Moving from Flood Resistance to Resilience:
“Still doing it the hard way” in Western Canada

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By

Alasdair David Morrison

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ABSTRACT

Flooding poses a significant threat to society, a threat that is likely to increase with changing climate. Over recent decades, the limitations of a historical reliance on command and control approaches to flood risk management (FRM) have been recognised and scholarly and practical effort has been made towards becoming flood resilient rather than flood resistant. Despite these efforts, the cost of flood events continues to rise. Progressing FRM in a way that increases resilience to flooding requires a better understanding of the challenges that exist when attempting to operationalise theoretical principles of resilience in practice. Empirical studies of FRM implementation, however, are not well represented in the literature. This thesis enhances understanding of the challenges involved in operationalising flood resilience concepts. To achieve this aim, scholarly literature self-identified by the authors as being related to flood risk management, governance and resilience was analysed, and the Prairie Provinces of Canada were utilised as a case study of FRM practice, priorities and preferences.

It was found that rather than tackling flood resilience as a defined research topic, FRM and flood resilience research is carried out in specialised disciplinary silos and which does not relate well to the challenges of implementing FRM. Within the Canadian Prairie Provinces, FRM practitioners understand the need for a diverse policy approach to flood risk and for more coordinated and collaborative management; however, challenges from fragmented governance exist in the region including unclear roles and responsibilities, policy conflicts, and inefficiency. Broadly effective emergency planning and response suggests that these challenges are not insurmountable. The FRM priorities of stakeholders are similar across the study area suggesting that there is an underlying foundation for an inter-provincial regional strategy. The heterogeneous policy preferences between provinces and homogenous preferences within provinces, however, present challenges to implementing coordinated multi-level FRM strategies. Importantly, it was found that existing flood policy instruments may not be effective in influencing policy choices, and that innovation is required in this area to progress more resilient FRM. Overall, the findings of this thesis strongly support: the need for close linkages between the academic and practice communities; that research and policy programs should treat FRM as a distinct, holistic, issue, and; that organisations or agencies are needed to facilitate the coordination of stakeholders and resources required to research, manage and continually improve FRM.

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For Cassandra and our baby. You made the journey possible.

Per ardua.

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List of Abbreviations

AB	Alberta
AHP	Analytic Hierarchy Process
BCF	Building Canada Fund
CDD	Canadian Disaster Database
DFAA	Disaster Financial Assistance Arrangements
EU	European Union
FDRP	Flood Damage Reduction Program
FRM	Flood Risk Management
HProt	High perceived protection
HSev	High severity of flooding
IWRM	Integrated Water Resource Management
IFM	Integrated Floodplain Management
LProt	Low perceived protection
LSev	Low severity of flooding
MB	Manitoba
MCDA	Multi-Criteria Decision Analysis
MProt	Medium perceived protection
Msev	Medium severity of flooding
NDMP	National Disaster Mitigation Program
NGO	Non-Governmental Organisation
NSERC	Natural Sciences and Engineering Research Council of Canada
NSF	National Science Foundation
OPBO	Office of the Parliamentary Budget Officer
PPWB	Prairie Provinces Water Board
SK	Saskatchewan
SSHRC	Social Sciences and Humanities Research Council of Canada

1. INTRODUCTION

1.1 Introduction

Globally, changing climate is associated with an increase in the severity and frequency of natural hazards including forest fires, droughts, and extreme weather events, and with increased risk to the health and well-being of society (Olmstead et al., 2014). In the past decade, for example, both Canada and the United States have experienced severe wildfires; between 2011 and 2019 California experienced 376 consecutive weeks of drought conditions (US Drought Portal); and many countries, including Canada, Australia, New Zealand, Germany, and the United Kingdom have experienced an increase in extreme flood events. Societal change also plays a significant role in the risk that climate-related events pose to communities. For example, land-use changes, increased urbanisation, agricultural practices, forest clearing, increased development on floodplains, and public risk perceptions and behaviours can exacerbate the impacts of natural disasters (Jongman et al., 2014; Mileti, 1999; Winsemius et al., 2016). In response to these changing climate conditions and increased risk, climate change adaptation has become a significant focus of both academic research and public policy (Berrang-Ford et al., 2015; Smith et al., 2011). International, national, state, and local government strategies, policies and frameworks now consider climate change adaption in their strategic planning. Examples of such climate change related policies and strategies include the United Nations' Framework on Climate Change, the United Kingdom's Committee on Climate Change, the Government of Ontario's Climate Change Strategy (Government of Ontario, 2015), and municipal climate change strategies under the Nova Scotia Municipal Climate Change Action Plan (Government of Nova Scotia, 2012).

