM that is disadvantageous to the first DM and all unilateral improvements from the state are blocked in this fashion, the initial state is considered to be sequentially stable (SEQ) (Fraser and Hipel, 1984). Other solution concepts include General Metarational stability (GMR) (Howard, 1971) and Symmetric Metarational stability (SMR) (Howard, 1971). The combined results are used to characterize the overall conflict stability. A weak equilibrium describes a state which is stable by some, but not all solution concepts. A state which is Nash stable for all DMs is a strong equilibrium. A state is unstable if any DM can unilaterally move the conflict from a focal state to a more preferred state (Fang *et al.*, 1993). Finally, a coalition can be used to reach a preferable outcome that is unavailable to a DM through unilateral actions, but achievable through cooperation with one DM or more. For example, in the Elmira case, the agreement that UR and MOE negotiated in 1991 (Kilgour *et al.*, 2001) was only available

Table I. Decision-makers and their options in the 2016 Elmira conflict investigation

Decision-maker and their options	Description
MOECC	**Ontario Ministry of Environment and Climate Change**
1. Issue new CO	MOECC issues new CO related to Canagagigue Creek management
Chemtura	**Chemtura Ltd.**
2. Delay	Chemtura delays through appeal of new CO
3. Accept	Chemtura accepts a new CO
4. Abandon	Chemtura files for bankruptcy
5. Volunteer	Chemtura volunteers to negotiate new clean-up measures
Local Government	**Regional Municipality of Waterloo and Township of Woolwich**
6. Escalate	Local Government escalates pressure for the issuance of a new CO
CAG	**Citizen Advisory Group**
7. Escalate	CAG escalates pressure for the issuance of a new CO

through cooperative actions between the MOECC and Uniroyal, who considered this outcome advantageous.

Model development and analysis using GMCR has been operationalized by decision support systems including GMCR I (Fang *et al.*, 1993), GMCR II (Fang *et al.*, 2003a, 2003b; Hipel *et al.*, 1997) and GMCR+ (Kinsara *et al.*, 2015a). These software programs provide interfaces for building conceptual models of disputes, performing stability calculations, and interacting with models through stability and sensitivity analyses (Kilgour and Hipel, 2005).

Research by Hipel *et al.* (1993) initiated conflict analysis of the Elmira dispute using GMCR. The model focused on negotiations that occurred after UR had appealed the original control order (Hipel *et al.*, 1993; Kilgour *et al.*, 2001). The decision-makers included the MOE, Uniroyal Chemicals Ltd., and LG. At that time, CAG was not modelled as an independent decision-maker as its preferences were similar to LG's, and it had limited influence over formal decision-making (Hipel *et al.*, 1993, 2008). Hipel *et al.* (1993) identified nine states that could occur in this conflict. A stability analysis found three strong equilibria, including the agreement that occurred (Hipel *et al.*, 1993, 2008). The model was then used for various illustrative and expansion purposes. Kilgour *et al.* (2001) integrated coalition analysis into GMCR, which was further expanded by Inohara and Hipel (2008a, 2008b). The functional capabilities of GMCR II, were illustrated by Hipel *et al.* (1999) and by Hipel *et al.* (2008). Using fuzzy preferences and fuzzy option prioritization to model uncertainty in preference information was explored by Bashar *et al.* (2012, 2014). Clearly, the Elmira conflict study has inspired many graph model expansions, but the model itself has remained static.

INVESTIGATING THE ELMIRA CONFLICT FOR 2016

This research calibrates an updated Elmira conflict model using materials from previous studies, as well as historic actions and statements recorded in the minutes of formal meetings and the media. The decision support system, GMCR+ (Kinsara *et al.*, 2015a), used for the modeling and analysis, provides advanced analytical functions including stability analysis, sensitivity analysis, coalition analysis, inverse GMCR, and visualization functions (Kinsara *et al.*, 2015a, 2015b).

Status of the conflict

At the time of model development, Chemtura and the MOECC have an agreement covering the remediation of the municipal aquifer. CAG is calling on MOECC and Chemtura to adopt more rigorous treatment strategies for DDT, dioxins and furans, along the Canagagigue creek.

