Exploring the Role of Geomatics in Disaster Management

by

Scott Westlund

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF ENVIRONMENT

Department of Environment and Geography

University of Manitoba

Winnipeg

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FACULTY OF GRADUATE STUDIES

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Of

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ACKNOWLEDGEMENTS

This thesis would not have been possible without the guidance and support of many people. I would like to thank my supervisor, Dr. Dion Wiseman, who was interested in my work from the beginning and supported this project as it went through its various iterations. I am grateful, too, for his help with the web-based survey questions and his thoughtful comments on earlier versions of this thesis. I also appreciated the timely support, interest, and helpful comments of my co-supervisor, Dr. Emdad Haque. I would like to thank my other committee members, Dr. David Walker and Dr. Niru Nirupama, for enthusiastically joining my committee and providing guidance at various points during the research, and for offering constructive comments on the draft thesis. I am also grateful for the assistance of Mr. John Lindsay and Dr. Toni Morris-Oswald, both of whose guidance significantly improved the web-survey questions. In addition, the case study would not have been possible without the work of Mr. Norman Tchir. Not only did he offer advice and provide information but he also invited me to various emergency management events which facilitated a deeper understanding of the emergency management context in Manitoba. I would also like to thank Mr. Jim Hines and my colleagues at Manitoba Conservation for their support and assistance in preparing the case study and emergency plan maps. Additionally, this work was partially supported by the Clayton H. Riddell Endowment Fund. Finally, I would like to thank Stephanie, my rock and provider of advice, your input is always valued and I am eternally grateful for your encouragement and support.

ABSTRACT

This mixed-method, interdisciplinary research explores the use of geomatics in disaster management. A taxonomy classifies examples into various integration levels to enable practitioners to identify successful uses of geomatics. Results from a web-based survey of practitioners and educators highlights the disconnect between education, practice and software development, and the benefits and challenges of using geomatics. Finally, a case study undertaken with the Rural Municipalities of Headingley, Cartier and St. Francois Xavier in Manitoba, Canada, incorporates the knowledge gained from the taxonomy and web survey into an operational emergency plan. The case study shows that appropriate geomatics integration is based primarily on an analysis of the requirement for expert knowledge, and physical and organizational challenges. The study also reveals an opportunity to use a participatory geomatics risk and hazard assessment approach to engage community members in the disaster management process to assist practitioners in developing plans that reflect community priorities and values.

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1. INTRODUCTION

Throughout the world the number of people living in regions susceptible to hazards is increasing and the potential for disaster brought on by events such as earthquakes, hurricanes, and flooding is growing (Mileti, 1999). For instance, as a result of the sense of safety provided by structural mitigation projects, the United States has seen a rapid population increase in regions prone to earthquakes as well as in low-lying costal communities susceptible to hurricanes and flooding (ibid). Additionally, in many developing countries, due to growing wealth inequality and rapid-urbanization, vulnerability has increased for the many people forced into informal settlements in search of work and affordable housing; these settlements are often located in areas subject to both natural and other environmental and social hazards (Chadha et al., 2007; Mileti, 1999; Oelofse, 2002; Wisner and Luce, 1995). It is under these circumstances that recent natural hazards have resulted in high numbers of fatalities, economic losses, damage to the environment, and have had adverse effects on the livelihoods of vulnerable populations (Haque and Burton, 2005). As anticipated by many, the trend of mounting economic losses and escalating vulnerability is continuing (Mileti, 1999). A recent Oxfam report indicates that the average number of yearly disasters has risen from 120 in the 1980s to around 500 in 2007, and the number of people affected by disaster events has risen by 68 percent to 254 million since 1985 (Sinnott, 2007).

Both the impact and response to disasters such as the 2004 Indian Ocean earthquake and tsunami, and Hurricane Katrina were unprecedented; however, in these and other cases, decision makers lacked key information such as critical base mapping data. Decision makers were also unable to effectively communicate with one another and relief organizations were not always aware of the regional priorities or tasks being undertaken by other agencies (Kelmelis et al., 2006; Yarbrough and Easson, 2005). In fact, the International Federation of Red Cross and Red Crescent Societies 2005 *World Disaster Report* labeled the tsunami relief effort as a "messy relief operation, in which information circulated badly and coordination at times appeared non-existent" (p. 81). If vulnerability continues to increase and the impact of hazard events continues to intensify, there will be an increasing need for improvements in disaster management.

WHAT IS DISASTER MANAGEMENT?

Haque (2000) defines a disaster as "a calamity which has resulted or may result in the loss of life or serious harm or damage to the safety, health or welfare of people; or damage to property or the environment" (p. 231). Within the context of this thesis, severe storms, floods, droughts, earthquakes, or fires are hazards, but in order for an event to be considered a disaster, it must impact humans or the built environment (Mileti, 1999). Disaster management is best articulated in the definition put forward by The United Nations International Strategy for Disaster Reduction:

> [Disaster management is the] systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards.
>
> —International Strategy for Disaster Reduction, 2004

The activities that are undertaken within the context of disaster management are often classified into phases of a disaster cycle or model (Cutter, 2006; Lemmens, 2005, Mileti, 1999).[1] The traditional phases include preparedness, response, recovery and mitigation. Examples of the activities that occur within these phases may include the identification and evaluation of risks (Ferrier and Haque, 2003), establishment of community emergency preparedness plans (Pearce, 2003), construction of mitigation structures or taking mitigating actions once risks are known (Haque, 2000; Haque and Burton, 2005), responding efficiently to disaster events (Fiorucci, et al., 2005), and completion of a reconstruction project after a disaster. Disaster management is an important function, one that is often overlooked and easily dismissed in lieu of other priorities.

THE USE OF TECHNOLOGY IN DISASTER MANAGEMENT

It seems that technology has permeated almost every aspect of society and is becoming increasingly important, particularly in the West. Many people now rely on iPods, cellular phones, e-mail, text messaging, and the Internet to go about their daily lives. The use of technology in disaster management began in the United States in the 1950s, in response to the threat of nuclear war with the Soviet Union (Mileti, 1999). Many people believe that technology makes us safe (ibid.). For example, structural mitigation approaches (e.g., engineered solutions, such as the floodway in Winnipeg, Manitoba, or the levees in New Orleans, Louisiana) and the installation of warning systems fosters a feeling of safety in many communities. However, many citizens, particularly in urban areas, are likely unaware of all of the risks and hazards in their community.

It seems inevitable that the use of technology will also become increasingly important in the field of disaster management and participants in this research highlight

[1] The term 'disaster management' is used throughout this thesis but it also could mean emergency management, emergency coordination, and disaster coordination.

both the potential benefits of technology as well as the caveats for its use. While a discussion of specific risks associated with the use of technology, such as technological failure, or a failure of the nation's communication or electrical infrastructure, is beyond the scope of this thesis, it is important to acknowledge the trade-off associated with the use of technology. When technology is implemented new risks are introduced and it is possible to become over dependent on it. Notwithstanding this, if used appropriately, technology can empower marginalized groups and provide an opportunity for those who may often be excluded from activities to participate and to be heard.

If further use of technology in disaster management is inevitable, it becomes important to investigate technology that could improve disaster management and benefit both disaster managers and the public (including communities and marginalized groups). For instance, as the public gains a better understanding of technology that has, to date, only been used by professionals, disaster managers may be able to harness its power to increase community capacity and participation, improve citizens' understanding of risk, and facilitate communication between the public and disaster managers and among practitioners themselves. Geomatics is an example of such technology.

WHAT IS GEOMATICS TECHNOLOGY?

Geomatics is the science of gathering, analyzing, interpreting, distributing and using geographic information to help us understand the earth and our location on it (Geomatics Canada, 2004). Geomatics draws upon, among other things, the use of global navigation satellite systems (GNSS) such as the global positioning system (GPS), geographic information systems (GIS), and remote sensing (RS).[2] The everyday use of spatial data collected with these technologies is increasing, with common civilian uses ranging from vehicle navigation to interactive maps. Geomatics technologies also provide accurate positioning and enhanced mapping capabilities to surveyors, allow the media to visually present a situation to the public, and allow law enforcement agencies to track and monitor the location of people and vehicles.

Geomatics is a location-based science and the use of geomatics in disaster management is a natural fit because location is a key element of disaster management. Almost everything in a disaster, including the event, resources, hazards, and people, are referenced by location (Gunes and Kovel, 2000; Kevany, 2005; Parker and Stileman, 2005). According to the current academic literature, however, not all disaster managers have embraced the use of geomatics technologies (Cai and MacEachren, 2005; Cutter, 2006; Jacobson, 2006; Misra and Enge, 2006). It is uncertain whether disaster managers are unaware of these technologies, are not educated in their use, or feel that geomatics solutions are too costly or inappropriate for use in this field.

PLACING GEOMATICS IN DISASTER MANAGEMENT THEORY

Mileti's (1999) *Disasters by Design* introduces the concept of "sustainable hazard mitigation" (p. 2). Mileti argues that part of the shift towards sustainable hazard mitigation requires that communities are empowered and develop *local* risk assessment maps to assess vulnerability at a *local* level. Similarly, Pearce (2003) suggests that disaster management practitioners must adopt a community-based approach to hazard identification, risk assessment, and emergency planning to ensure sustainable hazard

[2] Throughout the remainder of the thesis geomatics will refer to the use of GNSS, GIS and RS technologies.

mitigation. She suggests that community members must have the opportunity to integrate their local knowledge and community perspective into the disaster management process. As such, this research begins with the understanding that technology – specifically geomatics technology –can be used to increase community participation and empower marginalized groups by providing an opportunity for the entire community to participate in the hazard and risk identification process. However, practitioners and experts attempting to use geomatics with this intent must keep in mind that maps are "a reflection of our own ideological or cultural perception of the world" and that not all maps are equally accessible and understandable to all researchers, practitioners, community members, the public, and policy makers (Kassam and Graham, 1999, p. 201).

RESEARCH PURPOSE AND OBJECTIVES

The inspiration for this thesis came while attending the 3rd International Symposium on Geo-information for Disaster Management in Toronto, Ontario, in May 2007. Many presenters at the conference demonstrated the advances and important research currently taking place at universities and in the private sector regarding the use of geomatics in disaster management. It was, however, surprising that the use of local or practitioner knowledge in the solutions to disaster management problems seemed to be omitted. For example, many researchers reported deriving new algorithms for image analysis, developing software, and writing equations to quantify positioning errors, but the research outcomes generally lacked local meaning, appeared difficult to apply to day-to-day disaster management activities, and seemed mostly beyond the understanding of people outside the disaster or geomatics research community. Indeed, the solutions proposed often seemed too complex, inappropriate, or costly for most disaster management applications.

This led me to question whether the priorities of researchers, practitioners, and software developers are aligned with regard to issues related to emerging technologies. Do the solutions put forward by researchers and software developers at conferences and in academic journals meet the needs of practitioners? Can practitioners incorporate these solutions into their daily work? And do they want to? Marincioni (2007) asked similar questions in a study about the impact of information technology on the sharing of disaster knowledge. He reports a disconnect between academics and practitioners, in that only one-third of the practitioners who participated in his research regularly read academic literature.

In examining these questions, this thesis takes a pragmatic approach and builds on the growing body of work that seeks to move towards sustainable hazard mitigation. The purpose of this research is to explore the role of geomatics in disaster management and to investigate geomatics solutions in a real-world context while collecting information from, and working with, a disaster management practitioner.

Within this context, I had the following four objectives:

1) to demonstrate how geomatics is currently used in disaster management;
2) to evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development;
3) to develop criteria for practitioners to use when selecting the most appropriate geomatics technologies in specific disaster management scenarios; and
4) to outline recommendations for practitioners to incorporate a participatory geomatics risk and hazard assessment process that values local knowledge and increases community participation into disaster management.

RESEARCH METHODS

This study contains original research that was collected using a mixed-methods design within an interdisciplinary approach. This is pragmatic research that promotes sustainable hazard mitigation and seeks practical solutions that address real-world problems encountered by disaster management practitioners (Mileti, 1999). I selected several research methods – a literature review, development of a taxonomy, a cross-sectional web-based survey, and a case study – because this combination integrates the experience of educators, practitioners, and professionals into solutions for a problem (Creswell, 2003). This combination of methods also contributes to the validity of the conclusions because I was able to integrate data collected during the case study and survey with information obtained through the literature to draw conclusions.

This research began with a literature review to establish the baseline knowledge for the use of geomatics in disaster management and the direction of current research in this area. Based on the literature, I classified the uses of geomatics into a taxonomy to understand how geomatics technologies have been successfully used in various disaster management situations. The taxonomy is a visual tool that highlights the connection between geomatics and disaster management in a user-friendly format. It is particularly valuable as a way to disseminate information to practitioners who would like to use geomatics for the first time. It was necessary for me to develop the taxonomy because practitioners are seeking guidance on selecting a technology configuration that matches their requirements, circumstances, and applications. Additionally, because the taxonomy was built from expert knowledge, practitioners can benefit from the experience of others and learn about successful uses of geomatics so that they might focus their time and efforts on other priorities.

In seeking solutions to real-world problems it is important to obtain information from those who are working to solve these problems. The specific data required for this inquiry has not been included in previous research and as such, I sought to collect information directly from educators, disaster management practitioners, and the developers of geomatics technologies using a cross sectional web-based survey. This survey was designed to collect data on the actual use of geomatics tools in disaster management and the challenges for doing so. The data collected in this portion of the study was primarily quantitative and was analyzed using established statistical data analysis procedures. Some of the information gained and questions raised during this inquiry were then explored in the case study.

Finally, I used a case study to investigate the use of geomatics technologies within the emergency preparedness plan preparation process and expanded this knowledge to develop criteria for determining the most appropriate geomatics technologies for disaster management. Additionally, while working on the case study, an opportunity emerged to suggest that a geomatics-based participatory risk and hazard assessment approach can be integrated into disaster management. This case study was guided by the emergency coordinator for the Rural Municipalities of Headingley, Cartier, and St. Francois Xavier in Manitoba, Canada. These communities were an ideal setting for this case study because they were in the process of amending and updating their emergency plans to address issues encountered during the response to a tornado that caused extensive damage in the town of Elie, Manitoba, in June 2007. A case study approach was the best method for this research because both the case study design and the format of the narrative are flexible and allow for the use of different data collection techniques and the inclusion of personal experience and knowledge (Yin, 2003). For example, conducting an in-person interview allowed me to incorporate the knowledge gained directly from a practitioner, while attending workshops and seminars provided a venue to communicate and work closely with other practitioners, and working directly with one specific practitioner allowed me to gain direct personal experience of the process and procedures that are used to prepare an emergency plan.

SIGNIFICANCE OF THE RESEARCH

This project is academically significant because it contributes ideas for how the use of geomatics could help facilitate the shift towards sustainable hazard mitigation. The taxonomy provides disaster management practitioners with a summary of the current use of geomatics in this field and reveals the most appropriate geomatics configuration for activities undertaken in each phase of the disaster management cycle. The web-based survey results provide new information regarding the use of geomatics in disaster management and user insight into the challenges and benefits associated with its use. The web-survey results also provide evidence of a disconnect between practice, education, and software development. The case study outlines criteria that might be used by practitioners to determine an appropriate geomatics integration level and demonstrates that practitioners can enhance the risk and hazard assessment process by using a geomatics-based participatory risk and hazard assessment model. This approach provides an avenue for practitioners to engage community members and local community groups in planning and gives them the opportunity to set priorities for protecting life and infrastructure that reflect community priorities and values. In particular, this approach could be very interesting for marginalized groups because maps and assessments can be prepared in an easy-to-understand format that represents and reflects their views and concerns.

This research also explores the use of geomatics in a real-world context and this portion of the study has important practical applications. The criteria developed for determining the most appropriate geomatics technologies to obtain the information required for disaster management could guide the use of geomatics in other jurisdictions and ensure that they too, can achieve the benefits from the use of geomatics. Finally, a new emergency plan and improved mapping is available to the RMs of Headingley, Cartier and St. Francois Xavier for use in any phase of the disaster management cycle.

THESIS ORGANIZATION

This thesis is presented in eight chapters. Following the Introduction, Chapter 2 provides a literature review arranged according to three main themes: geomatics technologies, disaster management, and applications of geomatics to disaster management. Chapter 3 describes the specific research methods used to complete this study. In Chapter 4 I build a disaster management–geomatics taxonomy that demonstrates the ways in which geomatics technologies are currently, and efficiently, used in each phase of the disaster management cycle. Chapter 5 presents the results of the web-based survey. The survey results and their implications are further discussed and analyzed in Chapter 6. Using a case study approach, Chapter 7 examines the practical application of geomatics technologies for the Manitoba rural municipalities of Headingley, Cartier, and St. Francois Xavier, and provides suggestions for how a geomatics approach can be used to create meaning and improve disaster management. Finally, Chapter 8 summarizes the research and provides conclusions and recommendations for future research and practice.

2. IDENTIFYING THE GAPS: A REVIEW OF THE LITERATURE

This chapter draws on a global body of academic literature to assess the present state of adoption of geomatics in disaster management and to identify any gaps in current knowledge. This review includes textbooks and peer-reviewed articles published in academic journals with a geomatics and disaster management focus. Many of the examples are described in papers presented at one of the two most recent International Symposiums on Geoinformation for Disaster Management held in March 2005 and May 2007. Although much research has been conducted about the use of geomatics in disaster management, significant challenges remain for the use of geomatics in this field.

This literature review is divided into three sections. It begins with an exploration of geomatics technologies, including a brief overview and introduction to global navigation satellite systems (GNSSs), geographic information systems (GIS), and remote sensing (RS). These technologies have the potential to provide accurate, reliable geospatial data that can be used in all phases of the disaster management cycle. The second section defines and explores the tenets of disaster management relevant to this research, and introduces the traditional disaster management model. The third section focuses on the application of geomatics to disaster management and identifies some of the challenges that must be overcome before its use can be fully realized.

GEOMATICS TECHNOLOGIES

Geomatics technologies include GNSSs, GIS, and RS. These technologies are being applied successfully in many different professions and the potential applications to them, as well as to disaster management seem endless. GNSSs is the generic name that describes the new generation of satellite navigation systems. Several GNSSs are currently being developed and will provide enhanced positioning information as well as other communication and timing services to a variety of users. The Global Positioning System (GPS) is currently the most well known GNSS and it is rapidly becoming critical for many nations as more people and activities come to depend on it. A GPS receiver built into a cellular phone, vehicle, or hand-held positioning device can provide a reasonably accurate position anywhere on earth (Jacobson, 2006). Cell phones and vehicle navigation and tracking devices are currently the two largest markets and growth areas for GNSS technology and GPS has already been integrated into recreational activities such as hiking, boating, jogging and position-based games (Misra and Enge, 2006). Invasive uses such as tracking rental vehicles and people are also becoming more common. The design of new GNSSs is such that they can be integrated with GPS to provide improved position accuracy, robustness, and integrity, which are crucial to any positioning system. The use of GNSSs in all phases of disaster management seems to be somewhat behind the use of other geomatics technologies. Proof of this was found in Chiu et al.'s (2002) research about the response to a recent earthquake in Taiwan where only one of thirty-seven international rescue teams brought GPS as part of their standard rescue equipment. However, GNSSs are also be used in other phases of the disaster management cycle to ground truth maps or to mark the location of hazards or resources. The use of GNSSs in every-day life is increasing and with only minor adaptation, it may be possible to add positioning information into emergency response activities to improve the navigation and decision-making abilities of rescue workers, search-and-rescue teams, and disaster managers. However, this expansion may be limited by security concerns and the lack of a legal framework outlining the use of GNSSs. Physical limitations such as tree cover and dense urban environments will always exist, and positioning techniques that compensate for these conditions are now being investigated. Additionally, development of standards, policies, and procedures surrounding the use of GNSSs in disaster management are currently not well established.

A GIS consists of a powerful database linked to digital maps that allow users to retrieve geographically referenced (i.e. geospatial or location-based) information and the attributes or characteristics of those objects (Laurini and Thompson, 1992). The use of GIS in disaster planning and hazard assessment is well documented and has increased significantly in recent years (Kelmelis et al., 2006). GISs have been used to assess hazard vulnerability and risks, to plan, monitor and evaluate hazards, and to map response activities (Cai and MacEachren, 2005; Ferrier and Haque, 2003; Kaiser et al., 2003). Uses in the post-disaster period include the mapping of hazard zones, coast lines, forests, and water resources, and maintaining inventories of critical infrastructure and their locations (Kelmelis et al., 2006). Its use, however, in disaster management activities that require location analysis has neither been completely realized nor well documented (Cai and MacEachren, 2005; Vasardani and Flewelling, 2005). Expansion of the use of GIS and enhancements to risk and vulnerability prediction models for disaster management is limited by a lack of social models and the inability of GISs to manage social factors such as wealth disparity and variable vulnerability. Notwithstanding this, GIS is becoming commonplace in most public and private ventures that require geospatial information and many different software systems are widely available.

RS involves collecting, analyzing and interpreting information about an object without actually coming into contact with it (Rees, 1990). RS data is often used as base mapping information (e.g. pictorial background), to extract thematic map layers (e.g. land use, vegetation type), or to generate a digital elevation model. It usually consists of visible, mid- and near-infrared, and microwave length portions of the electromagnetic spectrum recorded using a variety of photographic and digital sensors mounted on aircraft and satellites. This type of data constitutes a large proportion of many GIS databases.

RS data is generally readily available and can be used and interpreted with specialized software by experienced users. Kerle and Oppenheimer (2002) describe the use of RS in response to a lahar (i.e. landslide) triggered by Hurricane Mitch in north-western Nicaragua. Their study concluded that RS would not have significantly improved the response to this event because the images were obscured by clouds, and they also encountered other logistical and data-related problems while using the imagery. Thus, they highlighted some of the challenges, advantages, and disadvantages for the use of RS in disaster management. However, since Kerle and Oppenheimer's attempt to use RS, new earth observation satellites have been launched, and further research has been done to improve RS data processing. Indeed, RS data played an important role in response to both the 2004 Indian Ocean earthquake and tsunami, and Hurricane Katrina (Kelmelis et al., 2006; Yarbrough and Easson, 2005).

DISASTER MANAGEMENT

The academic literature provides many strategies to minimize damages that may result from disasters. These include identifying risks, developing preparedness plans, building structures to lessen the impacts of events, and coordinating response or reconstruction efforts. All of these activities fall within the realm of disaster management and decisions related to the coordination of these activities are often assigned to a disaster management practitioner. Disaster managers work to save lives and reduce damage to property before, during, and after emergencies and disasters. Many communities and international organizations employ disaster managers and it is an important function. However, regardless of best efforts in planning and mitigation, disasters will continue to occur and as population densities increase in areas vulnerable to natural disasters in both the developed and developing world, logistical demands on disaster managers intensify and the need for improved disaster management will remain high.

Disaster management activities

Activities that occur within the context of disaster management are often classified into the phases of the disaster cycle or model (Cutter, 2006; Gunes and Kovel, 2000; Kelly, 1999; Lemmens, 2005; Neal, 1997). Traditionally these phases include preparedness, response, recovery, and mitigation, and were established to organize research and classify and describe activities. This model has been criticized for its inability to recognize the non-linear progression, interconnectedness or overlap of tasks undertaken in disaster management (Neal, 1997). For example, tasks undertaken in a recovery context often have mitigation and preparedness elements and these tasks are difficult to classify within traditional disaster phase models. There is currently much discussion amongst disaster management practitioners about the relevance of the traditional model. Based on recent postings to the International Association of Emergency Managers (IAEM) discussion list, many practitioners now believe that the model should also include a prevention component and others believe it should be expanded to eight phases (IAEM Discussion List, n.d.). Since there is no agreement amongst practitioners regarding the model, in this thesis, I continue to refer to the traditional model. Accordingly, I have grouped disaster management tasks into phases based on the following:

- *Preparedness* – Tasks undertaken within the preparedness phase include assessing risks, determining objective risk, clarifying perceived risk, estimating vulnerability, and identifying hazards (Ferrier and Haque, 2003). This activity also includes the development of emergency response plans (Lemmens, 2005).

- *Response* – During response, the emergency workers are at the scene of the event (ibid.) and the emergency manager and coordinators require appropriate information in a timely, easy-to-understand manner.

- *Recovery* – Tasks within the recovery phase occur after the immediate relief needs are met, and involve planning and reconstruction efforts in order to help survivors continue with their lives (Gunes and Kovel, 2000; Lemmens, 2005).

- *Mitigation* – Once the event has occurred or risks are known, mitigation tasks are undertaken to reduce losses from future events (Gunes and Kovel, 2000; Haque and Burton, 2005).

APPLICATIONS OF GEOMATICS TO DISASTER MANAGEMENT

The use of geomatics tools has already benefited some disaster managers and there is an increased willingness on the part of many practitioners to use them. For example, geomatics provided improved risk analysis, cartographic functionality, information about the location and extent of the affected area, the risk to life and infrastructure, estimates of the number of people potentially affected, and information about other hazards, which enhanced decision-making capabilities in response to the 2003 California wildfires, Hurricane Katrina, and the 2004 Indian Ocean earthquake and tsunami (Johnson, 2005; Kelmelis et al., 2006; Kerle and Oppenheimer, 2002; Yarbrough and Easson, 2005). However, it seems that not all practitioners are aware of geomatics technologies or know how to incorporate geomatics into disaster management. For example, the literature raises questions about how geomatics technologies are implemented and what level of implementation is required for effective decision making in all phases of the disaster management cycle (Holledig, 2005; Kelmelis et al., 2006; Vasardani and Flewelling, 2005). Practitioner uncertainty is further compounded because the data requirements, timelines, and final products are different for every project, and not every situation requires the use of all available geomatics tools to be effective. A possible explanation for the confusion amongst practitioners is that the information they require to make a decision about the use of geomatics in disaster management is not reaching them. For instance, Marincioni (2007) noted that only one-third of the practitioners who participated in his research regularly read academic literature and the presentations and conference proceedings from the 3rd International Symposium on Geo-information for Disaster Management highlighted a need for more local and user input into geomatics-related solutions to disaster management problems. As such, an opportunity exists to develop a new approach to disseminate information to practitioners (Mileti, 1999).

Other key ideas explored within the literature are that geomatics tools facilitate the flow of timely, relevant, and accurate geospatial information to improve decision-making, provide the ability to manage multiple activities, and facilitate communication through the use of visualizations, simulations, and maps. However, the use of geomatics to engage the public in understanding risk has yet to be fully explored. This is a significant omission because the use of geomatics may help build capacity within communities to analyze local hazards and encourage meaningful risk communication between residents and authorities. Additionally, geomatics can be used to solicit community support for disaster preparedness and will allow practitioners to build consensus and engage stakeholders in the emergency planning process (Mileti, 1999).

Geomatics can play a role and provide information to assist decision makers in all phases of the disaster management cycle. However, after a review of the literature it became apparent that geomatics has great potential to improve disaster management in the context of a large-scale event, a complex humanitarian emergency, or a catastrophe. In these cases, because the damage is so intense, all community functions are interrupted, local officials are unable to undertake their regular duties, and agencies from around the globe are asked to provide assistance (Rodríguez, et al., 2006). Practitioners from outside the event area do not have local knowledge and can use geomatics technologies for navigation purposes and to gain situational awareness and an understanding of local conditions including the local landscape.

CHALLENGES FOR THE USE OF GEOMATICS IN DISASTER MANAGEMENT

While increases in decision-making ability and communication appear significant, the scholarly literature also highlights the many challenges that face those using geomatics technology in disaster management. These challenges can be classified into organizational, economic, cultural, and hardware and software. Organizational challenges include the logistics of data acquisition, data quality, and data sharing. Economic challenges relate specifically to the costs of equipment, data acquisition and maintenance. Cultural challenges are exemplified by legal and security concerns. Hardware and software challenges include a lack of communication infrastructure, data storage capacity, and poor computer-user interfaces as well as physical challenges.

Organizational challenges

The use of geomatics and spatial data in disaster management is not well established and standards pertaining to data quality control, assurance, and sharing are not yet fully developed. A lesson learned from the Indian Ocean tsunami and other response efforts is that a coordinated response is required to ensure effective results, and the success of response efforts often depends on the ability of organizations to work together (Comfort and Kapucu, 2006; Holledig, 2005). Those using geomatics must address these organizational challenges and work together to improve the flow of information from acquisition to the decision maker (Kerle and Oppenheimer, 2002). Data must be acquired in a timely manner, be reliable and accurate, up to date, spatially referenced, in a standardized format, at an appropriate scale, relevant to tasks, presented to the decision maker in an easy-to-understand format, and compatible with other data (Cutter, 2006; Erharuyi and Fairbairn, 2005; Kelmelis et al., 2006; Parker and Stileman, 2005).

Since it is often impractical to collect data before an event, data must be collected quickly after the event and pieced together from many sources. This often requires negotiations with data holders to acquire data and communicating or sharing data with other organizations that may not have similar experience, that may not be comfortable working as part of a team, or that have not worked together in the past (Diehl and van der Heide, 2005).

Data sharing and team-work challenges can be resolved. For example, in 2003 a group called the Mountain Area Safety Taskforce (MAST) was formed from local municipalities, search and rescue teams, and data providers to develop an integrated multi-agency plan to fight wildfires in California. The group used geomatics to facilitate communication and gain an understanding of the common problem, which allowed them to join forces and perform better than any one agency could have on its own (Johnson, 2005). This team was able to overcome many of the organizational challenges, but still encountered significant challenges in terms of ensuring data quality and when integrating data from outside sources.

Economic challenges

Cost is a significant factor when implementing any new technology and could limit the use of geomatics in disaster management. No organization is able to populate databases waiting for a disaster to occur because this is beyond their physical and economic capabilities (Cutter, 2006). While the cost of GIS and GNSS software and equipment has been steadily decreasing, the prohibitive costs, labour, and expenses that occur in the data acquisition stage continue to increase. For example, costs to acquire and piece together existing data into a simple landmine location database for Yemen, Chad, and Thailand were estimated at $2 million USD (Benini et al., 2003). It is often no more cost effective to collect data after an event. For instance, after a landslide in Nicaragua, cloud cover obscured the satellite images on the initial pass, which made the images unusable. To change the satellite's data acquisition priority for an immediate second pass would have cost $1 million USD and, as a result, it took several weeks to obtain useful images (Kerle and Oppenheimer, 2002). Researchers developing a methodology to implement GIS to emergency response in Kansas also encountered economic challenges. They found that the data collection portion of the work was larger than expected and eventually they abandoned plans for an entire database due to increasing costs. Additionally, they noted that even had they been able to collect the data, the construction and maintenance requirements of the database were beyond the budget and time allocated for the project (Gunes and Kovel, 2000). Economic challenges will continue to be a significant barrier to the use of geomatics in disaster management and finding ways to minimize or resolve this challenge will be extremely difficult.

Cultural challenges

Next to economic challenges, the literature identifies cultural challenges as possibly the biggest impediment to the use of geomatics in disaster management. For instance, privacy concerns are a major factor limiting the use of GPS and its use to track workers, rental vehicles, and children has recently gained negative media attention (Jacobson, 2006). Also, there is an ongoing debate between users who see satellites as an "eye in the sky," which provide the opportunity to see things that cannot be seen from the ground, versus those who fear the "big brother" aspect and the use of data against the best interests of the public (von der Dunk, 2005). In addition, for citizens and rescue workers, particularly those working and living in areas with known risks and where events have occurred in the past, the use of geomatics may not be appropriate. In these locations response to hazards may be practiced and automatic and standard emergency procedures have likely been developed (Perry and Lindell, 2003). Also, the use of GIS for predicting and assessing damage is limited by a lack of social models and the inability to account for losses due to subsequent events or social factors such as poverty and community dynamics (Badal et al., 2005). These factors cannot be ignored and likely contribute to the reluctance towards the use of geomatics.

Also, although the use of spatial data and geomatics in the field of disaster management is increasing, a legal framework for its use is not well established. Several important international agreements that 'regulate' the use of data obtained from satellites include the UN Declaration on Principles Related to Remote Sensing of the Earth from Outer Space, Resolution 41/65 (von der Dunk, 2005), the International Charter 'Space and Major Disasters' (ibid.), the Global Monitoring for Environment and Security (GMES) project (Boes and Stoyneva, 2006; Lemmens, 2006), the Respond Project (Holledig, 2005), the United States Commercial Remote Sensing Policy (Lemmens, 2006), and the Code of Conduct for Disaster Relief (Walker, 2003). These agreements, resolutions, policies, codes and charters are not all binding legal documents, which makes it difficult to determine and assess violations, and almost impossible to impose a penalty for any violations. Before the use of spatial data becomes common and accepted practice, legal issues surrounding its use, including assigning liability, require further investigation. The lack of a legal framework may cause some data holders to think twice about contributing to relief efforts for fear of legal reprisal.

Hardware and software challenges

A common theme running through several examples in the literature is summed up by Cai and MacEachren (2005), who note that "the major impediments of GIS as a decision aid to crisis managers is not the availability of spatial data and analytical models, but instead the user's ability to access decision-relevant information through human-computer interfaces" (p. 416). This implies that there are currently no off-the-shelf GIS products that will adequately meet the needs of disaster managers. This statement is reiterated in several scholarly articles that describe situations in which users needed to add extra modules to GIS software or analyze data outside of the GIS to obtain the results required for decision making (Sugimoto et al., 2003; Toyos et al., 2006; Wu et al., 2001; Zerger and Wealands, 2004). This challenge can be overcome by working closely with practitioners to gain valuable insights on what is required in the software and communicating this information to system designers.

There is a common perception among practitioners that operating GIS software requires a high level of expertise. Indeed, many researchers identify the requirement for expertise, and the fact that there are very few experts, as a limiting factor for geomatics use (Benini et al., 2003; Cutter, 2006; Kaiser et al., 2003). Data storage and the amount of time it takes to search databases are also commonly discussed problems. Databases and image files contain large amounts of data and new database search tools or new ways to perform searches are required because large volumes of data often overwhelm data search tools (Kelmelis et al., 2006; Wachowicz and Hunter, 2005; Zerger and Wealands, 2004). The perception of complexity, the use of external modules, and current search capabilities all signal an opportunity to simplify the technology, develop training modules, and improve user-computer interfaces.

There are also physical limitations to the use of geomatics technology. GNSSs are line-of-sight positioning devices and although they works well in all weather conditions, a clear view of the sky is required to ensure that signals from satellites are received and positions are calculated correctly. Improving the ability to receive a GNSS and cellular signal is ongoing but there are limitations for using GNSSs in heavily forested and urban areas. Satellite image data is also affected by line-of-sight, and problems encountered when using visible spectrum satellite data include cloud cover, vegetation cover, poor resolution, and the time it takes to receive data from an initial or second pass (Kerle and Oppenheimer, 2002). Using all available data, such as data in the infrared spectrum, offers improvements in some areas and limitations in others. Also, if data from the Internet is being used and communication is conducted using cellular phones, the appropriate infrastructure must be in place in the event location for it to be effective (Kelmelis et al., 2006). The existence of communications infrastructure limits data sharing and the use of complex technologies in many developing countries. Models that propose ways to work around these physical limitations must be developed because they will always be present and are often beyond the control of disaster managers.

DECISION MAKING

The primary reason for the integration of geomatics into disaster management is to improve decision making. Traditional hierarchical decision-making models that use a top-down linear approach tend to break down in crisis situations and will definitely break down if communication lines are disrupted. Non-linear models that contain overlapping authorities, and do not start or end at certain points or stages, are better able to handle complex changing conditions. For example, the auto-adaptation model proposed by Comfort and Kapucu (2006) seems to have unlimited potential when used in conjunction with geomatics. This decision-making model is intended to improve inter-organizational performance and to encourage collaboration, and is the most suitable model for use in complex disaster events. The model is built on the ability to learn and adapt to new information, and acknowledges the requirement for an appropriate information support structure (ibid.). Some emergency plans may not address the possibility that the communication lines will be cut off or that decision makers could become victims. In an auto-adaptation model each component of the plan is independent from the others ensuring that duplication is avoided and all priorities are addressed. However, I was unable to locate documentation or examples of a geomatics-based decision-making system capable of addressing the non-linear nature of events and that can be incorporated into non-hierarchical emergency preparedness plans.

SUMMARY

Existing literature suggests that the use of geomatics is improving decision-making abilities and facilitating communication between politicians, authorities, emergency managers, and rescue workers. However, researchers and practitioners continue to face significant organizational, economic, cultural, and hardware and software challenges upon implementation. These challenges will be difficult to resolve, but the literature provides several recommendations for overcoming them. For example, managers can share data and only concentrate on task-specific data. However, even if these techniques are used, cost and data quality and quantity will continue to be issues and the data must be current and accurate so as not to cause undue delay or confuse decision makers (Benini, et al, 2003; Erharuyi and Fairbairn, 2005; Parker and Stileman, 2005; Wachowicz and Hunter, 2005). These challenges are explored throughout this thesis and a straightforward pragmatic use of remote sensing in disaster management that addresses them, as well as some of the questions being asked by practitioners, is described in Chapter 7.

3. METHODS

The research objectives for this study were broad and best answered through an analysis of a variety of data. As such, this research took an interdisciplinary approach using both qualitative and quantitative methods, which included development of a taxonomy, a web-based survey, and a case study. The use of these methods within an interdisciplinary approach allowed me to incorporate perspectives from both geomatics and disaster management professionals and the mixed methods design allowed the strengths of both qualitative and quantitative inquiry to be incorporated into this work (Johnson and Onwuegbuzie, 2004; Mileti, 1999). Additionally, the mixed methods design did not limit the type of data that was collected, and it provided an opportunity to use multiple data analysis techniques to ensure that the knowledge gained was complete and that the research results can better inform both theory and practice. Indeed, this study has placed equal emphasis on the qualitative and quantitative data and often uses one to corroborate the other when forming conclusions (ibid).

This chapter begins with a discussion of how the specific methods used in this study relate to the research objectives, followed by the rationale behind developing the geomatics taxonomy. It then describes the steps taken to set up the web-based survey, including details about the instrument design, the selection of SurveyMonkey as the online host, the selection of participants, and the administration of the survey. Survey validity and reliability is briefly discussed in this chapter and additional comments on reliability, validity, and errors and bias are included in Chapter 5 and 6. The chapter concludes with a discussion about the case study design.

Methods and the research objectives

Guided by the objectives, I conducted this research sequentially, starting with a review of the literature and the development of the taxonomy. This ensured that the knowledge gained during the initial research stages informed the subsequent inquiry. For instance, the questions included in the web-based survey were designed to confirm and quantify the challenges for the use of geomatics in disaster management that were highlighted in the literature. Furthermore, once I analyzed the survey data, I set up the case study to investigate some of the issues raised by survey participants.

As discussed in Chapter 1, my first research objective was to demonstrate how geomatics is currently used in disaster management. The most appropriate method to satisfy this objective was a review of scholarly literature to locate examples of the use of geomatics in disaster management. The literature review established the baseline knowledge, identified knowledge gaps, and indicated the direction of current research in this area. The examples of the use of geomatics were then further analyzed and became the basis for a geomatics–disaster management taxonomy, which classifies the current applications, and demonstrates how geomatics technologies have been used in this field.

My second research objective was to evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development. For this portion of the study it was important to understand the perspectives of those involved in disaster management. This was achieved through the use of an original, self-administered, cross-sectional web-based survey. Designing a survey and administering it over the Internet allowed data to be collected directly from a sample of educators, disaster management practitioners, and the developers of geomatics technologies. The survey revealed the perspectives of diverse participants within these groups, which were later integrated into the case study design. The survey instrument included open, Likert-scaled, and check-box type questions, and the data collected in this portion of the study was primarily quantitative in nature. The Internet was the most appropriate survey delivery method because it allowed for the development of a survey that was easy to use and understand. Additionally, the use of the Internet reduced data collection errors, operator entry errors (e.g. often only one response per question was allowed), and enabled efficient analysis of the results.

Once the perspectives of those working in disaster management were obtained, I began to work to integrate their questions, concerns and suggestions into the solution to a "real-world" problem. Yin (2003) suggests that a case study is the best way to analyze a real-world process and answer how and why questions. As such, my third objective, to develop criteria for practitioners to use when selecting the most appropriate geomatics technologies in specific disaster management scenarios, was achieved using a case study that was designed to meet the needs of the emergency coordinator and communities involved, as well as my own needs as the researcher. This method was particularly valuable since a case study provided the opportunity to take a wide view of the problem and analyze the context and process associated with a phenomenon without limiting the type of data or the data collection procedures (Meyer, 2001). For instance, the case study for this research, which involved the Rural Municipalities (RMs) of Headingley, Cartier, and St. Francois Xavier, incorporated information collected during a personal interview, informal conversations, a review of literature and documents, and information obtained through my personal participation in seminars and workshops. Since case study design and format is left up to the researcher, this method provided the flexibility to ensure that the point-of-view of educators and practitioners gained during the initial research stages could be incorporated into the final project outcomes and the case study narrative.

The fourth objective, to outline recommendations for practitioners to incorporate a participatory geomatics risk and hazard assessment process that values local knowledge and increases community participation into disaster management, is also addressed in the case study.

THE GEOMATICS TAXONOMY

The geomatics taxonomy was created using examples of the use of geomatics in disaster management found in the academic literature. Each example was assigned to a disaster management phase (e.g. preparedness, response, recovery, or mitigation) based on the work described, and based on the type, configuration, and degree of integration of the geomatics tools used, I classified the example into an integration level. This resulting taxonomy provides a basis for further investigation and enabled me to draw conclusions about how geomatics is currently used in disaster management.

THE WEB-BASED SURVEY

As indicated by the literature reviewed, spatial data and geomatics technologies have been used in disaster management but this use has not been fully realized. As such, the web survey was designed to evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development. To achieve this objective, I designed surveys to ascertain whether those involved in disaster management are aware of geomatics technologies, if the geomatics tools available are meeting practitioners' needs, and how these technologies are being used. More specifically, to ensure that the data collected would provide information that would enable me to evaluate the current use of geomatics in disaster management, the surveys were designed to fulfill four goals:

1) to determine what educators and disaster management practitioners know about geomatics technologies,
2) to determine whether disaster management programs offer instruction in the use of geomatics technologies;
3) to determine if/how geomatics is currently used in disaster management, the benefits for doing so, and the challenges to implementing it; and
4) to determine the importance of disaster management to the manufacturers of geomatics technologies.

In addition, each survey instrument, presented in Appendix A.1 to A.3, addressed several specific questions related to my overall research objectives. Identifying specific research questions ensured that the survey instruments were focused and the data collected were meaningful.

Selecting the survey mode

The target participant group for each survey was a specialized population with a well-established web presence. Indeed, several Internet user groups exist for disaster management practitioners, and I determined that using these groups was an excellent way to reach potential participants. As such, the best tool to undertake this portion of the research was a self-administered cross-sectional web-based survey. This seemed appropriate because the current consensus in the academic literature is that using the Internet to undertake survey research is acceptable and that the data from these surveys are valid and can be used with confidence (Dillman, 2007; Denscombe, 2006; Fowler, 2002; Fricker and Schonlau, 2002; Kaplowitz et al., 2004; Nesbary, 2000; Sills and Song, 2002). Moreover, for this research, a response rate similar to the 20-30% achieved by Kaplowitz et al. (2004) would be excellent. This target is not unrealistic because research has shown that response rates are typically quite good when participants are part of a specialized group and the invitations are extended via both e-mail lists and the notice boards used regularly by potential participants (Denscombe, 2006; Fricker and Schonlau, 2002; Kaplowitz et al., 2004; Sills and Song, 2002). If the invitation is 'endorsed' by another member of the listserv group, this may also improve the response rate.