Floods, in particular, are expected to become more frequent and more severe under changing climate conditions (Winsemius et al., 2016). Multiple, interlinked ecological systems including climate, surface water, groundwater, riparian and wetland ecosystems, vegetation patterns, geomorphology, and others influence the characteristics of flooding (Seiler, 2002). These ecological systems are influenced by human activity, including land-use and economic development, and by individual behaviours and systems of government (Wheater and Evans, 2009). Complex interactions within and between these ecological and social systems combine to influence the risk posed to society by floods (Alfieri et al., 2016). Society's historical and ongoing reliance on water for its well-being means that human development often exists in areas of high flood risk (Sivapalan et al., 2012). Flood risk management (FRM), as a result, has an important role to play in ensuring flood resilient communities, adapting to the effects of climate change, and mitigating for increased risk to society.

Managing flood risks ideally should account for the complexity, connectivity, and dynamic nature of social and ecological systems (Walker et al., 2004). Human activities, such as agriculture, infrastructure development, energy production, and conservation influence how ecological systems function and, as a result, affect the characteristics of floods and flood risk. Managing these ‘social-ecological’ systems, or systems in which human and ecological factors are intricately linked, requires that humans are considered part of, not apart from, nature (Berkes and Folke 1998; Folke et al., 2002). Social-ecological systems are dynamic, that is, they evolve in relation to their resilience, adaptability, and transformability in response to both environmental and social change (Folke, 2002; Walker et al., 2004). The goal of managing social-ecological systems is thus resilience – adapting to change to maintain system structure and function and, if the original structure and function become untenable, preparing for and supporting transformation to a new system state (Walker et al., 2004). Managing social-ecological systems and, by extension, flood risk, thus requires policies, processes, and institutions that seek to cope with and adapt to change rather than attempt to control or resist change (Folke, 2002).

This Chapter sets the context for the thesis. It explores prevailing resource management paradigms and how they relate to social-ecological systems management, explores the principles and current practices of flood risk management, and establishes the research purpose, objectives, and structure of the manuscript-style thesis.

1.2 Resource management paradigms and social-ecological systems

The management of social-ecological systems is broadly approached from one of two, often competing, paradigms: i) command and control management; and ii) strategic and adaptive management. These approaches are based on different underlying assumptions and concepts and result in substantial differences in policy choices and the ways in which systems of governance are organised (Pahl-Wostl, 2007a).

Command and control has been the prevailing approach to natural resource management worldwide since industrialisation (Holling and Meffe, 1996). The command and control approach is characterised by centralised and hierarchical governance structures and top-down decision making that separates natural resource management into discrete sectors or policy domains (Cox, 2016). When resource or environmental problems are encountered, actions are prescribed within the context of the specific resource sector or policy domain that are assumed sufficient to correct the problem. Actions that result from this approach tend to be reactionary and focused on management through technological and regulatory interventions (Pahl-Wostl, 2007b). Command and control management typically adopts the engineering conceptualisation of resilience: "efficiency, constancy and predictability – all aspects of the engineer's desire for a fail-safe design" (Schulze, 1996: 33). Engineering resilience describes the ability of a system to resist changing from an equilibrium state, and how quickly the system recovers to that equilibrium state when disturbed. Central to the command and control approach is an assumption that the system being managed is predictable, well bounded, and comprised of known cause-effect relationships (Holling and Meffe, 1996; Pahl-Wostl, 2007a). Under these assumptions, the complexity of resource management is reduced to distinct, manageable policy domains and simple linear problems (Pahl-Wostl, 2007b) with resilience theoretically achieved by solving problems as they arise.

The underlying assumptions of command and control management and engineering resilience are problematic when applied to social-ecological systems. Social-ecological systems are inherently complex and unpredictable, meaning that they cannot be broken down into simple, linear cause and effect relationships (Berkes and Folke, 1998; Pahl-Wostl, 2007a). Social-ecological systems are often irreducible and the management of individual components of those systems can be inappropriate (Berkes and Folke, 1998). Managing social-ecological systems within artificially well-defined policy domains or sectors does not adequately account for system complexity and feedback (Pahl-Wostl, 2007b). Command and control can provide effective short-term management solutions, but in not recognising the complex nature of social-ecological systems such policies threaten rather than support resilience (Armitage et al., 2012; Holling and Meffe, 1996; Pahl-Wostl, 2007b).