Decision-makers and their options

Table I summarizes each decision-maker and the options it controls, with decision-makers and their respective options listed on the left, and the formal name of the decision-maker along with a brief description of each option on the right. Note, that a new decision-maker, Citizen Advisory Group (CAG) has been added to the model to reflect the prominent role played by CAG as it has increasingly acted outside of a limited advisory capacity, by reaching out to media and initiating independent studies. In particular, CAG made recommendations to the MOECC that conflicted with government perspectives (Baetz and Tanguay, 1998). The designation CAG is actually a generalization that masks some complexity. In 1992 two citizen groups were established by the municipal and provincial governments. Over several years, internal disagreements between CAG and government entities resulted in splitting and restructuring of these groups. It was in the penultimate form, the Chemtura Public Advisory Committee, that CAG distinguished itself as a separate decision-maker. It is important to also acknowledge that private citizens were engaged in this conflict, outside of advisory groups, and influenced the preferences of CAG and LG. However, in a formal conflict model, a DM refers to an individual or entity with control over specific options in the dispute, rather than having an interest in the outcome, or influence over formal decision-makers.

Table II. Feasible States

	Options	Viable States							
MOECC	1. Issue New CO	N	Y	Y	Y	N	N	N	N
Chemtura	2. Delay	N	Y	N	N	N	N	N	N
	3. Accept	N	N	Y	N	N	N	N	N
	4. Abandon	N	N	N	Y	N	N	N	N
	5. Volunteer	N	N	N	N	Y	N	N	N
Local Government	6. Escalate	N	N	N	N	N	Y	N	Y
CAG	7. Escalate	N	N	N	N	N	N	Y	Y
State number		1	2	3	4	5	6	7	8

Conflict states

A conflict with four decision-makers controlling a total of seven options has 128 (2^7) mathematically possible states, but not all are possible or likely to occur in practice. For instance, Chemtura cannot choose to simultaneously apply for bankruptcy and negotiate voluntary treatment measures; these options are *mutually exclusive*, and any states in which these options are jointly chosen are infeasible. Another kind of *infeasible state* that may be removed is one that is highly unlikely to occur, such as a state in which LG chooses to escalate the conflict after the MOECC has issued a control order. Issuance of a control order, by the MOECC to Chemtura, to compel management of the contamination at the Canagagigue creek is the ultimate goal, and the primary source of conflict in this situation. Further, maintaining employment and the current financial arrangements outlined in the 1991 negotiated Agreement is important to LG, and could be at risk if Chemtura applies for bankruptcy. As such, it is reasonable to remove states in which the LG continues to escalate the conflict after this goal has been achieved. After all infeasible states are removed, eight states remain for analysis. These are shown in Table II. The left column lists the decision-makers, and the options that each decision-maker controls. The section to the right shows the feasible states, listed as columns. Each of these columns is comprised of options that combine to form a state. For each option 'N' indicates that the decision-maker controlling the option has not chosen it, while a 'Y' indicates that it has been selected. For example, at State 7, CAG has taken its option to escalate the conflict, LG has chosen not to escalate, and MOECC and Chemtura have not responded.

State transitions

When a decision-maker can independently move the conflict from one state to another state, he has an available *unilateral move*. For instance, LG can move the conflict from State 7 to State 8 by changing its option selection from 'N' to 'Y', whereas the options selections of the other decision-makers remain fixed. By this choice, LG escalates the conflict in cooperation with CAG. Once selected, some options can be reversed by the decision-maker. For instance, LG can stop escalating the conflict, thereby moving from State 8 back to State 7. Other option choices are considered *irreversible*, such as Option 1 in which MOECC issues a new control order, Option 3, in which Chemtura accepts a control order, and Option 4 in which Chemtura claims Bankruptcy.

Decision-maker's preferences

Decision-maker preferences and their rankings of states are based upon evidence of preferences as recorded in the minutes of formal meetings, media statements, and previous actions of each decision-maker, which have been referenced in previous sections of this text. The authors also benefitted from communication with an expert on this conflict. The authors then used a flexible method of inputting preferences that is available when using GMCR+; this method is called option prioritization (Hipel *et al.*, 1997; Fang *et al.*, 2003a, 2003b). It allows relative preferences to be input using logical preference statements about option selections. These statements are used to sort states from most to least preferred, including ties, based on the decision-maker's preference statements for specific options. Preference statements used to calibrate this model are provided in Table SII, with most important at the top and less important at the bottom for a given decision-maker. A relative preference ranking of states is then generated for each decision-maker. The preferred states for the MOECC, ranked from most to least preferred are (1, 5) 3, 7, 6, 8, 2, 4. States in parentheses are equally preferred. Following the same conventions, Chemtura's are 1, 7, 6, 8, 2, 4, 5, 3; LG's are (3, 5) 1, (6, 7, 8), 2, 4; and CAG's are 3, 5, 4, 2, 8, 7, 6, 1.