Survey instruments

Three survey instruments were developed using the protocol outlined below, and were used to complete this portion of the research. The survey instruments are named as follows:

- The Use of Technology in Emergency/Disaster Management – Educator Survey (Appendix A.4);
- The Use of Technology in Emergency/Disaster Management – Practitioner Survey (Appendix A.5); and
- The Use of Technology in Emergency/Disaster Management – Hardware/Software Developer Survey (Appendix A.6).

Once the survey objectives and specific research questions for each survey were established, I drafted a list of survey questions that would satisfy the specific research questions. My thesis supervisors reviewed and provided feedback about the draft survey questions, which I subsequently revised. The list of survey questions was then developed into a draft survey instrument and I produced a corresponding logic diagram to define the survey skip logic to be used. The draft instrument was reviewed by academics, geomatics and disaster management practitioners, and other graduate students to ensure content and face validity and to improve the question wording and layout. Each question on the final survey instrument was reviewed several times to ensure it was clear and concise to avoid confusing the participants.

In order to ensure that a variety of relevant data were collected the final survey instruments include Likert-scaled, check-box type, open-ended, and demographic questions. Many of the survey questions were designed to measure attitudes and levels of agreement and a seven-point Likert scale, that would be familiar to most participants, was used. This scale is anchored by 'strongly agree' and 'strongly disagree' with a 'neutral' option in the middle. Each point on the scale is labeled to avoid confusion and improve reliability (Weng, 2004). Questions were worded such that most participants would be inclined to respond on the extremes of the continuum rather then selecting 'neutral' for all questions (Fowler, 2002). The survey instruments also included several questions that used a five-point ranking scale. This scale was used because these questions required a different type of answer for which it is easier to assign a numerical value. A five-point scale also added variety and clearly distinguished this type of questions from the others in the survey.

Additionally, a 'don't know' option was provided for all scaled questions. This option was offered because an honest 'don't know' provided more information than a non-response for most questions. The 'don't know' option was placed at the end of the list of possible answers to allow participants to think about the options and then decide if they really didn't know the answer to the question (Lam et al., 2002).

The survey instruments also included check box type questions in which participants could choose answers from a pre-determined list. A list was used to limit the answer choices to specific information discussed in the literature. For example, the 'challenges' list contained items from each of the challenge groups identified, and the activities listed were based on examples of geomatics use discussed in the academic literature. In each case, an 'other' box was included so that participants can add an item that was not included in the list.

Open-ended questions that sought opinions, beyond what I as the researcher thought was important about the subject, were also incorporated into the survey instruments. This was done because although closed questions are easy to interpret and analyze, they do not always allow the participants to express their opinions. Open-ended questions provide an opportunity for participants to answer questions in their own words, thus reducing any frustration they might have felt when unable to select an appropriate response to the closed questions (Fowler, 2002).

Hosting the survey

Based on my research, no software package or web-based survey tool comes highly recommended or stands out. Crawford (2002) suggests that potential web-based survey tools should be evaluated with respect to cost, flexibility, robustness, and features such as screen design, logic design, and validation design. Based on a review of various tools using these evaluation criteria, I determined that the most appropriate survey tool for this research was SurveyMonkey.

SurveyMonkey seems to be the most affordable web-based survey tool available. A basic subscription is free, but for this research, I purchased access rights to SurveyMonkey Professional Version ($19.95 USD/month) with the added security option ($9.95 USD/month). The total monthly cost was $29.90 USD. This included 1000 responses per month and provided access to advanced features, such as unlimited survey size, skip logic, and the use of logos, as well as advanced data analysis features.

SurveyMonkey allowed me to design a visually appealing, logical, and accessible survey instrument, while providing enhanced security and privacy for participants. Additionally, participants were not required to use special software and the data analysis tools and features were powerful and relevant. Use of the professional version of SurveyMonkey also allowed me to incorporate logos and a custom layout and colour scheme, and provided the ability to apply skip logic and force participants to answer certain questions before proceeding. The use of skip logic is important because it reduces user frustration and non-responses by ensuring that users skip questions that do not apply to them (Fricker and Schonlau, 2002). Skip logic was incorporated into these surveys so that participants would skip questions about technologies they did not use. Participants were only forced to answer questions to which the skip logic applied.

SurveyMonkey is also concerned about security and has an explicit privacy policy. This is important for the maintenance of confidentiality and anonymity. As mentioned above, for an additional monthly fee, SurveyMonkey enabled SSL encryption. SSL encryption is the world-wide standard for encrypting information collected over the Internet. Although the data collected in these surveys were not sensitive in nature, SSL encryption ensured that the survey data were secure so that participants could feel more comfortable when completing the survey. I thus incorporated SSL encryption in an attempt to improve the response rate.

In addition, the SurveyMonkey host website was reliable and able to accept responses at all times of the day. It also provided the ability to block URL addresses to avoid multiple responses from the same person. Finally, SurveyMonkey provides excellent customer support and, in addition to the detailed instructions about how to set up a survey found on the website, all technical and billing questions were answered in a thorough and timely manner.

Accompanying documentation

It is extremely difficult to solicit participants for a web-based survey. As such, an important element in the recruitment of participants is professionalism. Participants were invited to partake in the survey using an e-mail invitation and a list-serve posting that directed them to the professionally designed project website. The initial contact stressed the low impact, limited time commitment, confidentiality, and value and importance of participant opinions (Lindsay, 2005). The project website provided additional details about the project and the research and was also used to launch the surveys.

Validity and reliability

Each survey instrument was reviewed for content and face validity and pre-tested by academics, practitioners, and other graduate students. Concurrent validity was determined by reviewing the results with conclusions made in similar studies. Internal reliability for both the Educator Survey instrument and the Practitioner Survey instrument was established by computing Cronbach's Alpha, a statistic used to measure the reliability of an instrument. The Cronbach's Alpha values are discussed in Chapter 5.

Following the advice of Fowler (2002), each survey instrument was pre-tested to ensure validity and gauge whether the instructions and questions were clear, whether the scales were appropriate, and whether there were any problems understanding the tool or determining the kinds of answers required. The Educator Survey instrument was pre-tested by a professor in the Natural Resources Institute at the University of Manitoba, a professor in the Department of Environment and Geography at the University of Manitoba, and a professor in the Geography Department at Brandon University. The Practitioner Survey instrument was pre-tested by Mr. Kenton Friesen, a disaster management practitioner. Feedback from the pre-testing was incorporated into the final survey instruments. Pre-test participants were also asked to track the amount of time required to complete each survey. I incorporated the feedback received during the pre-testing into the final survey instruments and the participant invitations.

Administering the survey

The web-based survey involved three distinct participant groups: educators, practitioners, and software/hardware developers.[3] Educators are instructors at educational institutions that offer programs in disaster management. They are the teachers who introduce disaster management theory and related technologies to future practitioners. This group also includes academics undertaking research in the field of disaster management who regularly attend conferences and publish in academic journals. Practitioners are the first responders, administrators, managers, and coordinators who, on

[3] Hereafter referred to as software developers.

a day-to-day basis, undertake preparedness, response, recovery, and mitigation activities. They focus on responding to, planning for, preventing, and mitigating hazards, as well as helping communities cope with and recover from disasters. Software developers design and build geomatics technology, and develop hardware for commercial use. They have advanced knowledge of geomatics and are adept at using and developing technology.

Participants

Educator Survey

On June 11, 2007, personal emails were sent to 137 educators at institutions offering various levels of disaster management courses. The e-mail invited these educators to participate in a survey designed to collect information about the use of technology in the disaster management courses offered at their institution. I used the list of contact names provided on the Colleges, Universities and Institutions Offering Emergency Management Courses located on the FEMA – EMI/USFA Training and Education Portal website (http://www.training.fema.gov/EMIWeb/edu/collegelist/) to identify potential participants. The invitation e-mail directed potential participants to my project website to read more about the project and to access the survey (http://home.cc.umanitoba.ca/~umwestl2/education/), and provided the information required by the University of Manitoba Joint Faculty Research Ethics Board. A follow-up reminder e-mail, containing similar information, was sent on September 23, 2007.

Practitioner Survey

Although disaster management practitioners are a finite population, there is no way to determine how many there actually are, or how to reach each of them. As such, several techniques were used to distribute invitations and to reach as many potential participates as possible.

On June 2, 2007, Mr. Kenton Friesen (a practitioner who participated in the pre-testing process) sent an e-mail invitation to members of the e-mail message boards established by IAEM Canada (International Association of Emergency Managers), DRIE Central (Disaster Recovery Information Exchange), Disaster Resistant University, PSEM Canada (Emergency Management Professionals of Post Secondary Institutions), and PSEM Manitoba. This invitation reached approximately 350 potential participants. Similarly, on June 7, 2007, I forwarded a message inviting members registered with the International Association of Emergency Managers (http://www.iaem.com/) discussion group to participate in the survey. According to the IAEM, it currently has 1656 members. On June 9, 2007, I sent a copy of the same message to the Emergency Management group established on Yahoo, and on September 11, 2007, I sent another message to the Yahoo Daily Brief group. These groups list their membership at 1989 and 853 respectively. The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) also agreed to include a link to the project website and a brief description of the survey purpose in its monthly mail-out on July 1, 2007. A follow-up reminder e-mail advising practitioners that the survey would close in two weeks was sent to each group (with the exception of the Yahoo Daily Brief group, whose members had just been invited) on September 11, 2007.

Members of these message boards are very active and at least several messages are posted each day. Often messages are cross-posted to each of the groups, indicating that many practitioners are members of more than one of the groups. Based on the membership numbers provided by each group, as well as copies of the 'bounced' e-mail messages received, and an estimate of the number of practitioners who are members of multiple groups, I predicted that the invitation to participate in the survey reached approximately 3000 practitioners.

Software Developer Survey

Participants for the software developer survey were recruited from the list of exhibitors that participated in the 17th World Conference on Disaster Management. Twenty-one potential participants were identified from the conference website and on July 31, 2007, I sent each one a personal e-mail invitation to complete the software developer survey. The e-mail invitation was identical to the one used to recruit participants for the educator survey.

Data collection

Once potential participants were identified and the invitations were sent out, the data collection was entirely automated. Each responses was logged by SurveyMonkey and I reviewed the results regularly and downloaded them periodically. Two weeks after sending out the reminder notice, the practitioner and educator surveys were closed on September 25, 2007, and October 8, 2007 respectfully.

Data analysis

The data analysis techniques and data presentation formats used in this thesis are functions of the types of data that were analyzed. I present the summed ordinal data, collected using the Likert-scaled questions, in tabular format to identify the modal response for each question. In addition, to ensure that the opinion of the majority of participants is clearly stated, each table also includes the answer choices selected by the majority of respondents. Furthermore, for those looking to conduct further analysis, the raw data for all scaled questions is provided in graphical format in Appendix B.

Internal reliability for the survey instruments were established by computing Cronbach's Alpha, a statistic used to measure the reliability of an instrument. To analyze the ordinal data I calculated the Spearman Rank Correlation Coefficient and compared the coefficient using the Mann-Whitney U test, a nonparametric alternative to the t-test (Grimm, 1993). This test determines whether the differences observed between groups are statistically significant. For this analysis, a calculated Zu value was compared to a critical Z value determined from a table of critical values for the Mann-Whitney U test (i.e., Zcrit = 1.96). If the calculated Z value is less than the critical value, then the null hypothesis is accepted and the two samples are said to come from the same population. In all cases, alpha was set at the 0.05 level for determining statistical significance.

It was also necessary to use the demographic data and other selected survey data to determine whether participants in different age groups or with different levels of education answered questions differently. For this analysis, I developed contingency tables and analyzed the data using a Chi-square test, which is commonly used to test for differences in responses between two or more groups. For this analysis, the calculated Chi-square statistic ($\chi 2$) is compared to a Chi-square critical value determined from a table of critical values for the Chi-square test ($\chi 2$ Crit. = 3.841, 1 degree of freedom). When the calculated $\chi 2$ value is less than the critical value, the null hypothesis is accepted and it can be said that there is no significant difference between what was observed and what was expected. Again, alpha was set at the 0.05 level for determining statistical significance. Since I often perform multiple hypothesis tests on the same data I contemplated using Bonferroni corrected alpha values to test the statistical significance; however, I determined that this was unnecessary because the 0.05 significance level provides enough assurance against a false appearance of significance.

Responses to the open-ended questions required interpretation and, as such, I coded and sorted the data so that responses could be counted and expressed as a rank or percentage. For questions that asked participants to rank challenges and activities, the final rankings were determined based on a scoring system. Three points were assigned to a response each time it was ranked first, two points were assigned each time it was ranked second, and one point was assigned each time it was ranked third. The points for each response were summed, and the responses with the highest total points were deemed to be the most important. These results are also presented in tabular format and the items listed at the bottom of the table were identified by participants but were not ranked among their top three choices. I have also included bar charts to accompany the ranked questions to validate the scoring system and depict the rank order.

THE CASE STUDY

The third and fourth objectives of this research were achieved with a case study approach that was completed during work on a "real-world" project in which geomatics technologies were used to produce maps for inclusion in the emergency plans for the Rural Municipalities (RMs) of Headingley, Cartier, and St. Francois Xavier in Manitoba, Canada. The preparation of these maps was guided by Mr. Norman Tchir, the emergency coordinator for each of the RMs. Mr. Tchir is an experienced emergency coordinator and has a wealth of knowledge and practical experience in disaster management. However, he is not familiar with geomatics and has limited experience with these specific technologies (N. Tchir, personal communication, September 12, 2007).

The case study format allowed for the use of several different data collection methods, and the case study design and implementation were based on suggestions by Berg (2004) and Yin (2003). Case study research does not limit the type or format of data, nor the collection techniques used to obtain the information required to complete a project. The case study design was thus flexible enough to allow various methods to be used during the course of the project as the need for additional information arose.

The case study research began with a review of the academic literature and other documents, such as emergency preparedness plan preparation guidelines, to ensure that I had the appropriate amount of background knowledge about emergency planning. I also attended a number of emergency management workshops and seminars, which discussed emergency planning and the use of geomatics tools to collect data on Canada's critical infrastructure. These settings provided an opportunity to make personal observations as well as to conduct informal discussions with disaster management practitioners and industry experts. Much of the information required for the case study was collected while working directly with a practitioner, during meetings, and via a personal interview. Additionally, my own involvement in the project allowed me to gain direct personal experience of the process and procedures used to prepare an emergency plan. The case study also relied heavily on the information obtained from the web-based surveys and geomatics taxonomy. In addition, the case study draws on a critical theory framework to highlight the importance of using local knowledge to improve preparedness planning, specifically the hazard assessment and risk analysis process.

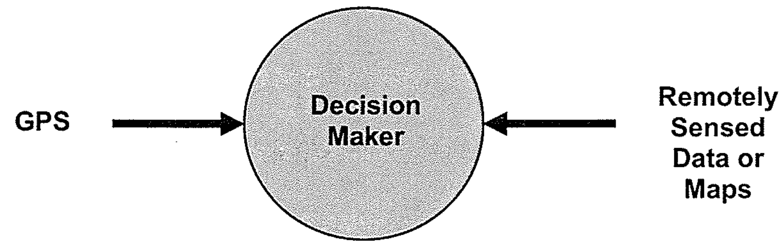
4. A GEOMATICS TAXONOMY

Although many disaster management practitioners have integrated geomatics technologies into their work, there is no current system to classify the use of geomatics in this field. This chapter develops a taxonomy that practitioners can use to differentiate between various geomatics integration levels in disaster management based on the type and configuration of these technologies. The graphical models are loosely based on models of integration proposed by Gao (2002). However, Gao's models focus on the flow of data between GPS, GIS, and RS and are applicable to resource management, environmental monitoring, and emergency response. The geomatics–disaster management models developed here are specific to disaster management and emphasize the role of the decision maker by focusing on the interaction between the decision maker and the technologies.

Many disaster management practitioners may not be familiar with the term geomatics; however, most practitioners have previous experience with geographic information and spatial data. Specifically, this experience was gained through the use of maps. Map production is an important component of geomatics and maps are likely the most common vehicle with which the data collected using geomatics tools is presented to decision makers. As such, the examples I have provided with each integration model often refer to maps. The base data required to produce these maps were collected with geomatics tools and several examples describe instances in which a map was also presented to a decision maker using geomatics tools.

LEVEL 1 INTEGRATION

Figure 1: Level 1 Integration Model



Definition

As depicted in *Figure 1*, the primary characteristic of the Level 1 integration model is the one-way interaction between the decision maker and a geomatics tool. In this configuration the decision maker refers to the geomatics tool and receives information directly from it. Typically, this information is useful but not critical and decisions are likely also supported by experience or other information. Examples of the type of information used include coordinates from a GPS receiver, and data from hard copy maps, and aerial or satellite images.

Common non-disaster management usage examples

Examples of non-disaster management uses that could be classified as Level 1 integrations include:

- a hiker using a GPS receiver to determine where he/she is located in relation to the beginning or end of a trail;
- a jogger using GPS to determine his/her speed and distance traveled;

- a boater using GPS to navigate to a favorite fishing spot, or to the dock;
- a participant using a GPS receiver to participate in geo-spatial games such as geocaching, or using a compass and a hard copy map for orienteering;
- a traveler using a commercially available paper or simple digital map to determine where he/she is in relation to a landmark or a city; and
- a time-keeper using GPS as a timing device to synchronize events.

Successful disaster management examples

Preparedness

Level 1 geomatics integrations are most effective when used in a knowledge-oriented process such as risk assessments or preparedness planning. For example, Fiorucci et al. (2005) present a framework for what they call a "static risk assessment" that includes the use of geomatics tools (p. 161). They used satellite images of a specific area that identified land use, topography, and vegetation type to determine the risk of forest fires over a large geographic area. The information collected also helped determine the resources that would be required to respond to an event in that area. In this example the researchers then plotted the location of the potential resources, which enhanced the maps and facilitated their ability to optimize resources.

Level 1 integrations of geomatics can also inform community-level preparedness planning. Geomatics tools can be used to produce simple hard-copy map(s) that show the potential hazards with respect to the location of people, buildings, and resources within a community. The satellite imagery required to produce this map is often available for free from open-source data providers. Once printed and viewed by all, this map can be an excellent starting point for the development of a community-based preparedness plan. A similar geomatics example is further explored in Chapter 7.

Response

An effective use of Level 1 integration during the response phase of a disaster event is the use of remote sensing techniques to produce maps for both decision makers and the public. A case in point was the use of satellite altimeter data after the 2004 Indian Ocean Earthquake and Tsunami. The altimeter data collected by several satellites hours after the earthquake allowed researchers to determine the magnitude of the plate deformations and the resulting ocean displacements, and was also used by media outlets as display tools to inform the public about the event (Ambrosius et al., 2005).

Recovery

A common example of a Level 1 integration into the recovery phase of a disaster is the use of survey tools, specifically GPS, to obtain positioning information to assist with reconstruction. An example of a more unique project that involves remotely sensed imagery was launched by Amnesty International in June 2007 (Locke, 2007a). Satellite photos of the troubled Darfur region in the Sudan were posted on Amnesty International's website to bring awareness about the conflict and regional problems to the general public, policy makers, and international courts (Amnesty International, 2007). The images also enabled the public to view the damage done in the region and provided an opportunity for experts to monitor development projects (Locke, 2007b).

Mitigation

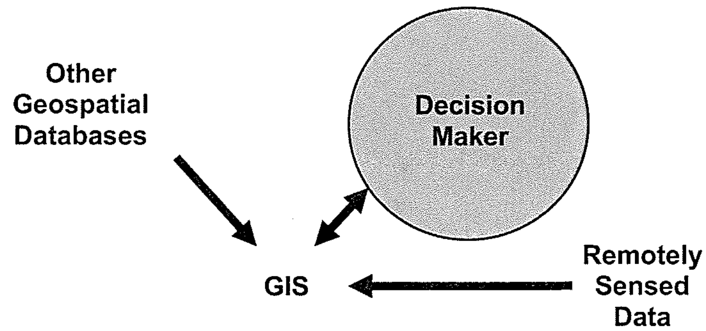
The use of GPS receivers to detect movement of the earth's crust is a Level 1 integration of geomatics in a mitigation context. GPS coordinates are collected to detect ground movements in cities or near faults and slopes. These movements may signify subsidence of critical infrastructure or may alert those monitoring the movements to a pending earthquake. Many researchers are pushing the boundaries of GPS in this context and are often trying to improve event prediction capabilities by detecting movements at the extreme limits of achievable accuracy. While pushing these limits is encouraged, there is often little acknowledgement of the errors in GPS or the need to use appropriate control network designs. For example, in several instances the monitoring stations were not stable and were initially established for other purposes. These shortcomings have introduced unnecessary errors into the monitoring systems (Abidin et al., 2001; Dinter and Schmitt 2001; Goebell and Wetzel, 2006).

Use of Level 1 integration

There are many examples of successful use of Level 1 integration of geomatics in disaster management activities. Based on the examples included in the academic literature, Level 1 integrations are best suited for use in the preparation of emergency plans and other preparedness activities.

LEVEL 2 INTEGRATION

Figure 2: Level 2 Integration Model



Definition

As depicted in *Figure 2*, Level 2 integration occurs when the decision maker interacts with a GIS database to obtain information. Using a GIS allows visualization and the production of maps with added meaning (Koohzare et al., 2006). The GIS is built using pre-existing remotely sensed data, often provided by an outside source. The remotely sensed data can include digital maps, aerial photography, digital terrain models, and satellite images. To build the GIS, remotely sensed imagery is combined with geospatial information that is keyed into the GIS or obtained from third party sources. Applying this level of integration allows decision makers to interface with the GIS, query, and run simulations.

Common non-disaster management usage examples

Examples of non-disaster management uses that could be classified as Level 2 integrations include:

- a city database built from line-work on registered survey plans. The database allows users to click on a parcel and retrieve the associated attributes (tax information, size, zoning, use, etc); and
- a database used in industry to review and track the characteristics of assets or equipment.

Successful disaster management examples

Preparedness

Mileti (1999) suggests that a good first step for integrating geomatics into disaster management would be the use of GIS and satellite data collection tools to develop simple hazard loss databases and risk assessment and vulnerability maps. This step requires the use of a GIS built from remotely sensed data. The literature contains many examples in which researchers simulated a disaster event (storm, flood, earthquake, etc.) using a special function or program within the GIS that produces a quantitative damage and casualty estimate (e.g. lives, economic losses, and the size of the affected area) (Aleskerov et al., 2005; Badal et al., 2005; Fernández et al., 2003; Moisuc et al., 2005; Remondo et al., 2003; Sugimoto et al., 2003; Usul and Turan, 2006). Information such as the area and number of people affected is critical to emergency managers, both before and after an event. It assists in the development of preparedness plans and gives best- and worst-case estimates to politicians and other authorities. Additionally, disaster managers can use this information to try out evacuation strategies and determine rescue priorities or access/egress routes (Castle and Longley, 2005). GIS also facilitates the communication of evacuation plans and other information, such as the extent of flooding, to the public and the media (Ferrier and Haque, 2003; van Zuilekom et al., 2005). However, based on the literature reviewed, existing prediction models for disaster management do not seem to factor social or physical conditions into their estimates. Social factors such as poverty, reactions to events, knowledge of risks, and community dynamics could influence losses (Badal et al., 2005). Current models also do not normally predict how physical soil conditions and building construction materials will impact economic losses and human casualties. The disadvantages of geomatics use in these circumstances result from weaknesses in the models rather than the technology itself.

Response

Immediately following a disaster event, many organizations respond quickly, and ensuring effective results during this phase of a disaster requires a coordinated response. The information they require to be most effective includes information about the response priorities, the location and extent of the affected area, the risk to life and infrastructure, details about how to access the area, estimates of the number of people affected, and information about other hazards that may exist (Kerle and Oppenheimer, 2002). A GIS is an ideal tool for determining, sharing, and presenting this type of information. The use of geomatics in this configuration facilitates a limited ability to coordinate a response among responding agencies.

The response to the Asian earthquake and tsunami provides an example of a Level 2 geomatics integration (Ambrosius et al., 2005; GIS supports tsunami disaster, 2005; Kelmelis et al., 2006). This disaster was unprecedented and the response efforts were extraordinary. Kelmelis et al. (2006) reflect that "the response of the geospatial community was both immediate and immense … data were acquired and made available beginning the day after the tsunami" (p. 866). This data included Landsat, ASTER

(Advanced Spaceborne Thermal Emission and Reflection Radiometer), ALI (Advanced Land Imager), and Hyperion satellite data, as well as satellite data obtained from other international sources including commercial satellite companies. These sources provided "virtually all possible data over the tsunami-affected area" (p. 869), contributing to the relief effort and helping emergency managers produce information for reconnaissance-level planning, disaster assessments, and response activities. The information was mostly in the form of maps provided to rescue workers in the field and to planners assessing the conditions and planning for massive international assistance efforts. These maps improved coordination and reduced duplication of effort (GIS supports tsunami disaster, 2005). A case in point was a map and database that demonstrated where various relief organizations were undertaking response activities. When shared with all the response agencies, this GIS helped ensure that the needs of local people were being met.

However, several problems were encountered during this response. These included data sharing issues, non-timely delivery of data, inaccurate data, too much data that overwhelmed search functions, and a lack of user experience with the technologies. Regardless of the problems, however, there were many positive results and lessons learned that will guide further research in this area.

Recovery

Databases developed to assist with recovery operations are also widely used in disaster management. For example, to assist aid workers in Iraq and to keep them up-to-date on the dangers in a particular area, a risk-GIS based on open source media reports was developed (Mubareka et al., 2005). This database allows aid workers to track instances of violence and deploy resources accordingly. Databases are also useful for determining the extent of damages caused by a disaster. For example, a GIS populated with satellite data as the background allowed researchers to determine the exact amount of land affected by a wildfire in Greece and a flood in Japan (Domenikiotis et al., 2003). This database also allowed the researchers to pinpoint the most heavily affected areas in each event and provided a way to communicate the extent of damage to others.

Mitigation

An underused strength of GIS is that it allows for the assessment of multiple risks and hazards simultaneously and can contribute to mitigation planning (Greiving et al., 2006). For example, geomatics can contribute to mitigation by improving access to historical records to better understand the physical process of events. Historical statistical databases that contain information about avalanches, floods and ground movements can help quantify effects, and identify weak spots and areas for possible intervention to better prepare for future events (Hien et al., 2005; Koohzare et al., 2006; Moisuc et al., 2005). Estimating affected areas, predicting the scale of events, planning for immediate and long-term needs, and educating both those who may be affected and those making the decisions on how to react to events are also common uses of geomatics in a mitigation context (Greiving et al., 2006).

Many of the same databases that are developed for and used in a preparedness context can also be used for mitigation activities. For example, the results from simulations can be used to identify the need for, or the best location of mitigating structures. In the case of the 1997 Red River Valley flood in Manitoba, a GIS built using Radarsat images was used to delineate the extents of the flood limits and demonstrated how flood prevention structures worked (Haque, 2000). The same database also identified the extent of flood damage.

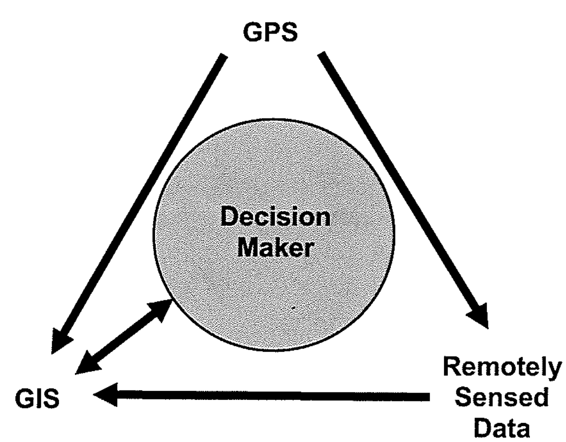
In other examples researchers built a database using digital elevation models and lava flow data from flow models. GIS was used to quickly provide predictions on what areas would potentially be affected by lava flows after a volcanic eruption in the Philippines and Japan (Toyos et al., 2006). This prediction allowed them to develop a mitigation strategy for the area. A similar database was developed for Cairns, Australia, to identify areas subject to high flood risk (Zerger and Wealands, 2004).

Use of Level 2 integration

The use of Level 2 geomatics integration in disaster management appears to be most effective for simulation and modeling within a preparedness or mitigation context.

LEVEL 3 INTEGRATION

Figure 3: Level 3 Integration Model



Definition

As shown in *Figure 3*, the use of GIS data with a GNSS such as GPS is the main difference between Level 3 integration and the other models presented so far. Integration with a GNSS is an advantage because if the database features relate to a known map projection or coordinate system, they can be confirmed on the ground with GPS (i.e. ground truthing). In Level 3 integration, GIS acts as the main interface; however, the decision maker does have access to remotely sensed and non-real-time GPS data. Generally, GPS data is not entered into the GIS in real-time but the coordinates can be relayed from the field and manually added to the GIS. Similar to the other integration levels the remotely sensed data is pre-existing data, often provided by an outside source. In some instances additional data, collected with GPS, is added to the GIS to fill in data gaps to enhance and improve the GIS.

Common non-disaster management usage examples

An example of a non-disaster management use that is classified as a Level 3 integration includes survey engineering, in which GPS is often used to ground truth aerial photographs in order to build a GIS database. Once the database is built, the decision maker uses it to calculate areas or volumes.

Successful disaster management examples

Preparedness

There are relatively few examples of the use of Level 3 integrations in a preparedness context. However, the uses that were described in the academic literature seemed to produce excellent results. For example, researchers used an integrated approach to flood forecasting for the Meuse River in Belgium. They incorporated different types of remotely sensed data (a digital terrain model built using laser scanning and swath bathymetry, aerial photographic surveys during flooding and field surveys completed after flooding) with flood models and real-time network sensors that recorded rainfall levels and flow rates (weather radar, ultrasonic flow meters, laser sensors) to predict and efficiently manage the consequences of a flood event (Dal Cin et al., 2005). This GIS was also used to predict real-time downstream flood levels.

Similarly, in Taiwan a GIS was used to identify areas of significant slope that may be in the path of a debris flow triggered by typhoon rainfall. The initial GIS was built by layering current and historical aerial photographs and digital elevation model data (Yu et al., 2006). Once areas that are potentially affected by debris flows were identified, preparedness plans were produced.

Response

Practitioners used Level 3 geomatics integrations during the relief effort to Hurricane Katrina and the 2003 California Wildfires. In the California example, a GIS was built using satellite images and other base mapping to provide base maps for the fire fighters. The fire fighters took these maps to the field and relayed GPS coordinates for the leading edge of the fire back to the command centre. The command centre updated the maps to show the progression of the fire. This fire progression map was eventually layered with base maps containing elevation data and the transportation networks for others to use for their response tasks (Crisis proves the value of GIS, 2004).

Level 3 integrations were also implemented immediately after Hurricane Katrina. In this instance responding agencies knew that an event was going to occur and, using airborne sensors, were able to collect geographic data before Hurricane Katrina made landfall (Corbley, 2006). After the Hurricane passed through the area, airplanes were sent up again to collect post-event data. The data from the second flight was used to expedite claim payment for total loss, prioritize relief efforts, and facilitate recovery planning. In this example a significant issue was encountered: all the landmarks, signs, and surface features, including the control monuments, were significantly damaged, destroyed, or under water (Yarbrough and Easson, 2005). The response teams were forced to use GPS both in the airplane and on-the-ground because it was the only way to navigate and position the images. However, the use of GPS became an added advantage and the coordinates of important landmarks such as hospitals were added to the database so that rescue workers could navigate directly to them with GPS.

Recovery

Level 3 geomatics integrations are commonly used in the developing world to meet national development goals. Specific examples of the use of GIS in recovery include the preparation of maps showing vegetation data overlaid with rainfall estimates to predict food shortage areas, land use planning, mapping disease distribution and outbreak, risk assessment, and monitoring and evaluation (Kaiser, et al., 2003). In addition, in combination with GPS, GIS is used to conduct population surveys, map population movement, and establish the location of future or temporary settlements. The data collected during the response to the 2004 Asian earthquake and tsunami is now being used for post-disaster activities including the mapping of hazard zones, forests, water resources, renewable and nonrenewable resources, critical infrastructure, and marine resources (Kelmelis et al., 2006).

In developed countries, Level 3 geomatics integrations are often used after an event to provide proof of losses to insurance companies in order to expedite payment of insurance settlements (Badal et al., 2005; Corbley, 2006; Domenikiotis et al., 2003).

Mitigation

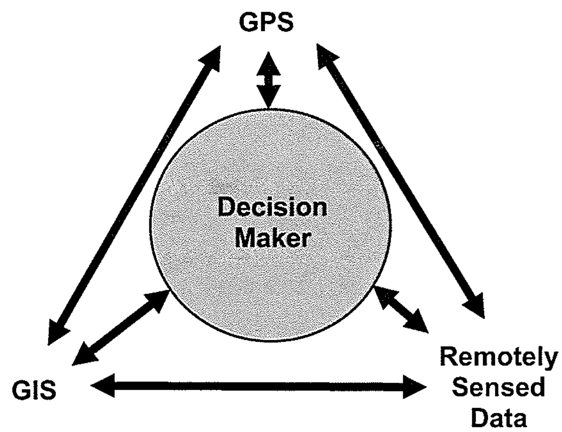
Mitigation tasks include the construction of engineered structures, monitoring ground movement, and relocating vulnerable people to areas of lower risk. Level 3 integration was used in Mozambique where geomatics mapping and hazard assessment tools allowed decision makers to determine if areas selected for the relocation of settlements are more susceptible to other hazards such as drought, flooding or severe storms (Gall, 2004). In another case, researchers used a GIS to display slope instability, geology, and rainfall data from monitoring sensors that are analyzed using artificial intelligence techniques. This system was designed to assess the landslide risk (Lazzari and Slavaneschi, 1999).

Use of Level 3 integration

Level 3 integrations are effective for response, recovery and mitigation activities and the uses of geomatics that fall into this integration level are much more complex than the uses described in the previous levels. However, when combining GPS, GIS, RS, and data from other sources it is important to use a common coordinate base. This will ensure that the data adds meaning to the imagery and background information and that data can be shared.

Level 4 Integration

Figure 4: Level 4 Integration Model



Definition

Building on previous levels of integration, Level 4 integration incorporates an interface between the decision maker and all of the geomatics data sources and tools, as shown in *Figure 4*. Examples include monitoring field activities using real-time GPS tracking, and collecting remotely sensed data in real-time to constantly improve and enhance the GIS. Automated decision-making modules such as vehicle routing are often incorporated into this type of integration.

Common non-disaster management usage examples

The potential uses for geomatics technology seem endless. A case in point is a geomatics system developed by The Hear Now Inc., which embedded a GPS receiver and two-way radio into a dog collar. The use of the collar allows a police officer to track the real-time location of his/her dog from a hand-held GIS device. Further, the system also allows the police officer to issue commands to the dog through the two-way radio (The

Hear Now Inc., 2006). Similar and scaled-down systems are available to average dog owners.

Automated decision making

The concept of automated decision making was introduced in the definition of a Level 4 integration. Automated decision making systems (often called expert systems, artificial intelligence, or decision support systems) are gaining popularity in disaster management. Automated decision making systems merge the fields of decision science, disaster management and geomatics (Cornélis, 2005). Automating decisions is desirable because it allows emergency managers to focus on other priority activities. These systems are not yet able to completely simulate human decision making but researchers are making advances in that direction.

One such system is the HorizoN Sentry system developed by DigiUtopikA. This system puts the user in a virtual world and is ideal for running simulations in preparedness, mitigation, and response situations. The communication structure links live sensors, GPS, GIS, and satellite images to a computer that acts as the decision maker and gives instructions to other systems. The database is built using past and present data and scenario generation tools. This system is currently undergoing testing in controlled circumstances with great success (Branco et al., 2005). The downside of HorizoN Sentry is that the software is very complex, the data needs are extremely high, and the implementation costs are enormous. The system currently runs only on workstation-type computers, although handheld capabilities are being developed. While this system is almost too elaborate for current users and the costs and data needs will limit its application to areas where detailed mapping is available, it has garnered interest from both search and rescue organizations and civil protection teams.

Successful disaster management examples

Response

An excellent example of the use of Level 4 geomatics integration was the multi-agency response to the 2003 California wildfires. Geomatics played an important role in the response and was used by the multiple government organizations and private agencies fighting the fires to facilitate communication, and to visualize and understand the problem. GIS was used to organize data and people and most likely none of the responding organizations could have undertaken this effort on their own. In this instance, GIS provided "a shared vision of the problem and an understanding of priority actions required to reduce the consequences of this event to life, property, and natural resources" (Johnson, 2005, p. 156).

A second example of the use of Level 4 geomatics integration was provided by Borri and Cera (2005). They developed a GIS-based decision making tool used by ambulance drivers. Knowledge gained during interviews with ambulance drivers allowed them to determine how drivers select the best route to an emergency. The resulting tool simulates the ambulance drivers' reasoning and automatically selects the best route to an emergency and displays it on a map within the ambulance. The biggest drawback of this methodology is that a decision-making model, that assumes decisions will be based on previous experience, may not be valid in an inter-organizational dynamic response environment (Comfort and Kapucu, 2006).

A similar system, also designed for use in ambulances, was developed by Dong (2005). It combines GIS and GPS and connects the dispatch centre and emergency response vehicles via cellular phone networks. The ambulance location is displayed on laptop computers both in the vehicles and at the command centre. The vehicle location is tracked with GPS receivers and transmitted in near real-time back to the command centre where the location is plotted and viewed on digital maps. When an emergency location is identified, the system automatically selects the most efficient vehicle and directs it to the emergency. The potential challenges for implementing this system include using out-of-date databases and the inability of the system to factor in road closures, traffic problems, the availability of the ambulance, and people's reactions to emergency events.

The advantage of the use of geomatics in this configuration is the ability to automatically select the best route. For example, organizations delivering relief supplies do not want to have to cross the same river several times while traveling between population centers (Verjee, 2005). Furthermore, a GIS-based decision support system and a dynamic network traffic congestion model can be used to determine minimum cost routing (Wu et al., 2001).

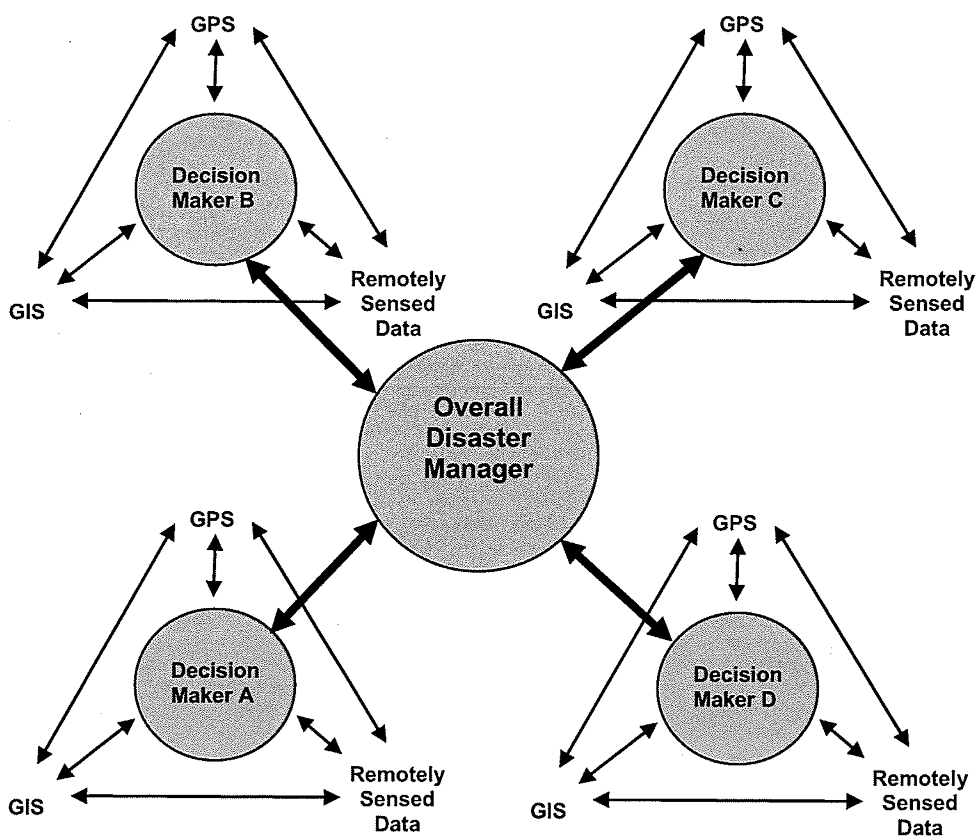
Use of Level 4 integration

Complex integrations, such as Level 4 integrations, are ideally suited for coordinating a multi-agency response effort. As noted earlier, to ensure effective results, response agencies must work together to coordinate their response. Additionally, in order to be successful, emergency response tasks should focus on priority areas and emergency managers should ensure that rather than taking simply any action, rescue workers are taking the most appropriate action (Perry and Lindell, 2003). An integrated Geomatics

Information System that is able to answer questions of who is doing what, where, and when, has not yet been the focus of an academic article. This type of system would look similar to other Level 4 integrations and would significantly improve the ability to coordinate multiple rescue teams and ensure that rescue efforts are focused on priority areas and tasks.

LEVEL 5 INTEGRATION

Figure 5: Level 5 Integration Model



Definition, and use of Level 5 integration

Level 5 integrations are the highest level of geomatics integration and ensures maximum efficiency during a multi-agency emergency response. As depicted in *Figure 5*, this level of integration is achieved when several Level 4 integration models are linked, allowing a central or overall disaster manager (emergency coordinator) to direct and communicate with decision makers from several different agencies involved in the response. The two-way communication link between agencies and the overall response coordinator is represented by the thick arrows in the model. This link could involve the exchange of data ranging from hardcopy maps, infrastructure reports, situational awareness information in the form of technical reports or briefing notes, to the exchange of GIS data layers and the sharing of resources. This link could be achieved through the use of geomatics, the Internet, phones, radios, or other communication technologies and techniques. The provision for additional links also provides the opportunity to incorporate data from other non-geomatics sources (cellular phones, digital cameras, personal digital assistants, hand-held radios, etc.) into the overall decision-making process. For example, emergency coordinators may be interested in pictures of the disaster scene taken by a local resident with a digital camera. I was unable to locate documentation of a working example of this type of integration in the disaster management literature, possibly due to the significant organizational, economic, cultural, and hardware/software challenges that currently exist.

Non-disaster management use

A system originally designed for aviation users that was adapted to assist pedestrians navigating in urban environments was the only model of Level 5 integration found in the literature (Ott et al., 2005). It appears that this system could theoretically be adopted for use in a multi-agency disaster response. In this example, several different positioning techniques are used to determine the users' locations. These locations are transferred via the Internet between mobile units and a service centre. Once the position is received at the service centre images, based on 3-dimensional city or terrain models of the surrounding area are rendered. The image is available for use at the service centre and on the mobile unit and is continually updated as the users change position. Currently, this type of system does not seem practical. The data and communications requirements are extremely onerous. It is unlikely that anyone will have sufficient up-to-date imagery in the exact area affected by an event. There is much work to be done before this type of application is commercially viable and this type of geomatics use becomes commonplace.

5. RESULTS

This chapter describes the web-survey results as they relate to the web survey goals and inform the discussion in Chapter 6, the case study in Chapter 7, and the conclusions in Chapter 8.

RESPONSE RATE

Based on the academic literature regarding web-based surveys, the response rates to the Educator and Practitioner Surveys met expectations and allow generalization to the wider population. However, the software developer survey was unsuccessful.