Alternative, holistic approaches to managing natural resources, referred to in this thesis as 'strategic' and 'adaptive', are considered more appropriate for addressing the complex and often unpredictable nature of social-ecological systems (Biggs et al., 2015; Folke et al., 2002; Karpouzoglou et al., 2016; Olsson et al., 2006). Strategic management processes promote planning that is proactive rather than reactive; planning that is carried out with respect to the influences of, and on, other policy areas; planning that addresses short, medium, and long term priorities; planning that takes into account a range of potential future scenarios; and decision-making authority that is devolved to appropriate levels and that ensures meaningful involvement of stakeholders (Akamani and Wilson, 2011; Carvalho-Ribeiro et al., 2010; Green et al., 2013). Adaptive management processes accept the need to act even when there is scientific uncertainty, and that the action taken should aid understanding of the cause of a problem (Lee, 1999; Pahl-Wostl, 2008; Walters and Holling, 1990). This requires accepting that policies which appear to be logical and justifiable based on the best available information may prove to be less effective than desired because of unknown (at the time of development) or confounding factors. Policies become experiments, the results of which are used to improve performance iteratively through policy cycles (Walters and Holling, 1990).

Underlying strategic and adaptive approaches is an ecological understanding of resilience: "persistence, change and unpredictability – all attributes embraced and celebrated by biologists with an evolutionary perspective and by those who search for safe-fail designs" (Schulze, 1996: 33). Resilience in this context is measured by the magnitude of disturbance that can be withstood before the system passes a threshold where recovery is no longer possible, and the system is instead forced to an alternate, though not necessarily less healthy, state (Liao, 2012; Schulze, 1996). Strategic and adaptive management assumes that social-ecological systems are largely unpredictable, do not have well-defined boundary conditions, are comprised of complex relationships and feedback loops, and have no single, stable equilibrium state (Holling and Meffe, 1996; Liao, 2012; Pahl-Wostl, 2007b). Strategic and adaptive management accepts the often-irreducible complexity and unpredictability of social-ecological systems. Policies derived using a strategic and adaptive management approach tend to be collaborative (Partidario, 2012), consider interactions at multiple social and ecological scales, and work with natural processes rather than attempt to control them (Pahl-Wostl, 2007a). This does not preclude the use of linear, technical solutions commonly associated with command and control, but rather requires that these solutions are contextualised within the broader social-ecological system and are monitored and adjusted as necessary (Pahl-Wostl, 2008). A strategic and adaptative approach to flood risk management is appropriate given the complex, social-ecological nature of flood risk.

1.3 Flood risk management

Flood risk management (FRM) has been conceptualised in a variety of ways, but most often as an alternative to flood protection or flood hazard management (Hall et al., 2003; Schanze, 2006). Discourse has evolved from framing flood management primarily in terms of land drainage and flood defence, to ‘living with floods’ (de Bruijn et al., 2007) and coupling flood hazards with concepts of sustainability, resilience, vulnerability, and uncertainty (de Bruijn et al, 2007; Mileti, 1999). Schanze (2006), for example, identifies two, mutually exclusive interpretations of FRM: first, existing flood defence structures are assumed to be reliable and only the residual risk of flooding is analysed and actions put in place to mitigate that residual risk; second, flood risk analysis underpins strategic decision making to reduce flood risk, with flood protection being one of many potential risk management options. Consistent with this second interpretation of FRM, de Bruijn et al. (2007) argue that linking flood management to understandings of sustainability, resilience, vulnerability, and uncertainty requires that floods are approached as part of a complex system. Ideally, then, FRM adopts a dynamic systems approach which reduces risk through multiple approaches, including resistance, and which recognises that ongoing social, climatic and physical change are to be expected (de Bruijn et al., 2007).

The management of flood risk takes place within the broader concepts of water resource management and strategic land-use planning (Fig 1.1). In particular, FRM has been associated with Integrated Water Resource Management (IWRM) (Grabs et al., 2007; Green, 2004; WMO, 2009). The Global Water Partnership (GWP) defines IWRM as “a process which promotes the coordinated development and management of water, land, and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (WMO, 2009). IWRM assumes that water resources are most effectively managed when there is integration between water policy, land-use policy, environmental policy, and economic development (Benson et al., 2015), and that planning is carried out at the basin scale (de Bruijn et al., 2007). Integrated Flood Management (IFM) applies the IWRM concept to the management of floods, requiring a holistic, catchment-scale approach that maximises the efficient use of floodplains while protecting public safety, as well as promoting decision making that is decentralised, multi-scalar, transparent, and inclusive of multiple perspectives (GWP, 2000).