Stability analysis

Analysis reveals five equilibria, including States 2, 3, 4, 7 and 8, whereas States 1, 5, and 6 are unstable. State 3 is highly preferred by MOECC, LG and CAG, but it is controlled by Chemtura, for which it is a least preferred state. Thus, State 3 is unlikely to occur. States 2 and 4 are similarly controlled by Chemtura. Although CAG and LG control states 7 and 8, this offers little advantage in the real-world dispute, as they are not highly preferred states for these decision-makers. Application of solution concepts is shown in tableau format (Fraser and Hipel, 1984) in Table III. Each decision-maker is shown with the states ranked from most preferred to least preferred, from its own perspective. Unilateral improvements are listed underneath each state, for each decision-maker. Above each state it's stability is indicated by an 'r' for Nash stability, an 's' for SEQ stability, and a 'u' for unstable. Overall stability is

Table III. Application of solution concepts in tableau format

								MOECC
X	X	E	E	X	E	E	E	Overall Stability
r	r	r	r	r	r	r	r	DM stability
1	5	3	7	6	8	2	4	DM preference Vector
								UIs
								Chemtura
r	r	r	r	r	r	u	r	DM stability
1	7	6	8	2	4	5	3	DM Preference Vector
						1		UIs
								Local Government
r	r	r	s	r	r	r	r	DM stability
3	5	1	6	7	8	2	4	DM Preference Vector
			1					UIs
								Citizen Advisory Group
r	r	r	r	r	r	u	u	DM stability
3	5	4	2	8	7	6	1	DM Preference Vector
						8	7	UIs

Lines placed under states indicate that the states are equally preferred for the focal DM. Overall states stability is indicated by an ‘E’ for equilibrium or an ‘X’ for unstable. Individual DM stability results are shown with ‘r’ indicating Nash stable, ‘s’ indicating SEQ stable, and ‘u’ indicating unstable

then indicated by ‘E’ for states in equilibrium, or ‘X’ for unstable states. To illustrate this process, consider State 2, which has no unilateral improvements listed under it for any decision-maker. Thus, State 2 is Nash stable for all decision-makers and is in equilibrium. By contrast, consider state 6. LG has a unilateral improvement from State 6 to State 1. From State 1, CAG can move the conflict to State 7. Because LG prefers state 7 less than State 6, State 6 is SEQ stable for LG. This process is illustrated in Table SIII, for which Y-N notation is used. Note that in the unilateral improvement from State 6 to State 1, only LG’s strategy changes. Similarly, only CAG changes its strategy in response.

Sensitivity analyses

Through sensitivity analyses it is possible to explore ‘what if’ questions. The authors entertained the question: “*What if the MOECC was more sensitive to public pressure?*”. To reflect this, the preference ranking of MOECC was adjusted to (1, 5) 3, 7, 6, 2, 4, 8. This resulted in no change to the earlier stability findings. To probe the role of public pressure over the conflict outcome, an analysis was then conducted to ask “*What if Chemtura were more sensitive to conflict escalation?*”. The Chemtura preferences were altered to 1, 5, (7, 6, 8), 2, 4, 3. State 5 consequently changed from being unstable to a weak equilibrium. In this scenario, a state transition from 5 to 1 can be sanctioned by the CAG moving from State 1 to State 7. Finally, an analysis was performed to ask “*What if the LG and CAG were more resistant to escalating the conflict?*”. The preference rankings for LG and CAG were both altered to (5, 3) 1 (8, 7, 6) 2, 4. In this scenario, State 6 is a weak equilibrium that is unstable for LG because it has the ability to transition to State 1. Similarly, State 7 is unstable for CAG whereas State 1 is stable. Hence, if the LG and CAG were less inclined to escalate the conflict, the dispute would be more likely to reach and to remain at State 1, in which no conflict escalation occurs.

EVOLUTION OF THE ELMIRA CONFLICT

Table IV shows this conflict’s evolution from the previous to the current model. The model developed by Hipel *et al.* (1993), addressing contamination of the Elmira municipal aquifer, is displayed on the left. Arrows indicate a change in option choice, which causes a change in state, when reading from left to right. For example, under 1991 Status Quo, LG alters its option choice, resulting in a change of state. Further changes, also illustrated by arrows, move the conflict into a cooperative equilibrium. The progression from the cooperative equilibrium to the current model, 2016 Status Quo, is shown on the right.