Educator Survey

Of the 137 invitations sent to educators, 35 people accessed the survey and 34 submitted completed surveys for an overall response rate of 25%. If the results from this sample are generalized to the entire population, the survey findings will be accurate to +/- 15% at the 95% confidence level. The confidence interval is a function of the response rate but in this instance the 15% confidence interval, although fairly large, is not significant because most responses are grouped at extreme ends of the scales, not in the middle where uncertainty could lead to a misinterpretation of the data.

Practitioner Survey

Approximately 3000 practitioners were invited to participate in the Practitioner Survey. Of the 173 practitioners who accessed the survey, 135 submitted completed surveys; the overall response rate was 4.5%. As such, generalizing the results from this sample population to the entire population will be accurate to +/- 8% at the 95%

confidence level. Similar to the Educator Survey, the 8% confidence interval is not significant because most responses are at the extreme ends of the scales.

In addition, in response to Question 50, "Are you interested in participating in future studies," 54 practitioners provided a contact e-mail address and indicated they were interested in participating in further study. During the week of October 15, 2007, I sent a follow up e-mail with a set of additional questions and a consent form to those who provided an e-mail address. However, only two practitioners answered the additional questions and, as such, this data was not incorporated into the results.

Software Developer Survey

Of the 21 software developers invited to participate, not one even looked at the survey. I did, however, receive one request for a copy of the results. The non-response was surprising because the survey instrument was successfully pre-tested by four software developers from three large corporations active in the disaster management field. As a result of the non-response the Software Developer Survey was abandoned. However, the non-response suggests that either the developers of geomatics technologies are not interested in participating in web-based surveys, or there is a significant disconnect between software developers, and educators and practitioners. This disconnect is discussed in more detail in Chapter 6.

SURVEY INSTRUMENTS – INTERNAL RELIABILITY

Internal reliability for each survey instrument was determined by calculating Cronbach's Alpha, a statistic used to measure the reliability of an instrument. For the Educator Survey, the Alpha value was 0.74 for perceptions of technology and 0.90 for questions regarding geomatics expertise. For the Practitioner Survey, the Alpha was 0.73 for perceptions of technology, 0.88 for questions regarding perceptions of geomatics, and 0.78 for questions relating to education and the use of technology. Since Alpha values of 0.7 or higher indicate a high level of consistency (SPSS, n.d.), the values calculated for both surveys indicate a high level of internal reliability within the survey instruments.

DETAILED RESULTS

The web-based surveys were designed to satisfy research objective two, which was to evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development. Accordingly, the survey results are organized and discussed to reflect the survey goals established in Chapter 3, as follows:

1) to determine what educators and disaster management practitioners know about geomatics technologies;
2) to determine whether disaster management programs offer instruction in the use of geomatics technologies;
3) to determine if/how geomatics is currently used in disaster management, the benefits for doing so, and the challenges to implementing it; and
4) to determine the importance of disaster management to the manufacturers of geomatics technologies.

As outlined in Chapter 3, the results have been tabulated and each table includes either the specific survey question and/or the answer choices as they appeared in the survey instruments, the modal response/opinion, and the majority response/opinion. The values in the columns labeled N represent either the number of responses for that particular answer choice or the number of responses to the question. Note that the skip logic included in the web-surveys ensured that questions specific to GIS, GPS, and RS were only asked if participants indicated that they used these technologies, and as such, the number of responses to some questions is often much lower than the overall number of survey responses. The raw data collected for each scaled question is provided in graphical format in Appendix B.

Participants

To contextualize the surveys responses, it is important to begin with a demographic overview of the respondents. As shown in *Table* 1, while a variety of different people contributed to the survey, in both the educator and practitioner categories, the majority of respondents were living in either the United States or Canada, and the majority were male. Of the educators, 7 respondents were women and 27 were men. The majority, 73%, was between 45 and 65 years of age, and 56% had completed a doctoral degree. Respondents to the Educator Survey taught at institutions in the United States (26), Canada (6), New Zealand (2), and Nepal (1).

Of the practitioners who submitted a complete survey, only 22% were women. The majority, 57%, was between 45 and 65 years of age, and approximately 80% of respondents had completed at least a Bachelor's level education. The majority of responses to the Practitioner Survey were received from the United States (60%), Canada (30%), India (2%), and Mexico (1%).

Table 1: Demographics

Item	Educators	Practitioners
Gender		
Male	79%	78%
Female	21%	22%
Age		
Under 30	3%	5%
30 to 44	21%	36%
45 to 65	73%	57%
66 or older	3%	2%
Participant's highest level of education		
High School	-	3%
Certificate or diploma	-	18%
Bachelor's level	12%	38%
Master's level	32%	35%
Doctoral level	56%	6%
Level of courses offered at institution[i]		
Certificate or diploma	51%	-
Bachelor's level	37%	-
Master's level	49%	-
Doctoral level	14%	-
Associate Degree	6%	-
Level of emergency/disaster management work[i]		
Local (first responder agency)	-	20%
Local (emergency management)	-	48%
Provincial, state, and/or regional	-	30%
National	-	17%
International	-	5%
NGO	-	7%
Hospital	-	3%
Private sector consultant	-	4%
University	-	5%
Training	-	2%
Location of institution/participant		
United States	74%	60%
Canada	17%	30%
New Zealand	6%	-
Nepal	3%	-
India	-	2%
Mexico	-	1%
Portugal, United Kingdom, Nigeria, France, Germany, Kenya, New Zealand, Puerto Rico, Australia, and South Korea (1 response received from each country)	-	< 1%

i. Responses add to more than 100% because participants were asked to select all answers that apply.

Attitudes towards technology

The survey included a number of general questions to gauge respondents' attitudes towards the use of technology in disaster management. As indicated by the results summarized in *Table 2*, 62% of educators and 43% of practitioners strongly agree that technology currently plays an important role in disaster management and 79% of educators and 58% of practitioners strongly agree that in the future, technology will become increasingly important in this field.

Table 2: Attitudes toward technology

Statement	**Group**	**N**[i]	**Modal Opinion**	**Combined Majority**[ii]
Currently, technology plays an important role in emergency/disaster management.	Educators	34	Strongly Agree (62%)	Strongly Agree + Agree (82%)
	Practitioners	169	Strongly Agree (43%)	Strongly Agree + Agree (74%)
In the future, the use of technology in emergency/disaster management will become increasingly important.	Educators	34	Strongly Agree (79%)	Strongly Agree + Agree (97%)
	Practitioners	168	Strongly Agree (58%)	Strongly Agree + Agree (87%)

i. N indicates the total number of responses received for each question.
ii. The Combined Majority column contains the sum of the responses received in the Strongly Agree and Agree categories.

Furthermore, the results reveal that almost 80% of survey participants agree that technology currently plays an important role in disaster management, but when asked about the future, *almost all* of the participants agree that the use of technology will become increasingly important. This implies that practitioners expect that technology will become more widely available and it will be better able to meet their needs.

However, as mentioned in the Chapter 1, trade-offs are involved in increasing the use of technology in disaster management, and the survey results provide insight into what these might be. For example, *Table 3* shows that 35% of practitioners expect technology to provide advances in communication and improvements in the speed with which decisions are made. However, more interestingly, 17% of practitioners fear that disaster managers will become overly dependant on technology. This trade-off is further explored in Chapter 6.

Table 3: The implications for increased technology use

Item	Practitioners
Advances in communication	19%
Increasing the use of technology might not be the best approach it leads to over-reliance, increases vulnerability and the things that can go wrong, and widens the gap between have and have-nots	17%
Increase in speed of data acquisition resulting in quicker decision making	15%
Improved response	8%
More information available for decision making	8%
Improvements to situational awareness	6%
Improvements to public warnings and notifications	5%
Advances in the ability to share data	4%
Wider range of resources available to responders	4%
Minimize interaction between humans	3%
Increase need to education and train staff	3%
Increase in accuracy	2%
Those unwilling to use it will suffer	2%
Increasing expectations from public and management	1%
Increasing costs to undertake work	1%
Improvements to preparedness planning	1%
Decrease in the number of lives lost	1%

Survey participants also highlighted several factors that hinder the use of technology in disaster management. As outlined in *Table 4*, 26% of educators and 32% of practitioners indicated that a lack of knowledge about technology is the greatest hindrance to its use in the field. This finding suggests that disaster managers might be having difficulty implementing technological solutions because they are too complex, which is evidence of a disconnect between practice and software development.

Table 4: Hindrances for the use of technology

Item	Educators	Practitioners
Lack of knowledge and training in the use of technology	26%	32%
Cost	21%	22%
Lack of funding for technology	21%	8%
Lack of clearly defined usage standards	15%	4%
Attitudes of regulators and leaders towards technology	-	11%
Unwillingness to adopt technology and embrace change	7%	7%
Lack of access to equipment/software	4%	2%
Poor results from previous uses	4%	-
Lack of marketing on the part of geomatics technology developers	-	4%
Technology is too complex	-	3%
Integration between agencies	-	3%
Technological problems	2%	-
Reliance on power	-	2%
Fear of over reliance on technology	-	2%

In addition, more than 20% of both educators and practitioners highlighted cost as a barrier to the use of technology. This is interesting because, in the context of a major disaster event, the costs associated with technology (i.e. hardware, software purchase, training, etc.) are minimal compared to the amount spent during a response effort and for the clean-up afterwards. This finding suggests that disaster managers believe that governments, and ultimately taxpayers, are not willing to spend money planning for events that may never occur, even if the initial investment is minimal compared to the ultimate costs involved in a disaster event. However, investing in technologies that could improve a community's capacity to plan for, respond to, and recover from a wide variety of hazards is probably money well spent, since this could result in a better overall response in which recovery occurs more quickly and costs are lower (Pearce, 2003).

Knowledge of geomatics

The survey results point to an increase in the use of technology in disaster management but there will be consequences for doing so. The literature review and taxonomy suggest that the use of geomatics might improve communication and decision-making abilities, as was highlighted by practitioners in the survey. However, using geomatics requires a certain level of knowledge and, as the results also indicate, a lack of knowledge about technology is possibly the most significant hindrance to its adoption. Accordingly, the survey was also designed to determine what educators and disaster management practitioners know about geomatics technologies.

Participants were asked to rate their current knowledge of geomatics on a scale of 1 to 5. *Table 5* reveals that the modal response for the Educator Survey was 3 and the majority of participants selected either 2 or 3, which means that educators generally only have a moderate level of knowledge of geomatics. Practitioners ranked themselves even lower than the educators, with a modal response of 2, while the majority of practitioners (58%) indicated that they have a low level of knowledge of geomatics (either 1 or 2).

Table 5: Participants geomatics knowledge ranked on a scale of 1 to 5

Statement	**Group**	**N**	**Modal Response**	**Combined Response**[i]
Please rate your current knowledge of geomatics technology.	Educators	34	3 (53%)	2 + 3 (74%)
	Practitioners	107	2 (33%)	1 + 2 (58%)

i. The Combined Response column contains the sum of the responses received in the categories noted.

It is evident that the knowledge level of the majority of respondents in both groups falls close to the low end of the scale and it seems there are very few geomatics experts currently working in disaster management. This lack of geomatics knowledge supports the assumption that the use of geomatics in disaster management is not fully realized. It also raises questions as to the focus of current research and suggests that applications for disaster management at the 1, 2 or 3 integration levels might be better suited for disaster management practitioners. Additionally, the fact that most practitioners who responded to the survey have a low level of geomatics knowledge becomes especially interesting when compared to the number of practitioners who indicated that they plan on using geomatics in future disaster management activities. As shown in *Table 6*, it seems that even though most of the practitioners who responded to the survey have a low level of geomatics knowledge, 70% of them plan on using it anyway. This suggests that even with limited knowledge about them, practitioners realize that even low level geomatics integrations can provide benefits and geomatics can be a useful tool in disaster management.

Table 6: The number of practitioners who plan to use geomatics in the future

Question	**N**	**Yes**	**No**
Do you plan to use geomatics technologies in future emergency/disaster management activities?	127	70%	30%

It is possible to overcome a lack of knowledge of technology by increasing training and education. Indeed, *Table 7* reveals that 70% of practitioners who responded to the survey agree or strongly agree that all emergency/disaster managers should be educated in the use of GIS and GPS, and 61% generally agree that they should be educated in the use of RS. Additionally, 79% of educators agree that disaster management programs should include courses in the use of geomatics.

Table 7: Geomatics in disaster management programs

Statement	Group	N[i]	Modal Opinion	Combined Majority[i]
All emergency/disaster management programs should include courses that provide instruction in the use of GIS, GPS, and RS.	Educators	28	Strongly Agree (39%)	Strongly Agree, Agree + Generally Agree (79%)
All emergency/disaster managers should be educated in the use of GIS	Practitioners	112	Strongly Agree (39%)	Strongly Agree + Agree (70%)
All emergency/disaster managers should be educated in the use of GPS.	Practitioners	81	Strongly Agree (41%)	Strongly Agree + Agree (70%)
All emergency/disaster managers should be educated in the use of RS.	Practitioners	76	Agree (34%)	Agree + Generally Agree (61%)

i. The Combined Majority column contains the sum of the responses received in the categories noted.

These findings suggest that both practitioners and educators consider geomatics to be important to disaster management and that it should be part of educational programs and ultimately applied in the field. Furthermore, the results presented in *Table 8* demonstrate that most practitioners either strongly agree or agree that GIS and GPS are crucial component of disaster management (GIS 68%, GPS 58%) and that they are currently underused (GIS 64%, GPS 55%). However, practitioners believe that these technologies are only somewhat critical to the success of disaster management activities (50% agree or generally agree that the use of GIS is critical and 48% agree or generally agree that the use of GPS is critical). This suggests that the use of technology is not the only factor that ensures the success of activities undertaken in disaster management.

Table 8: The importance of geomatics

Statement	Group	N	Modal Opinion	Combined Majority[i]
GIS is a crucial component of emergency/disaster management.	Educators	27	Strongly Agree (59%)	Strongly Agree + Agree (85%)
	Practitioners	111	Strongly Agree (39%)	Strongly Agree + Agree (68%)
GIS is underused in emergency/disaster management.	Practitioners	107	Agree (35%)	Strongly Agree + Agree (64%)
The use of GIS is critical to the success of the emergency/disaster management activities I am involved with.	Practitioners	111	Agree (29%)	Agree + Generally Agree (50%)
GPS is a crucial component of emergency/disaster management.	Educators	19	Strongly Agree (53%)	Strongly Agree + Agree (89%)
	Practitioners	82	Strongly Agree (31%)	Strongly Agree + Agree (58%)
GPS is underused in emergency/disaster management.	Practitioners	78	Strongly Agree (35%)	Strongly Agree + Agree (55%)
The use of GPS is critical to the success of the emergency/disaster management activities I am involved with.	Practitioners	81	Generally Agree (30%)	Generally Agree + Agree (48%)
RS is a crucial component of emergency/disaster management.	Educators	18	Strongly Agree (50%)	Strongly Agree + Agree (78%)
	Practitioners	76	Generally Agree (46%)	Agree + Generally Agree (68%)
RS is underused in emergency/disaster management.	Practitioners	70	Agree (33%)	Agree + Generally Agree (63%)
The use of RS is critical to the success of the emergency/disaster management activities I am involved with.	Practitioners	74	Generally Agree (30%)	Agree + Generally Agree (51%)

i. The Combined Majority column contains the sum of the responses received in the categories noted.

It is interesting to note that the results also show that a large majority of educators agree or strongly agree that geomatics technologies are critical to disaster management (GIS 85%, GPS 89%, and RS 78%). Indeed, this suggests that educators might believe that these technologies have great potential to assist efforts in disaster management. However, despite the apparent criticalness of these technologies, *Table 7* indicated that only 39% of educators strongly agreed that they should be included in disaster management programs. This is either a reflection of the geomatics knowledge level of educators with respect to the ability to teach geomatics or an indication that they believe the use of technology is not the only way to ensure successful disaster management.

Geomatics in disaster management programs

Both educators and disaster managers revealed that they have limited knowledge of geomatics, but their survey responses convey their belief that education in these technologies should be part of disaster management programs. As such, the second goal of the survey was to determine whether disaster management programs offer instruction in the use of these technologies. *Table* 9 reveals that more than half the programs offer some instruction in geomatics, with 79% of disaster management programs providing some type of instruction or courses in GIS, 59% providing instruction involving GPS, and 56% incorporating RS into the curriculum.

Table 9: Number of educational programs offering GIS, GPS and RS courses

Question	Yes	No
Do any courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Geographic Information Systems (GIS)?	79%	21%

Question	Yes	No
Do any courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Global Positioning System (GPS) technology?	59%	41%
Do any courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Remote Sensing (RS) technology (e.g., aerial photographs or satellite images in printed or digital format)?	56%	44%

Based on these figures, it seems that information about geomatics should be reaching a significant number of new disaster management practitioners. Furthermore, as summarized in *Table 10*, it seems that students enrolled in the disaster management programs that include a geomatics component are gaining a moderate level of expertise in the use of geomatics technologies. Educators believe that by the time of graduation, their students have gained geomatics expertise similar to the knowledge levels of the educators themselves. As such, future disaster managers may rank themselves higher on the geomatics knowledge scale than the respondents to this survey.

Table 10: Graduating student's geomatics expertise ranked on a scale of 1 to 5

Statement	Group	N	Modal Response	Combined Response[i]
Please rate the level of GIS expertise that graduates gain from your program.	Educators	25	3 (48%)	2 + 3 (76%)
Please rate the level of GPS expertise that graduates gain from your program.	Educators	18	3 (50%)	2 + 3 (78%)
Please rate the level of RS expertise that graduates gain from your program.	Educators	16	2 (44%)	2 + 3 (81%)

i. The Combined Response column contains the sum of the responses received in the 2 and 3 categories

Use of geomatics in disaster management

Despite the apparent lack of knowledge of geomatics within the disaster management field revealed through my surveys, the literature review and taxonomy indicated that at least some practitioners are using geomatics in all phases of the disaster management cycle to solve a variety of problems. Fittingly, the third goal of the survey was to determine, directly from practitioners and educators, if/how geomatics is currently used in disaster management, the benefits for doing so, and the challenges to implementing it. Based on this knowledge, the results here were somewhat surprising. *Table 11* indicates that the majority of survey respondents believe that the use of geomatics is not common (56%, 59%). Furthermore, when asked about applying it in disaster management, the response that was most selected by survey participants is that it is challenging to do so (47%, 38%).

Table 11: Using geomatics

Statement	Group	N[i]	%
Please select the statement that most closely represents your opinion on the use of geomatics in emergency/disaster management.	Educators	34	
	Practitioners	129	
Geomatics is widely used in emergency/disaster management	Educators		29%
	Practitioners		16%
Geomatics use is not common in emergency/disaster management	Educators		56%
	Practitioners		59%
Geomatics is currently not used in emergency/disaster management	Educators		3%
	Practitioners		5%
Don't know	Educators		12%
	Practitioners		20%

Statement	Group	N[i]	%
Please select the statement that most closely represents your opinion on the application of geomatics in emergency/disaster management.	Educators	34	
	Practitioners	130	
It is easy to apply geomatics technologies in emergency/disaster management	Educators		29%
	Practitioners		16%
It is challenging to apply geomatics technologies in emergency/disaster management but it can be done	Educators		47%
	Practitioners		38%
Right now, it is too difficult to apply geomatics technologies in emergency/disaster management	Educators		9%
	Practitioners		15%
It is impossible to apply geomatics in emergency/disaster management	Educators		0%
	Practitioners		1%
Don't know	Educators		15%
	Practitioners		30%

i. N indicates the total number of responses received for each question.

On the other hand, these questions generated a higher-than-expected number of 'Don't know' responses, which might indicate that they were difficult for participants to answer. This could mean that the high 'don't know' response is a reflection of the overall lack of knowledge of geomatics held by all participants. They might believe that they don't know enough about geomatics to determine whether it is being used or how difficult it is to apply. Notwithstanding this, these results indicate that the majority of survey respondents believe that geomatics is not commonly used in this field.

If its use is not common, then how many practitioners are actually using it? *Table 12* shows that well over 60% of practitioners have used each of the geomatics technologies. Thus, it seems that its use, at least at a low integration level, is more widespread than practitioners believe and practitioners may be unaware that their colleagues are using geomatics. This supports the need to find better ways of sharing information amongst disaster managers and highlights an opportunity to use my geomatics taxonomy as a tool to distribute information to them.

Table 12: The number of practitioners using geomatics

Question	N	Yes	No
Do you use or have you used Geographic Information Systems in emergency/disaster management activities?	169	73%	27%
Do you use or have you used Global Position System technology in emergency/disaster management activities?	162	64%	36%
Do you use or have you used Remote Sensing technology in emergency/disaster management activities?	147	61%	39%

It is also interesting to look more closely at the number of practitioners who have used each individual technology. *Table 12* indicates that GIS is the most popular geomatics technology but it is very surprising that only 61% of practitioners indicated that they have used RS. The survey instrument defined RS as the use of aerial photographs or satellite images in printed or digital format, and these types of images can be incorporated into almost any project. Furthermore, if the results presented in *Table 8* are re-visited, it appears that when compared to the other technologies, practitioners believe RS is the least critical technology, that it is not as underused as GIS and GPS, and only a small majority (51%) agree or generally agree that the use of RS is critical to the success of disaster management activities. These results confirm that RS is the least used, and is also considered to be the least useful, geomatics technology. These results are not surprising when compared to the average practitioner's level of knowledge of geomatics, however, they also reflect a need to better distribute information to practitioners.

After learning that practitioners are using geomatics technology, questions regarding its actual practical uses can be addressed. *Table 13* provides a list of the activities for which practitioners have used geomatics. The scores for each activity were determined based on the scoring criteria defined in Chapter 3. The scores make it possible to rank the activities based on actual use. *Figure* 6, *Figure* 7, and *Figure 8* visually depict the rankings and the final order and clearly indicate exactly how practitioners are using geomatics. Indeed, the results indicate that practitioners use both GIS and RS for preparedness planning, decision making, and producing maps for emergency responders, whereas GPS is used for preparedness planning, producing maps for emergency responders, and allocating resources. Examples of each type of use were discussed in the taxonomy.

Table 13: How practitioners use geomatics

Activity	N^i	Score
GIS		
Preparedness planning	90	95
Decision making during emergency response activities	86	92
Producing maps for emergency responders	86	90
Evacuation mapping and planning	73	55
Producing vulnerability maps	71	44
Risk mapping	72	43
Simulation and modeling	70	43
Allocating/coordinating resources during emergency response	59	36
Predicting impact zones	67	31
Distributing information to the media or public	54	21
Disaster recovery planning	55	20
Determining mitigation needs	38	15
Estimating damages	37	14
Distributing information to victims	34	6
Training	1	-
Event comparison	1	-
Situational awareness	1	-
GPS		
Preparedness planning	58	71
Producing maps for emergency responders	48	59
Allocating/coordinating resources during emergency response	47	46
Risk mapping	33	43
Decision making during emergency response activities	42	38
Producing vulnerability maps	30	34
Evacuation mapping and planning	32	32
Estimating damages	24	21

Activity	N[i]	Score
Determining mitigation needs	11	20
Simulation and modeling	28	13
Distributing information to victims	12	7
Predicting impact zones	18	6
Distributing information to the media or public	17	6
Disaster recovery planning	28	5
Locating exact location of hazards	4	-
Navigation	1	-
Tracking resources and personnel	1	-
RS		
Preparedness planning	53	88
Decision making during emergency response activities	45	48
Producing maps for emergency responders	51	41
Risk mapping	36	32
Simulation and modeling	35	29
Evacuation mapping and planning	36	25
Producing vulnerability maps	36	22
Predicting impact zones	34	22
Allocating/coordinating resources during emergency response	30	20
Estimating damages	27	17
Disaster recovery planning	33	16
Determining mitigation needs	24	9
Distributing information to the media or public	23	3
Distributing information to victims	11	2
Documenting transportation needs	1	-
Evacuation studies	1	-
Security	1	-

i. N indicates the number of respondents who selected each item.

Figure 6: Summary of practitioner's top ranked GIS activities

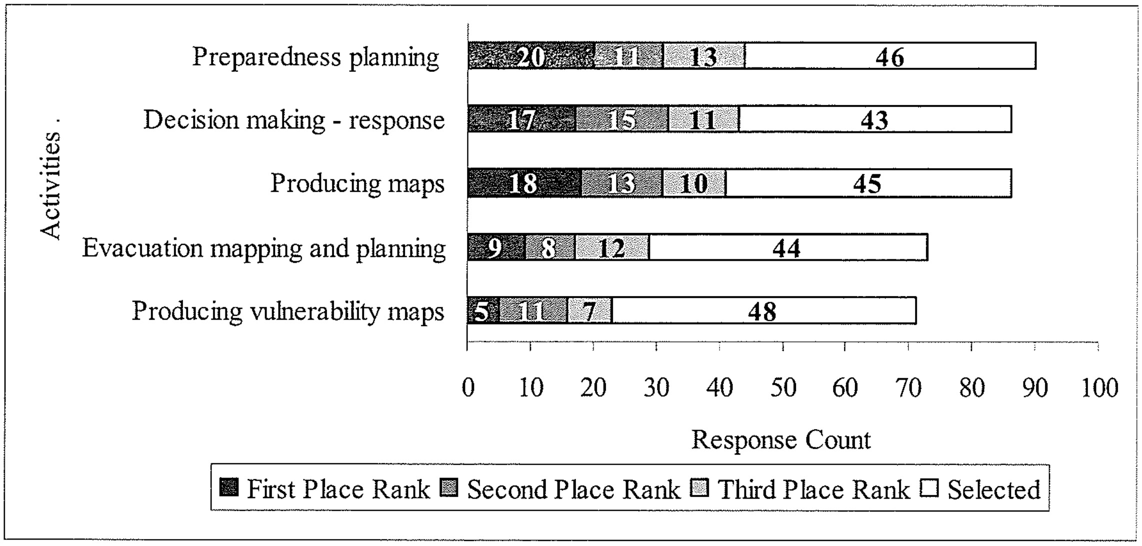


Figure 7: Summary of practitioner's top ranked GPS activities

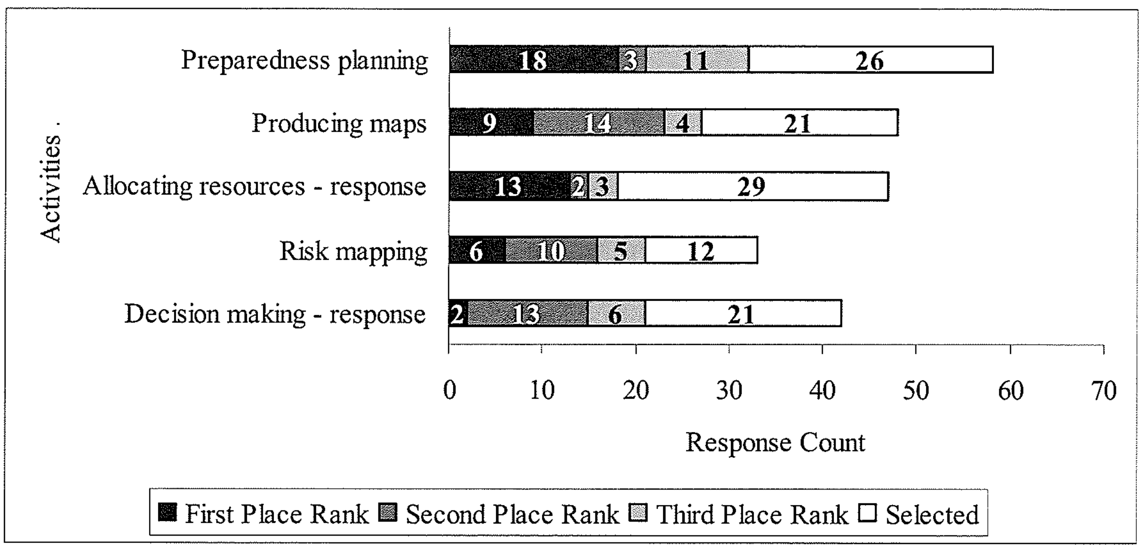
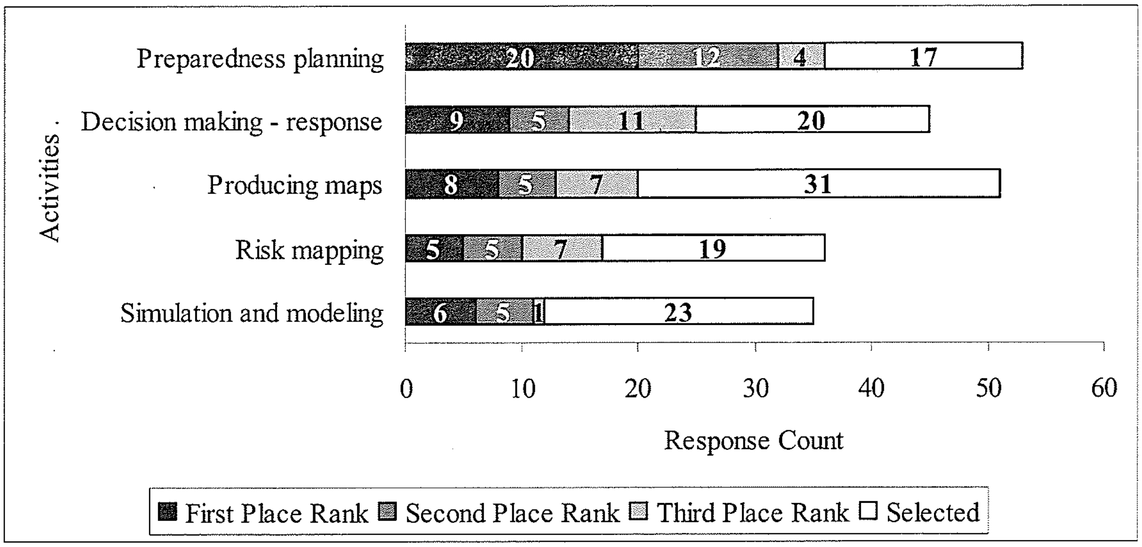


Figure 8: Summary of practitioner's top ranked RS activities



The results discussed earlier showed that practitioners are willing to use geomatics even though they have limited knowledge of it. This suggests that they expect to realize benefits when they apply it. Thus, identifying the benefits of using geomatics is important for improving future software/hardware and can indicate areas for more efficient applications. Based on the data summarized in *Table 14*, approximately 30% of practitioners consider the graphical functionality and the ability to visualize a situation to be the most significant benefits for using GIS and RS, and 25% of practitioners find that GPS simplifies the management of responders and 19% believe that it improves navigation. These benefits seem to provide the enhanced communication and decision-making abilities that are important to practitioners.

Table 14: The benefits for using geomatics

Item	**Response**
GIS	
It is a graphic tool (visualization)	29%
Provides improved situational awareness	18%
Supports decision making	12%
Allows production of instant maps	12%
Provides location information	11%
Facilitates better planning	6%
Provides ability to share information	3%
Improves response	3%
Allows for simulations	3%
Improves flexibility	1%
Improves search and rescue	1%
Increases accuracy and reliability	1%
GPS	
Simplifies management of responders (can deploy as needed)	25%
Navigation aid	19%
Incident plotting	19%
Increases accuracy, dependability, and reliability	13%
Provides ability to track (people/resources)	11%
Provides location information	9%
Improves search and rescue	5%
RS	
It is a graphic tool (visualization) that depicts the real world	37%
Rescue and recovery damage assessments	19%
Developing emergency plans	13%
Improved situational awareness	13%
Better response	7%
Increases accuracy and reliability	5%
Shows location of shelters	4%
Improves decision making	2%

In addition to the benefits, it is important to understand what types of challenges to expect when implementing technology. As such, survey participants were asked to select and rank the challenges for the use of geomatics in disaster management. The items listed in *Table 15* were identified by survey respondents as the most significant challenges for the use of geomatics. The most significant challenges seem to be economic and organizational, which confirms the factors highlighted in the literature review.

Table 15: The challenges for implementing geomatics

Item	Educators		Practitioners	
	N[i]	Score	N[i]	Score
Cost of software	21	29	60	87
Cost of equipment (hardware)	18	26	55	68
Communication between departments/agencies etc.	24	21	73	60
Expert knowledge is required	16	19	54	69
No standards or procedures in place outlining the use of geomatics in emergency/disaster management	14	13	56	38
Cost to collect data	16	11	54	71
Data quality and accuracy	16	10	49	44
Unable to acquire data quickly	10	8	36	17
Technical issues	14	8	39	27
Don't know how to use geomatics technologies	12	8	37	42
Lack of data	9	4	28	16
Existing software is not adequate for emergency/disaster management	5	4	20	10
Geomatics technology is too complex	3	2	21	1
Legal framework for the use of geomatics in emergency/disaster management does not exist	6	2	8	4
Lack of communication or other infrastructure	7	2	24	8
Lack of funding	-	-	5	11
Potential academic turf wars	2	2	-	-
Existing hardware is not adequate for emergency/disaster management	2	1	7	2
Too much data available	5	-	13	1
No time for staff to address issues	1	-	-	-
No training available	1	-	1	2
No capacity	1	3	-	-
Privacy concerns	-	-	3	7
Data requires continual maintenance and upgrades	-	-	1	-
Management not convinced it is required	-	-	1	-
Resistance to change from older emergency managers	-	-	1	-
Unable to acquire the technology	-	-	1	-
There are no benefits to using geomatics technologies in emergency/disaster management	-	-	2	7

i. N indicates the number of respondents who selected each item.

However, the survey data also shows that survey participants consider the need for expert knowledge to be much more significant than was indicated in the literature. It is also interesting to note that although they were discussed in detail in the literature, cultural challenges such as privacy concerns and the lack of a legal framework were ranked relatively low and these do not seem to be significant challenges to respondents.

The survey data collected also allows the challenges to be placed into a priority order. However, if the challenge order was based solely on selection frequency, communication between departments and agencies would be at the top of the list for both groups. Further analysis of the rankings reveals that although communication is a challenge, it was not ranked in the top three nearly as often as the economic challenges. *Figure 9* and *Figure 10* are graphical representations of the selection frequency and ranks for each of the top five challenges listed in *Table 15*. *Figure 9* reveals that based on the data collected from educators, the economic factors are more significant to more people. For instance, 67% of the participants who chose the cost of software as a challenge ranked it among the top three, whereas only 38% of participants who chose communication ranked it among the top three. It is clear that communication is a challenge; however, based on the overwhelming number of people who ranked cost items in the top three, there is little doubt that cost is the most significant challenge for the use of geomatics in disaster management. It is also interesting to note that even though the costs were split into two categories, both appear at the top of the list for both groups.

Figure 9: Top challenges for implementing geomatics – Educator Survey

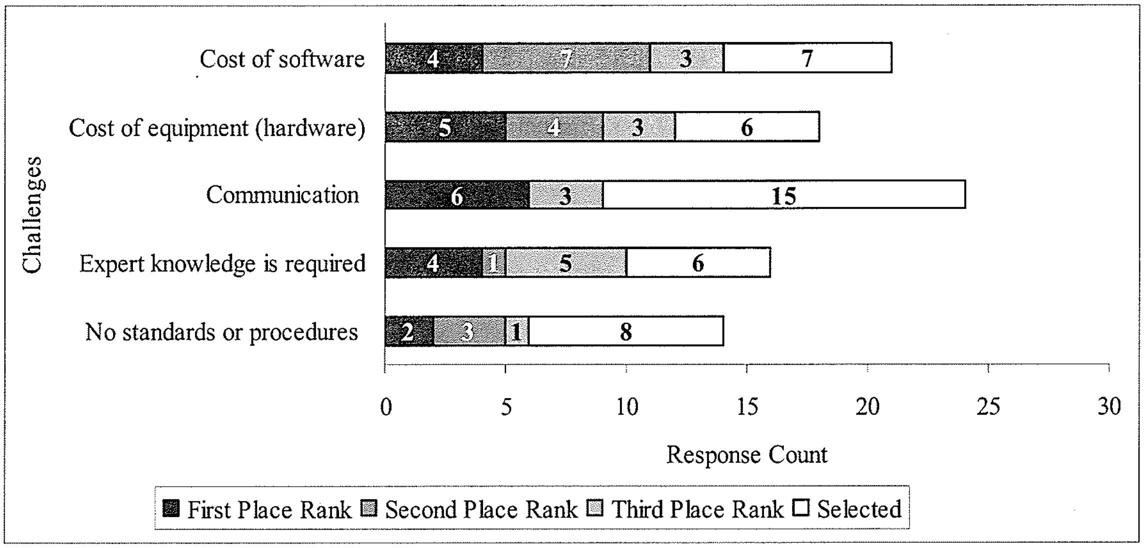
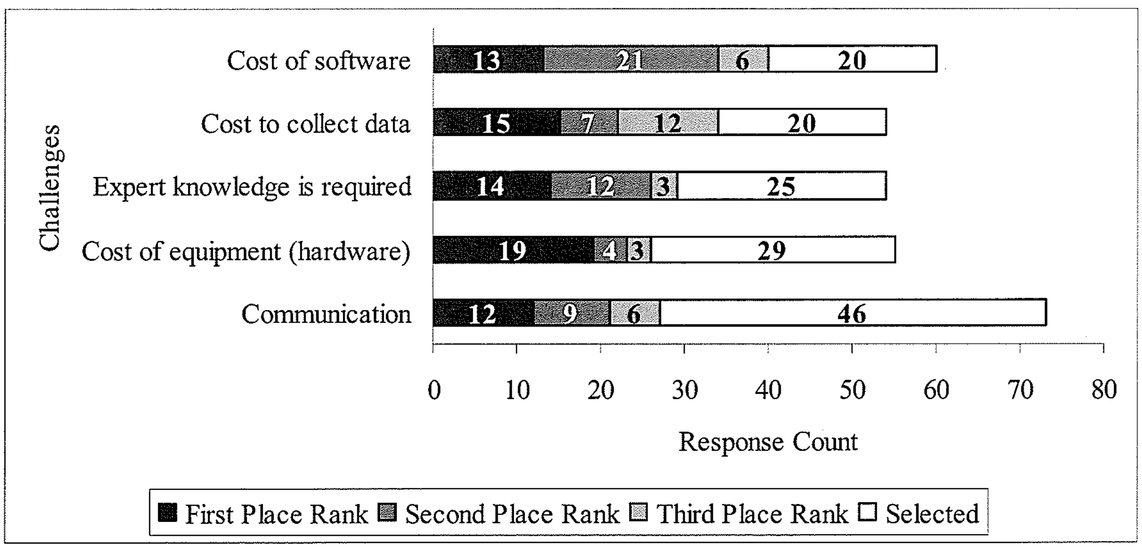


Figure 10: Top challenges for implementing geomatics – Practitioner Survey



Software developers

The fourth goal of the survey was to determine the importance of disaster management to the manufacturers of geomatics technologies. As noted earlier, however, the Software Developer Survey was unsuccessful and no data were collected. The non-response could indicate that disaster management is not an important market for the manufacturers of geomatics technologies. However, since there are hardware and software products available, the disaster management field must be of some importance to software developers. Indeed, at the very least, this response rate is an indicator of a significant disconnect between practice and software development.

Evidence of this disconnect is further found in some of the responses provided by practitioners to the hardware and software questions. For example, the data presented in *Table 16* indicates that most practitioners either generally agree or are neutral when asked if the currently available software is adequate and affordable. And when asked if GIS software is adequate for their needs, 56% of participants selected neutral and generally agree. Similarly, opinions are divided on GIS software affordability and 50% of the respondents selected answers on either side of the neutral answer. The results for GPS are slightly more positive, wherein 70% of participants generally agree or agree that the available GPS equipment is adequate and 61% generally agree or agree that it is affordable. However, practitioners seem less enthusiastic about RS and although more than 50% of practitioners generally agree that RS products are adequate for their needs, opinions are divided on affordability (50% selected answers on either side of the neutral choice). This disconnect between practice and the producers of geomatics technologies is further explored in Chapter 6.

Table 16: Hardware/software

Statement	Group	N[i]	Modal Opinion	Combined Majority[i]
GIS software that is available 'off-the-shelf,' meets all of my emergency/disaster management needs.	Practitioners	106	Generally Agree (31%)	Generally Agree + Neutral (56%)
The GIS software that will meet all of my needs is affordable.	Practitioners	105	Neutral (28%)	Generally Agree + Neutral (53%)
GPS equipment that is available 'off-the-shelf,' meets all of my emergency/disaster management needs.	Practitioners	79	Generally Agree (46%)	Generally Agree + Agree (70%)
The GPS equipment that will meet all of my needs is affordable.	Practitioners	80	Generally Agree (39%)	Generally Agree + Agree (61%)
The RS products that are available meet all of my emergency/disaster management needs.	Practitioners	70	Generally Agree (50%)	Generally Agree + Neutral (67%)
The RS products that will meet all of my needs are affordable.	Practitioners	68	Neutral (26%)	Generally Agree + Neutral (49%)

i. The Combined Majority column contains the sum of the responses received in the categories noted.

SUMMARY

Most survey respondents agree that technology plays an important role in disaster management and that it will continue to do so into the future. Survey respondents also agree that all practitioners should be educated in the use of geomatics technologies; however, they themselves admit to only having a low level of knowledge of it. Notwithstanding their knowledge level, 73% of the disaster management practitioners reported having used GIS, while 64% have used GPS, and 61% have used RS. Additionally, 70% of respondents indicated that they plan to use geomatics in the future. Both educators and practitioners indicate that the use of geomatics is important enough that all disaster management education programs should include instruction in the use of GIS, GPS and RS. And the results indicated that currently 79% of disaster management programs include a GIS component, 58% include a GPS component, and 56% include a RS component. The results also show that a large number of practitioners are using geomatics and they agree that each technology is a critical component of disaster management. However, there are a number of challenges for using it in the field, which include the cost of software, the cost of equipment (hardware), communication between departments/agencies, the requirement for expert knowledge, and a lack of standards. Additionally, practitioners are not convinced that the GIS, GPS, and RS products currently available are affordable or meet their needs. Yet, they also indicated that they are able to achieve some benefits – namely, that geomatics provides enhanced visualization capabilities.

6. DISCUSSION

The web-based survey was an excellent way to collect a large amount of new data to address my specific research questions and to evaluate the current use of geomatics in disaster management. This chapter begins with a discussion about the use of a web-based survey and the survey instruments, including a description of the validity of the instruments and the errors and bias associated with a web-survey. Other professions have also encountered challenges with the use of new technologies in their field. This chapter connects the use of technology in disaster management with the integration of technology into other professions and society as a whole by discussing the survey results within the context of new technology use in other fields and by comparing the survey results with a disaster management study undertaken by Marincioni (2007). I also use the results from the web-survey to achieve my second objective, which was to evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development.

THE WEB-BASED SURVEY

Since the survey mode influences the reliability and validity of the results, the selection of the web as the survey mode was made only after careful review and consideration. Indeed, using web-based methods provides distinct advantages over traditional mail or telephone surveys, but several disadvantages also exist.

One advantage of a web-based survey is that it provides the ability to rapidly collect responses and to reach a large number of potential participants quickly and economically (Fowler, 2002). In this instance the use of e-mail and the web allowed the invitations to be widely distributed with minimal costs. Kaplowitz et al. (2004)

determined that a similarly targeted survey administered on the web costs approximately $1.30 per return. Although a comparable mail survey attracted 10% more participants, the costs were approximately $11 per return. As such, inviting more than 3000 participants via mail in both Canada and abroad would have exceeded my modest project budget. Additionally, using a web-based survey avoided tasks such as printing, copying, addressing, and distributing hardcopy surveys via the mail and thus, further reduced the time and effort required to administer the survey. There are also several other advantages to using the web including the ability to design a user-friendly research tool that is easy to access, eliminates researcher error while recording responses, and provides automated data analysis capabilities (Kaplowitz et al., 2004).