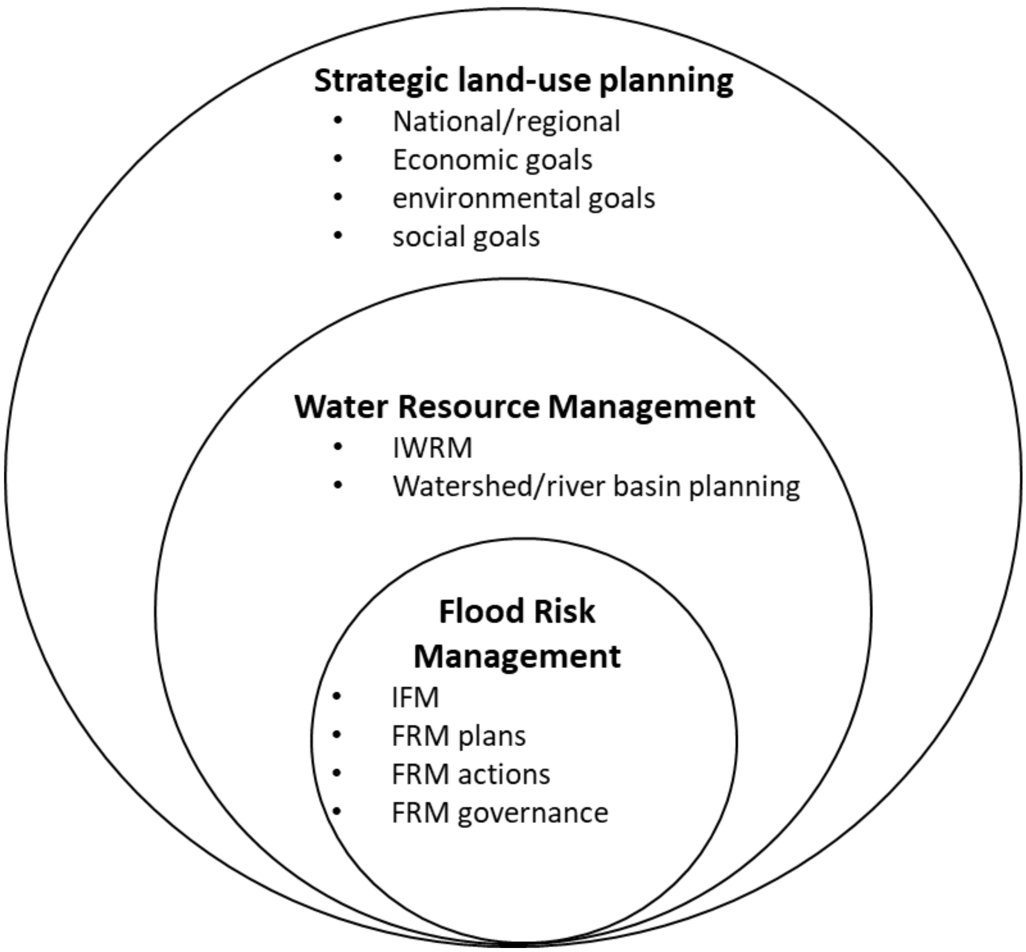

Figure 1.1 Relationship of FRM to broader water and land-use management concepts

The effectiveness of IWRM in achieving more sustainable water management, however, has been challenged (Benson et al., 2015; Biswas, 2008; Giordano and Shah, 2014; Lautze, 2011). Criticisms of IWRM include that it does not clearly define what should be integrated and how that can be achieved (Lautze et al., 2011), that it often becomes a formalised set of processes that obstructs rather than supports flexibility (Giordano and Shah, 2014), and that it is too technical an exercise without enough reference to the political aspects of water management and thus unable to overcome inter-jurisdictional fragmentation and conflicts (Schmidt, 2013). These criticisms do not suggest that there is no value in IWRM or IFM concepts, but that to be most effective these concepts require a greater understanding of the many influences on flood strategy and policy implementation (Giordano and Shah, 2014; Lautze et al., 2011).

The term ‘flood risk management’, then, comes with significant baggage and the potential for confusion over its use has been noted by scholars (de Bruijn, 2004; Schanze, 2006). Contemporary academic research and practice approach FRM as the act of managing flood risk (e.g., Birkholz et al., 2014: Gilissen et al., 2016: Hegger et al., 2016a; Klijn et al., 2008; Melbourne Water Corporation, 2015; Scottish Environment Protection Agency, 2015), rather than as a theoretical concept or framework. This thesis conceptualises FRM simply as what we *do* to manage floods and *how* we do it. FRM is thus defined as the strategies, policies, procedures, legislation, and actions developed and implemented for reducing the adverse impact of flooding on society.