DISCUSSION OF STABILITY ANALYSIS RESULTS

Currently, the most-preferred options for LG and CAG are controlled by Chemtura, a situation that holds true for the stability analysis, and for each scenario explored through sensitivity analyses. This situation highlights an

Table IV. Evolution of the Elmira conflict

Decision-makers and their options	1991 Status Quo		Non-cooperative Equilibrium		Cooperative Equilibrium		Updated decision-makers and their options	2016 Status Quo
MoE							**MOECC**	
1. Modify	N		N	→	Y	→	1. Issue new CO	N
Uniroyal							**Chemtura**	
2. Delay	Y		Y	→	N		2. Delay	N
3. Accept	N		N	→	Y	→	3. Accept	N
4. Abandon	N		N		N		4. Abandon	N
							5. Volunteer	N
Local Government							**Local government**	
5. Insist	N	→	Y		Y	→	6. Escalate	N
						↘	**Citizen Advisory Groups**	
							7. Escalate	Y

The left side of the table shows the model developed by Hipel *et al.* (1993) addressing NDMA contamination of the Elmira municipal wells. The option ‘Modify’ refers to modification of a CO for treatment of aquifer contamination. Arrows show changes in strategy that result in conflict evolution. The current conflict status is shown to the right of the table. “Issue new CO” refers to a CO related to management of contamination impacting the Canagagigue Creek

important power asymmetry in the dispute: Chemtura dominates the conflict because of a lack of important options under the unilateral control of the other decision-makers.

The sensitivity analyses indicate that had both LG and CAG been less inclined to escalate the conflict, the dispute would likely have reached and remained at State 1, wherein no conflict options are taken. Thus, early attention to CAG’s concerns in relation to broader site issues, specifically to the quality of the Canagagigue Creek, might have produced a more-enduring equilibrium. These findings reflect those of Walker *et al.* (2010) in their analysis of a successful brownfield redevelopment project in Kitchener, Ontario, Canada. Both studies highlight the importance of the quality of the working relationships between conflicting decision-makers in successfully managing brownfield sites. Text S2 provides further discussion highlighting some aspects of the research findings in the context of brownfield management in Ontario, Canada.

CONCLUSIONS

By revisiting the ongoing water management conflict in Elmira, Ontario, Canada, using the Graph Model for Conflict Resolution, this investigation has expanded upon the earlier analysis of the dispute, which was completed in 1993 (Hipel *et al.*, 1993). By tracing the connections between the groundwater conflict that was investigated in 1993, and enduring concerns over contamination of the Canagagigue creek, an updated model of the evolution of the dispute has been generated. Important parameters that have been updated include the recognition of a new decision-maker, identification of a new option available to the MOECC, and the development of a formal representation of the evolution of this conflict. This updated model of the Elmira water contamination conflict provides opportunities to better understand the situation, and for future research to explore new avenues for reaching an enduring and socially acceptable resolution. For instance, while an equilibrium indicates an outcome that is likely to endure if it is reached, any equilibrium state may be more or less acceptable according to the perspective of a single decision-maker. In the Elmira dispute, dissatisfaction with the equilibrium reached in 1991 contributed to efforts by CAG to change the model parameters, resulting in the conflict evolution presented herein. Conflict analysis techniques can support decision-makers as they seek outcomes that are more preferred by all parties. One option is found in a recent extension to GMCR, the Inverse Approach to the Graph Model of Conflict Resolution (Kinsara *et al.*, 2015b), which facilitates identifying preferences a target decision-maker should adopt to reach a specified outcome. This information can be used to motivate decision-makers to take preferable actions to work towards mutually beneficial outcomes (Kinsara *et al.*, 2015b).

Conflict models can also facilitate negotiations by supporting the development of common perspectives of the situation (Okada and Sakakibara, 2004); clarifying the diverse, and often conflicting interests and viewpoints, of different decision-makers; identifying trade-offs; and collaboratively generating solutions that integrate multiple preferences (Yousefi *et al.*, 2007). By explicitly addressing and dealing with conflicting objectives, decision-makers can more clearly discuss and reach mutual agreements and socially acceptable outcomes (Yousefi *et al.*, 2007). Along these lines, the utilization of GMCR for third party negotiations has shown that a coordinator or other third-party negotiator can use these models to facilitate communication with multiple decision-makers (Hipel *et al.*, 2015). Finally, participatory modeling using GMCR can reduce the risks of misunderstandings during the negotiation process (Okada and Sakakibara, 2004). Decision-makers with shared understandings of the conflict may develop mutual agreements that bypass the need for prolonged appeals, and conflicts that delay site remediation. Specific to the Elmira conflict, this updated model aims to clarify the evolution and current status of the situation, and to facilitate the future application of innovative conflict resolution strategies.

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SUPPLEMENTS

Text S1. List of abbreviations
Text S2. Discussion of brownfield management in Ontario, Canada
Figure S1. Map of Elmira, Ontario, Canada
Table SI. Definitions of Solution Concepts
Table SII. Preference statements used in the 2016 Elmira conflict investigation
Table SIII. Process of move and countermove in SEQ stable State 6

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