The disadvantages to using a web-based survey are highlighted by Sills and Song (2002) and common problems that may arise include participant bias, non-response due to the ease with which people can ignore invitations to participate, questionable sample validity, and the potential for technological issues. Additionally, motivational tools to increase response rate have not been tested for the Internet and the methods used to improve response rates to mail surveys may not translate to this mode (Kaplowitz et al., 2004). Recent years have also seen an increase in unsolicited and fraudulent e-mails, which have eroded user confidence about the validity of e-mails (Sills and Song, 2002). In addition, a common problem for any self-administered research instrument is that the interviewer is not directly involved with the questioning and cannot provide clarification to the participants (Fowler, 2002).

Survey Instruments – validity

Each survey instrument was divided into four sections and took approximately ten minutes to complete. All three survey instruments were reviewed for content and face validity and pre-tested by academics, practitioners, and other graduate students. Concurrent validity was determined by comparing the information collected in this survey with the information gleaned from the literature and the results of a survey of disaster management organizations conducted by Marincioni (2007).[4] The results of both the Educator and Practitioner Surveys confirm the challenges and attitudes towards the increased use of technology identified in the literature, and these results show trends similar to those found in Marincioni's research. As such, it appears that the results achieved with these survey instruments are consistent with previous research in this area.

Errors and bias

Errors and bias have the potential to significantly affect the response rate and may even invalidate the survey results. For these surveys, the two most obvious and significant errors, non-response and non-coverage errors, are a function of the survey mode. The survey was designed so that the most common non-response errors – technical problems, a seeming lack of confidentiality, and difficulty in understanding the question and questionnaire – would not factor into the response rate achieved (Sills and Song, 2002). Indeed, the low response rate to the Practitioner Survey does not indicate a non-response error. It is likely due to the fact that many potential respondents may have immediately deleted the invitation e-mail. Furthermore, the response rate to the Educator Survey may have been higher due to the overall willingness of educators to participate in

[4] Note that although Marincioni's results were published in 2007, his survey research was actually conducted in 2001 (F. Marincioni, personal communication, January 8, 2008).

research and the more personal nature of the invitation e-mail (I sent the invitations from my University of Manitoba e-mail account). However, as outlined previously, both surveys achieved a response rate sufficient to allow the results to be generalized to the wider population, thus making the non-response error less significant.

The disaster management community is large and includes a wide variety of professions including local first responders, emergency managers, secondary responders, consultants, and those working for universities, non-governmental organizations, and national and international agencies. This survey reached several people within each group but a non-coverage error still exists because of the survey mode and recruitment strategy. Not every disaster manager belongs to the e-mail user groups to which invitations were sent. Additionally, not every member of the population has access to or is able to use a computer to complete a survey. Hence, the results do not include input from those that are not part of the online communities nor from those who are not computer literate. However, this survey is about technology and its use in disaster management, hence, responses from those who use technology as a tool and those who are technology literate are more desirable. Indeed, the sample seems to be highly representative of the target population, and provides important data.

Other error sources include item non-response errors and incomplete surveys. In some instances it may be desirable, even critical that an answer is obtained from every participant for every question. The design of these surveys was such that answers were only required for questions that incorporated skip logic. This was done because the value of receiving responses for some questions was more important than receiving a complete survey from each participant. Accordingly, to avoid discouraging participation, respondents were encouraged to skip questions and exit the survey at any time. The completion rate for the Educator Survey was 97%, but only 78% for the Practitioner Survey. Comments left by practitioners in lieu of legitimate responses indicate that the lower completion rate was due to participant fatigue. Participants felt the survey was too long and contained repetitive questions. As a result, answers to the important questions near the end of the survey were not received from those practitioners who exited the survey early. In addition, based on the response rate to the hardware/software developer survey, and the apparent participant fatigue noted in the Practitioner Survey, a lesson learned is that successful pre-testing does not guarantee anything.

Despite my best efforts the survey results also include an element of bias. The survey was focused on the use of geomatics technologies, however, geomatics was specifically not mentioned in the survey title, thus avoiding the risk of only receiving responses from those who are familiar with, or have used geomatics. Although many participants completed and submitted the entire survey, one practitioner seemed to take issue with my approach and provided the following comment:

> This was a set up survey which focused not on technology in emergency management, but it seems to point at a special interest of the author - geomatics. Technology goes beyond radios and GIS/mapping. Trying to compartmentalize will divert dollars from all-hazard, all-phase approaches to specific interests of this grad student. Next time - why don't you just say it's a survey about mapping/photography technology?
>
> —Anonymous Practitioner, Question 54, Practitioner Survey

Based on this and other comments, I believe the strategy used to reduce bias was successful. For example, the information provided by this particular practitioner regarding the all-hazards approach is extremely valuable and was incorporated into the case study. Additionally, two participants commented that the use of the term ‘technology’ was too general because technology could include almost anything invented by humans. Notwithstanding these minor issues, the responses received indicate that participants have a wide range of expertise with and knowledge about geomatics.

A TECHNOLOGY-BASED SOCIETY

Technology is penetrating almost all facets of life in the twenty-first century. Social networking is done online, ‘Google’ has become a verb, news spreads quickly through blogs and YouTube, and texting has spawned a new language. Some people even seem to base their social worth on the number of Facebook friends they have. The use of communication technologies appears to have become almost an obsession for some, particularly those considered ‘Gen Y’ (Tancer, 2007). While an exploration of how, or if, the Internet, social networking, and cell phone communication can contribute to disaster management is beyond the scope of this thesis, it is interesting to contemplate whether the technological explosion that is occurring throughout today’s society is mirrored in the field of disaster management; or if not, why.

The ease with which many younger members of society have increased their use of technology makes it seem as though the adoption of any technology is straight forward and automatic. Even though ‘adopting technology’ seems to be extremely common and simple there is not much academic literature available on the adoption of technology in disaster management. However, significant research has been conducted within an educational context and many articles have been published that highlight the barriers to adopting technology in schools and in the classroom.

Indeed, the barriers to the adoption of technology in education are very similar to the challenges faced by disaster managers. For example, a literature review completed by

Finley and Hartman (2004) determined that the most significant barriers to technological adoption in education are: a) the lack of available training; b) the lack of a clear vision or plan for its use; c) a lack of support from senior management; d) an institutional culture that does not support the use of technology; e) a fear that the increased use of technology will lead to over-reliance and the loss of the ability to think; and f) technology further increases the division between advantaged and disadvantaged groups.

When initially developing this research project, I did not consider that technology could widen the gap between advantaged and disadvantaged groups; however, the conditions in disaster management are often not that different from those in education. For example, Finley and Hartman (2004) note that in the United States, students attending public schools in areas with a higher percentage of poor people do not have the same access to computers as students who attend schools in wealthier areas. Thus, students in the schools with fewer computers do not receive the same amount of instruction or gain as much experience with them. Similarly, in disaster management, wealthier communities can afford to implement state-of-the-art warning or monitoring systems and build mitigation structures, while residents living in small, rural, or poor communities may not have the means to implement such solutions. Another facet of this issue was expressed by a disaster management practitioner as follows:

> On the negative side, [the use of technology will create] a greater class disparity between educated wealthy communities and poor uneducated [ones]. [The result will be] that the poor will have less control over their community's recovery and reshaping after a disaster. The poor will lose their voice as greater credence is given to technology than is given personal experience.
>
> —Anonymous Practitioner, Question 5, Practitioner Survey

Thus, it seems important for disaster management professionals to continue to use community-based approaches and to strive for sustainable hazard mitigation to ensure that the public and communities are empowered by technology.

THE ADOPTION OF TECHNOLOGY IN DISASTER MANAGEMENT

There is evidence that the use of technology in disaster management is increasing and almost all of the participants in this research agree or strongly agree that, in the future, technology will become increasingly important to disaster management. This is supported by Marincioni's (2007) recently published survey results that suggest a large majority of emergency managers believe that technology holds great potential for disaster relief. However, Marincioni also noted that in certain cultural settings, the prevailing attitude towards technology may be that "IT are powerful tools through which it is possible to improve disaster communication and education. However, IT are not the final solution for emergency management." (p. 462). Indeed, survey respondents have mixed feelings towards the adoption of technology and have identified several trade-offs to increased technology use. These include the possibility that disaster managers will become over-reliant on it, public expectations will increase, and risks may increase.

It is possible that disaster managers may become overly reliant on technology. Indeed, 17% of disaster management practitioners believe that over-reliance on technology is a serious issue and many don't think that technology is the answer. For example, a typical practitioner comment summarizing the fear of over reliance is as follows:

> One change I that I believe we will encounter is more reliance on technology that may hinder future responses and "thinking on one's feet". If technology is seen as the "save all" in the future then we will not retain

> skills needed to respond if that technology is knocked out or not available. However, technology is not the enemy, we must combine both technology and human knowledge (improvising as well) to develop effective emergency management for both the present and the future.
>
> —Anonymous Practitioner, Question 5, Practitioner Survey

This over-reliance could minimize human interaction and take the 'human element' out of the job. Additionally, others are worried that technology might eliminate jobs. It was suggested that some experienced disaster managers might find it difficult to adapt to technology and fall behind. These issues were conveyed as serious concerns and are summed up by one survey participant as follows:

> Technology brings about better communication and more reliable data for quick decisions which help us manage a disaster. The use of technology will greatly help us evacuate people in a timely fashion. But I don't want to see the use of modern technology eliminate many who work in this field due to their lack of high tech training or perhaps age related resistance to change. Sometimes there is a little wisdom that comes with age, and that should be valued too.
>
> —Anonymous Practitioner, Question 5, Practitioner Survey

In theory, technology provides quick, reliable, access to information at any time. However, there is concern amongst practitioners that the increased use of technology will lead to the public perception that emergency managers have access to information 24-hours-a-day, 7-days-a-week, and thus, response results will improve significantly. The increased public expectations may put additional pressure on disaster managers to achieve results. For example one practitioner noted that:

> In the past, taking hours or days to move information was acceptable. Now, minutes are frustrating.
>
> —Anonymous Practitioner, Question 5, Practitioner Survey

Indeed, it is very difficult to measure the impact and to see the results or benefits of the use of technology (Stephenson and Anderson, 1997). However, based on my research, it seems that practitioners are realizing benefits. For example, the survey findings indicate that 15% of practitioners believe technology facilitates the acquisition of accurate data in a timely manner, which results in quicker, more accurate decisions. Additionally, technology helps take the guess work out of disaster management and one practitioner noted that:

> Technology allows emergency managers to operate quicker and more accurately within the fast-paced environment of an emergency or disaster. The movement of situational information and the provision of resources at the impact points can be expedited by timely, accurate information to prepared response and recovery personnel.
>
> —Anonymous Practitioner, Question 5, Practitioner Survey

However, the benefits with respect to lives saved or reduced property damage are difficult to quantify.

Along with the potential and real benefits, increasing the use of technology may also increase risk, bring about added destruction, and increase vulnerability. For example, our technological infrastructure is subject to attack and the use of technology to construct mitigation structures has led to increased vulnerability for many and as mentioned in Chapter 1, despite the adoption of technology in disaster management, the number of people affected and the economic losses due to recent hazard events both continue to rise (Mileti, 1999). Additionally, as noted by Hewitt (1983), the use of technology to improve prediction capability may lead some to believe that nature has been controlled and risk has been removed.

Thus, based on the trade-offs it seems that not all costs associated with the use of technology are economic (Hewitt, 1983). However, there is evidence that despite these issues the use of technology in disaster management is increasing. For instance, when the results of my survey are compared to those obtained by Marincioni (2007), who collected his data in 2001 (F. Marincioni, personal communication, January 8, 2008), it appears that the use of geomatics technologies has almost doubled in the past six years. According to Marincioni's research, in 2001, 36% of respondents to his survey had access to GIS, 39% to GPS, and 34% to remote sensing technologies. Meanwhile, my survey indicates that 73% of respondents use GIS, 64% use GPS, and 61% use RS.

Access to technology has improved significantly since 2001, but are there other possible explanations for the apparent increase in use? Further examination of the results from both surveys indicates that the profession has not actually changed significantly. For instance, in the United States it is still dominated by men and predominantly those in their 50s. However, the number of female disaster managers has increased slightly by approximately eight percent. Based on the demographic data, a major change does appear to exist in the educational background of today's disaster manager. In Marincioni's research only 18% of respondents have a formal educational background in disaster management. Marincioni notes that they have, however, "attended a wealth of short-term specialised courses in emergency management" (p. 464). He also adds that 35% of disaster managers below the age of 40 have academic training or degrees in disaster management. In contrast, almost 80% of respondents to my survey have at least a bachelor's degree (although I did not ask whether the degree was related to disaster management). Based on this difference, either my survey attracted more people with higher education or the overall education level of the profession has increased, leading to the corresponding increase in the use of technology.

The adoption of technology in disaster management is very complex and there are both benefits and trade-offs for doing so. However, the use of technology is increasing in disaster management and based on historical patterns it will continue to do so, albeit at a slower pace than in society as a whole (Stephenson and Anderson, 1997).

THE DISCONNECT WITH SOFTWARE DEVELOPMENT

As mentioned previously, due to the non-existent response rate, the software developer survey was abandoned shortly after issuing the initial invitation. The lack of interest shown by software developers could be interpreted as strong evidence of a disconnect between them and the other groups involved in disaster management. Indeed, the data gathered from both the Educator and Practitioner Surveys indicate that there is a disconnect with software development in that educators and practitioners don't believe that the software currently available is affordable or meets their needs. Thus, it is extremely unfortunate that, because software developers did not respond, only one side of this disconnect can be explored.

For those in the Educator group the disconnect is with respect to the software itself. Many respondents to the Educator Survey commented that software is overpriced, which makes it impossible for educational institutions to keep current. In addition, many respondents noted that the hardware/software available from one company is often not compatible with the hardware/software produced by another. This makes research, data sharing, and the choice of software for demonstration/teaching purposes very difficult. In general, educators believe that software developers do not seem to understand the requirements of either educators or disaster management practitioners, and that the software currently available is not adequate for use in this field.

Based on the survey results the disconnect with practitioners goes much deeper than just software. For example, many practitioners believe that software developers do not recognize disaster management as an important market. Practitioners claim that software developers are forcing them to use products developed for other applications, even though this software may not be appropriate for use in disaster management. Additionally, many practitioners are skeptical about software developers because claims that have been made in the past have rarely come true. One respondent to the Practitioner Survey, referring to a major Canadian software developer, put it this way:

> [They are] trying to sell a universal bill of goods that may have been developed for one client that just doesn't cut the mustard, and they want your first born child to modify it to suit our needs. A right rip-off.
> —Anonymous Practitioner, Question 49, Practitioner Survey

Practitioners also commented that they receive very little support from software developers. Training courses and technical support targeted at the disaster management community do not seem to be common. In addition, several practitioners stressed that software developers and other geomatics professionals don't understand the requirements of the disaster management community or the activities they undertake. One respondent reflected that:

> Emergency managers don't know what geomatics can do for us, and geomatics experts don't understand enough about emergency management to see new ways of using the technology to help us.
> —Anonymous Practitioner, Question 49, Practitioner Survey

The advent of new technologies is often seen by the public as a positive development but in the opinion of disaster managers, constant updates and new versions of software give the impression that old systems are unreliable or faulty. They also note that even if they could afford to stay current, practitioners do not want to implement the newest software products because they do not want to have to deal with software bugs.

As such, they prefer to use proven technology because a technological problem during a disaster event could result in both the loss of life and infrastructure.

The survey results indicate that cost is a significant challenge and hinders the use of technology in disaster management. Furthermore, survey respondents note that it is very difficult for local jurisdictions and educational institutions to investigate costly technological solutions. In response to rising costs, survey participants suggested that the use of free, widely available, open-source information may be a good option. However, based on previous experience, they believe there is unwillingness on the part of software developers to explore the use of open-source information. Indeed, the survey results indicate that both sample populations believe the profit-driven, proprietary approach taken by software companies is limiting the use of geomatics technology in disaster management. For example, practitioners find it is extremely difficult to experiment with geomatics tools to explore solutions that could benefit society as a whole because data can't be shared and software is not interoperable. Additionally, the survey results indicate that opinions of practitioners are divided on whether the products currently available meet their needs and are affordable. All of these factors are likely contributing to practitioner and educator frustration, which widens the gap with software development.

However, the survey results indicate that despite the disconnect with software development and the challenges associated with the use of geomatics, 70% of respondents are planning to use it for future projects. Thus, finding ways to bridge the gap between software development, practice, and education is increasingly important. One practitioner had the following suggestion for the publishers of emergency management magazines for closing the gap with software development:

> Stop letting the software developers and tech folks write the articles for emergency management publications. [Let practitioners] point out easy to understand, practical benefits of the technology.
>
> —Anonymous Practitioner, Question 54, Practitioner Survey

Based on this and other similar comments, practitioners are interested in knowing how they can achieve real benefits on a day-to-day basis through practical, simple, cost-effective applications of technology. As such, practitioners seem to be more interested in learning about how they can integrate and benefit from lower level geomatics integrations rather than being overwhelmed by the cutting edge level 4 or 5 integrations that will be difficult for them to incorporate into actual practice.

EXPLORING THE DISCONNECT BETWEEN EDUCATION AND PRACTICE

Clearly a disconnect exists between the disaster management community and software development. Is the same also true in education and practice? There seems to be subtle evidence of such a disconnect, however, there are many similarities between these groups. Indeed, in general, the results from the scaled questions provide very little evidence of a disconnect between education and practice. For example, both groups selected similar challenges for the use of geomatics and identified similar factors that hinder the use of technology, and both groups agree that technology currently plays an important role in disaster management, the use of geomatics is not common, and it is challenging to apply it in this field. However, evidence of the subtle disconnect is found in the survey results that show educators believe technology will become more critical to disaster management and based on the open-ended questions, they are having difficulty aligning teaching priority with practical use. Indeed, it appears that any disconnect between education and practice may be much more subtle than originally anticipated.

The similarities

Although they do not provide evidence of a disconnect between education and practice, answers to questions related to the challenges for the use of geomatics in disaster management reinforced the challenges identified in the literature review (i.e. economic, cultural, organizational, hardware/software, and physical challenges). Additionally, there were no surprises that the top five challenges identified by both groups are almost identical. Identifying similar challenges, as listed in *Table 17,* indicates that both groups share similar struggles for the use of geomatics. These results also reflect the disconnect with software development in that cost, and the need for expertise is ranked so high.

Table 17: Challenges for the use of geomatics in disaster management

Rank	Educators	Practitioners
1.	Cost of software	Cost of software
2.	Cost of equipment (hardware)	Cost to collect data
3.	Communication between departments/agencies etc.	Expert knowledge is required
4.	Expert knowledge is required	Cost of equipment (hardware)
5.	No standards or procedures in place outlining the use of geomatics in emergency/disaster management	Communication between departments/agencies etc.

Even though this list of challenges reflects what was learned from the literature, it provides two pieces of new information. First, the challenges can be ranked with certainty. Second, the need for expert knowledge appears to be much more significant than originally thought. In the literature, this challenge is discussed primarily in the context of a software use issue, rather than an overall challenge for the use of geomatics. As such, it was originally grouped as part of the hardware/software challenge category. However, based on the increased significance demonstrated by the survey results, this challenge can be put into its own category. As discussed previously, a possible explanation that the need for expert knowledge was not identified as a significant challenge in the academic literature may be that all the articles included in my review were written by academics or experts with knowledge and experience in geomatics. Additionally, all of the articles reviewed contained examples where the application of geomatics was successful. The academic literature includes very few examples or discussions about serious problems and failures when geomatics is applied to disaster management.

It is also interesting to note that both groups ranked the need for expert knowledge higher than organizational, hardware/software, and physical challenges. This was an interesting and unexpected result; the decision to include this challenge in the survey instrument was somewhat of an afterthought because it was not specifically addressed in the literature. Fortunately, it is possible to address this challenge. One suggestion might be to introduce practitioners to simple, straightforward geomatics applications that offer benefits and improve their work. This might help to take some of the mystery out of the technology.

In addition to the challenges, practitioners and educators have also identified similar hindrances for the use of technology in disaster management. In addition, based on the results summarized in *Table 18*, with the exception of the 'attitudes towards technology' item, each hindrance could also be classified into one of the challenge categories (economic, cultural, organizational, hardware/software, and physical).

Table 18: Factors that hinder the use of technology in disaster management

Rank	Educators	Practitioners
1.	Lack of knowledge of technology	Lack of knowledge and training in the use of technology
2.	Cost	Cost
3.	Lack of funding for technology	Attitudes of regulators and leaders towards technology
4.	Lack of clearly defined usage standards	Lack of funding for technology
5.	Unwillingness to adopt technology and embrace change	Unwillingness of society and management to adopt technology and embrace change

The similarities between what both groups' consider to be hindrances indicates that there is agreement between them and these results do not speak directly to a disconnect; however, the fact that they both identify a lack of knowledge of technology as the most significant hindrance is further justification for the creation of a new challenge category. Additionally, it is interesting to note that participants raised the issue of a lack of funding for technology and cost as separate items. Survey participants defined 'cost' as the purchase price of an item and a 'lack of funding for technology' was exemplified by a practitioners who indicated that senior management will approve spending if it is directed towards generators and flashlights but will not approve the purchase of Emergency Operating Centre (EOC) software.

The results also indicate that opinions on the usage of geomatics and attitudes towards technology appear to be similar. For example, the Educator Survey results indicate that 79% of disaster management programs include a GIS component, 58% include a GPS component, and 56% include an RS component. These numbers are similar to the number of practitioners who use or have used GIS (73%), GPS (64%), and RS (61%). The results in *Table 19* also suggest that geomatics is an important part of both the practice of disaster management and educational programs. Indeed, both groups agree that all practitioners should know how to use geomatics technologies and that it should be part of the curriculum of all disaster management programs.

Table 19: Attitudes towards geomatics

Statement	Educators	Practitioners
Geomatics use is not common in emergency/disaster management.[i]	56%	59%
It is challenging to apply geomatics technologies in emergency/disaster management but it can be done.[ii]	47%	38%
Currently, technology plays an important role in emergency/disaster management.[iii]	Strongly Agree	Strongly Agree
All emergency/disaster management programs should include courses that provide instruction in the use of GIS, GPS, and RS.[iv]	Strongly Agree	—
All emergency/disaster managers should be educated in the use of GIS.[v]	—	Strongly Agree
All emergency/disaster managers should be educated in the use of GPS.[vi]	—	Strongly Agree
All emergency/disaster managers should be educated in the use of RS.[vii]	—	Agree

(Zcrit = 1.96, p>.05)
i. Zu = -1.30; ii. Zu = -1.45; iii. Zu = -1.76;
iv. Responses to question 20 in the Educator Survey were used as a baseline for the statistical analysis of responses for Practitioner Survey questions 15, 27, and 39 (notes v, vi, and vii in the table above).
v. Zu = -0.95; vi. Zu = -0.88; vii. Zu = -0.35

A review of the information collected on the way geomatics technologies are used in practice and the emphasis placed on them in teaching is the best way to uncover a disconnect between education and practice. The literature review and taxonomy provided many examples of the use of geomatics in disaster management, the majority of which seem to fit into the Level 1, 2 and 3 integration models described in Chapter 4. The survey results confirm this, and practitioners are using GIS and RS most often for preparedness planning, decision making during emergency response activities, and for producing maps for emergency responders. GPS is used for all of those tasks as well as for allocating/coordinating resources during an emergency response. Furthermore, the survey results also indicate that the most significant benefit for the use of these tools is that GIS and RS provide visualization capabilities. Other benefits are also being realized, including enhanced situational awareness, the ability to manage responders (e.g. can be deployed as needed), improved navigation and incident plotting, and damage assessments.

With respect to education and practice, evidence of a disconnect would be that the priority of educators (i.e. what is being taught to students) is inconsistent with the way in which the tools are being used in practice. The results in *Table 20* show a large majority of practitioners (often > 75%) believe that all technologies are very useful in all phases of the disaster management cycle. Similarly, with the exception of the use of GIS in recovery activities and GPS for mitigation, the majority of educators (> 60%) place a high priority on teaching GIS, GPS and RS in disaster management programs.

Table 20: Teaching and use priorities

Statement			N	Modal Response	Combined Response[i]
When teaching GIS, what priority is placed on each phase of the disaster management cycle?					
	Educators	Response	24	5 (38%)	5 + 4 (63%)
		Recovery	24	3 (33%)	2,3+ 4(66%)
		Mitigation	23	5 (52%)	5 + 4 (74%)
		Preparedness	24	5 (54%)	5 + 4 (71%)
Please evaluate the use of GIS in each phase of the disaster management cycle.					
	Practitioners	Response	114	5 (74%)	5 + 4 (91%)
		Recovery	113	5 (67%)	5 + 4 (84%)
		Mitigation	109	5 (57%)	5 + 4 (88%)
		Preparedness	112	5 (57%)	5 + 4 (82%)

Statement		N	Modal Response	Combined Response[i]
When teaching GPS technology, what priority is placed on each phase of the disaster management cycle?				
Educators	Response	17	5 (65%)	5 + 4 (82%)
	Recovery	17	4 (35%)	4 + 5 (65%)
	Mitigation	17	4 (41%)	4 + 3 (76%)
	Preparedness	17	4 (41%)	4 + 5 (65%)
Please evaluate the use of the GPS technology in each phase of the disaster management cycle.				
Practitioners	Response	84	5 (76%)	5 + 4 (92%)
	Recovery	81	5 (63%)	5 + 4 (80%)
	Mitigation	80	5 (41%)	5 + 4 (59%)
	Preparedness	84	5 (45%)	5 + 4 (75%)
When teaching RS technology, what priority is placed on each phase of the disaster management cycle?				
Educators	Response	15	4 (40%)	4 + 5 (80%)
	Recovery	15	5 (33%)	5 + 4 (60%)
	Mitigation	15	5 (40%)	5 + 4 (67%)
	Preparedness	16	5 (50%)	5 + 4 (75%)
Please evaluate the use of RS technology in each phase of the disaster management cycle.				
Practitioners	Response	72	5 (63%)	5 + 4 (86%)
	Recovery	69	5 (67%)	5 + 4 (93%)
	Mitigation	69	5 (54%)	5 + 4 (75%)
	Preparedness	73	5 (53%)	5 + 4 (84%)

i. The Combined Majority column contains the sum of the responses received in the categories noted.

The disconnect

Based on the answers provided to the scaled questions there seems to be agreement between these groups. However, this conflicts with the information provided by participants for the open-ended questions. For instance, the tone taken by practitioners and the opinions expressed are slightly more pessimistic and indicate a higher level of frustration with technology. They seem especially troubled by costs, the attitudes of regulators and leaders, and the unwillingness of management to facilitate change. Similarly, educators commented that they are finding it increasingly difficult to provide instruction in the use of technology because they are unsure about the priorities of practitioners and are unable to standardize their teaching due to the inconsistent application of technology in practice (particularly software). One educator summarized this issue as follows:

> In New Zealand there is no clear guidance on what EOC [emergency operating centre] software is used, consequently many agencies are using different programs that are not interoperable with one another. Equally it is difficult to teach comprehensive courses in EOC software where there is not a single program being used by the emergency management sector.
>
> —Anonymous Educator, Question 18, Educator Survey

So although the focus of educational programs is to teach students how to use software, there is no guarantee that the same software will be used in practice.

Educators also highlighted other underlying factors preventing the incorporation of geomatics technologies into disaster management education. For example, several educators shared that they are unable to adequately prepare students to use geomatics technologies due to "the culture of academia," a "lack of knowledge on the part of faculty," and a general lack of funding. One educator commented that even when there is funding for a technological initiative, it is too difficult to choose which technology to use, since some technologies may not be compatible with other systems or provide the desired results. This delays the process and often a decision is never made.

Additionally, respondents noted that each institution has a unique focus for its disaster management program and it is difficult to provide future disaster managers with all the skills they require to enter this profession. However, the following suggestion, provided by an educator, speaks to the development of collaborative programs:

> Each institution has a different orientation to the disaster and emergency management degree it offers. GIS and remote sensing techniques are widely used in the field of science and engineering but not in

> management. Clearly, there is a need for more collaborative programs that can bring technology, management, and social components together.
> —Anonymous Educator, Question 18, Educator Survey

This is an excellent idea and would not only introduce students to interdisciplinary work but would also allow them to gain a broad knowledge base.

At first glance the survey results seem to indicate that there is a difference in baseline geomatics knowledge between the Educator and Practitioner Survey populations. Indeed, many participants in the Educator Survey have doctoral degrees, and thus, it might be expected that they have more expertise and would rank themselves higher on the geomatics knowledge scale. However, the Mann-Whitney U test conducted on the data indicates that there is no significant difference between the groups. Notwithstanding this, it is interesting to note that only 6 of the 142 respondents from both groups identified themselves as an 'expert,' while the majority of respondents ranked themselves at, or close to, the 'no knowledge' end of the scale.

Based on the survey results approximately 80% of educators indicated that they strongly agree or agree that GIS, GPS, and RS are critical parts of disaster management and 97% agree or strongly agree that technology will become increasingly important in the future. When compared to the approximately 60% of practitioners who agree or strongly agree that GIS and GPS are critical to disaster management and the 68% who agree or generally agree that RS is critical, educators seem to somewhat overstate the criticalness of geomatics. Additionally, comments provided by practitioners seem slightly more pessimistic and based on the data collected with the open-ended questions, 17% believe that the increased use of technology might not be the best approach to manage disasters. Practitioners are also more cautious and note that technology is subject to attack and outages, increases vulnerability and the things that can go wrong, and widens the gap between the have and have-nots. Additionally, practitioners are concerned that the increased use of technology will lead to an over-reliance on technology and that disaster managers will lose the ability to do their job or to think without it. Survey results that indicated there was a difference between the groups are summarized in *Table 21.*

Table 21: Attitudes towards and knowledge of geomatics technology

Statement	Educators	Practitioners
In the future, the use of technology in emergency/disaster management will become increasingly important.[i]	79% Strongly Agree	58% Strongly Agree
GIS is a crucial component of emergency/disaster management.[ii]	59% Strongly Agree	39% Strongly Agree
GPS is a crucial component of emergency/disaster management.[iii]	53% Strongly Agree	31% Strongly Agree
RS is a crucial component of emergency/disaster management.[iv]	50% Strongly Agree	46% Generally Agree
Please rate your current knowledge of geomatics technology.[v]	3	2

(Zcrit = 1.96) i. Zu = -2.07; ii. Zu = -2.00; iii. Zu = -2.49; iv. Zu = -2.61; v. Zu = -1.65

The disconnect amongst practitioner groups

The answers to the open-ended questions provide the evidence for the existence of a subtle disconnect between practice, education and software development and these results also seem to provide evidence of tension amongst different practitioner groups. The following quotes from two different practitioners reveal this dynamic:

> If you do the same old, same old, you will get the same old results.
> —Anonymous Practitioner, Question 54, Practitioner Survey

> If it fails: Chaos.
> —Anonymous Practitioner, Question 5, Practitioner Survey

These practitioners seem to be expressing a certain level of frustration regarding the use of technology. Comments provided in the survey suggest that one group of practitioners is troubled that organizations do not invest time and money in technology and that administrators and management are not able or willing to see the benefits of technology. The second group, however, is weary of using technology and worries that practitioners will become too dependent on it. The concern expressed by this group is that it will fail with catastrophic results from both a human and economic perspective.

Based on the responses to the open-ended questions there is some evidence that this tension could be related to a generational gap between respondents. Many respondents, who seem to be younger practitioners, commented on the unwillingness of older disaster managers to adapt to the changing times. The generational issue was also touched upon by educators, who referred to "technophobia" and a "good old boy's network" (Anonymous Educators, Question 18, Educator Survey). The more senior disaster managers seem to want to rely on proven methods to do the work and do not want time or money allocated to learning to use new technologies. They were also concerned that practitioners are endangering lives and infrastructure by learning to use technology "on-the-fly."

Based on these comments further investigation of this generational tension was required and I used the demographic data to establish contingency tables and performed Chi-Squared tests to compare the responses. However, as demonstrated in *Table 22*, *Table 23*, *Table 24*, *Table 25*, and *Table 26* the answers of both younger and older practitioner groups were similar for questions related to technology, future use of geomatics, current level of knowledge, the number of geomatics users, or the level of education received. These results thus suggest that any generational frustration may be limited to a small number of practitioners.

Table 22: Contingency table for age versus challenges

Number of respondents who identified that the use of technology was a stumbling block[i]	**Practitioners 44 years old or younger**	**Practitioners 45 years old or older**
Yes	15	23
No	40	53

$\chi^2 = .14$ (χ^2 Crit. = 3.841, df = 1); p = 0.7093

i. A Yes response indicates that a respondent selected at least two of the following challenges from the list provided in Question 47 on the Practitioner survey: expert knowledge is required, don't know how to use geomatics technologies, geomatics technology is too complex, or technical issues.

Table 23: Contingency table for age versus future use of geomatics

Number of respondents who indicated they plan to use geomatics in future emergency/disaster management activities[i]	**Practitioners 44 years old or younger**	**Practitioners 45 years old or older**
Yes	39	49
No	15	22

$\chi^2 = .15$ (χ^2 Crit. = 3.841; df = 1); p = 0.6976

i. Yes and No responses were determined based on responses to Question 46 on the Practitioner survey: Do you plan to use geomatics technologies in future emergency/disaster management activities?

Table 24: Contingency table for age versus level of knowledge

Number of respondents who indicated they have the following level of geomatics knowledge[i]	**Practitioners 44 years old or younger**	**Practitioners 45 years old or older**
1 or 2	27	34
3	13	18
4 or 5	6	7

$\chi^2 = .07$ (χ^2 Crit. = 5.991, df = 2); p = 0.9618

i. The responses to Question 43 on the Practitioner Survey (Please rate your current level of knowledge of geomatics technologies) were grouped into three categories representing low, average or high levels of geomatics expertise for this analysis because there were insufficient responses in the expert category to undertake a statistical test.

Table 25: Contingency table for age versus use of geomatics technologies

Number of respondents who indicated they are geomatics users[i]	**Practitioners 44 years old or younger**	**Practitioners 45 years old or older**
Yes	34	52
No	20	24

$\chi^2 = .42$ (χ^2 Crit. = 3.841, df = 1); p = 0.5169

i. A geomatics user is defined as someone who has used at least two geomatics technologies. The number of Yes responses was determined using the responses to Questions 6, 18, and 30 on the Practitioner survey (Do you use or have you used GIS/GPS/RS in emergency/disaster management activities?).

Table 26: Contingency table for age versus level of education

Number of respondents who indicated they have a particular level of education[i]	Practitioners 44 years old or younger	Practitioners 45 years old or older
Bachelor's degree, Certificate, or High School	34	43
Master's degree or Doctoral degree	20	32

$\chi^2 = .41$ (χ^2 Crit. = 3.841, df = 1); p = 0.5199

i. Number of respondents was determined from the demographic data and education levels were divided into Bachelor's degree or less and Master's degree and higher.

SUMMARY

The literature review, taxonomy, and web-based survey all provide valuable information regarding the use of geomatics in disaster management. For instance: 1) a Level 1 geomatics integration is ideally suited for preparedness activities and geomatics is commonly used to prepare maps for emergency responders; 2) technology usage seems to be increasing and although it is difficult to quantify in terms of lives or infrastructure saved, the use of geomatics is beneficial because it adds a visual element, improves situational awareness, facilitates damage assessments and management of resources, and aids navigation; 3) practitioners want to use geomatics but often the solutions available are expensive, require expert knowledge to implement and may not be the best solution in their context; 4) the most significant challenge to overcome is cost, thus any use of geomatics can't be too expensive; and 5) not all costs are economic, thus, the application of technology must be beneficial and must not eliminate the human element from decision making. Survey participants also identify a disconnect between practice, education and software development in that the technological solutions currently available do not meet the needs of educators or practitioners. Additionally, it seems that it might be difficult for educators to establish teaching priorities to ensure that future disaster managers are prepared to use technology in this field.

7. CASE STUDY: USING GEOMATICS TO PREPARE EMERGENCY PLAN MAPS

Both the literature review and web-based survey results indicate that not all disaster management practitioners currently use geomatics technologies. This is possibly due to the economic challenges and the requirement for expert knowledge. Nonetheless, based on the benefits identified by participants in the web-based survey, maps produced using geomatics tools could be extremely useful during the risk and hazard assessment process. Additionally, geomatics technologies could be used to engage and empower communities and can contribute to sustainable hazard mitigation efforts. However, it appears that disaster managers may not be well informed about geomatics and there is a need for improvements in the ways information is distributed to them.

The following case study emerged while preparing the emergency response plan maps for the Rural Municipalities (RMs) of Headingley, Cartier and St. Francois Xavier in Manitoba. I begin by introducing the study area and providing a user profile, followed by explaining the needs analysis that led to the use of a level 1 integration and remote sensing tools to prepare the image based maps. This decision-making process is further analyzed to develop criteria for practitioners to use when selecting the most appropriate geomatics technologies in specific disaster management scenarios. Since geomatics tools have the ability to provide information that is critical to risk and hazard assessment it is important to consider using geomatics within a participatory risk and hazard assessment process that values local knowledge and increased community participation. Finally, the case study concludes with an evaluation of the specific project outcomes.

Background

On June 22, 2007, a severe tornado struck the rural town of Elie, Manitoba (population approximately 550). This tornado was later reported as the first known F5 tornado in Canada (Canadian Press, 2007; Manitoba Community Profiles, n.d.). Immediately after the tornado passed through the community, the emergency plan was implemented.[5] Fortunately, the implementation of the plan was successful, a response operation was undertaken and no injuries or deaths resulted from the tornado. However, a need for amendments and improvements to the plan was identified. All the important information was there, but first responders encountered several issues in that some of the information was not current or easily accessible, and no quick reference maps were available. As such, the emergency responders were required to rely exclusively on local knowledge for navigation and situational awareness (N. Tchir, Elie Tornado presentation, Emergency Coordinator's Workshop, November 7, 2007). This was especially a problem since many outside response workers came to the community to help, and these workers had limited knowledge of the local context.

As a result of the issues identified with the plan, Norman Tchir, the emergency coordinator for the RMs of Headingley, Cartier and St. Francois Xavier, undertook a review, and was responsible for updating the emergency plans for several of Manitoba's rural municipalities. Within this context, my responsibility to the project was to address the lack of maps. The final outcome of my work was a set of maps that became part of the emergency plan for each RM. These maps were produced using historical aerial photographs within the context of a level 1 geomatics integration.

[5] In Manitoba, in order to comply with the Emergency Measures Act, each RM must have an up-to-date emergency plan that is approved by the Manitoba Emergency Measures Organization (EMO) (Manitoba EMO, n.d.; Manitoba Laws, 2008)).

INTEGRATING GEOMATICS INTO EMERGENCY PLANNING

User profile

The study area, maps of which are presented in Appendix I, consists of the RMs of Headingley, Cartier, and St. Francois Xavier. These RMs are located west of the City of Winnipeg, along the Trans-Canada Highway and the Assiniboine River, in Manitoba, Canada (the approximate centre of the study area is 49° 54' 00" N, 97° 40' 00" W or 49.9° latitude, -97.67° longitude). The three municipalities contain approximately 833 km^2 (205 840 acres) of primarily agricultural land, but due to their proximity to Winnipeg, each RM also includes several small communities and towns (Manitoba Community Profiles, n.d.). Similar to most RMs in Manitoba, the budget for disaster management and emergency planning is limited and disaster management is given a lower priority than critical municipal services such as garbage collection, snow clearing, and the delivery of other municipally funded services (N. Tchir, personal communication, March 8, 2008). Based on practitioner comments in the web-based survey, this situation is fairly typical. Also, as expressed by Mr. Tchir, "most of Manitoba's Rural Municipalities have limited mapping in their emergency plans, but it is something they are looking to enhance" (N. Tchir, personal interview, November 28, 2007). However, the community decision makers have limited geomatics capacity and limited access to geospatial data and based on my conversations, it seems that no community in Manitoba has yet integrated geomatics into the preparation of its emergency plans.

In most jurisdictions in Manitoba, the preparation of the emergency plan is the responsibility of an emergency coordinator who works closely with both the elected municipal council and the municipal staff. Mr. Tchir is a 'typical' emergency coordinator and from a demographical and geomatics knowledge perspective, he can be grouped with the majority of practitioner respondents to the web-survey. His time is divided between several municipalities, which also seems common and one survey participant noted that the emergency coordinator position in their community is staffed on a part-time basis because the municipal council does not realize the importance of the mandate (Anonymous Practitioner, Question 49, Practitioner Survey).

Needs analysis

For this project Mr. Tchir requested a map that could be included in the amended emergency plans for the RMs of Headingley, Cartier, and St. Francois Xavier. As there is currently no standard format for emergency plan maps in Manitoba and not every plan includes a map, the format only needed to suit the specific project and the user needs. Thus, when Mr. Tchir and I first discussed my involvement in this project and the production of maps for the emergency plans, several possible geomatics solutions immediately came to mind. However, while it might have been extremely useful to develop a GIS database to integrate digital maps of the area with the ability to query parcel information, I quickly understood that such a solution would be inappropriate from a user perspective. Accordingly, this case shows that before working to implement geomatics, it is important to undertake a user needs analysis. This needs analysis can be conducted in two parts. First, it is necessary to determine the geomatics integration level. Next, one can establish a list of the geomatics tools likely to provide the best results under the project circumstances.

In this instance, the decision process for determining the ideal geomatics integration level was straightforward. The geomatics taxonomy indicates that a Level 1 or

Level 2 integration is best suited for activities within the preparedness phase of the disaster management cycle. Furthermore, the user had specific map format requirements, limited geomatics knowledge, a specific use for the map, and limited access to existing data. Based on these criteria, a Level 1 geomatics integration was determined to be most suitable. This decision was based primarily on the user's limited geomatics capacity and the required map format. Specifically, most of the decision makers (emergency plan users) have limited experience with GIS, and further to that, the budget allocated for this project is not sufficient to construct a GIS, nor is any money allocated to fund ongoing maintenance (N. Tchir, personal communication, September 12, 2007). Furthermore, the maps needed to be accessible to all users, no matter their location. The emergency plans are traditionally kept in easily transportable binders that decision makers – the Royal Canadian Mounted Police (RCMP), the RM municipal offices, and all municipal councilors – carry with them (particularly while on vacation or away from a computer) in order to have access to the information necessary for initiating emergency procedures. As such, any maps produced for this project needed to be in a format suitable for these binders (N. Tchir, personal communication, September 12, 2007). In addition, the maps needed to provide the information that decision makers require to make decisions during all phases of the disaster management cycle.

In this case study, the integration level was based primarily on an analysis of the user knowledge level and format specifications, taking into account the requirement for expert knowledge, and the physical and organizational challenges. As such, even though cost was ranked as the most significant challenge by web-survey respondents, it is not necessarily a significant factor in determining the integration level. Rather, cost becomes more significant when deciding which geomatics tools to use.

The decision about which geomatics tool(s) would provide the best results for the project was approached in a similar manner. In this particular case study, the decision to use a Level 1 integration meant that the technology choice was limited to either GPS or RS. Since the desired project outcome was a set of maps, the best geomatics tool in this case was RS; specifically, an image map based on either aerial photography or satellite imagery. A map produced with RS tools is ideal for such a project, since many of the web-survey participants commented that a view from the sky puts things into perspective and that often "a picture is worth a thousand words." Related to this, Mr. Tchir requested that the maps for the RMs' emergency plans should have a pictorial background because images add a visual component to the plan. He explained that an image showing the ground features, such as buildings, rivers, roads, trees, and other potential hazards, would provide an idea of the best way to access specific areas and would facilitate emergency planning. For example, first responders must approach an ammonia leak from the up-wind direction. A pictorial map can be used to determine whether this is possible and the route that can best support vehicles. This type of information is especially important in a rural setting because access is often seasonally dependent (N. Tchir, personal interview, November 28, 2007). Additionally, an image-based map can clarify, simplify, and enhance the written components of each plan and allow for the removal of several sections of text from the plans. This is desirable because "as soon as something is written down, there is interpretation required. Maps allow for visualization and it is much easier to use a picture or map to explain something" (N. Tchir, personal interview, November 28, 2007).

Project outcome

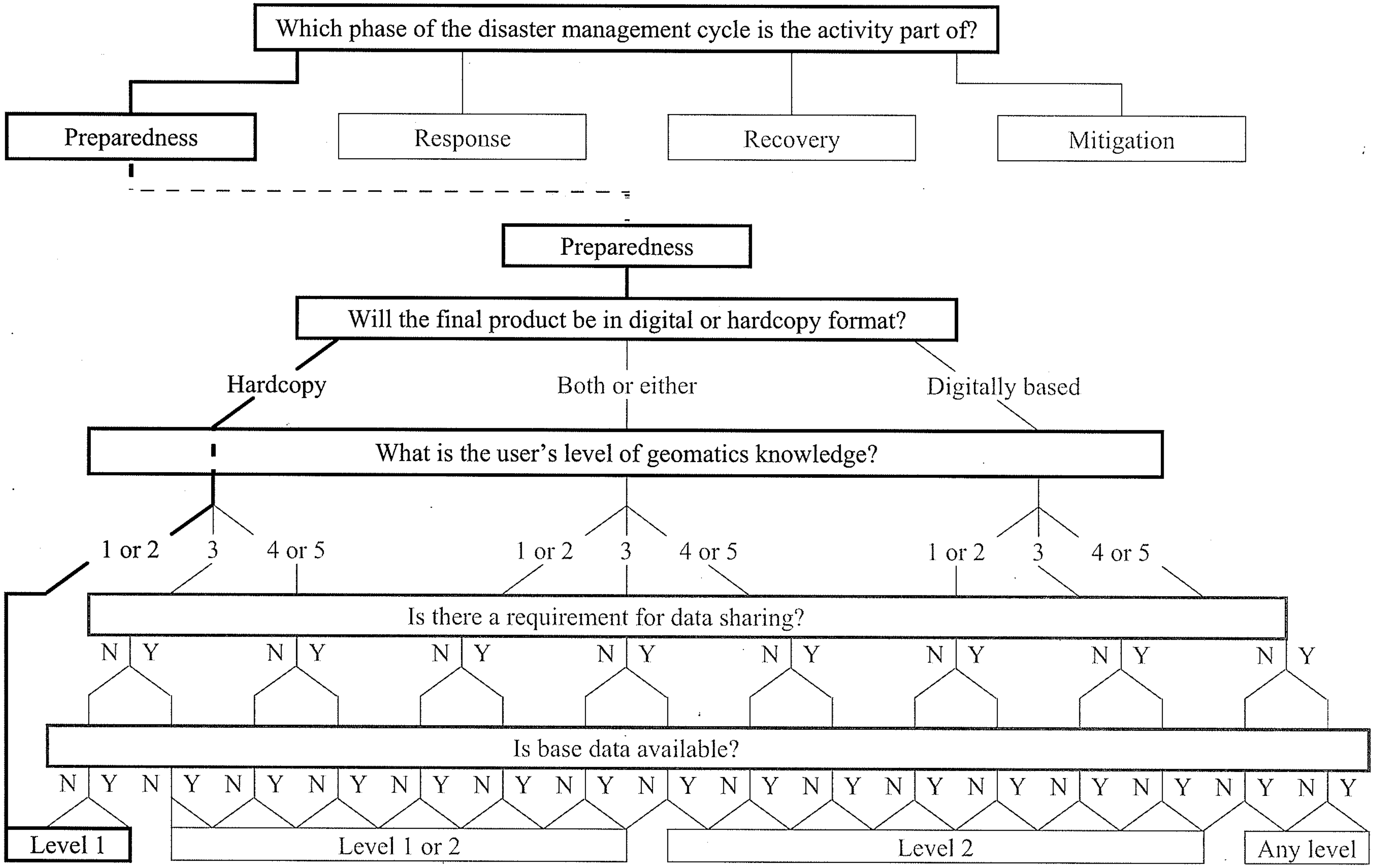
The objective of this case study is to develop criteria for practitioners to use when selecting the most appropriate geomatics technologies in specific disaster management scenarios. However, this project also involved the selection of a specific geomatics tool to produce emergency plan maps. Indeed, many RS tools can be used to produce emergency plan maps. For example, historical and new aerial photographs, photographs from an Unmanned Aerial Vehicle (UAV), satellite imagery from IKONOS, Quickbird, Spot, Landsat 7, and National Oceanic and Atmospheric Administration (NOAA) satellite sensors all provide images of various levels of detail, and the project area can be viewed with open-source software such as Google Earth. While all of these options were evaluated, historical aerial photography was used to produce a set of maps for each of the three RMs emergency plans. The decision to use historical aerial photography was based on a more detailed needs analysis within respect to each of the challenges for the use of geomatics in disaster management. The main reasons for choosing historical photographs included their extremely low cost (free), the absence of cultural challenges, and the adequate resolution. The decision-making process, along with a discussion of the advantages and disadvantages of each of the potential imagery sources, is provided in Appendix C. A reduced version of the final maps produced for this project is included as Appendix I.

INTEGRATING GEOMATICS INTO DISASTER MANAGEMENT

The taxonomy and survey results indicate that geomatics can be used in any phase of the disaster management cycle. However, without previous experience in geomatics, it may be difficult to determine the best configuration for a particular project or user. Fortunately, the manner in which the geomatics integration level and geomatics tools were chosen for the emergency preparedness case study might provide a basic template for practitioners. Indeed, the process that was developed while undertaking the user needs analysis for this project could be used by any emergency manager to determine the most appropriate integration level and technologies required within any phase of the disaster management cycle.

Figure 11 is a flowchart that lays out the decision-making process used to determine the geomatics integration level for emergency preparedness. The path taken to reach the conclusion that a Level 1 integration was appropriate for the user in this case study is marked by a heavy black line.

Figure 11: Decision flowchart



As previously noted, even though web-survey respondents consider economic factors to be the most significant challenge for the use of geomatics in disaster management, economics were not a major factor in this decision. Rather, it seems that when making a decision regarding the level of geomatics integration, it is more important to pose questions to ensure that the integration will provide desirable results, be appropriate for the user's knowledge level, and facilitate the work that needs to be done.

In this case the user was implementing geomatics for the first time and as noted by many scholars, including Obermeyer and Pinto (2007), successful implementation of technology requires that it be technically valid, appropriate for the organization, and effective. Using these guidelines helps to ensure that the technology will be used (which is the definition of a successful integration for some) and that it will provide benefits. It must be noted that successful implementation also depends on a number of other factors such as defined goals, sufficient resource allocation, management support, training, timelines, flexibility, and communication. However, drawing on the example of this case study, it seems that selecting a geomatics integration level based on the critical implementation factors of technical validity, appropriateness, and effectiveness is a key to a successful technological adoption.

There is no question that implementation of technology costs money. Indeed, for this case study, the RMs indicated that they wanted to spend as little as possible to obtain the information required for the emergency plan maps. However, this constraint was only part of the process in selecting the specific geomatics tool used to collect the information required and the knowledge that the technological implementation would be appropriate and provide benefits, provided a rationale for the expense. As highlighted by Obermeyer and Pinto (2007), "what at first appears to be an irrational economic decision is converted to a rational decision when the crucial factors in the implementation process are taken into account" (p. 28).

If the decision flowchart used to choose an integration level in the preparedness phase is based primarily on an analysis of organizational and physical challenges, and the user's knowledge level, is this true for the other phases? It would appear so, but a decision flowchart for the other phases would be slightly different, quite possibly more complex, and likely vary case by case. While, however, each case is unique, some questions that should be considered in different phases are outlined in *Table 27.*

Table 27: Questions to help determine integration level for other phases

Phase	**Possible questions**
Response	• Is this a multi-agency response effort? Do we want to work at the international, national, or local level? • Do others on the project team have similar capacity? • Are electricity and communication infrastructure always available? • Is automated decision making required?
Recovery	• Is the software compatible with the software used by other team members? • Are there data sharing arrangements in place? • Who is leading the rescue/recovery operation? • Is the data for the project area readily available? Is it in a useable format?
Mitigation	• Are simulating and modeling capabilities required? • Does the data provided by outside sources require further analysis or quality control checks before being integrated into the database?

Once the integration level is determined, the second part of the decision-making process regarding the choice of a specific geomatics tool is heavily dependent on the specific project circumstances. Indeed, any integration higher than level 2 will involve all three geomatics tools discussed in this thesis. Notwithstanding this, based on the preparedness example used for this case study, it is likely that the decision about geomatics tool(s) will be based more on the economic and cultural challenges for using geomatics in disaster management. (Many remotely sensed image products were evaluated for this case study; a detailed review is included in Appendix C.) However, based on the process laid out in this case study, if the integration level decision is made with consideration to the requirement for expert knowledge, and the organizational and physical challenges, the specific tools can be evaluated knowing that they will be appropriate for the project and will provide benefits such as those identified by practitioners who responded to the web survey. As such, it is important both when deciding on the integration level and when deciding which geomatics tools are appropriate, to keep in mind the words of a practitioner in the web survey:

> We are in this profession because we care about people. Anything technology has to offer to help prepare, mitigate, respond or assist in the recovery in relation to disasters is welcomed. Just don't overwhelm folks with the dazzle of the high tech tools.
>
> —Anonymous Practitioner, Question 54, Practitioner Survey

THE USE OF GEOMATICS

A participatory geomatics risk and hazard assessment approach

> Disaster management (all four stages) is best achieved by community level participation. How to best make use of the technology so that it can be used by communities to manage disaster is a challenge.
>
> —Anonymous Educator, Question 29, Educator Survey

Using geomatics tools to prepare emergency plans may only be the first step to integrating geomatics technologies into the disaster management cycle. For instance, the educator quoted above and some other academics suggest that disaster management must involve the use of local knowledge and should be undertaken using a participatory approach (Mileti, 1999; Pearce, 2003). Based on this research, it seems that geomatics technology and the development of the type of maps prepared for this project could play an important role in increasing community input and building community capacity. For example, Jordan and Shrestha's (1998) research in Nepal demonstrated that the general public was excited by a photo-type map, possibly because it was more meaningful to them than a written document, or a traditional survey or sketch map. As such, in the sections below, I reflect critically on how geomatics might contribute to disaster management by facilitating the use of local knowledge and providing opportunities to increase community participation.

Local knowledge

There has been much debate regarding the role of citizens in disaster management, particularly in emergency preparedness and response, amongst practitioners in the International Association of Emergency Managers (IAEM) discussion group (IAEM, n.d.). Many practitioners believe that because the average citizen is not trained or authorized, their involvement should be limited within the disaster management process. Others are more realistic and recognize that local people have knowledge and access to information that the practitioners may not have. Indeed, the participation of citizens and more specifically, local knowledge, is critical to all phases of disaster management.

What is local knowledge?

Local knowledge is information about a specific geographic region that is held by residents of that region. Most local residents have detailed knowledge of the risks and hazards affecting their community (Wisner and Luce, 1995). When this knowledge is used to *empower communities* it can benefit both the community and disaster management practitioners (Beilin and Boxelaar, 2003). In this instance the definition of empowerment is taken from critical theory to mean a situation in which community members "participate in the construction of meaning, and create their own practices" (ibid, p. 7).[6] Thus, in order to be empowering, any disaster management actions must directly involve community members so that they may take control of their lives (Lincoln and Guba, 2003). Such actions must also work towards improving quality of life, disaster resiliency, community vitality, and environmental quality, and build equity between men and women, youths and adults, and people from different classes (Mileti, 1999). Under these circumstances local knowledge informs expert knowledge, and practitioners must remember that every resident has something to offer, whether it is information about hazards, vulnerabilities, or assets, and it is important to integrate this knowledge to improve disaster management.

An example of the use of local knowledge

A simple example of the use of local knowledge was provided by Mr. Kenton Friesen, the emergency coordinator for the University of Manitoba, during a class lecture (U of M, NRI 7320 lecture, March 19, 2007). Mr. Friesen presented his approach to improving emergency planning at the University of Manitoba by incorporating the knowledge of staff and students into the hazard identification and response planning process. To help him plan for hazard events, he was asking staff and students what they considered the risks and hazards to be. Mr. Friesen recognized that he was not personally aware of all the potential hazards (both real and perceived) and that the people who spend time on campus are a valuable source of information. He believed that incorporating local knowledge would allow him to do his job better.

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[6] Critical theory is a social theory, oriented towards critiquing and changing society as a whole.

Increasing community participation with geomatics

Disaster management experts, such as Cutter (2006), Mileti (1999), and Pearce (2003), are calling for a 'bottom up', people-focused approach that engages communities in the disaster management process. Based on my research, it appears that geomatics has the potential to enhance community participation. For example, maps similar to the ones prepared as part of this research project have been successfully used to provide aerial views of the land to, and solicit feedback from, local residents during forestry and resource management participatory mapping projects in Nepal (Jordan and Shrestha, 1998). Indeed, the maps themselves and the use of remote sensing and other geomatics technologies piqued community interest, and encouraged and facilitated local input. This increase in community participation suggests that the use of geomatics could help to mitigate the problem of community indifference towards disaster management (Marincioni, 2007). Indeed, the use of participatory GIS approaches, where community residents are given the opportunity to communicate with experts through the use of spatial data, maps, and GIS tools, is also gaining momentum in many fields (Kienberger, 2007). The use of geomatics to engage the public in the disaster management process could facilitate a movement towards a community-based approach and to shift the process from the hands of experts and disaster management practitioners to the community, thus empowering local people to participate in the emergency plan preparation process.

Participatory hazard assessment: A geomatics approach

If geomatics can successfully engage community members in the disaster management process, then it may be beneficial to examine its use within a community-based participatory risk and hazard assessment approach. Each emergency plan prepared in Manitoba contains a hazard and risk analysis component, which is completed using an all hazards approach in conjunction with the United States Federal Emergency Management Agency (FEMA) model for risk and hazard assessment (S. Napier, personal communication, November 7, 2007). An example of a generic hazard analysis is shown in *Table 28*. Emergency coordinators in Manitoba use this analysis to help develop the emergency plans. They review each item on the list and assign it a value between 0 and 5 depending on the likelihood of that particular event occurring in the community.

Table 28: Example of a typical 'Hazard Analysis Worksheet'

Hazard Analysis Worksheet

Rankings of community disaster probability
0 – Not applicable to my community
1 – Not probable
2 – Low probability
3 – Moderate probability
4 – High probability
5 – Nearly certain

Blizzard or Massive Snowstorm	0	1	2	3	4	5
Chemical Contamination or Spill	0	1	2	3	4	5
Dam Break	0	1	2	3	4	5
Drought	0	1	2	3	4	5
Electrical Power Blackout	0	1	2	3	4	5
Epidemic	0	1	2	3	4	5
Flash Flood	0	1	2	3	4	5
Forest or Bush Fire	0	1	2	3	4	5
Freezing Ice Storm	0	1	2	3	4	5
Major Frost and Freeze	0	1	2	3	4	5
Major Gas Main Break	0	1	2	3	4	5
Major Hail Storm	0	1	2	3	4	5
Major Industrial Explosion	0	1	2	3	4	5
Major Water Main Break	0	1	2	3	4	5
Massive Automobile Wreck	0	1	2	3	4	5
Meteorite Fallout	0	1	2	3	4	5
Mud or Landslide	0	1	2	3	4	5
Oil Spill	0	1	2	3	4	5
Pipeline Explosion	0	1	2	3	4	5
Plane Crash in Community	0	1	2	3	4	5
Radiation Fallout	0	1	2	3	4	5
River Flood	0	1	2	3	4	5
Sand/Dust Storm	0	1	2	3	4	5
SARS	0	1	2	3	4	5
Severe Fog Episode	0	1	2	3	4	5
Smog Episode	0	1	2	3	4	5
Sudden Waste Disposal Problem	0	1	2	3	4	5
Tornado	0	1	2	3	4	5
Water Pollution	0	1	2	3	4	5
Water Shortage	0	1	2	3	4	5

Emergency coordinators use this worksheet to obtain an idea of the risks and hazards that need to be addressed in each emergency plan. However, it may be beneficial to also use a map so that visual or spatial components may be incorporated into the assessment. For instance, the use of a map would provide additional information important to emergency planning, such as the relative/spatial location of risks and hazards to people and infrastructure, access/egress route alternatives, and information about the type of structures potentially affected by hazard events.

Furthermore, if a local knowledge component is integrated into the map, the emergency plan could better reflect community priorities. For example, maps could include information known by local residents, such as hazardous chemical storage facilities, other local hazards, and important community infrastructure for which specific emergency planning might be required. Additionally, the maps provide an opportunity for emergency coordinators to communicate with the public and to visually depict meeting places or escape routes to community residents in an easy-to-understand format.

CASE STUDY CONCLUSIONS

> The maps we prepared for this project are unique, no other emergency plan in Manitoba will have maps with this much detail.
> —N. Tchir, personal interview, November 28, 2007

The level 1 geomatics integration framework adopted for the case study provided a supportive context for successfully using remote sensing tools to produce a set of photo maps that have become part of the emergency plans for the RMs of Headingley, Cartier, and St. Francois Xavier. A copy of the maps that were produced for this project are included as Appendix I. Due to economic considerations, these maps were prepared using historical aerial photographs freely available to any disaster management practitioner in

Manitoba. It is likely that similar imagery could be obtained in other jurisdictions and used to produce maps for their emergency preparedness plans. Access to aerial photography and archive satellite imagery is relatively inexpensive and widespread, even in developing countries. For example, the Government of Canada maintains the National Air Photo Library, while the provinces of Alberta and Manitoba maintain their own aerial photography archives, too. Similarly, Jordan and Shrestha (1998) used information from the country-wide aerial photographs collected by the local Department of Survey in Nepal to undertake their research.

A level 1 integration and production of the photo-based maps are an appropriate project outcome in this case and were a good introduction to geomatics tools for all users involved in this project. They were not overwhelmed by the technology and the application was appropriate for their skill level. As such, it is likely that they may be willing to adopt other technologies and build on this example in future projects.

While the use of specific geomatics tools depends heavily on economic and project circumstances, an appropriate integration level can be determined based primarily on the requirement for expert knowledge, and physical and organizational challenge factors. This approach establishes the foundation for a successful technology implementation.

The research also demonstrates that geomatics can be used as a tool to incorporate local knowledge into the disaster management process and can engage communities in emergency planning. Therefore, a geomatics approach provides an opportunity for practitioners to set priorities for protecting life and infrastructure in a manner consistent with community priorities and values.

8. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to explore the use of geomatics in disaster management. Specifically, I set out to: 1) demonstrate how geomatics is currently used in disaster management, 2) evaluate the current use of geomatics in disaster management, and determine whether there is a disconnect between practice, education, and software/hardware development, 3) develop criteria for determining the most appropriate geomatics technologies to obtain the information required for disaster management, and 4) outline recommendations for practitioners to incorporate a participatory geomatics risk and hazard assessment process that values local knowledge and increases community participation in disaster management. This research was successful and all the objectives established at the outset were addressed.

CONCLUSIONS

In Chapter 4, I demonstrated that geomatics is being used in all phases of the disaster management cycle, and based on examples found in the academic literature I developed a geomatics-disaster management taxonomy. The taxonomy reveals that lower level integrations are ideally suited for preparedness activities and there are several examples of successful use of most integration levels. However, high-level integrations that would be most beneficial in a multi-agency emergency response are not well documented. Nonetheless, this taxonomy may enable disaster management practitioners to identify successful uses of geomatics technology and could serve as a guide for selecting a technology configuration that matches their requirements, circumstances, and applications. The taxonomy will be particularly useful to disseminate information to practitioners. For example, it might allow practitioners who would like to use geomatics for the first time to benefit from the experience of others and quickly learn about successful geomatics uses.

The web-based surveys designed for this research were useful tools to collect new information regarding the use of geomatics technologies directly from practitioners and educators involved in disaster management. Based on the web-survey results, both educators and disaster management practitioners have mixed feelings about increasing the use of technology in this field. For example, survey participants highlighted the many potential benefits of technology, such as enhancing communication, improving situational awareness, and helping visualize and understand the full extent of a problem or situation. However, many respondents also noted that technological solutions are often expensive, there is a risk that practitioners could become over-dependent on it, it is subject to outages, and stressed that it could remove the human element from decision making or reduce face-to-face interactions.

The objective of the web-survey was to evaluate the current use of geomatics, and determine whether there is a disconnect between practice, education, and software/hardware development. To accomplish this, the web-survey questions were set up to address four goals: 1) to determine what educators and disaster management practitioners know about geomatics technologies, 2) to determine whether disaster management programs offer instruction in the use of geomatics technologies; 3) to determine if/how geomatics is currently used in disaster management, the benefits for doing so, and the challenges to implementing it; and 4) to determine the importance of disaster management to the manufacturers of geomatics technologies.

The results demonstrate that most educators and practitioners working in the disaster management field only have limited knowledge of geomatics. However, despite this, practitioners are still using it and educators are including it in educational programs. In addition, both groups believe that it should continue to be part of these programs. The web-survey results also highlight that the use of geomatics is more common than disaster management practitioners think, which suggests there is a need for improvements in the ways in which information is distributed to practitioners. It also appears that geomatics is useful in all phases of the disaster management cycle and there are benefits to using it, such as improvements in situational awareness, navigation, and visualization capabilities. Despite this, the results suggest that RS is the least-used technology and practitioners consider it the least useful of the three technologies even though aerial or satellite photos that might provide a picture of an area are readily available, often at a nominal cost. The web-survey results also re-affirm the challenges for the use of geomatics in disaster management which include economic, organizational, cultural, and hardware/software challenges. However, the web-survey results suggest that even though the economic challenges are considered to be the most significant, the need for expert knowledge is hindering the use of geomatics, and other technology, in this field.

The results provide evidence of a disconnect between education, practice, and software development. Although software developers did not respond to the survey and it is impossible to determine the importance they place on disaster management, other participants believe that the technological solutions currently available do not meet the needs of educators or practitioners. For example, the results indicate that even though they do not have a high level of knowledge of geomatics practitioners want to use it but often the solutions available are too expensive, require expert knowledge to implement, provide limited data sharing and interoperability, and may not even be the best solution in their context. Furthermore, educators find it difficult to keep current with technology and are unable to determine which software should be used in educational programs. Additionally, because the use of technology in practice is so variable, it seems difficult for educators to establish teaching priorities to ensure that future disaster managers are prepared to use technology in this field.

The case study worked to incorporate the knowledge obtained from the taxonomy and respondents to the web-survey into an operational emergency plan in a way that met the needs of the practitioners and the communities involved. The case study provided an opportunity for me to work alongside an emergency coordinator on a 'real-world' problem and demonstrated that RS and other geomatics techniques can be incorporated into the emergency plan development process. The project outcome of the case study was a set of emergency plan maps that became part of the emergency plan for the RMs of Headingley, Cartier, and St. Francois Xavier.

My work on the emergency plan and the decision making process used to determine the most appropriate technologies to obtain the information required for emergency preparedness, enabled me to develop criteria for determining the most appropriate geomatics technologies to obtain the information required for disaster management. The work on this project demonstrated that, while the use of specific geomatics tools depends heavily on economic and project circumstances, an appropriate geomatics integration level can be selected based primarily on the requirement for expert knowledge, and physical and organizational challenge factors. This approach might better establish the foundation for a successful technology implementation.

This research also uncovered a potential opportunity to use geomatics to engage community members and incorporate public perspectives into disaster management activities. Indeed, the participatory geomatics risk and hazard assessment approach could be used to engage citizens in the disaster management process and assist practitioners in developing plans that reflect community priorities and values.

Recommendations

Geomatics solutions for disaster management practitioners are available and practitioners who are using geomatics are realizing the benefits. However, not all practitioners are well versed or willing to adopt this technology. As such, to encourage further use, solutions must be tailored specifically to practitioners' needs and developed from the perspective of practitioners. I recommend that a user-needs assessment be undertaken before developing solutions to disaster management problems, and it is important for software developers to be aware that most disaster management professionals are not geomatics experts who would like a simple tool to interface with the data they require to make decisions.

A participatory geomatics risk and hazard assessment approach could contribute to sustainable hazard mitigation by integrating community perspectives. A potential use of this approach by practitioners is to display a simple image-based map at a town hall or emergency planning meeting. Based on results from other professions, it is likely that using geomatics would excite the communities and could increase community participation, which in turn would lead to better planning, mitigation, response, and recovery. Research into the actual use of a geomatics approach to participatory risk and hazard assessment would be very interesting and could provide disaster management practitioners with valuable information.

As the use of technology increases throughout society, those working in disaster management must work to keep up. Local people with GPS-enabled cell phones and cameras could be an important asset to emergency managers. As such, it is important for the disaster management community to embrace the use of technology and to seek input from others when incorporating technology into their field.

Further study in this area

> Remote data acquisition of all kinds will grow in importance. High-resolution satellite photography and mapping may be accessible more widely, as will relatively inexpensive automated low-altitude aerial-monitoring platforms. The importance of GIS is also likely to grow, but its technology may also become incorporated relatively invisibly into other applications. The combination of remote sensing, improved communications and possibly tracking technologies, may eventually be used more in complex emergencies to assist with security planning, and provide more rapid emergency assistance to relief workers.
> —Stephenson and Anderson, 1997, p. 323

This quote summarizes Stephenson and Anderson's (1997) idea of the future of geomatics technology in disaster management, however, even though the use of geomatics has increased immensely since the time of their article, there are still opportunities for investigating further uses in this field. During the course of this research, I noted several opportunities for research specifically related to geomatics and disaster management. These include research into the use of GIS and satellite imagery to build hazard data archives, as well as research that explores how to establish policies and procedures for the use of geomatics, how to establish a data-sharing methodology or a standard data format for easy storage of large quantities of data, and how to develop a legal framework for the use of spatial data in disaster management.

REFLECTIONS

Although this research was successful, there are several aspects that I would do differently if conducting this research again. For example, in each section of the survey, I asked respondents to identify the countries in which they used each of the geomatics technologies. These questions did not generate useful information and, based on the respondents' comments, some participants may have become frustrated by these questions and exited the survey before finishing. In hindsight, these questions should not have been included. I also noted that each time participants were asked to select all applicable items from a long list of choices (e.g. Educator Survey Question 23, Practitioner Survey Questions 8, 20, 32, and 47), the item at the top of the list received the largest number of responses. This could be a coincidence because the choices placed at the top of each list are legitimate choices, however, in future survey instruments I might vary the choice placement.

I was very encouraged by the number of survey participants who indicated that they were interested in further study, and I spent a significant amount of time developing a follow-up questionnaire designed to provide additional information about the use of technology in disaster management. However, of the 54 practitioners who expressed interest, only 2 answered my additional questions and, as such, I was unable to incorporate the follow-up data into the research results.

In questions 17, 29, and 41 on the Practitioner Survey, I asked participants to outline the benefits of using each geomatics technology. The wording of this question may have been presumptuous and implied that there are actually only benefits. The wording choice may have influenced or biased the results. It is feasible that those who have not experienced benefits skipped this question or felt uncomfortable suggesting that there are none. Additional attention to the question wording could have resolved this issue.

Finally, I did not define 'technology.' As pointed out to me by one respondent, technology could mean anything from the use of a wheel to the development of a GIS database that incorporates GPS, video, and RS technologies. A specific definition of what was meant by technology in the context of this research may have been helpful for some participants.

This research project, and in particular its application to the case study involving the RMs of Headingley, Cartier, and St. Francois Xavier, was worthwhile and timely in that it benefited the communities involved. The amended emergency plans for the RMs of Headingley, Cartier, and St. Francois Xavier, which included the maps prepared as part of the case study portion of this research, were approved in early 2008 by the municipal council and are now officially part of their emergency plans. Additionally, I spoke with other emergency coordinators in Manitoba who were interested in the mapping and geomatics approach taken as part of this project, thus potentially influencing the development of future emergency plans and emergency planning for all municipalities in the province.

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APPENDIX A: SURVEY RESEARCH OBJECTIVES AND INSTRUMENTS

A.1 EDUCATOR SURVEY – RESEARCH OBJECTIVES

- With respect to the use of geomatics, is there a disconnect between what is taught at educational institutions and what is occurring in practice?
- What do instructors at educational institutions with disaster management programs think about the use of technology in emergency/disaster management?
- When teaching geomatics, on which phase of the disaster management cycle do educators focus?
- How many educational institutions offering emergency/disaster management programs offer instruction in the use of geomatics technologies?
- In which technologies do students attending educational institutions offering emergency/disaster management programs receive instruction/training?
- Do educators believe their program enables students to become experts in the use of geomatics technologies?

A.2 PRACTITIONER SURVEY – RESEARCH OBJECTIVES

- What do emergency/disaster management practitioners think about the use of technology in emergency/disaster management?
- Is there a disconnect between practice, teaching at educational institutions offering emergency/disaster management programs, and software developers with respect to the use of geomatics in emergency/disaster management?

- In what circumstances is geomatics used for emergency/disaster management?
- Are there benefits to applying geomatics to emergency/disaster management?
- Are the current geomatics products available for use in emergency/disaster management adequate?
- How many practitioners currently use geomatics?
- Are there practitioners who are interested in the possibility of future study?

A.3 Software Developer Survey – Research Objectives

- In which phase(s) of the disaster management cycle can the hardware/software products be used?
- Are the products currently available 'off-the-shelf' adequate for use in emergency/disaster management?
- What do software developers think about the use of technology in emergency/disaster management?
- How many manufacturers/developers create hardware/software products that can be used in emergency/disaster management activities?
- Is there a disconnect between the use of geomatics in practice and the companies developing these tools?

A.4 Educator Survey Instrument

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 1 - Introduction

Thank you for participating in the technology in emergency/disaster management education survey. Your knowledge and opinions are important, and will be used for academic research related to the use of technology in disaster management.

To receive a copy of the survey results, please e-mail: scott_westlund@umanitoba.ca

1. What level of emergency/disaster management courses are offered at your institution?
(please check all that apply)

- ☐ Stand-alone certificate or diploma
- ☐ Bachelor's level
- ☐ Master's level
- ☐ Doctoral level
- ☐ Other (please specify)

2. In which country is your institution located?

Please consider the following statements and select the level of agreement that most closely represents your opinion.

3. Currently, technology plays an important role in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

4. In the future, the use of technology in emergency/disaster management will become increasingly important.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 2 - GIS Technology in Emergency/Disaster Management Education

The questions in this section will help us determine which technologies are included in the curriculum at educational institutions offering courses in emergency/disaster management.

5. Do any of the courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Geographic Information Systems (GIS)?

- ◯ Yes
- ◯ No

If you select 'No', you will be directed to question 9.

Section 2 - GIS in Emergency/Disaster Management Education

6. When teaching Geographic Information Systems (GIS), what priority is placed on each phase of the disaster management cycle?

	No Priority	2	3	4	High Priority	Don't Know
Response	◯	◯	◯	◯	◯	◯
Recovery	◯	◯	◯	◯	◯	◯
Mitigation	◯	◯	◯	◯	◯	◯
Preparedness	◯	◯	◯	◯	◯	◯

7. Please rate the level of GIS expertise that graduates gain from your program.

	No Expertise	2	3	4	Experts	Don't Know
Expertise Scale	◯	◯	◯	◯	◯	◯

8. GIS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	◯	◯	◯	◯	◯	◯	◯	◯

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 2 - GPS Technology in Emergency/Disaster Management Education

9. Do any of the courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Global Positioning System (GPS) technology?

○ Yes
○ No

If you select 'No', you will be directed to question 13.

Section 2 - GPS in Emergency/Disaster Management Education

10. When teaching Global Positioning System (GPS) technology, what priority is placed on each phase of the disaster management cycle?

	No Priority	2	3	4	High Priority	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

11. Please rate the level of GPS expertise that graduates gain from your program.

	No Expertise	2	3	4	Experts	Don't Know
Expertise Scale	○	○	○	○	○	○

12. GPS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

Section 2 - RS Technology in Emergency/Disaster Management Education

13. Do any of the courses offered as part of the emergency/disaster management program at your institution include instruction on the adoption, implementation, or application of Remote Sensing (RS) technology (e.g., aerial photographs or satellite images in printed or digital format)?

○ Yes
○ No

If you select 'No', you will be directed to question 17.

Section 2 - RS in Emergency/Disaster Management Education

14. When teaching Remote Sensing (RS) technology, what priority is placed on each phase of the disaster management cycle?

	No Priority	2	3	4	High Priority	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

15. Please rate the level of RS expertise that graduates gain from your program.

	No Expertise	2	3	4	Experts	Don't Know
Expertise Scale	○	○	○	○	○	○

16. RS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 2 - Other Technologies

17. Please list any other technologies that are part of your institution's emergency/disaster management courses.

18. In your opinion, what hinders the use of technology in emergency/disaster management?

Section 3 - Geomatics in Emergency/Disaster Management

Geomatics is the science of gathering, analyzing, interpreting, distributing, and using geographic information to help understand the earth and our location on it. Geomatics includes the use of the global positioning system (GPS), geographic information systems (GIS), and remote sensing (RS).

The questions in this section relate specifically to geomatics technologies and are designed to solicit your opinion on the use of GPS, GIS, and RS in emergency/disaster management.

19. Please rate your current level of knowledge of geomatics technologies.

	No Knowledge	2	3	4	Expert	Don't Know
Knowledge Scale	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 3 - Geomatics in Emergency/Disaster Management

20. All disaster/emergency management programs should include courses that provide instruction in the use of GIS, GPS, and RS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

21. Please select the statement that most closely represents your opinion on the use of geomatics in emergency/disaster management.

- ○ Geomatics is widely used in emergency/disaster management
- ○ Geomatics use is not common in emergency/disaster management
- ○ Geomatics is currently not used in emergency/disaster management
- ○ Geomatics will never be used in emergency/disaster management
- ○ Don't know

22. Please select the statement that most closely represents your opinion on the application of geomatics technologies in emergency/disaster management.

- ○ It is easy to apply geomatics technologies in emergency/disaster management
- ○ It is challenging to apply geomatics technologies in emergency/disaster management but it can be done
- ○ Right now, it is too difficult to apply geomatics technologies in emergency/disaster management
- ○ It is impossible to apply geomatics in emergency/disaster management
- ○ Don't know

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 3 - Challenges for Using Geomatics in Emergency/Disaster Management

23. Of the following, which do you consider to be the most significant challenges for integrating geomatics technologies into emergency/disaster management? (please check all that apply)

- [ ] Communication between departments/agencies, etc.
- [ ] Data quality and accuracy
- [ ] Lack of data
- [ ] Too much data available
- [ ] Unable to acquire data quickly
- [ ] Cost of equipment (hardware)
- [ ] Cost of software
- [ ] Cost to collect data
- [ ] Technical issues
- [ ] Geomatics technology is too complex
- [ ] Existing software is not adequate for emergency/disaster management
- [ ] Existing hardware is not adequate for emergency/disaster management
- [ ] Expert knowledge is required
- [ ] Legal framework for the use of geomatics in emergency/disaster management does not exist
- [ ] Lack of communications or other infrastructure (phone, internet, electricity)
- [ ] No standards or procedures in place outlining the use of geomatics in emergency/disaster management
- [ ] Don't know how to use geomatics technologies
- [ ] There are no benefits to using geomatics in emergency/disaster management
- [ ] Other (please specify)

24. Of the challenges you selected above, please rank the top three challenges (with 1 as the most significant challenge).

1.

2.

3.

The Use of Technology in Emergency/Disaster Management - Educator Survey

Section 4 - Demographics/Conclusion

25. Are you interested in participating in future studies? If so, please provide a contact email address. (This will not result in unsolicited e-mail. See Privacy Policy.)

26. In which of these groups is your age?

- ○ Under 30
- ○ 30 to 44
- ○ 45 to 65
- ○ 66 or older

27. What is the highest level of education that you have completed?

- ○ High school
- ○ Stand-alone certificate or diploma
- ○ Bachelor's level
- ○ Master's level
- ○ Doctoral level

28. Are you male or female?

- ○ Female
- ○ Male

29. Please use this space to provide any additional comments regarding the use of technology in emergency/disaster management.

To receive a copy of the results of this survey, please e-mail: scott_westlund@umanitoba.ca

A.5 Practitioner Survey Instrument

The Use of Technology in Emergency/Disaster Management - Practitioner Survey

Section 1 - Introduction

Thank you for participating in the technology in emergency/disaster management practitioner survey. Your knowledge and opinions are important, and will be used for academic research related to the use of technology in disaster management.

To receive a copy of the survey results, please e-mail: scott_westlund@umanitoba.ca

1. At which level do you undertake emergency/disaster management work? (please check all that apply)

- ☐ Local (first responder agency)
- ☐ Local (emergency management)
- ☐ Provincial, state, and/or regional
- ☐ National
- ☐ International
- ☐ NGO
- ☐ Other (please specify)

2. Please identify the country from which you are completing this survey.

3. Currently, technology plays an important role in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

4. In the future, the use of technology in emergency/disaster management will become increasingly important.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

5. In your opinion, what are some of the implications or changes that might result from increasing the use of technology in emergency/disaster management?

Section 2 - GIS Technology in Emergency/Disaster Management Practice

The questions in this section will help us determine which technologies practitioners use while performing emergency/disaster management activities.

6. Do you use or have you used Geographic Information Systems (GIS) in emergency/disaster management activities?

- ◯ Yes
- ◯ No

Section 2 - GIS in Emergency/Disaster Management Practice

7. Please evaluate the use of Geographic Information Systems (GIS) in each phases of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	◯	◯	◯	◯	◯	◯
Recovery	◯	◯	◯	◯	◯	◯
Mitigation	◯	◯	◯	◯	◯	◯
Preparedness	◯	◯	◯	◯	◯	◯

8. From the following list, which activities have you undertaken using Geographic Information Systems (GIS)?
(please check all that apply)

- ☐ Preparedness Planning
- ☐ Simulation and modeling
- ☐ Producing vulnerability maps
- ☐ Risk mapping
- ☐ Evacuation mapping and planning
- ☐ Predicting impact zones
- ☐ Estimating damages
- ☐ Distributing information to the media or public

- [ ] Distributing information to victims
- [ ] Allocating/coordinating resources during emergency response
- [ ] Producing maps for emergency responders
- [ ] Decision making during emergency response activities
- [ ] Disaster recovery planning
- [ ] Determining mitigation needs
- [ ] Other (please specify)

9. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1.

2.

3.

Section 2 - GIS in Emergency/Disaster Management Practice

Please consider the following statements and select the response that most closely reflects your opinion.

10. GIS software that is available 'off-the-shelf,' meets all of my emergency/disaster management needs.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

11. The GIS software that will meet all of my needs is affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

12. GIS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

13. GIS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

14. The use of GIS is critical to the success of the emergency/disaster management activities I am involved with.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

15. All emergency/disaster managers should be educated in the use of GIS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

16. In which countries have you integrated GIS into emergency/disaster management activities?
(if more than five, please list the five countries in which you have used it the most).

17. Briefly outline the benefits of using GIS in emergency/disaster management.

Section 2 - GPS Technology in Emergency/Disaster Management Practice

18. Do you use or have you used Global Positioning System (GPS) technology in emergency/disaster management activities?

- ◯ Yes
- ◯ No

Section 2 - GPS in Emergency/Disaster Management Practice

19. Please evaluate the use of the Global Positioning System (GPS) in each phases of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	◯	◯	◯	◯	◯	◯
Recovery	◯	◯	◯	◯	◯	◯
Mitigation	◯	◯	◯	◯	◯	◯
Preparedness	◯	◯	◯	◯	◯	◯

20. From the following list, which activities have you undertaken using Global Positioning System (GPS) technology?
(please check all that apply)

- ☐ Preparedness Planning
- ☐ Simulation and modeling
- ☐ Producing vulnerability maps
- ☐ Risk mapping
- ☐ Evacuation mapping and planning
- ☐ Predicting impact zones
- ☐ Estimating damages
- ☐ Distributing information to the media or public
- ☐ Distributing information to victims
- ☐ Allocating/coordinating resources during emergency response
- ☐ Producing maps for emergency responders
- ☐ Decision making during emergency response activities
- ☐ Disaster recovery planning
- ☐ Determining mitigation needs
- ☐ Other (please specify)

21. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1.
2.
3.

Section 2 - GPS in Emergency/Disaster Management Practice

Please consider the following statements and select the response that most closely reflects your opinion.

22. GPS equipment that is available 'off-the-shelf,' meets all of my emergency/disaster management needs.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

23. The GPS equipment that will meet all of my needs is affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

24. GPS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

25. GPS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

26. The use of GPS is critical to the success of the emergency/disaster management activities I am involved with.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

27. All emergency/disaster managers should be educated in the use of GPS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

28. In which countries have you integrated GPS into emergency/disaster management activities?
(if more than five, please list the five countries in which you have used it the most).

29. Briefly outline the benefits of using GPS in emergency/disaster management.

Section 2 - RS Technology in Emergency/Disaster Management Practice

30. Do you use or have you used Remote Sensing (RS) technology (e.g., aerial photographs or satellite images in digital or printed format) in emergency/disaster management activities?

○ Yes
○ No

Section 2 - RS Technology in Emergency/Disaster Management Practice

31. Please evaluate the use of Remote Sensing (RS) technology in each phases of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

32. From the following list, which activities have you undertaken using Remote Sensing (RS) technology?
(please check all that apply)

- ☐ Preparedness Planning
- ☐ Simulation and modeling
- ☐ Producing vulnerability maps
- ☐ Risk mapping
- ☐ Evacuation mapping and planning
- ☐ Predicting impact zones
- ☐ Estimating damages
- ☐ Distributing information to the media or public
- ☐ Distributing information to victims
- ☐ Allocating/coordinating resources during emergency response
- ☐ Producing maps for emergency responders
- ☐ Decision making during emergency response activities
- ☐ Disaster recovery planning
- ☐ Determining mitigation needs
- ☐ Other (please specify)

[ ]

33. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1. [ ]
2. [ ]
3. [ ]

Section 2 - RS in Emergency/Disaster Management Practice

Please consider the following statements and select the response that most closely reflects your opinion.

34. The RS products that are available meet all of my emergency/disaster management needs.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

35. The RS products that will meet all of my needs are affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

36. RS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

37. RS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

38. The use of RS is critical to the success of the emergency/disaster management activities I am involved with.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

39. All emergency/disaster managers should be educated in the use of RS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

40. In which countries have you integrated RS into emergency/disaster

management activities?
(if more than five, please list the five countries in which you have used it the most).

41. Briefly outline the benefits of using RS in emergency/disaster management.

Section 2 - Other Technologies

42. Please list any other technologies that you use in emergency/disaster management activities.

Section 3 - Geomatics in Emergency/Disaster Management

Geomatics is the science of gathering, analyzing, interpreting, distributing, and using geographic information to help understand the earth and our location on it. Geomatics includes the use of the global positioning system (GPS), geographic information systems (GIS), and remote sensing (RS).

The questions in this section relate specifically to geomatics technologies and are designed to solicit your opinion on the use of GPS, GIS, and RS in emergency/disaster management.

The Use of Technology in Emergency/Disaster Management - Practitioner Survey

Section 3 - Geomatics in Emergency/Disaster Management

43. Please rate your current level of knowledge of geomatics technologies.

	No Knowledge	2	3	4	Expert	Don't know
Knowledge scale	○	○	○	○	○	○

44. Please select the statement that most closely represents your opinion on the use of geomatics in emergency/disaster management.

- ○ Geomatics is widely used in emergency/disaster management
- ○ Geomatics use is not common in emergency/disaster management
- ○ Geomatics is currently not used in emergency/disaster management
- ○ Geomatics will never be used in emergency/disaster management
- ○ Don't know

45. Please select the statement that most closely represents your opinion on the application of geomatics technologies in emergency/disaster management.

- ○ It is easy to apply geomatics technologies in emergency/disaster management
- ○ It is challenging to apply geomatics technologies in emergency/disaster management but it can be done
- ○ Right now, it is too difficult to apply geomatics technologies in emergency/disaster management
- ○ It is impossible to apply geomatics in emergency/disaster management
- ○ Don't know

46. Do you plan to use geomatics technologies in future emergency/disaster management activities?

- ○ Yes
- ○ No

Section 3 - Challenges for Using Geomatics in Emergency/Disaster Management

47. Of the following, which do you consider to be the most significant challenges for integrating geomatics technologies into emergency/disaster management? (please check all that apply)

- [ ] Communication between departments/agencies, etc.
- [ ] Data quality and accuracy
- [ ] Lack of data
- [ ] Too much data available
- [ ] Unable to acquire data quickly
- [ ] Cost of equipment (hardware)
- [ ] Cost of software
- [ ] Cost to collect data
- [ ] Technical issues
- [ ] Geomatics technology is too complex
- [ ] Existing software is not adequate for emergency/disaster management
- [ ] Existing hardware is not adequate for emergency/disaster management
- [ ] Expert knowledge is required
- [ ] Legal framework for the use of geomatics in emergency/disaster management does not exist
- [ ] Lack of communications or other infrastructure (phone, internet, electricity)
- [ ] No standards or procedures in place outlining the use of geomatics in emergency/disaster management
- [ ] Don't know how to use geomatics technologies
- [ ] There are no benefits to using geomatics in emergency/disaster management
- [ ] Other (please specify)

48. Of the challenges you selected above, please rank the top three challenges (with 1 as the most significant challenge).

1.
2.
3.

49. In your opinion, what hinders the use of technology in emergency/disaster management?

The Use of Technology in Emergency/Disaster Management - Practitioner Survey

Section 4 - Demographics/Conclusion

50. Are you interested in participating in future studies? If so, please provide a contact email address. (This will not result in unsolicited e-mail. See Privacy Policy.)

51. In which of these groups is your age?

- Under 30
- 30 to 44
- 45 to 65
- 66 or older

52. What is the highest level of education that you have completed?

- High school
- Stand-alone certificate or diploma
- Bachelor's level
- Master's level
- Doctoral level

53. Are you male or female?

- Female
- Male

54. Please use this space to provide any additional comments regarding the use of technology in emergency/disaster management.

The Use of Technology in Emergency/Disaster Management - Practitioner Survey

To receive a copy of the results of this survey, please e-mail: scott_westlund@umanitoba.ca

A.6 HARDWARE/SOFTWARE DEVELOPER SURVEY INSTRUMENT

The Use of Technology in Emergency/Disaster Management - Hardware/Software

Section 1 - Introduction

Thank you for participating in the technology in emergency/disaster management survey. Your knowledge and opinions are important, and will be used for academic research related to the use of technology in disaster management.

To receive a copy of the survey results, please e-mail: scott_westlund@umanitoba.ca

1. Emergency/disaster management practitioners and organizations are an important market for us.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

2. Currently, technology plays an important role in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

3. In the future, the use of technology in emergency/disaster management will become increasingly important.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

4. In your opinion, what are some of the implications or changes that might result from increasing the use of technology in emergency/disaster management?

The Use of Technology in Emergency/Disaster Management - Hardware/Software

Section 2 - GIS Technology in Emergency/Disaster Management

The questions in this section will help us determine what technologies are designed, manufactured, sold, and/or distributed for use in emergency/disaster management.

5. Does your company design, manufacture, sell, and/or distribute Geographic Information Systems (GIS) technology that could be used in an emergency/disaster management situation?

○ Yes
○ No

If you select 'No', you will be directed to question 14.

Section 2 - GIS in Emergency/Disaster Management

6. Please evaluate the usefulness of the Geographic Information Systems (GIS) products that you design, manufacture, sell, and/or distribute in each phase of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

7. From the following list, which activities can the GIS products that you design, manufacture, sell, and/or distribute be used in?
(please check all that apply)

☐ Preparedness Planning
☐ Simulation and modeling
☐ Producing vulnerability maps
☐ Risk mapping
☐ Evacuation mapping and planning
☐ Predicting impact zones
☐ Estimating damages
☐ Distributing information to the media or public
☐ Distributing information to victims
☐ Allocating/coordinating resources during emergency response

- [ ] Producing maps for emergency responders
- [ ] Decision making during emergency response activities
- [ ] Disaster recovery planning
- [ ] Determining mitigation needs
- [ ] Other (please specify)

8. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1.
2.
3.

Section 2 - GIS in Emergency/Disaster Management

Please consider the following statements and select the response that most closely reflects your opinion.

9. The GIS products you design, manufacture, sell, and/or distribute meet the needs of all emergency/disaster managers.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

10. Your GIS products are affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

11. GIS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

12. GIS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Hardware/Software

13. All emergency/disaster managers should be educated in the use of GIS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

Section 2 - GPS Technology in Emergency/Disaster Management

14. Does your company design, manufacture, sell, and/or distribute Global Positioning System (GPS) technology that could be used in an emergency/disaster management situation?

○ Yes
○ No

If you select 'No', you will be directed to question 23.

Section 2 - GPS in Emergency/Disaster Management

15. Please evaluate the usefulness of the Global Positioning System (GPS) products that you design, manufacture, sell, and/or distribute in each phase of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

16. From the following list, which activities can the GPS products that you design, manufacture, sell, and/or distribute be used in?
(please check all that apply)

- ☐ Preparedness Planning
- ☐ Simulation and modeling
- ☐ Producing vulnerability maps
- ☐ Risk mapping
- ☐ Evacuation mapping and planning
- ☐ Predicting impact zones

- [ ] Estimating damages
- [ ] Distributing information to the media or public
- [ ] Distributing information to victims
- [ ] Allocating/coordinating resources during emergency response
- [ ] Producing maps for emergency responders
- [ ] Decision making during emergency response activities
- [ ] Disaster recovery planning
- [ ] Determining mitigation needs
- [ ] Other (please specify)

17. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1.
2.
3.

Section 2 - GPS in Emergency/Disaster Management

Please consider the following statements and select the response that most closely reflects your opinion.

18. The GPS products you design, manufacture, sell, and/or distribute meet the needs of all emergency/disaster managers.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

19. Your GPS products are affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

20. GPS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Hardware/Software

21. GPS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	◯	◯	◯	◯	◯	◯	◯	◯

22. All emergency/disaster managers should be educated in the use of GPS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	◯	◯	◯	◯	◯	◯	◯	◯

Section 2 - RS Technology in Emergency/Disaster Management

23. Does your company design, manufacture, sell, and/or distribute Remote Sensing (RS) technology (e.g., aerial photographs or satellite images in digital or printed format) that could be used in an emergency/disaster management situation?

◯ Yes

◯ No

If you select 'No', you will be directed to question 32.

Section 2 - RS Technology in Emergency/Disaster Management

24. Please evaluate the usefulness of the Remote Sensing (RS) products that you design, manufacture, sell, and/or distribute in each phase of the disaster management cycle.

	Not Useful	2	3	4	Very Useful	Don't Know
Response	○	○	○	○	○	○
Recovery	○	○	○	○	○	○
Mitigation	○	○	○	○	○	○
Preparedness	○	○	○	○	○	○

25. From the following list, which activities can the RS products that you design, manufacture, sell, and/or distribute be used in?
(please check all that apply)

- ☐ Preparedness Planning
- ☐ Simulation and modeling
- ☐ Producing vulnerability maps
- ☐ Risk mapping
- ☐ Evacuation mapping and planning
- ☐ Predicting impact zones
- ☐ Estimating damages
- ☐ Distributing information to the media or public
- ☐ Distributing information to victims
- ☐ Allocating/coordinating resources during emergency response
- ☐ Producing maps for emergency responders
- ☐ Decision making during emergency response activities
- ☐ Disaster recovery planning
- ☐ Determining mitigation needs
- ☐ Other (please specify)

26. Of the activities you selected above, please rank the top three activities (with 1 as the most common activity).

1. ______
2. ______
3. ______

The Use of Technology in Emergency/Disaster Management - Hardware/Software

Section 2 - RS in Emergency/Disaster Management

Please consider the following statements and select the response that most closely reflects your opinion.

27. The RS products you design, manufacture, sell, and/or distribute meet the needs of all emergency/disaster managers.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

28. Your RS products are affordable.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

29. RS is a crucial component of emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

30. RS is underused in emergency/disaster management.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

31. All emergency/disaster managers should be educated in the use of RS.

	Strongly Agree	Agree	Generally Agree	Neutral	Generally Disagree	Disagree	Strongly Disagree	Don't Know
Agreement Scale	○	○	○	○	○	○	○	○

The Use of Technology in Emergency/Disaster Management - Hardware/Software

Section 2 - Other Technologies

32. From the following list please select any other technologies that you recommend for use in emergency/disaster management activities. (please check all that apply)

- [ ] Computer system
- [ ] Laser measuring device
- [ ] GIS software
- [ ] Handheld computer
- [ ] Automated decision software
- [ ] Cellular or satellite phone
- [ ] Satellite imagery
- [ ] Laptop computer
- [ ] Aerial photography
- [ ] Digital camera
- [ ] Topographic maps
- [ ] Paper maps, field book
- [ ] GPS receiver
- [ ] Other (please specify)

33. Of the technologies you selected above, please rank the three technologies you recommend most often (with 1 as the most recommended technology).

1.
2.
3.

The Use of Technology in Emergency/Disaster Management - Hardware/Software

Section 3 - Geomatics in Emergency/Disaster Management

Geomatics is the science of gathering, analyzing, interpreting, distributing, and using geographic information to help understand the earth and our location on it. Geomatics includes the use of the global positioning system (GPS), geographic information systems (GIS), and remote sensing (RS).

The questions in this section relate specifically to geomatics technologies and are designed to solicit your opinion on the use of GPS, GIS, and RS in emergency/disaster management.

34. Please rate your current level of knowledge of geomatics technologies.

	No Knowledge	2	3	4	Expert	Don't Know
Knowledge Scale	○	○	○	○	○	○

Section 3 - Geomatics in Emergency/Disaster Management

35. Please select the statement that most closely represents your opinion on the use of geomatics in emergency/disaster management.

- ○ Geomatics is widely used in emergency/disaster management
- ○ Geomatics use is not common in emergency/disaster management
- ○ Geomatics is currently not used in emergency/disaster management
- ○ Geomatics will never be used in emergency/disaster management
- ○ Don't know

36. Please select the statement that most closely represents your opinion on the application of geomatics technologies in emergency/disaster management.

- ○ It is easy to apply geomatics technologies in emergency/disaster management
- ○ It is challenging to apply geomatics technologies in emergency/disaster management but it can be done
- ○ Right now, it is too difficult to apply geomatics technologies in emergency/disaster management
- ○ It is impossible to apply geomatics in emergency/disaster management
- ○ Don't know

Section 3 - Challenges for Using Geomatics in Emergency/Disaster Management

37. Of the following, which do you consider to be the most significant challenges for integrating geomatics technologies into emergency/disaster management? (please check all that apply)

- [ ] Communication between departments/agencies, etc.
- [ ] Data quality and accuracy
- [ ] Lack of data
- [ ] Too much data available
- [ ] Unable to acquire data quickly
- [ ] Cost of equipment (hardware)
- [ ] Cost of software
- [ ] Cost to collect data
- [ ] Technical issues
- [ ] Geomatics technology is too complex
- [ ] Existing software is not adequate for emergency/disaster management
- [ ] Existing hardware is not adequate for emergency/disaster management
- [ ] Expert knowledge is required
- [ ] Legal framework for the use of geomatics in emergency/disaster management does not exist
- [ ] Lack of communications or other infrastructure (phone, internet, electricity)
- [ ] No standards or procedures in place outlining the use of geomatics in emergency/disaster management
- [ ] Don't know how to use geomatics technologies
- [ ] There are no benefits to using geomatics in emergency/disaster management
- [ ] Other (please specify)

38. Of the challenges you selected above, please rank the top three challenges (with 1 as the most significant challenge).

1.
2.
3.

39. In your opinion, what hinders the use of technology in emergency/disaster management?

Section 4 - Demographics/Conclusion

40. Are you interested in participating in future studies? If so, please provide a contact email address. (This will not result in unsolicited e-mail. See Privacy Policy.)

41. In which country is your office located?

42. In which of these groups is your age?

- Under 30
- 30 to 44
- 45 to 65
- 66 or older

43. What is the highest level of education that you have completed?

- High school
- Stand-alone certificate or diploma
- Bachelor's level
- Master's level
- Doctoral level

44. Are you male or female?

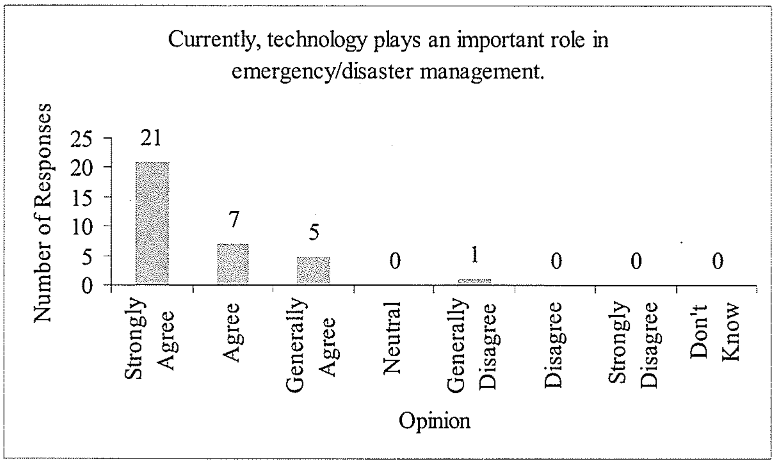
- Female
- Male

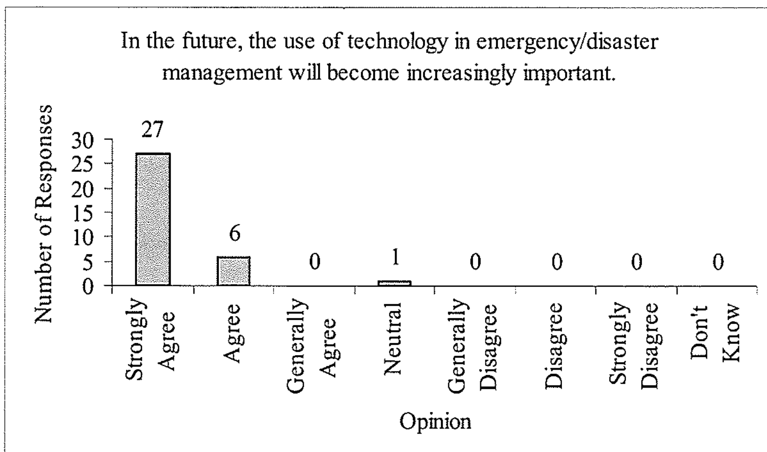
45. Please use this space to provide any additional comments regarding the use of technology in emergency/disaster management.

To receive a copy of the results of this survey, please e-mail

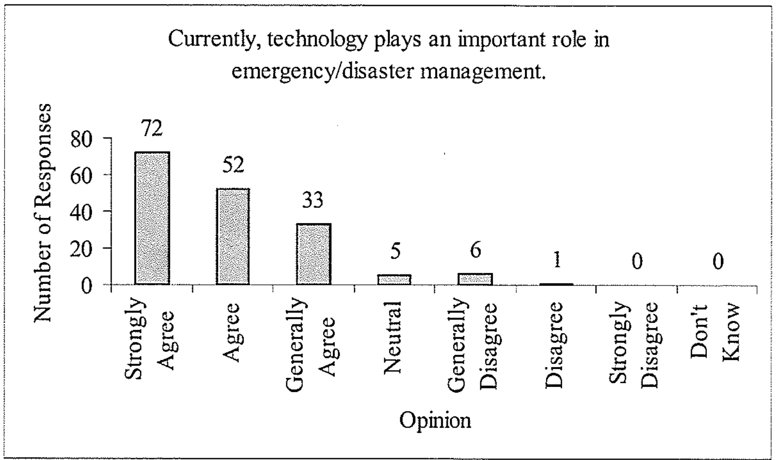
APPENDIX B: DETAILED SURVEY DATA FOR SCALED QUESTIONS

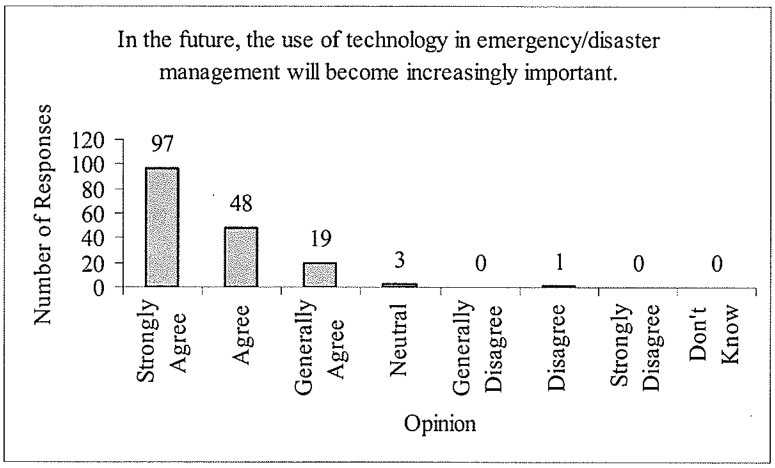
B.1 Complete Results for Table 2 – Educator Survey



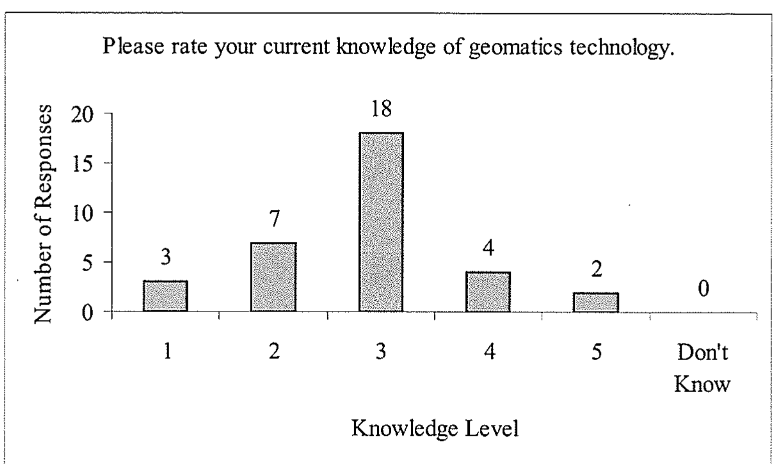


B.2 Complete Results for Table 2 – Practitioner Survey

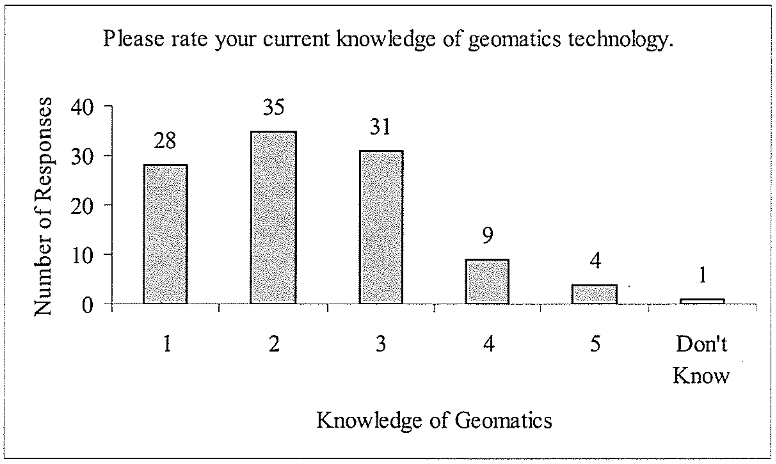




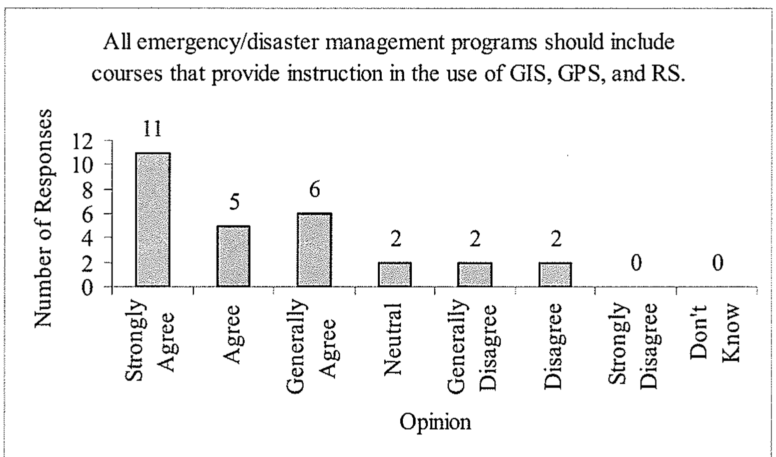
B.3 Complete Results for Table 5 – Educator Survey



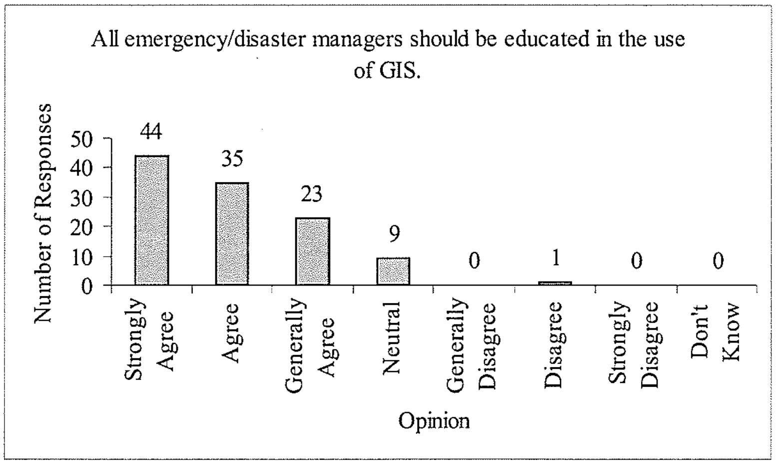
B.4 COMPLETE RESULTS FOR TABLE 5 – PRACTITIONER SURVEY

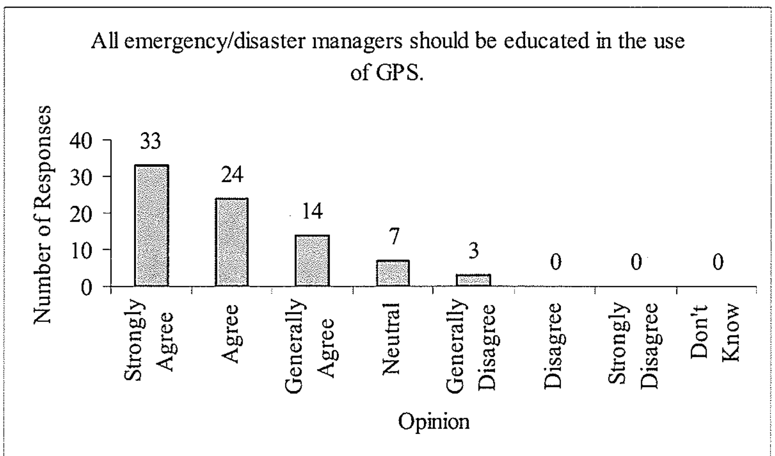


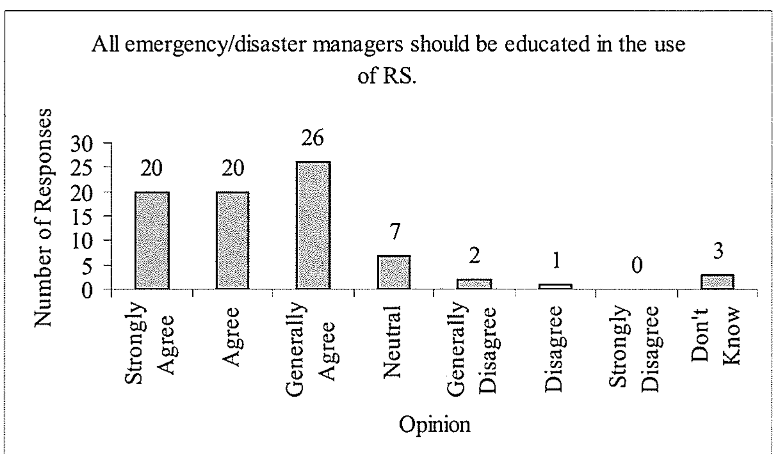
B.5 COMPLETE RESULTS FOR TABLE 7 – EDUCATOR SURVEY



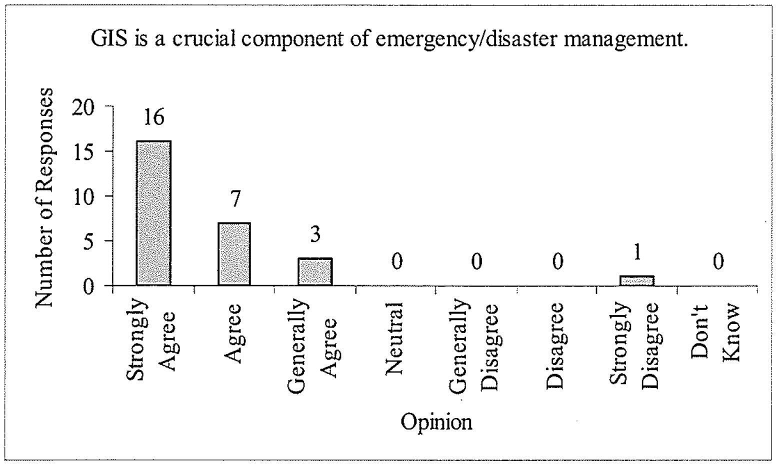
B.6 Complete Results for Table 7 – Practitioner Survey

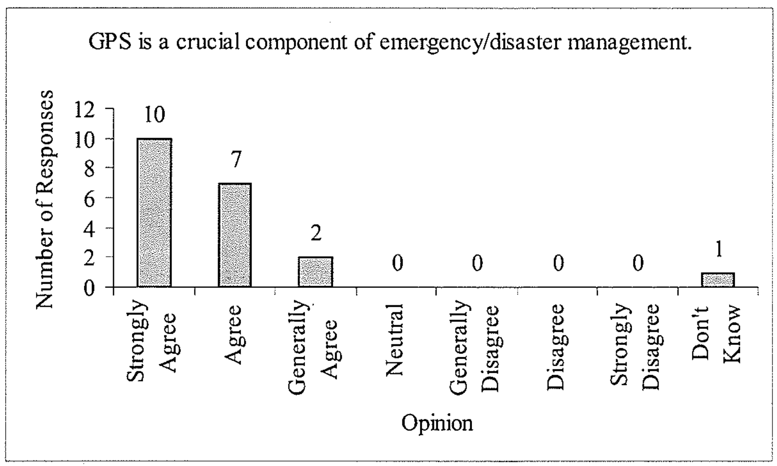


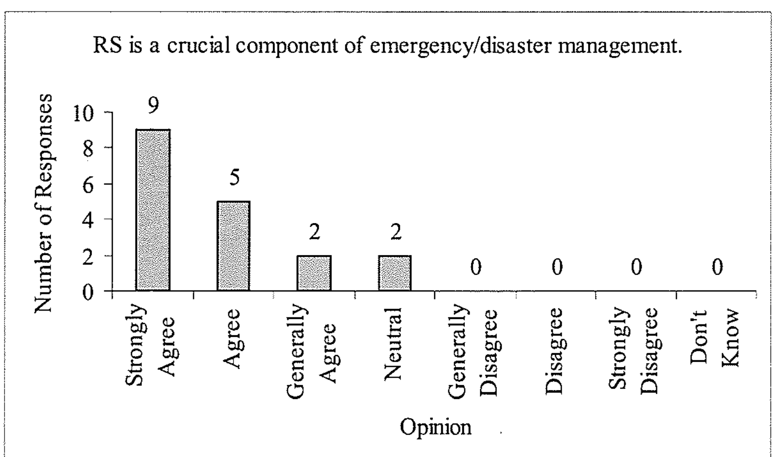




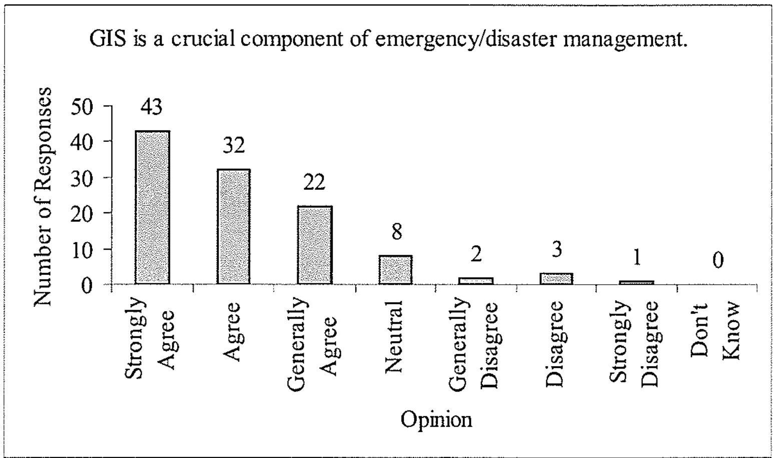
B.7 Complete Results for Table 8 – Educator Survey

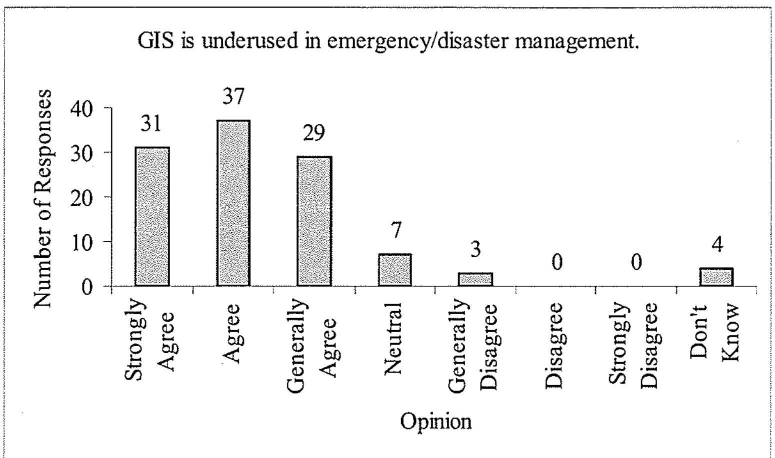


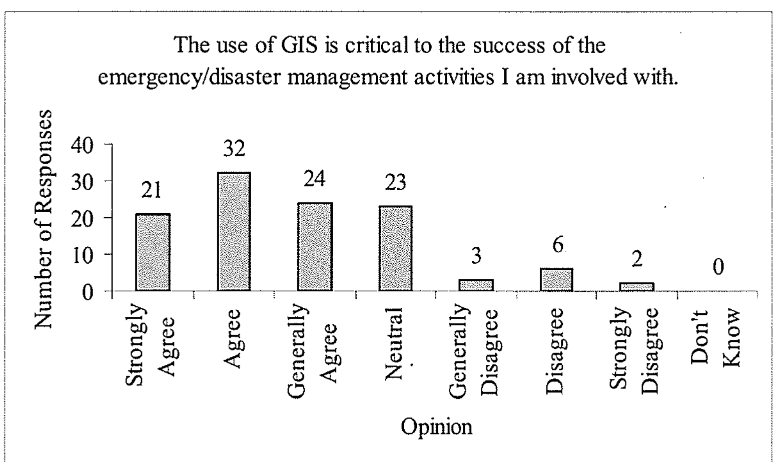


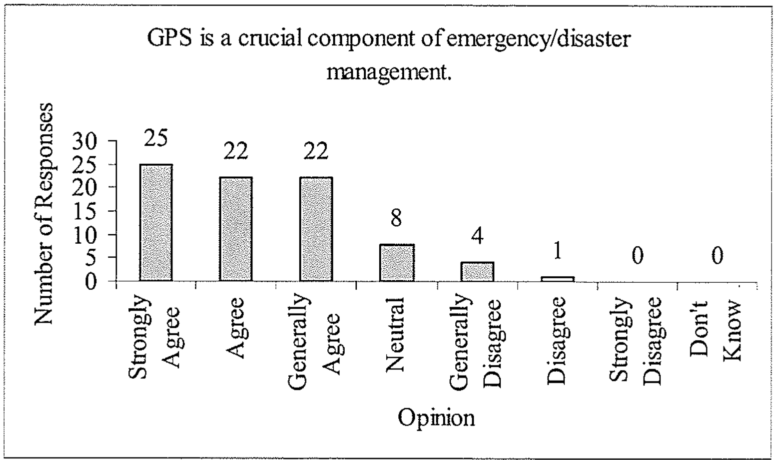


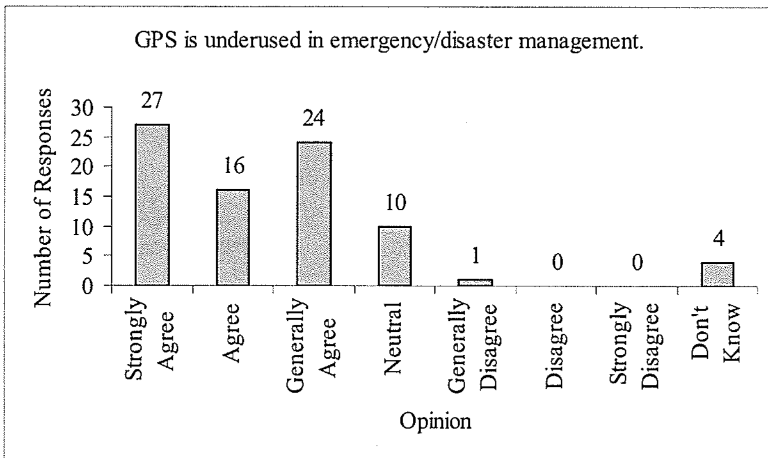
B.8 Complete results for Table 8 – Practitioner Survey

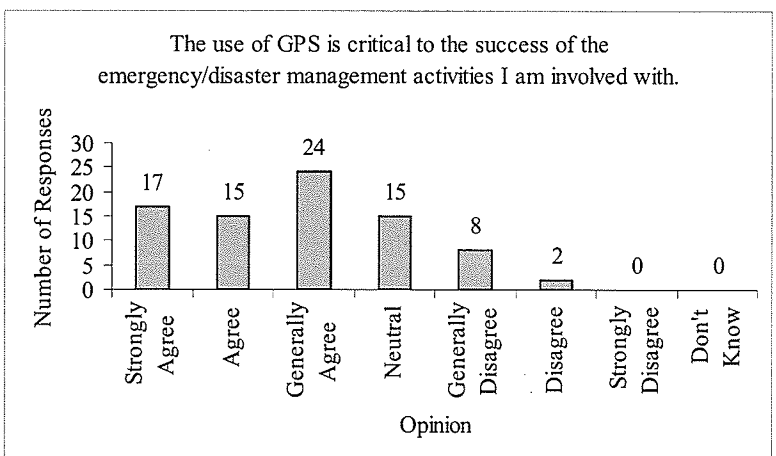


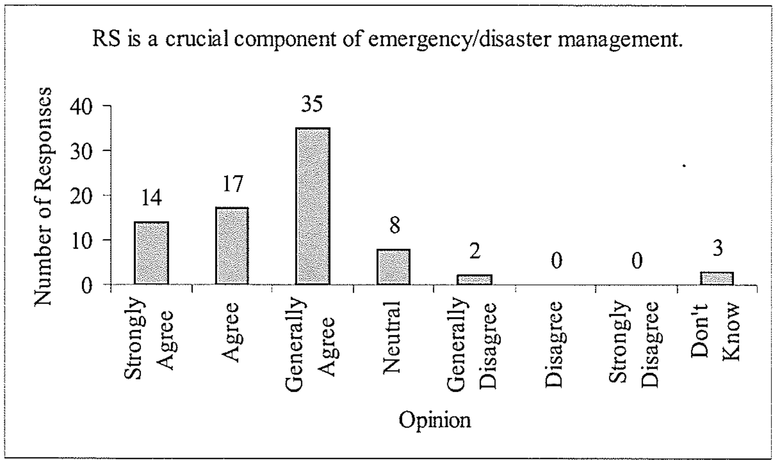


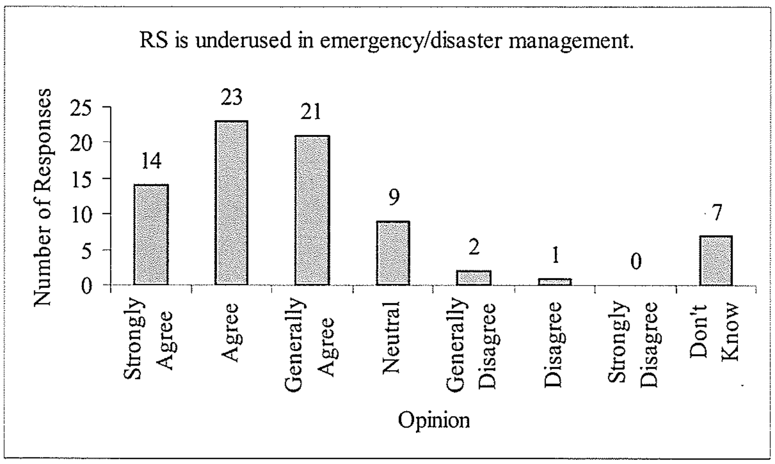


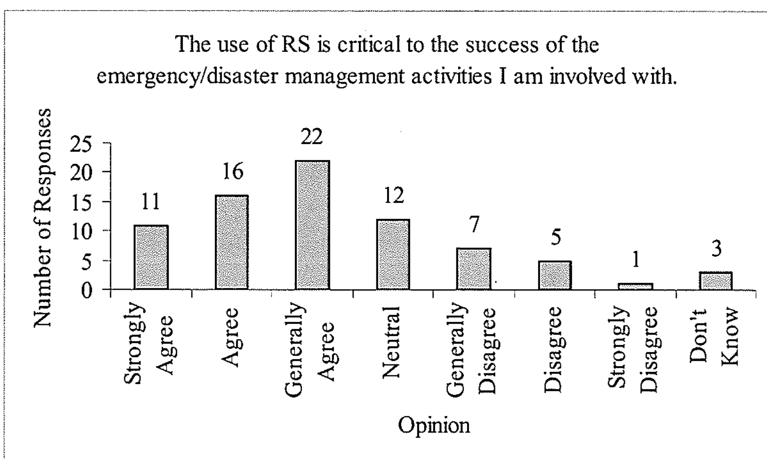

GPS is a crucial component of emergency/disaster management.
Number of Responses
30
25
20
15
10
5
0
25
22
22
8
4
1
0
0
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion


GPS is underused in emergency/disaster management.
Number of Responses
30
25
20
15
10
5
0
27
16
24
10
1
0
0
4
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

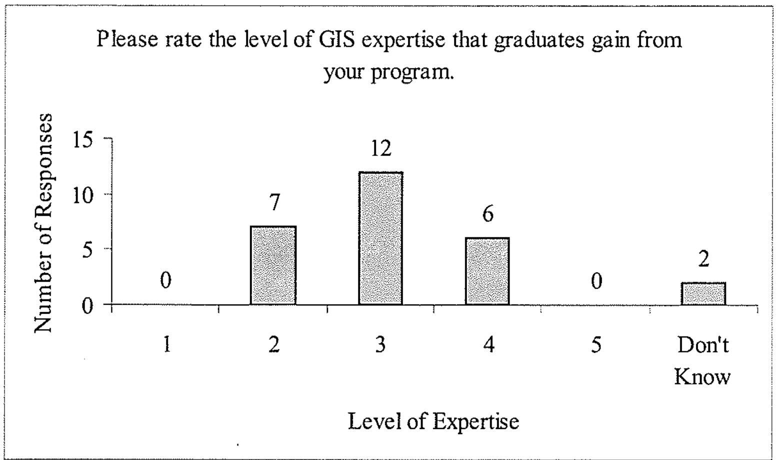

The use of GPS is critical to the success of the emergency/disaster management activities I am involved with.
Number of Responses
30
25
20
15
10
5
0
17
15
24
15
8
2
0
0
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

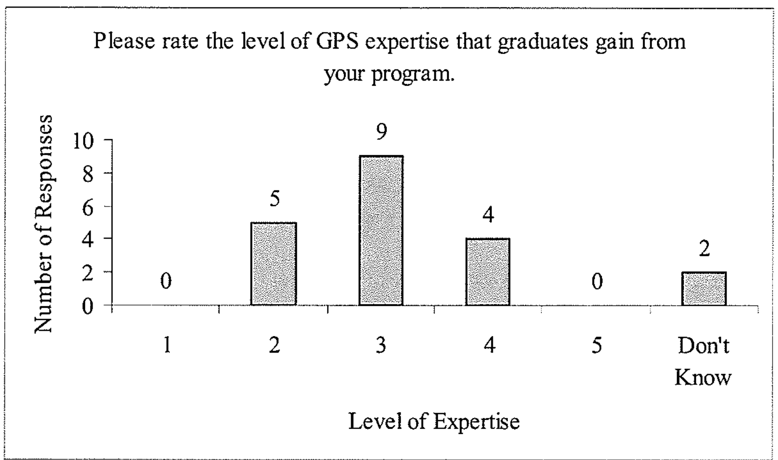

RS is a crucial component of emergency/disaster management.
Number of Responses
40
30
20
10
0
14
17
35
8
2
0
0
3
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

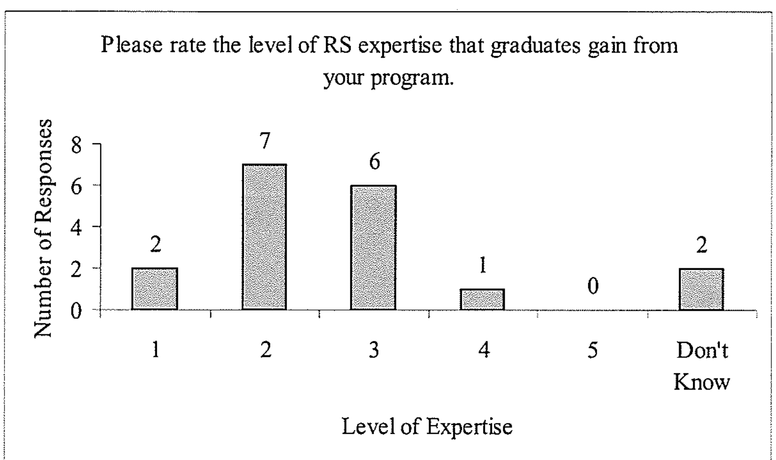

RS is underused in emergency/disaster management.
Number of Responses
25
20
15
10
5
0
14
23
21
9
2
1
0
7
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion


The use of RS is critical to the success of the emergency/disaster management activities I am involved with.
Number of Responses
25
20
15
10
5
0
11
16
22
12
7
5
1
3
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

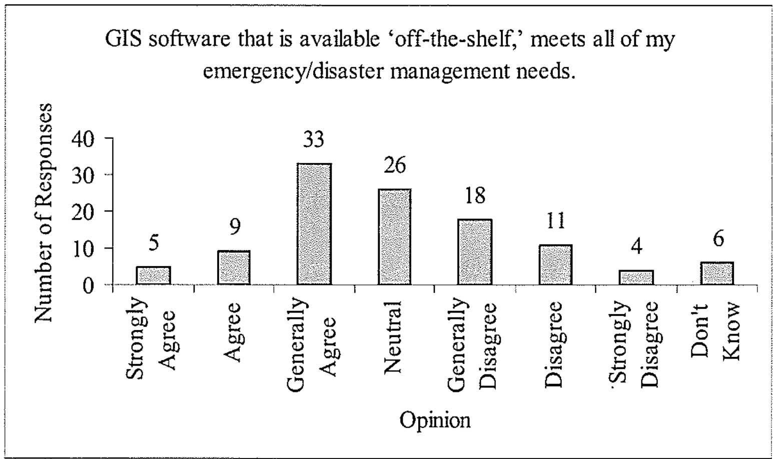
B.9 Complete results for Table 10 – Educator Survey

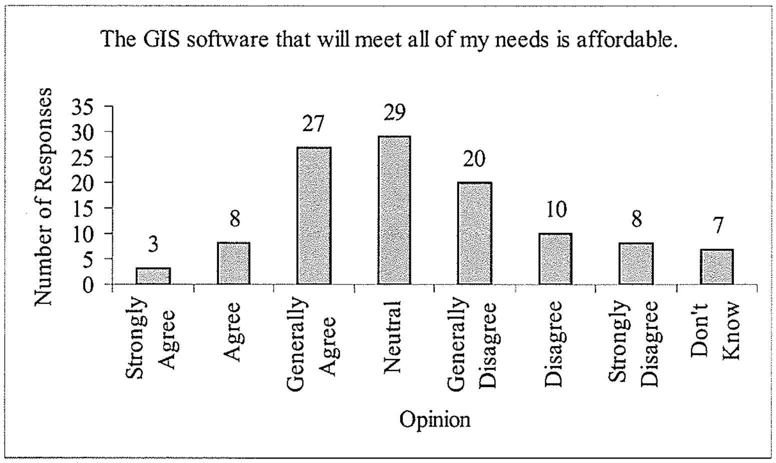


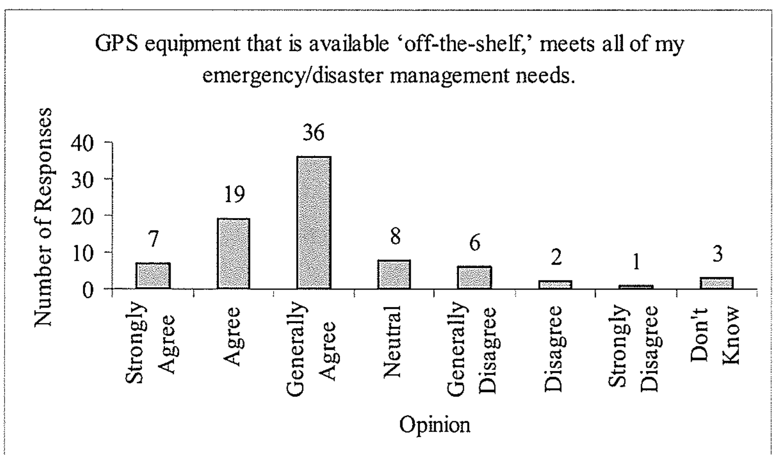


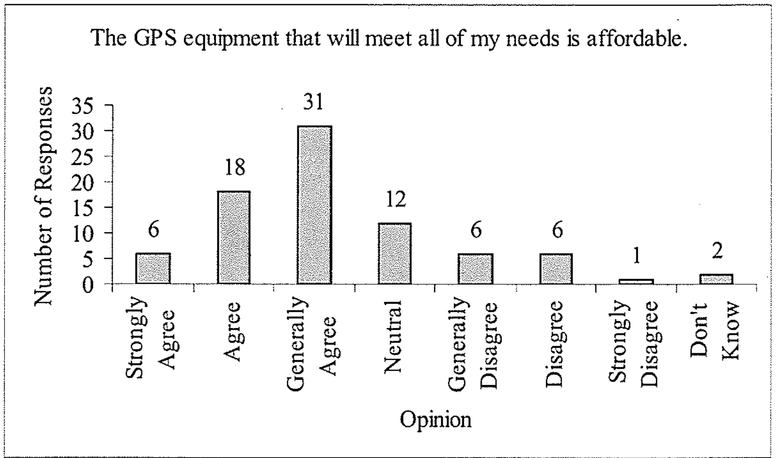


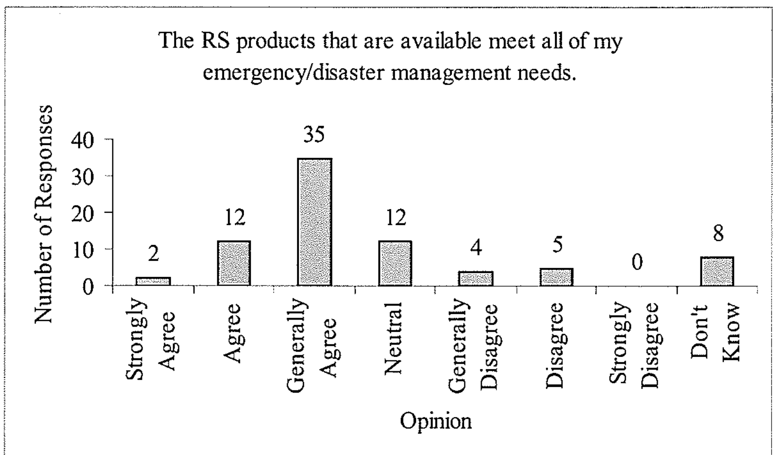
B.10 Complete results for Table 16 – Practitioner Survey

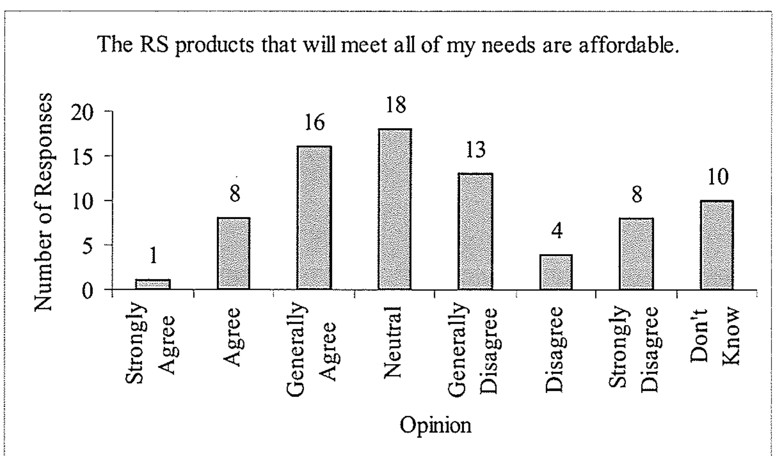




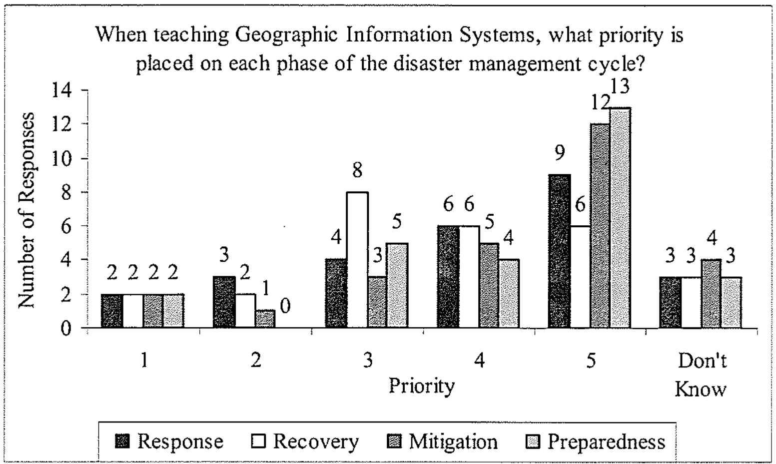


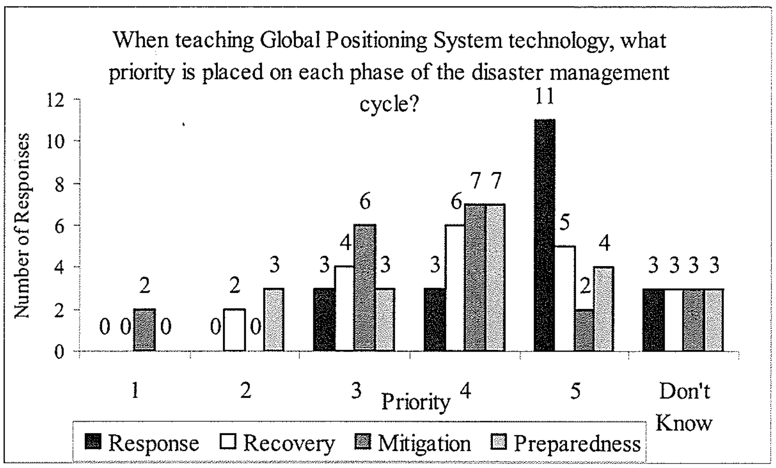

The GPS equipment that will meet all of my needs is affordable.
Number of Responses
35
30
25
20
15
10
5
0
6
18
31
12
6
6
1
2
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

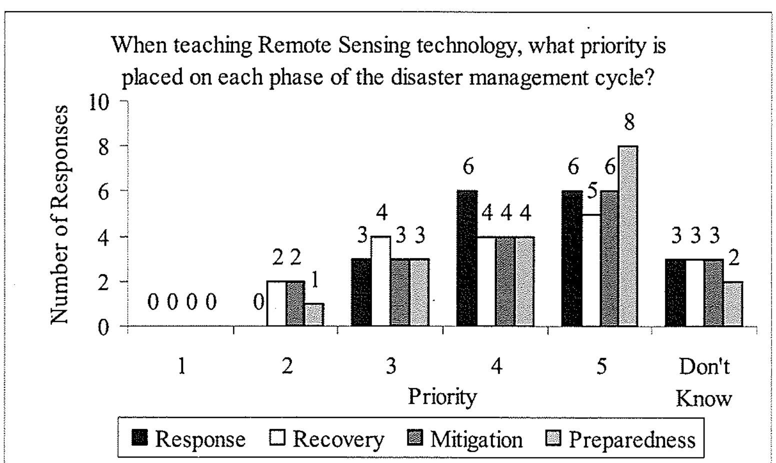

The RS products that are available meet all of my emergency/disaster management needs.
Number of Responses
40
30
20
10
0
2
12
35
12
4
5
0
8
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion


The RS products that will meet all of my needs are affordable.
Number of Responses
20
15
10
5
0
1
8
16
18
13
4
8
10
Strongly Agree
Agree
Generally Agree
Neutral
Generally Disagree
Disagree
Strongly Disagree
Don't Know
Opinion

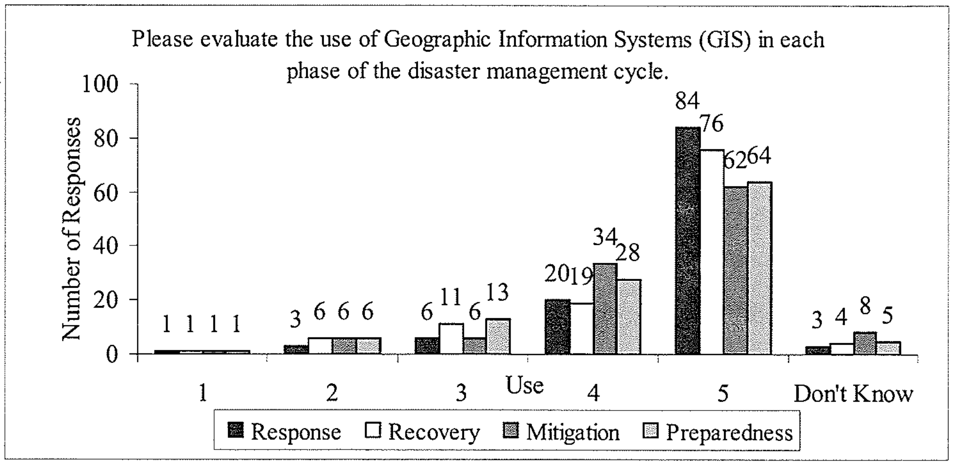
B.11 Complete results for Table 20 – Educator Survey

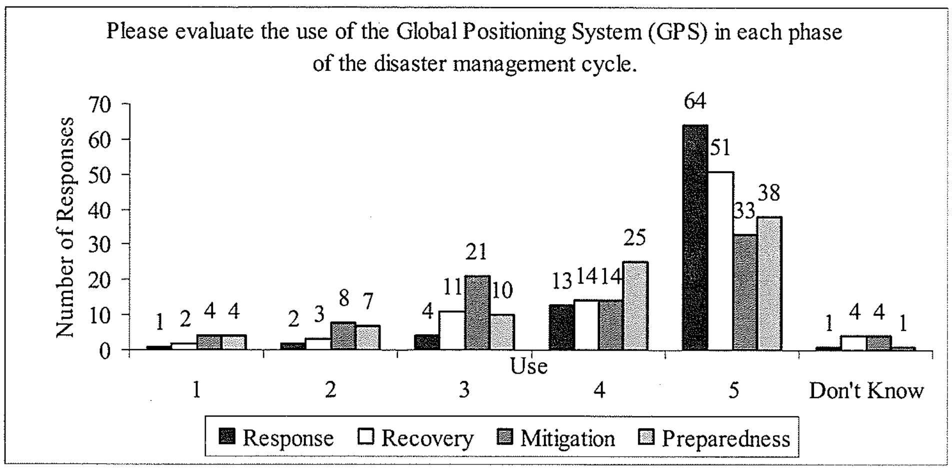


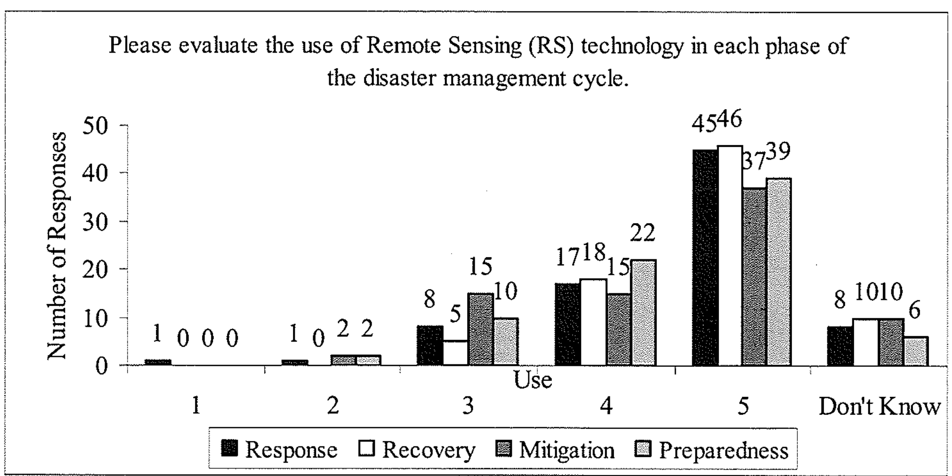




B.12 Complete results for Table 20 – Practitioner Survey







B.13 Other technologies

Survey respondents identified the other technologies used in disaster management as follows:

Other technologies

Rank	Educators	Practitioners
1.	Specialized computer software (CAMEO, HAZUS, EOC type)	Communication technologies
2.	Communication technologies	Specialized computer software
3.	Information technologies	Information technologies
4.	Monitoring equipment	Notification systems
5.	-	Low tech devices
6.	-	Monitoring equipment

APPENDIX C: SELECTING A REMOTE SENSING TOOL TO PREPARE EMERGENCY PLAN MAPS

This appendix supplements the case study and describes the process used to review and select a remote sensing image source for the production of the emergency plan maps. The list of potential image sources for this project was selected based on the academic literature, which indicates they have been used successfully in other disaster-management-related applications. The potential imagery sources include new and historical aerial photographs, photographs from an Unmanned Aerial Vehicle (UAV), satellite imagery from IKONOS, Quickbird, Spot, Landsat 7, and National Oceanic and Atmospheric Administration (NOAA) satellite sensors, and open-source imagery from Google Earth.

C.1 EVALUATION CRITERIA

Prior to evaluating each imagery source, it is important to outline the evaluation criteria, base assumptions, and other factors that influenced the evaluation. For this project each image source was evaluated based on its ability to provide sufficient coverage for the entire project area. However, because the study area is very large it can not be covered in a single image and it is assumed that the amount of processing and data manipulation required to produce the final maps of the entire project area will not vary greatly from one image source to another. Additionally, in all cases $600 should be added to the costs provided in *Table 31*. This cost will cover the printing of the maps stored at the EOC and the maps included in the binders. The assumptions and other factors described in the sections below also apply to the imagery source identified.

Historical Aerial Photography

To use historical aerial photography to produce the maps, sufficient historical imagery for the entire study area must be available from the archive files stored at the regional or provincial government office. Once located the images must be such that they can be stitched together into an overall map and manipulated as required.

New Aerial Photography

To obtain new aerial photography for the study area, a flight will have to be planned and executed. The evaluation is based on the assumption that a firm that supplies aerial photography services can be contracted to assist with the project and they will obtain the approvals necessary to conduct the flight, fly the study area, collect and process the imagery, and provide a map of the entire study area in a format that can be further manipulated.

UAV Photography

Similar to the aerial photographic option, new imagery collected with a UAV will have to be collected for the study area to complete the project. Indeed, my initial thesis proposal included completing a UAV flight in Elie to collect updated images for the area. However, it was not possible to locate an organization with a UAV willing to collaborate on or undertake this project. The reasons for their unwillingness to participate included their inability to obtain adequate liability insurance and the fact that they did not believe Transport Canada would grant permission to conduct a flight in this area due to its proximity to urban development and the Trans-Canada Highway. However, prior to abandoning this component of the research, I also investigated the possibility of renting a UAV and conducting the flight myself; however the issues mentioned above proved to be insurmountable. The scores and information provided in the evaluation of the UAV reflect the problems encountered while attempting to arrange a UAV flight in Elie.

Open-source data providers

It seems that many practitioners are turning to open source software and data providers to seek solutions to disaster management problems. Using open source software such as Google Earth, requires purchasing a software license and the professional version. For this project, the assumptions surrounding the use of Google Earth Pro include that the imagery can be manipulate as required and maps can be printed directly from the software.

Satellite imagery

Similar to the historical aerial photography option, the major assumption surrounding the use of satellite imagery is that sufficient imagery is available from a satellite data provider to map the entire study area and that images can be stitched together to cover the entire project area. Additionally, the cost of imagery is based on the type of sensor as well as the resolution that can be achieved by the sensor. QuickBird, SPOT, and IKONOS satellite imagery is available in various resolutions and this analysis is based on obtaining the best available imagery for each sensor.

In order to choose the best imagery for this project, I developed a scoring system to address the ability of each source to meet the challenges for the use of geomatics in disaster management. The scoring criteria were established from the perspective of disaster management practitioners and were such that the challenges and concerns raised by technology users would be addressed in the selection of an imagery source. The scoring categories incorporated both quantitative and subjective criteria, and included cost, resolution, availability, quality, and format, and the requirement for expert knowledge. At the end of the analysis the image source with the highest total score would be used to produce the maps. A detailed description of the criteria is outlined in the sections below, along with a summary of the evaluation criteria in *Table 29*. Scores in each category range from 0 to 5, with a maximum total score of 30. The results of the analysis for each image source, broken down by category, are provided in *Table 30*.

Economic challenges

Based on the academic literature and the results from the web-based survey, economic challenges are the most significant barrier to the use of geomatics in disaster management. For this project, economic challenges related specifically to the cost to acquire the imagery. Accordingly, cost estimates to obtain sufficient imagery to map the entire study area was obtained for each image source. The actual cost estimates, based on the information provided by data suppliers, are listed in *Table 31* and reflect the costs that will be incurred by a disaster management practitioner operating in this study area.

Organizational challenges

The organizational challenges included the logistics of data acquisition, data quality, and data sharing. This broad category encompassed a mix of numerical and qualitative criteria. As such, scores in the organizational category were broken up into two parts to ensure that one of the most important factors for selecting imagery, the resolution, was given adequate consideration.

Image resolution in a satellite imagery or aerial photographic context refers to the size of the smallest object that can be detected in an image (Rees, 1990). For example, in a high-resolution 0.6 m image, features that are 0.6 m^2 in size will be represented by 1 pixel. Similarly, in a low-resolution 10 m image each pixel will cover 10 m^2 on the ground and objects smaller than 10 m^2 will not be visible. In order for an image-based map to be useful for emergency planning and response, the on-the-ground details such as buildings, roads, and other infrastructure must be clearly visible; thus, low-resolution images (10 m, 1 km) are not appropriate for use in this situation (see Appendix D for a sample of a 10 m resolution image). Indeed, the image resolution required for this application must be better than 3 m in order to produce a useful map. This threshold is somewhat subjective but the 2.4 m resolution QuickBird image provided by the Government of Manitoba (included as Appendix E) demonstrates the resolution at which features such as roads, houses, sheds, and utility infrastructure are clear and easily identified with the naked eye when printed on a standard size page.

Although obtaining an image with an appropriate resolution was critical, other organizational criteria were also extremely important. Due to the more qualitative nature of these considerations the scores in this category were assigned subjectively and were based on the ability of the image source to address the five questions listed in *Table 29*. Each image source was awarded a score between 0 and 1 for each question, with a maximum score of 5 awarded in this category.

The requirement for expert knowledge

Results from the web-based survey indicated that practitioners consider the need for expert knowledge to be a significant challenge for the use of geomatics. As such, the criteria for the scores assigned in this category related to the age of the imagery, the availability, the ease with which it could be obtained, and whether it is consistent throughout the study area. These items were posed as questions and each image source was assigned a score between 0 and 2.5 based on how well each question was addressed.

Hardware and software challenges

Hardware and software challenges included the availability of communications infrastructure, data storage capacity, and computer-user interfaces. For this project most of the data were obtained from outside sources. As such, the hardware and software challenges were minimized. For example, new aerial photography or satellite image data ordered directly from a data provider was delivered in a useable format and no further manipulation with specialized software was required. The score in this category was based on the ease with which imagery can be obtained and used.

Cultural challenges

Cultural challenges are exemplified by legal, privacy, and security concerns. For this particular project the cultural challenges include the logistical, administrative, and legislative issues for collecting data. For example, Canada has strict legislation in place governing UAV use and there are also logistical considerations for collecting new aerial photography; however, there appear to be no restrictions on the use of satellite data. Additionally, to legally use Google Earth for commercial purposes, a professional license is necessary. The scores in this category reflect the degree of potential logistical or cultural problems that might arise for the collection and use of the imagery.

Evaluation criteria summary

The following table summarizes the criteria used to evaluate each image source.

Table 29: Basic criteria used to evaluate each image source

Challenge	**Scoring criteria**
Economic	Costs were ranked from least to most expensive, in which the least expensive imagery was given a score of 5, while the others were assigned a decreasing score based on the ranking. A score of 0 was assigned to the most expensive imagery.
Resolution	The image resolutions were ranked from highest to lowest. The image source that provides imagery with the best resolution was assigned a score of 5 and the image with the second best resolution was assigned a score of 4, and so on. A score of 0 was assigned to images with resolutions above the threshold.
Organizational	A score between 0 and 1 was assigned based on the answers to each of the following questions (with a maximum score of 5 in this category): - How old is the imagery? - Is imagery available for the entire study area? - Is the imagery readily available? - Is the imagery easy to obtain? - Is the imagery consistent throughout the study area (season, resolution, age)?
Expert knowledge	A score between 0 and 2.5 was assigned based on the answers to each of the following questions (with a maximum score of 5 in this category): - If this imagery is used, is expert knowledge required to produce or use the final map? - Does the data need to be manipulated to produce the final product?
Hardware/ software	A score ranging from 5 (requires no specialized software) to 0 (requires highly specialized software) was given in this category based on the answer to the following question: - Is specialized software required to use this imagery?
Cultural	A score of 5 was awarded if there seemed to be limited problems associated with the use of the imagery. A score of 0 in this category indicates that it was extremely difficult to obtain the approvals necessary to obtain imagery using this tool.

Producing the maps

The maps for this project were produced using Arc Explorer and AutoCAD. Some experience with these software packages is required in order to manipulate the data and print the final maps. However, the final maps can be delivered in PDF format so that they can be easily viewed and printed by any user. To produce the maps, the imagery data was stitched into a map of the entire project area. However, because the study area was large, it was impossible to format this map to fit into a binder, thus making it necessary to divide the overall map into 11 smaller regions. As such, each map was prepared at a scale of 1:20,000 or 1:10,000 to ensure that all ground details important for emergency preparedness were visible to the naked eye in the full size version (24 in. x 36 in.). The scale was such that these maps could also be reduced (11 in. x 17 in.) and still be useable.

Taking the historical out of historical data

Due to the costs associated with obtaining new data this project also investigated the use of historical and archive imagery. The disadvantage of using archive imagery is that it can be out-of-date. However, this issue can be resolved by enhancing the imagery with data layers provided by other sources. For instance, for this particular project area, information layers such as a current legal property line mapping layer, were available from the Government of Manitoba. This data layer was built using registered legal survey plans (based on the metadata that accompanied this layer, it was up-to-date as of mid-2007) and was overlaid on the imagery to 'update' it.

C.2 RESULTS

Based on the project criteria, the assumptions made, and the analysis method used, aerial photography was the best image source for this project. Furthermore, due to its extremely low cost (free), the absence of cultural challenges, and the adequate resolution, historical aerial photographs provided the best option for producing the maps and satisfying the project objectives. However, based on the total scores and specific characteristics listed in *Table 30* and *Table 31*, it appears that new aerial photographs, IKONOS satellite data, or Google Earth are image sources that could also potentially be used to achieve the project objectives. The results of the analysis for each image source are provided in the sections following the summary table.

Table 30: Summary of scores in each category

Source / Challenge	Historical aerial photographs	New Aerial Photographs	IKONOS	Google Earth	SPOT	QuickBird	Landsat 7	NOAA	UAV
Economic	5	3	2	4	1	1	5	5	0
Resolution	4	5	4	2	4	5	0	0	5
Organizational	3	2.7	3	4	3	2	4	4	2.1
Expert knowledge	3	5	3	3	3	3	2	2	3
Hardware/ software	3	3	4	4	4	4	3	3	3
Cultural	5	3	5	4	5	5	5	5	0
Total	**23**	**21.7**	**21**	**21**	**20**	**20**	**19**	**19**	**13.1**

Unmanned Aerial Vehicle (UAV)

Based on the analysis criteria described, the UAV achieved a total score of 13.1. The current regulations surrounding UAV use made it the least appropriate image source for this project. However, the UAV was an interesting option to investigate and may have future potential for this type of application.

In his recent article and conference presentation, Lewis (2007) presented the new generation of civilian UAVs as inexpensive and easy to use. As such, it seemed that the UAV provided a data collection tool with unlimited potential for this type of project.

Indeed, the image quality and resolution (sub-metre) that can be achieved using this tool are excellent (hence a score of 5 in the resolution category); however, the current legislative and logistical issues make it impractical to use a civilian UAV to collect image data (hence a score of 0 in the cultural challenge category, and a low score in the organizational challenge category).

As of early 2008, it appears that civilian UAV technology is far ahead of the legislation governing its use. In Canada, UAV flights must be undertaken in accordance with the rules and regulations set out by Transport Canada. Section 602.41 - Part VI of the Canadian Aviation Regulations, mandate that UAVs must be operated in accordance with a Special Flight Operations Certificate (SFOC) (Canadian Aviation Regulations, 2008). The SFOC is required to ensure the safety of both the public and other airspace users (UAV, 2007). The SFOC application process is onerous. Users must provide specific details about the planned flight, a safety, security and emergency plan, equipment specifications, the exact flight path and altitude, flight times and dates, emergency contact information, pilot credentials, and any other information that may be requested by the Minister. Furthermore, Transport Canada requires that an application package be submitted at least 20 working days prior to a flight, to ensure that they are able to review and approve the application before issuing the SFOC. For preparedness use, when time is not of the essence and the area to be investigated is known in advance, the approval time and SFOC application requirements are a challenge but not insurmountable. Additionally, in some instances and jurisdictions it may be possible that first responders or other organizations (e.g. a fire commissioner) could overrule the authority of Transport Canada and deploy a UAV without prior approval. However, as written, the current requirements for the use of a UAV seem to severely limit the potential of this tool for emergency response operations.

The Transport Canada regulations also limit the altitude at which a UAV can fly, so that it remains within the operator's visual range at all times (Lewis, 2007). The maximum flight height requirement had two significant impacts on this project. First, the lower flight height allows for higher resolution and more detailed imagery; however, more photos are required to ensure full coverage of the project area. At maximum altitude, the UAV collects approximately 19 images per 1 km^2 (G. Lewis, personal communication, November 6, 2007). Thus, to map the entire study area, approximately 16,000 images would be required. Handling this many images would prove difficult from a logistical, camera, and computer memory perspective, as well as an image processing perspective. Second, it seems almost impossible to quickly fly an area this large while keeping the UAV in visual range at all times. Resolving these issues would increase the costs associated with the use of this tool, making it prohibitively expensive.

As an emerging technology, UAVs seem safe and no major accidents have been reported; however, there is potential that they could cause property damage or injury. While the same is true for all aircraft, from an insurance perspective UAVs are considered to be a unique technology and are not classified within the same category as convention aircraft. This is primarily because they are unmanned, and although they are flown from the ground, there is no pilot on-board to take the controls and crash the UAV in a more desirable location or to manually avert a mid-air collision (Anonymous Transport Canada employee, personal communication, October 17, 2007). As such, the rules and guidelines surrounding appropriate liability insurance coverage have not been defined. Additionally, because the UAV user community is very small, the cost to obtain sufficient liability insurance is extremely high: annual premiums are expected to be more than $100,000 and it is difficult to find an insurance company willing to underwrite its use (Anonymous agent with The Co-operators insurance company, personal communication, September 25, 2007).

Accordingly, there are many legislative and logistical issues to be addressed before the UAV will be practical for use in any phase of the disaster management cycle. However, if it becomes possible to use UAV technology, it will provide several advantages. For example, the image resolution is far superior to any of the other imagery investigated, the price over a small area is quite low, a UAV is mobile and can take off and land without a runway, and images can be made available mere hours after a flight (Lewis, 2007). If permission to use a UAV could be easily obtained, it would be an ideal way to collect up-to-date imagery to fill in small data gaps, or as a way to supplement existing imagery. Further investigation into the use of UAV technology is required and there is a need to address the legislation currently restricting its use.

National Oceanic and Atmospheric Administration (NOAA) satellite data

NOAA images are often used to track, identify and monitor weather-related phenomena, such as tropical storms, rainfall, and Arctic ice. Imagery is readily available, free of charge, on the Internet from weather-related organizations such as Environment Canada. Indeed, whenever pictures depicting hurricanes, cyclones, or large weather-related events appear on television or the web, they are provided by NOAA satellites (NOAA, n.d.).

The use of NOAA satellite imagery was investigated for this project because of its widespread use, low cost, and availability. However, with a total score of 19, NOAA satellite images were not deemed appropriate for use in this project. They are low resolution (1000 m pixel size) images, which makes it impossible to identify specific ground features or determine accurate positions (hence a score of 0 in the resolution category). For example, when NOAA satellite imagery was used to detect hot spots associated with wildfires or volcanic eruptions, the image resolution limited the ability to pinpoint the actual hot spot location (Oppenheimer, 1998). Indeed, an overall score of 19 for NOAA imagery seems too high and it is likely that the score was artificially inflated due to its low cost, availability, and the lack of cultural challenges associated with its use. A review of the NOAA image was important because it helped to establish and confirm the threshold resolution value previously determined. A sample NOAA image of Manitoba, dated July 19, 2007, was provided by the Government of Manitoba and is included as Appendix F.

Landsat 7

Landsat 7 provides medium-resolution satellite imagery that, according to the USGS Landsat Project website, supports "global change research, agriculture, forestry, geology, resource management, geography, mapping, water quality, and oceanography" (USGS, 2007). Landsat 7 imagery is useful in understanding development patterns and it has been used successfully in other disaster management applications. Archive Landsat imagery is available free of charge or at a minimal cost over the Internet and the 30 m resolution makes it possible to distinguish between urban, grassy, and wooded areas, as was successfully done in research by Nirupama and Simonovic (2006). However, this resolution is not appropriate for the RMs involved in this research because the ground details important for emergency planning are not visible. A sample 30 m resolution image provided by the Government of Manitoba is included in Appendix G. Elie, the community that experienced the tornado, is in the centre of the frame.

QuickBird

QuickBird imagery is the highest resolution satellite imagery (0.6 m) currently available to commercial users (DigitalGlobe, n.d.). Although the image resolution is excellent and the image source achieved a total score of 20, QuickBird was not selected as the most appropriate image source for this project, nor was it found to be the best satellite imagery alternative. Indeed, the findings of this analysis both support and contradict the findings of Wang et al. (2004), who compared the use of IKONOS and QuickBird images for classifying mangrove species in Panama. Similar to their study, I determined that, from a visual perspective, both products are appropriate for use in this context; however, my findings differed from theirs with respect to the cost of obtaining the imagery. As indicated in *Table 31*, of all the options analyzed, QuickBird imagery was the most expensive satellite imagery available.

In addition to the high cost of the imagery, the coverage is sporadic for the study area, which limited the practicality of the use of QuickBird imagery for this project. When I searched for archive imagery, I found that imagery was available for areas closer to Winnipeg but not for the areas near Elie (MapMart, 2007). As such, an on-demand acquisition would likely be required to obtain imagery to fill in the data gaps, further increasing the cost. Moreover, once these data gaps are filled, significant manipulation would be required to produce the final maps and the imagery might not be consistent throughout the entire study area. For instance, it may have different resolutions and have been collected during different seasons. These issues were factors in the lower scores in both the hardware/software and expert knowledge categories.

SPOT

As reflected in the total scores for each of the image sources, SPOT imagery is very similar to the imagery available from both QuickBird and IKONOS sensors. Indeed, SPOT imagery is often used for disaster management. SPOT is part of the International Charter on Space and Major Disasters, which means that they provide satellite imagery to NGOs and other international organizations for humanitarian purposes during times of crises (Spot, n.d. b). SPOT imagery is available in resolutions that range from 2.5 m to 20 m and according to the company's website, their imagery is readily available, georeferenced, and easy to use (Spot, n.d. a).

Google Earth

A question raised by decision makers at the RMs involved in this study was: Can we use Google Earth for this project? (N. Tchir, personal communication, September 12, 2007). The fact that they asked this question speaks directly to the ability of Google Earth to introduce mapping, geomatics, and spatial data to the non-expert (Pezanowski et al., 2007). Accordingly, Google Earth was added to the list of potential image sources.

Notwithstanding its popularity, with a total score of 21, Google Earth was not the best source of imagery for this project. However, it does have simple viewing and data manipulation functionality that is appropriate for use at the RMs. However, it has limited topology functions (i.e. 3D surface modeling ability) and users wishing to undertake complex analysis on the data may miss the added features of satellite imagery and aerial photography (i.e. multi-spectral 3D data), and GIS (i.e. the ability to query objects, draw lines, and shade areas) (Li et al., 2005). For this particular project, it was not the most desirable image source because of the variable resolution across the study area. In areas close to the City of Winnipeg, the image resolution was excellent, and was in the 2 m range; however, the resolution changed and ground details in the rural areas west of the city were difficult to distinguish. Google Earth scored well in most other analysis categories and if the study area was limited to the urban areas, it would be an excellent choice for this particular user.

IKONOS

With a score of 21, IKONOS is the highest ranking satellite image source and is a viable alternative to aerial photography. Indeed, if historical aerial photographs were not available for this study area, IKONOS imagery could be used to produce the maps required for this project. IKONOS was launched in 1999 and was the first commercial high-resolution satellite sensor (Kartal et al., 2004). IKONOS provides very-high resolution imagery (< 1 m) in both colour and black and white, and there is an extensive image archive (GeoEye Imagery, 2007). Research completed after the 2004 Indian Ocean tsunami concluded that it was easier to detect roads, and other small-scale details in IKONOS satellite imagery than it was using either Landsat or SPOT imagery (Aitkenhead et al., 2007). Research also suggests that there is very little difference between IKONOS and the very-high resolution imagery available from QuickBird (Wang et al., 2004). Archive imagery for the entire area of this study in Manitoba was collected in 2006; however, some scenes were collected when the ground was snow covered.

Regardless, the price, listed in *Table 31*, is very competitive (W. Ferris, Digital Environmental Management Inc., personal communication, November 14, 2007).

New Aerial Photographs

Based on the total scores, aerial photography was determined as the best source of imagery for this project. Furthermore, if historical images are not available, the RMs could initiate the collection of new aerial photography to produce the maps required to meet the project objectives. Aerial photographs provide excellent resolution (0.5 m), complete coverage, enhanced data processing capabilities, and current aerial photographs can be used for other purposes, such as drainage studies and land use planning, or sold to land owners, developers, and recreational groups to recover a portion of the costs (a sample aerial photograph provided by Prairie Agri Photo is included as Appendix H). The most significant disadvantage of new aerial photography is the time it takes to obtain imagery and to produce the final maps.

Historical aerial photographs

With a total score of 23.7, the historical aerial photograph option is the best choice for this project. This is primarily due to the acceptable resolution, low cost, and availability of the imagery. Within the province, historical aerial photographs are available free of charge from the Government of Manitoba through the Manitoba Land Initiative (MLI) website (https://web2.gov.mb.ca/mli/). The images available in September 2007 were 2 m resolution, black and white aerial photographs taken in the mid 1990s (there are plans to update and replace the aerial photographs in the near future). The images are georeferenced to the North American Datum 1983 and are available for download in 5 km^2 tiles. They can be viewed in most GIS software packages. In this instance, seamless coverage was available for the entire study area.

Table 31: Summary of image source characteristics

Source	Cost ($CDN)[7]	Resolution[8]	Coverage	Age	Data delivery
Historical aerial photographs	Free from MLI	2 m Black and white	Photos taken at one time for entire study area can be stitched together with appropriate software.	+/- 10 years	Instant download of archive images from MLI
New aerial photographs	$7000[a] for entire area $1000[a] per square mile on demand	0.5[a] m Colour	Photos for entire study area provided by contractor. Minimal data manipulation necessary.	Current	Several weeks Image ready in 6 hours for a single scene
IKONOS	$8200[b] for archive	0.8 c 1 m Colour, or black and white	Photos for entire study area can be stitched together with appropriate software.	2006	Archive – 5-day delivery; new collection 60 days
Google Earth	$400[c] annual fee	2.5 – 10 m Colour	Entire study area can be viewed but resolution is mixed and coverage is not consistent.	2004 –2007	Immediate
SPOT	$12,500[d] for archive; $13,500 for on-demand flight	2.5 m Colour	Photos for entire study area can be stitched together with appropriate software.	July 2007 from archive or current	Archive – 3-day delivery

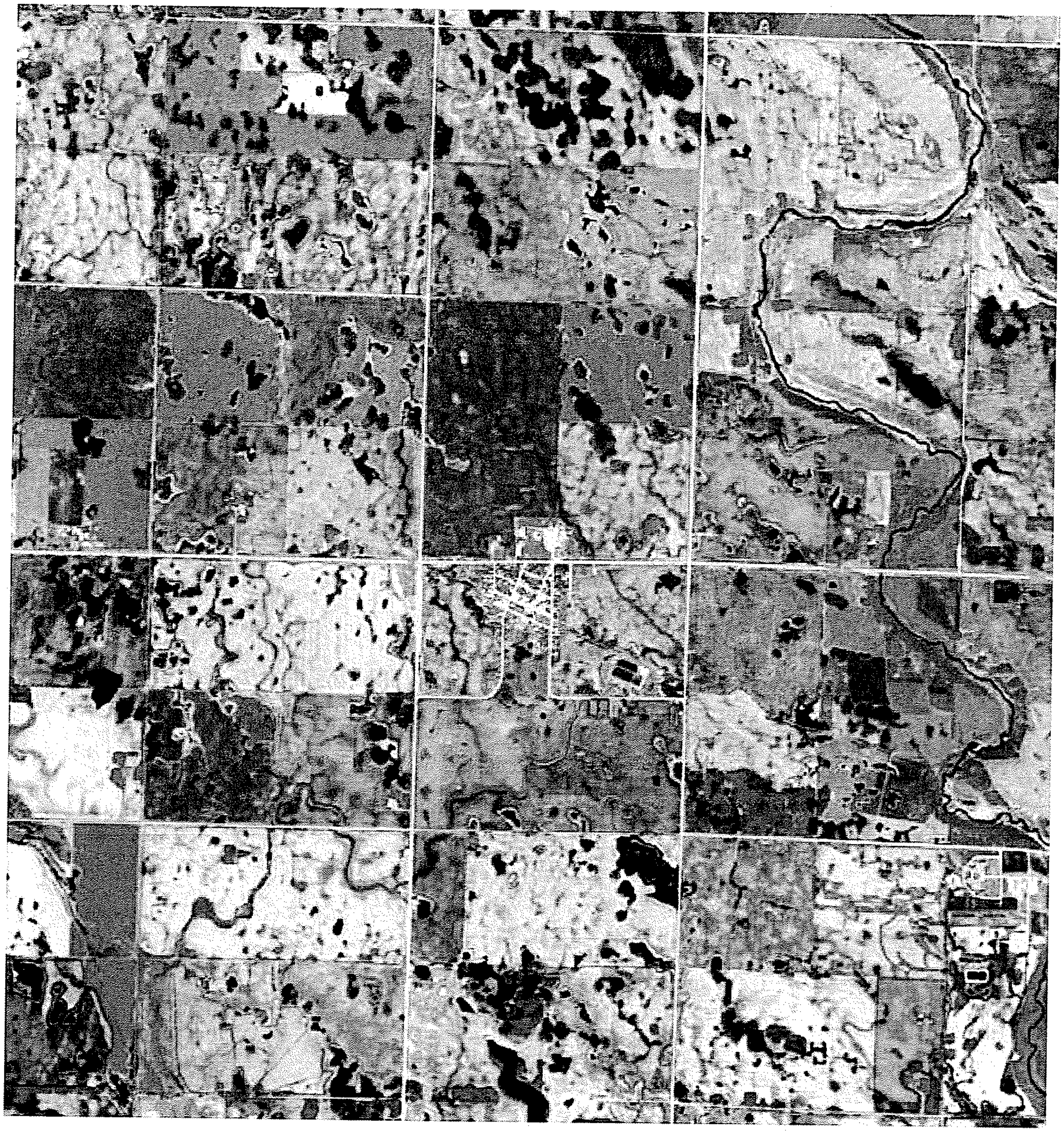
[7] Prices for lower resolution imagery provided by the same satellite may be lower than the values shown. The costs listed include all processing fees, delivery charges, and any other additional fees. Costs are rounded to the nearest even number and are subject to change. Prices and data availability for other areas may be significantly different.
[8] The resolution listed represents the best resolution available for each data source.

Source	Cost ($CDN)[7]	Resolution[8]	Coverage	Age	Data delivery
QuickBird	$15,000[e] archive; $18,500 on-demand	0.60 – 1 m Colour	Photos for most of the study area can be stitched together with appropriate software. Areas around Winnipeg are well covered, Elie is not. Image will not be consistent.	Current or historical 2002 – 2007	Archive – immediate to 3 days, new collect 5 to 10 days
Landsat 7	Free archive from USGS. [9] $950[f]/scene	30 m	Study area is included in 1 scene.	Historical 2000 - 2007	Instant download of archive images from USGS; Instant download
NOAA	Free	1000 m	Study area is included in 1 scene	Current	Instant download from weather website
UAV	High for entire study area $600[g] per photo at a local level	0.20 – 0.50[g] m Colour	Impractical to photograph entire study area using this tool	Current	Many hours for entire project area; Data for individual images delivered within hours once approval to fly UAV is obtained.

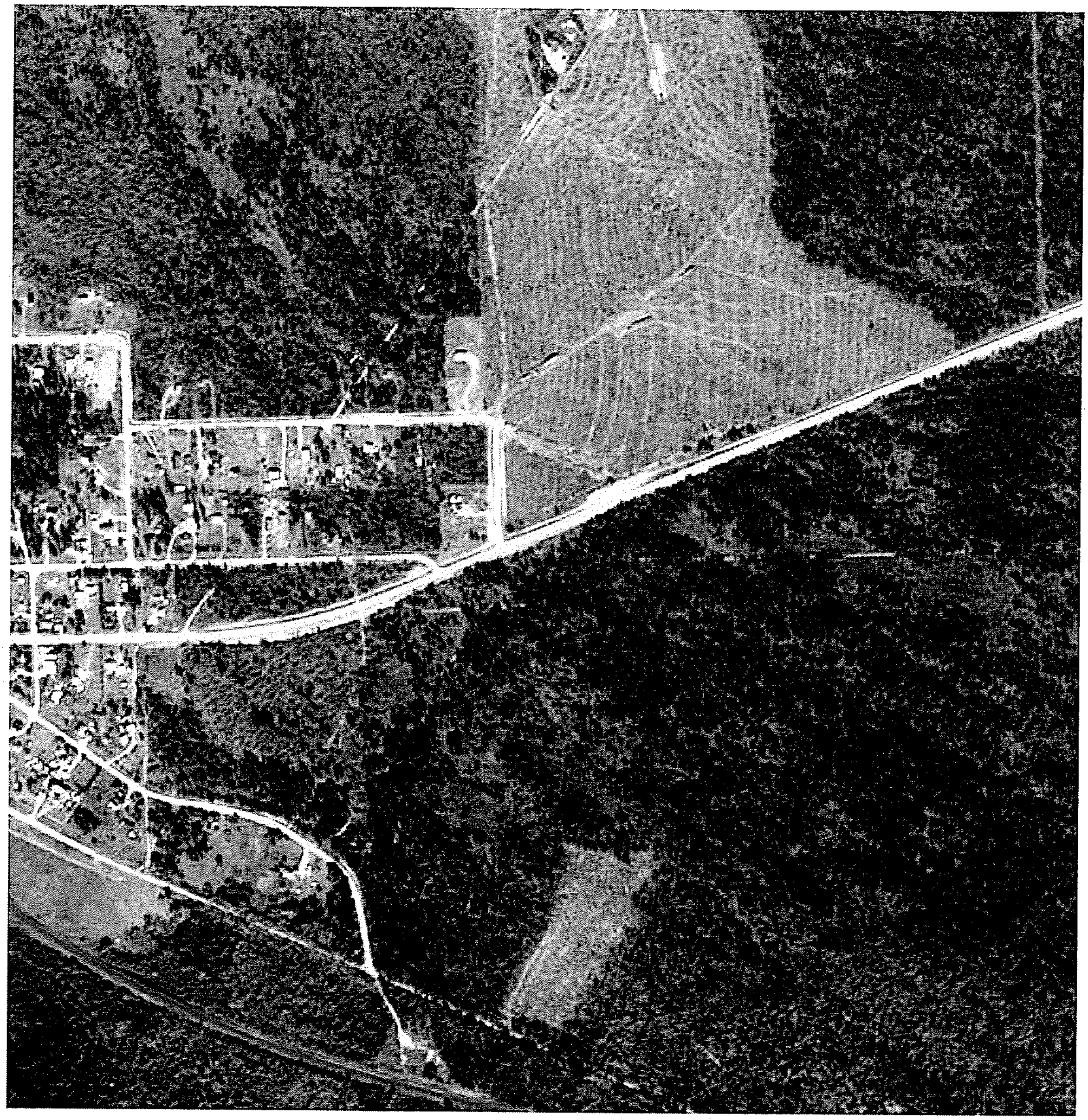
a) Quote and resolution values provided by Prairie Agri Photo (MB) (J. McKinnon, personal communication, December 10, 2007).
b) Quote provided by Digital Environmental Management Inc. (W. Ferris, personal communication, November 14, 2007).
c) Price listed is for Google Earth Pro (November, 2007).
d) SPOT image pricing calculated based on information in the 2008 price list at: http://www.spotimage.fr/automne_modules_files/standard/public/p335_ba582c667a21f3b7d1108ad9773629fdSPOTListePrix_2008-1101.pdf (accessed January 2008).
e) QuickBird archive price determined from: http://www.mapmart.com/WorldSatelliteImagery/satellite.htm (accessed January 2008).
f) Landsat 7 image pricing calculated based on information provided in the price list at: http://www.landinfo.com/l7.htm (accessed January 2008).
g) Price per image and resolution value provided by On Demand Imagery (G. Lewis, personal communication, November 6, 2007).

[9] U.S. Geological Survey

APPENDIX D: SPOT SATELLITE IMAGE (10 METRE)

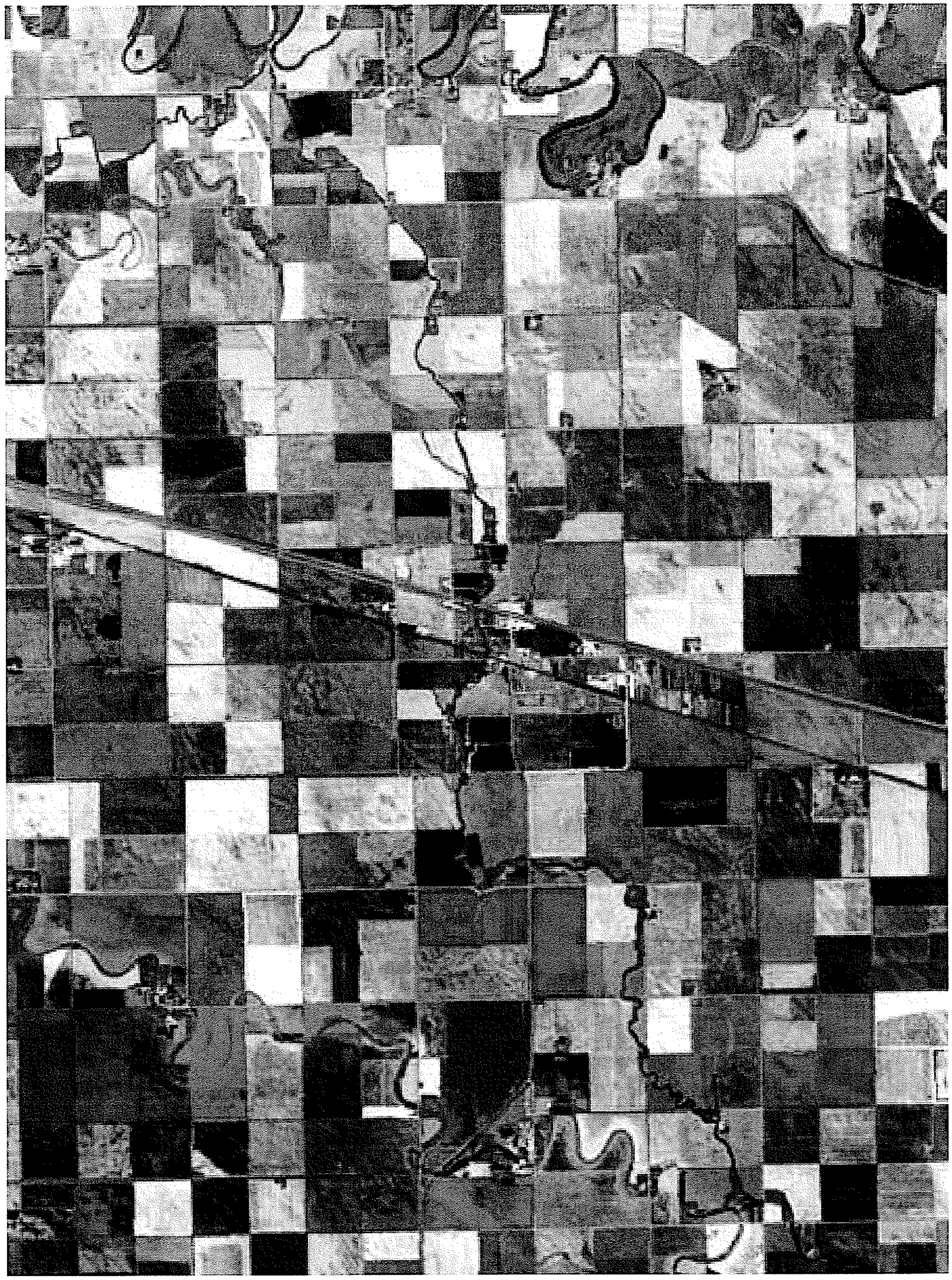


APPENDIX E: QUICKBIRD SATELLITE IMAGE (2.4 METRE)



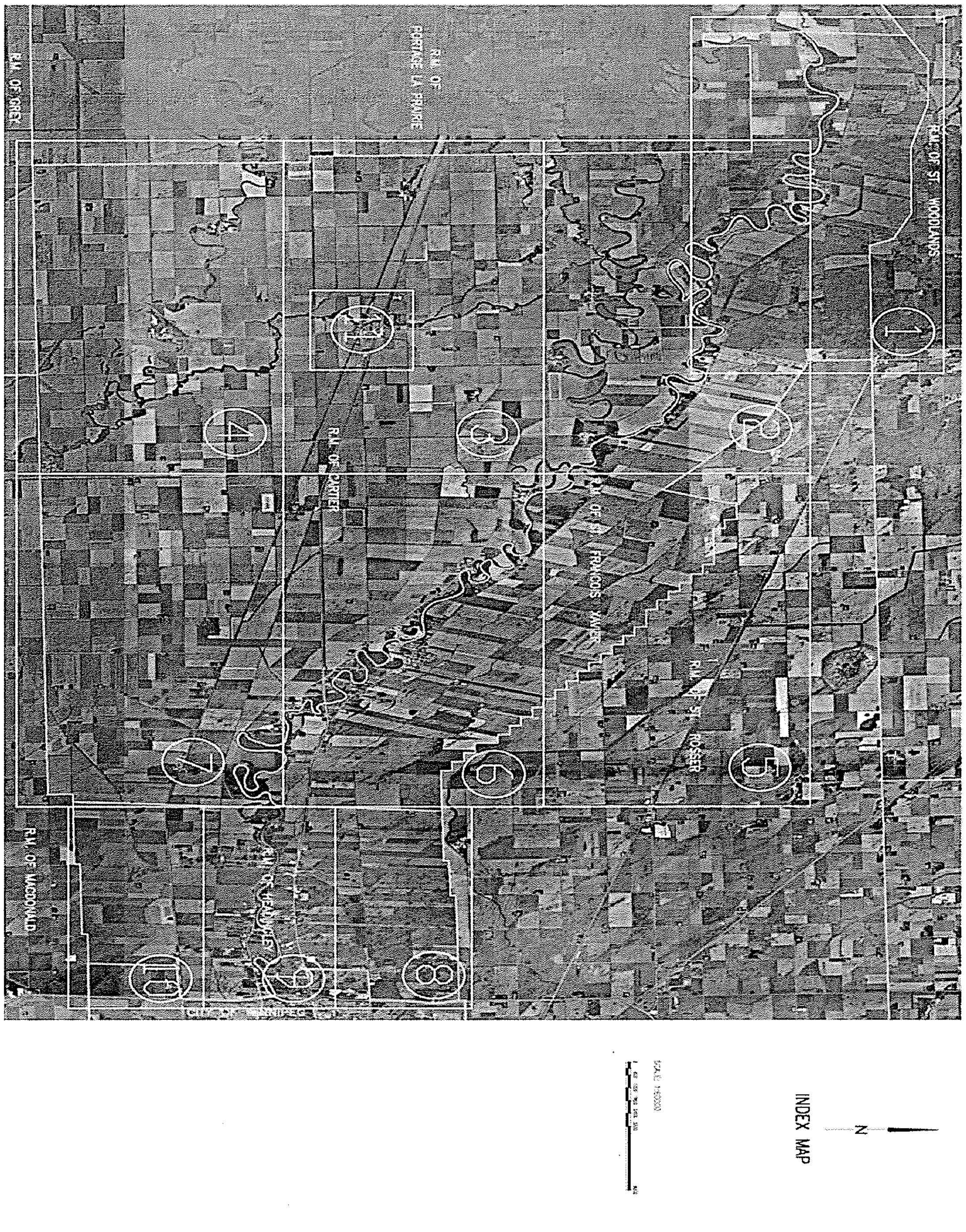
APPENDIX F: NOAA SATELLITE IMAGE

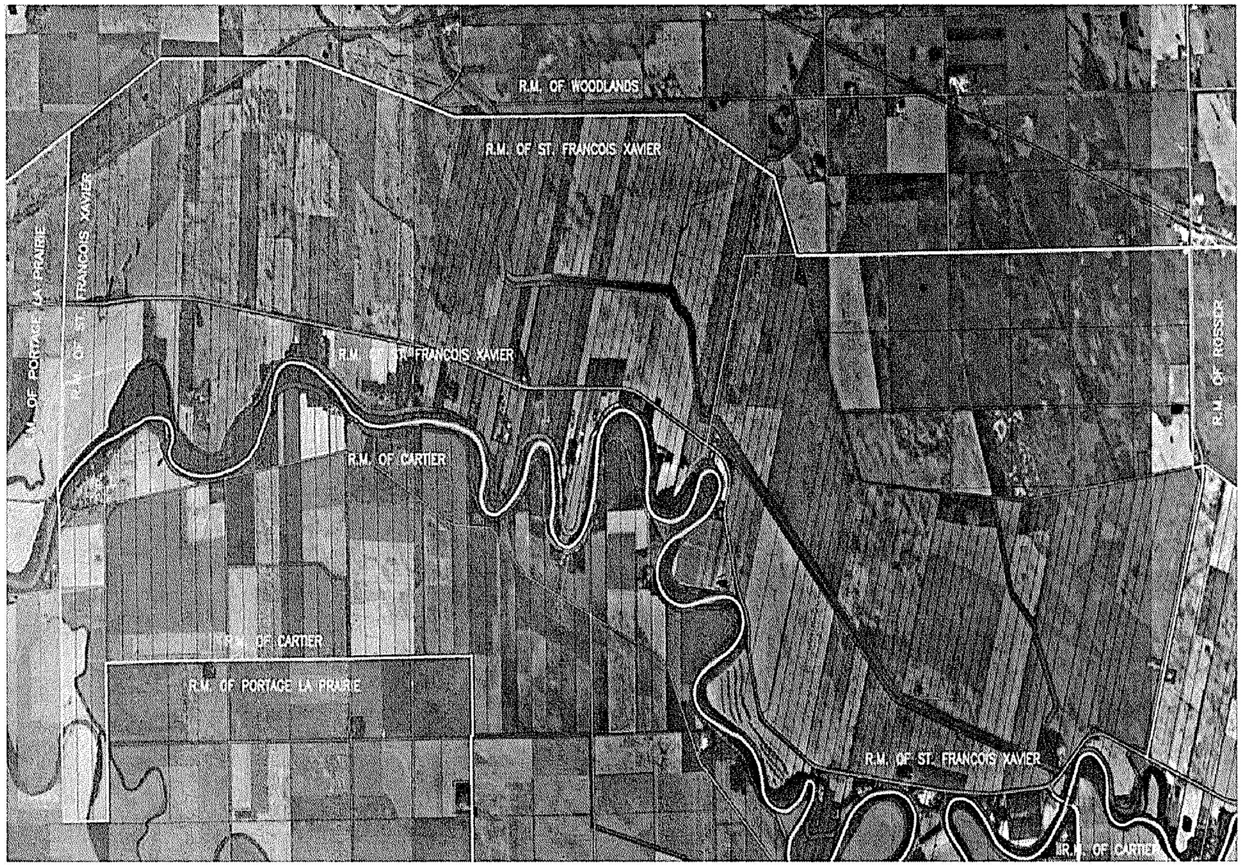
APPENDIX G: LANDSAT 7 (30 METRE)



APPENDIX H: QUARTER SECTION AIR PHOTO

APPENDIX I: CASE STUDY (REDUCED VERSION OF PROJECT MAPS)





N

MAP 1

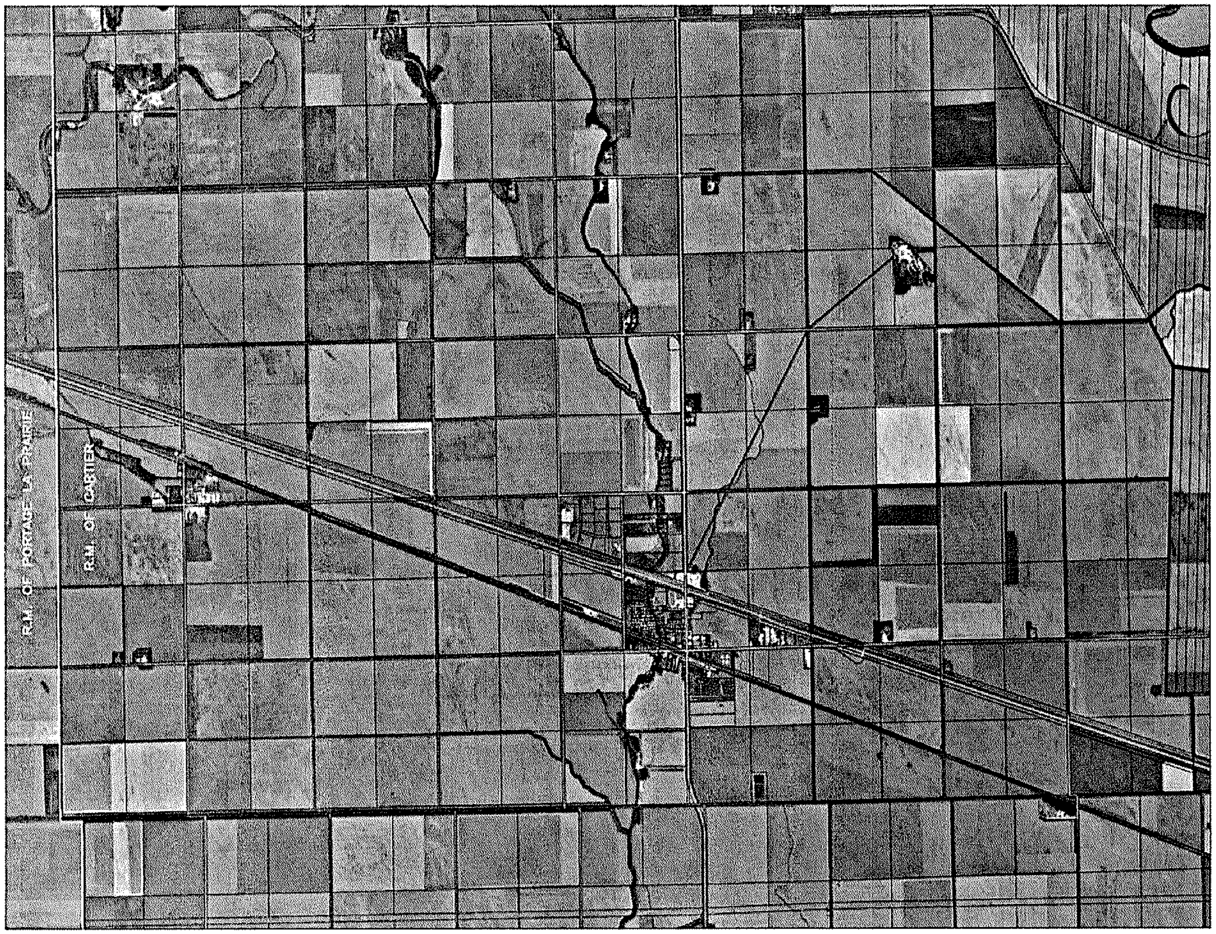
R.M. OF ST. FRANCOIS XAVIER
R.M. OF CARTIER
R.M. OF WOODLANDS
R.M. OF ROSSER
R.M. OF PORTAGE LA PRAIRIE

SCALE: 1:20000

N

MAP 2

R.M. OF ST. FRANCOIS XAVIER
R.M. OF CARTIER
R.M. OF ROSSER
R.M. OF PORTAGE LA PRAIRIE

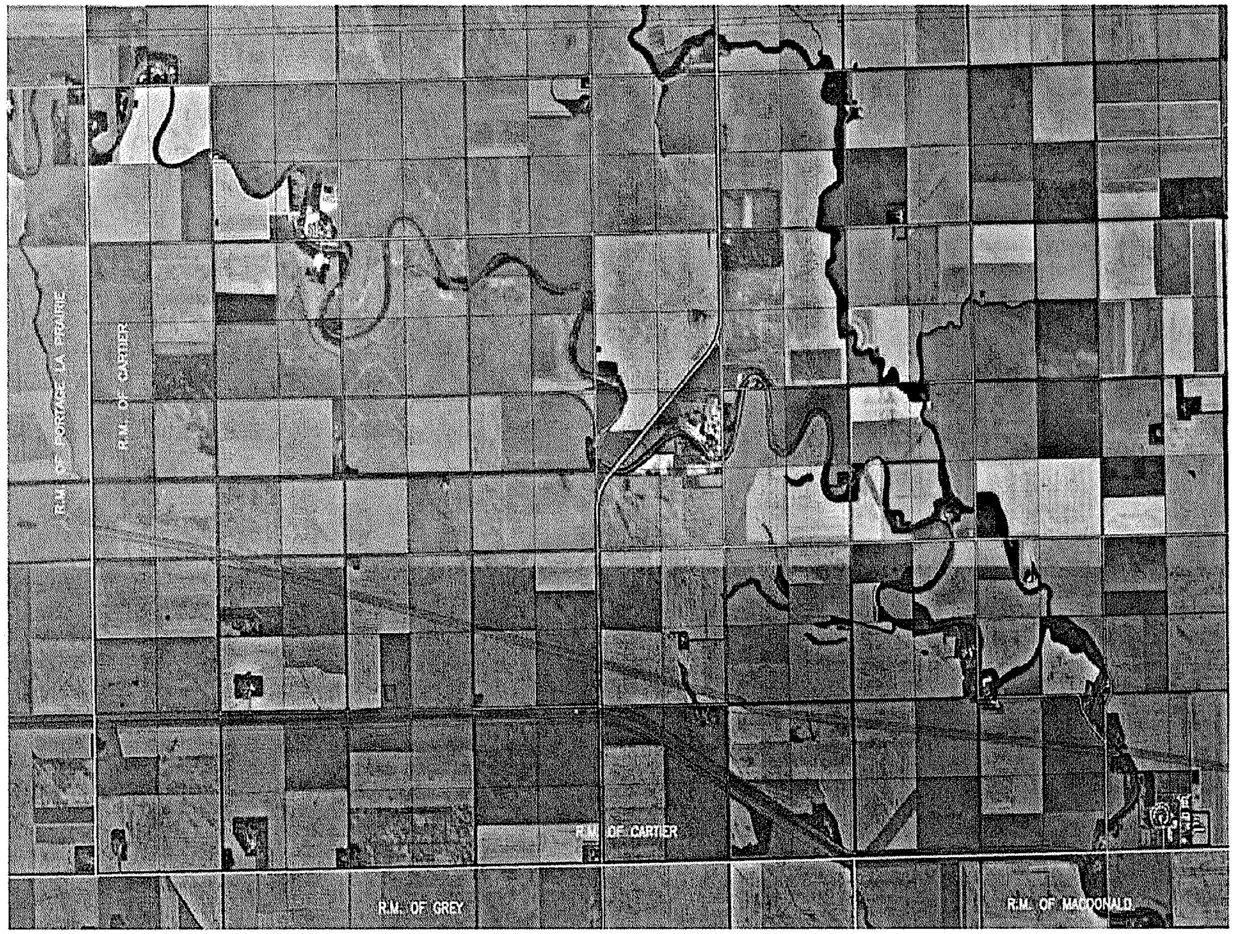


N

MAP 3

R.M. OF CARTIER
R.M. OF PORTAGE LA PRAIRIE

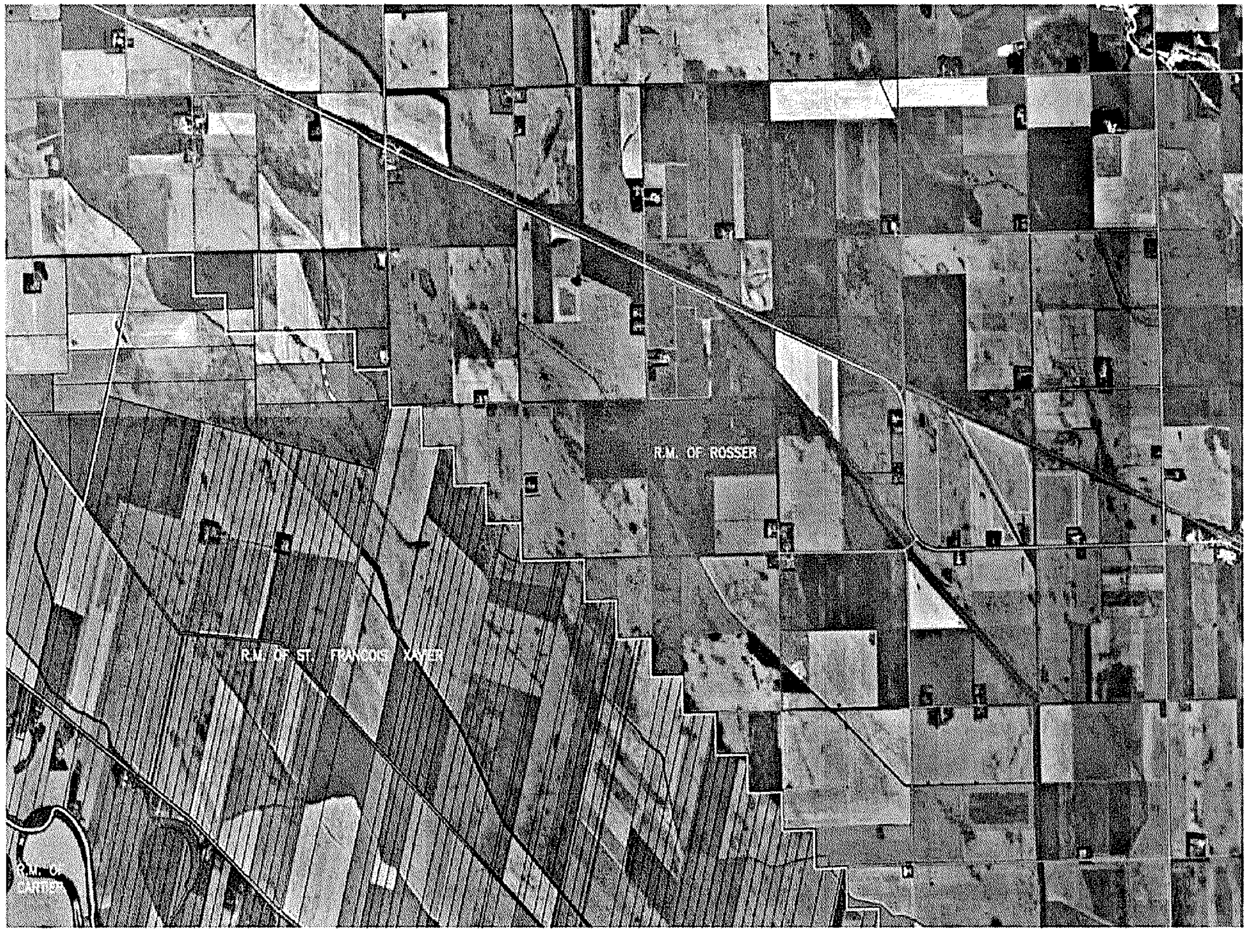
SCALE: 1:20000



N

MAP 4

R.M. OF CARTIER
R.M. OF PORTAGE LA PRAIRIE
R.M. OF MACDONALD
R.M. OF GREY



N

MAP 5

R.M. OF CARTIER
R.M. OF ST. FRANCOIS XAVIER
R.M. OF ROSSER

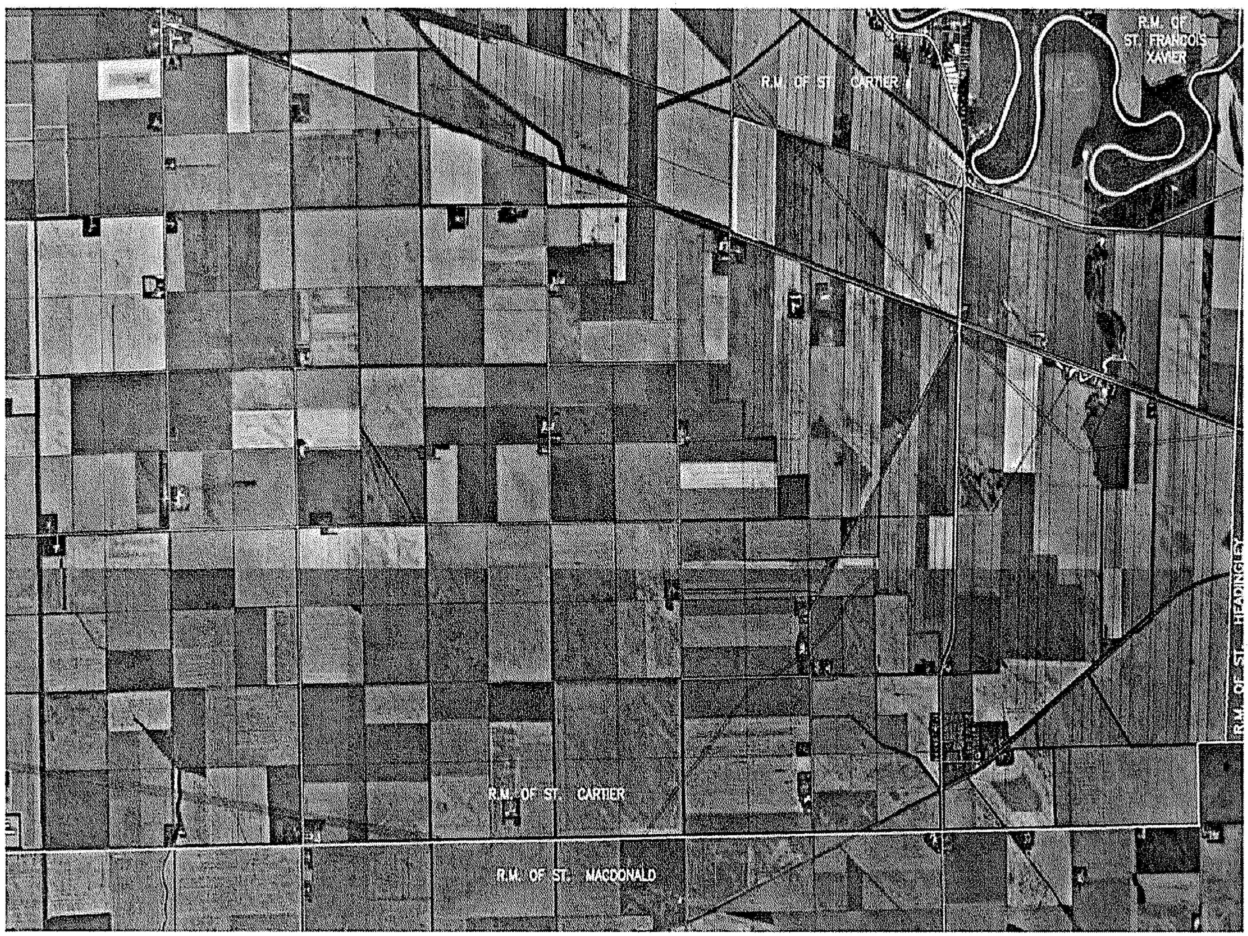
SCALE: 1:20000

N

MAP 6

R.M. OF CARTIER
R.M. OF ST. FRANCOIS XAVIER
R.M. OF ROSSER

SCALE: 1:20000



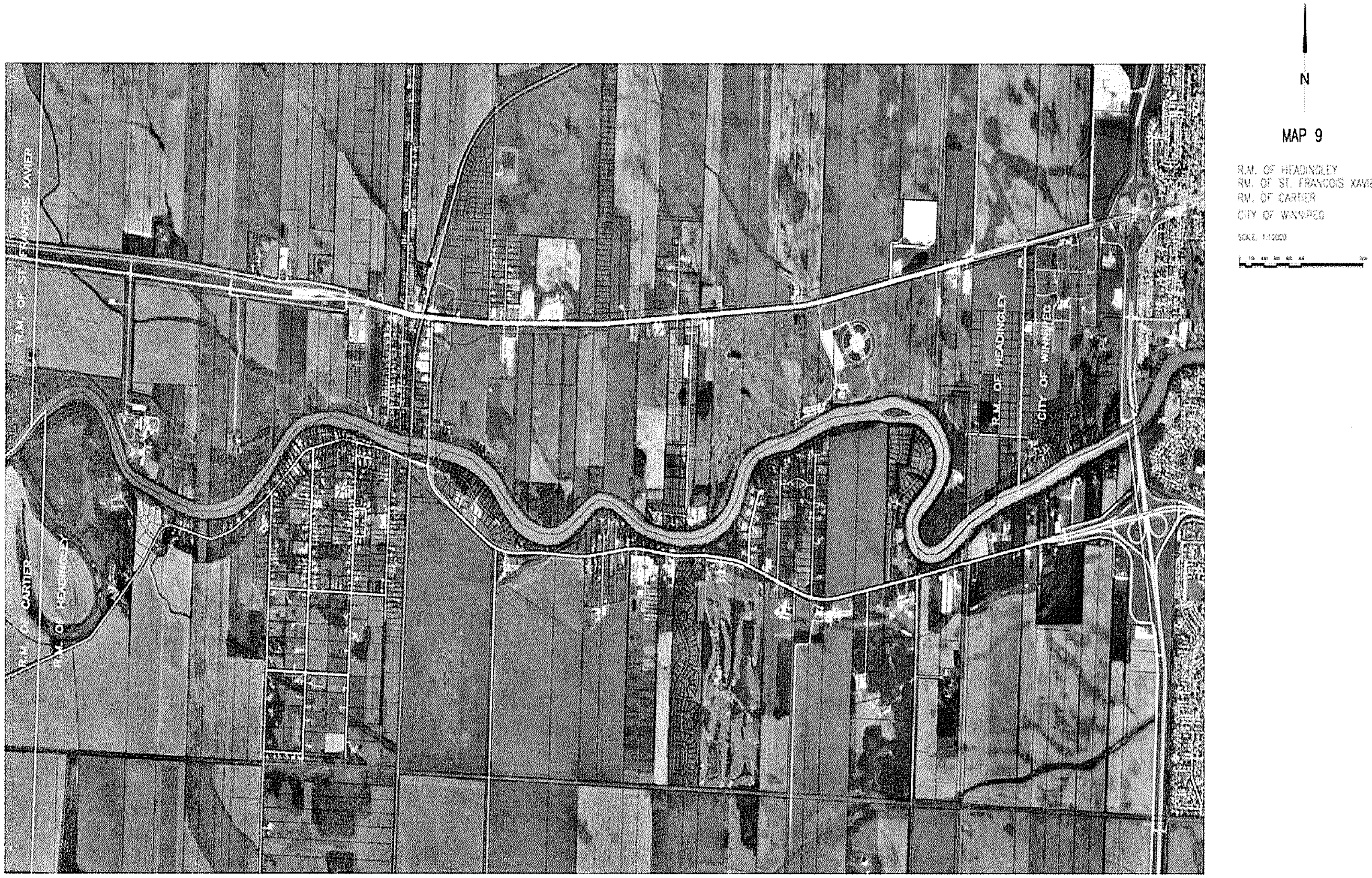
N

MAP 7

R.M. OF CARTIER
R.M. OF ST. FRANCOIS XAVIER
R.M. OF MCDONALD
R.M. OF HEADINGLEY

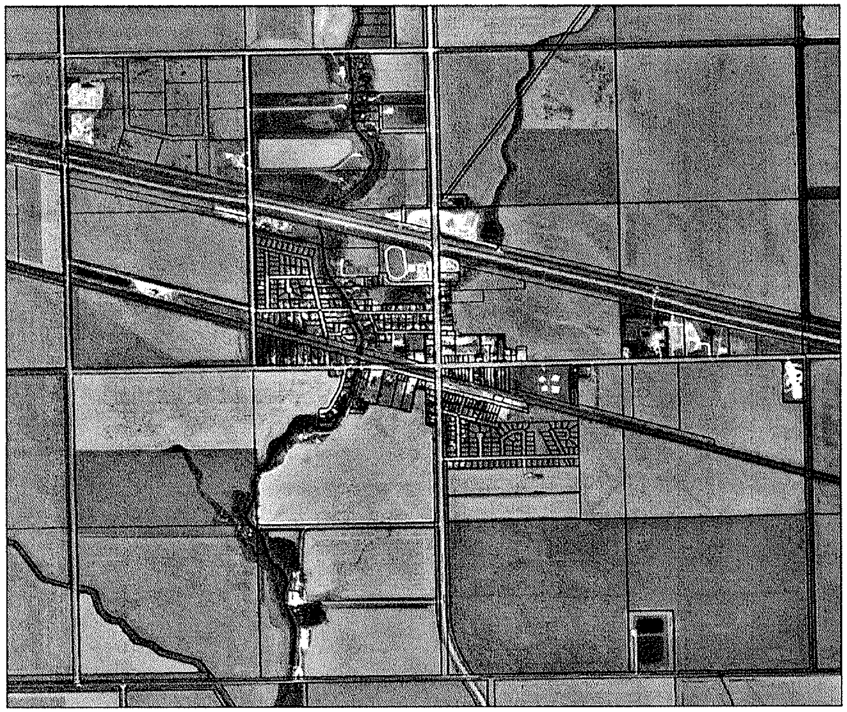
SCALE: 1:20000


N
MAP 8
R.M. OF HEADINGLEY
R.M. OF ST. FRANCOIS XAVIER
R.M. OF ROSSER
CITY OF WINNIPEG
R.M. OF ROSSER
R.M. OF HEADINGLEY
R.M. OF ST. FRANCOIS XAVIER
R.M. OF HEADINGLEY
R.M. OF HEADINGLEY
CITY OF WINNIPEG


N
MAP 9
R.M. OF HEADINGLEY
RM. OF ST. FRANCOIS XAVIER
RM. OF CARTIER
CITY OF WINNIPEG
R.M. OF ST. FRANCOIS XAVIER
R.M. OF HEADINGLEY
CITY OF WINNIPEG
R.M. OF CARTIER
R.M. OF HEADINGLEY

MAP 10

R.M. OF HEADINGLEY
RM. OF MCDONALD
RM. OF CARTIER
CITY OF WINNIPEG



N

MAP 11

ELIE

SCALE: 1:10000

0 100 200 300 400 500 1000

APPENDIX J: ETHICS APPROVAL CERTIFICATE

UNIVERSITY OF MANITOBA | OFFICE OF RESEARCH SERVICES
Office of the Vice-President (Research)

CTC Building
208 - 194 Dafoe Road
Winnipeg, MB R3T 2N2
Fax (204) 269-7173
www.umanitoba.ca/research

APPROVAL CERTIFICATE

30 May 2007

TO:	**Scott Westlund** Principal Investigator	(Advisor D. Wiseman)
FROM:	**Wayne Taylor, Chair** Joint-Faculty Research Ethics Board (JFREB)	
Re:	**Protocol #J2007:067** **"Exploring the use of Geomatics in Disaster Management"**	

Please be advised that your above-referenced protocol has received human ethics approval by the **Joint-Faculty Research Ethics Board**, which is organized and operates according to the Tri-Council Policy Statement. This approval is valid for one year only.

Any significant changes of the protocol and/or informed consent form should be reported to the Human Ethics Secretariat in advance of implementation of such changes.

Please note:

- **if you have funds pending human ethics approval, the auditor requires that you submit a copy of this Approval Certificate to Kathryn Bartmanovich, Research Grants & Contract Services (fax 261-0325), <u>including the Sponsor name</u>, before your account can be opened.**

- **if you have received multi-year funding for this research, responsibility lies with you to apply for and obtain Renewal Approval at the expiry of the initial one-year approval; otherwise the account will be locked.**

The Research Ethics Board requests a final report for your study (available at: http://umanitoba.ca/research/ors/ethics/ors_ethics_human_REB_forms_guidelines.html) **in order to be in compliance with Tri-Council Guidelines.**

Bringing Research to Life

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CTC Building
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www.umanitoba.ca/research

AMENDMENT APPROVAL

31 July 2007

TO: **Scott Westlund**
Principal Investigator

FROM: **Wayne Taylor, Chair**
Joint-Faculty Research Ethics Board (JFREB)

Re: **Protocol #J2007:067**
"Exploring the use of Geomatics in Disaster Management"

This will acknowledge your e-mail dated July 27, 2007 requesting amendment to the above-noted protocol.

Approval is given for this amendment. Any other changes to the protocol must be reported to the Human Ethics Secretariat in advance of implementation.

Bringing Research to Life

APPENDIX K: INFORMED CONSENT (INDIVIDUAL)

UNIVERSITY OF MANITOBA

Department of
Environment and Geography

Winnipeg, Manitoba
Canada R3T 2N2
Telephone (204) 474-9667
Fax (204) 474-7699
environment_geography@umanitoba.ca

Informed Consent Form (Semi-Directed Interview)

Research Project Title: Exploring the use of geomatics in disaster management

Researcher: Scott Westlund (Master's student), Department of Environment & Geography, University of Manitoba.

This consent form, a copy of which will be left with you for your records and reference, is only part of the process for informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

You are about to participate in an interview and provide information on your experiences, opinions, and concerns regarding hazard risk and vulnerability assessment, and the use of geomatics technologies. You will be asked a series of open-ended questions that are intended to ascertain how, and specifically why, geomatics is implemented, and the benefits and challenges for doing so. Documenting your knowledge of the use of geomatics in managing disaster events is essential and will contribute to the disaster management profession.

This interview will take approximately 60-90 minutes. You will not be compensated for participating in the interview. During this time, a series of open-ended questions will be used to facilitate conversation with the researcher. Your participation in this dialogue is highly encouraged. Please feel free to speak your mind.

If appropriate, an audio recorder may be used to document the interview. The information captured will be used to generate a transcript of the proceedings. Should you wish not to be recorded, we will accommodate your request.

In order to highlight the importance of your accomplishments and experiences, we will normally identify people by name in any research outcomes that arise from these interviews. However, our research is iterative and you will always be able to choose to remain anonymous, if you so wish. Additionally, you will be free to withdraw at any point in the research.

The outcomes of this research will include a graduate thesis, and peer reviewed research papers. Once the data analysis is complete, I will provide you with a document that summarizes the outcomes of this research.

All of the information that you provide will be stored in a locked cabinet, accessible only by the researchers, for the duration of the project (5 years). All audio and originally written records will be destroyed once the research is complete or on or before June 1, 2012.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation.

If you have any questions about the research, please contact Scott Westlund
, Dr. Dion Wiseman, Brandon University
or Dr. Emdad Haque, University of Manitoba

The University of Manitoba Joint-Faculty Research Ethics Board has approved this research. If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 204-474-7122, or e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

______________________________	______________________________
Participant's Signature	Date
______________________________	______________________________
Researcher's Signature	Date