1.3.1 The concept(s) of flood risk management

If the goal of managing social-ecological systems is to promote system resilience, then the goal of managing flood risk can be conceptualised as promoting resilience to flooding. There is no formal definition of ‘flood resilience’ but scholarly research on flood resilience is broadly focused on the ability of society to cope with, recover from, and adapt to flooding (Kotzee and Reyers, 2016; O’Sullivan et al., 2012; Schelfaut et al., 2011). This definition implies certain characteristics that FRM must possess to support resilience, including: i) the need to learn from flood experiences and to apply that knowledge to develop more resilient FRM strategies and improve coping and recovery (Tompkins and Adger, 2004); and ii) that a range of proactive and reactive policy approaches or strategies is applied (Lin Moe et al., 2007). These approaches generally include some combination of flood prevention, flood mitigation, flood defence, flood preparation and response, and flood recovery (Gilissen et al., 2016) in order to develop multiple redundancies, address risk from different sources and characteristics of floods, and accept that some floods are unavoidable.

Historically, the predominant Western approach to FRM has been almost exclusively rooted in command and control management (Burch et al., 2010; Heintz et al. 2012), that is, attempting to “predict and control” the flood by intercepting and redirecting flood waters to prevent damage to human interests (Pahl-Wostl, 2007a). For example, for many hundreds of years, flood planning in Europe has favoured hard engineering methods to control flood waters and prevent or reduce flood impacts (Tol and Langen, 2000). The typical approach is to estimate flood risk from predictions of the magnitude and probability of flood events (Klijn et al., 2008). The probability of a flood of a specific magnitude is the annual exceedance probability (AEP); a 1% AEP flood is the magnitude of flood that is predicted to have a 1% chance of happening in any given year (USGS, 2018). AEPs are used in engineering design to provide flood protection up to the magnitude represented by the AEP, and for mapping flood plains based on zones of different levels of flood risk. Policies and actions are then developed with respect to the assumed level of flood risk (e.g. Commonwealth of Australia, 2017; Government of Alberta, 2017; Government of Ontario, 2002).

The use of AEPs becomes problematic if the assumed statistical distributions of expected frequencies of a design flood are incorrect (Godden and Kung, 2011). Historically, flood frequency modelling has assumed that climate varies between known, fixed extremes, which we now understand not to be true (Milly et al., 2008). Previous calculations of flood risk are therefore likely to be inaccurate and flood policies based on these calculations are likely to overestimate the level of protection they provide (Heintz et al., 2012; Rosner et al., 2014). Our understanding of the hydrology and geomorphology of river basins is also far from complete, complicating attempts to predict how these systems respond under stress (Teng et al., 2017). Adding to this complexity and uncertainty is that human actions, such as dam building, de- or re-forestation, agricultural practices, and urban development lead to changes in physical characteristics of the landscape that influence flood frequency and severity (Magilligan and Nislow, 2005; Michener and Houhoulis, 1997; Wheater and Evans, 2009).

Under a command and control management design, flood planning can become over-reliant on defensive structures to reduce flood risk (Liao, 2012; Smits, 2006). Significant costs are involved in the construction and maintenance of engineered flood defences and, as a result, flood defences can often represent the single or major focus for flood planning (Burch et al., 2010). To deal with changing flood risk, for example from changing demographics or climate variation, it is often less expensive (at least in the short term) or more politically acceptable to improve or increase the capacity of existing flood control structures, rather than to invest in a range of new alternatives (Smits, 2006; Burch et al., 2010). A major problem, however, is that where reliance is placed solely on flood control structures, such as levees, the protected land, buildings, and infrastructure have no need of incorporating flood protection into their design since, in principle, they are protected within an acceptable risk margin (Liao 2012). This perpetuates the reliance on these structures and inhibits the development of alternative actions to mitigate the negative effects of flooding (Smits, 2006; Liao, 2012).

The limitations of over-reliance on command and control FRM are regularly exposed by severe flood events. When protective structures fail or flood events exceed the AEP, damage is inevitable and usually significant. In the USA in 2005, for example, the failure of flood defences in Louisiana and Mississippi during hurricane Katrina caused over $90 billion (USD) of damages, 1,815 deaths, and resulted in 273,000 people evacuated from their homes (CNN, 2013; Jonkman et al., 2008). In Europe in 2007, rainfall exceeded flood policy AEP design levels and resulted in over €18.5 billion (EUR) of damages, 55 deaths, and the evacuation of over 250,000 people (Becker and Grunewald, 2003). In Canada in 2013, rainfall above AEP design levels resulted in $3 billion (CAD) of damages, five deaths, and over 100,000 people evacuated from their homes (Pomeroy et al., 2016; Canadian Disaster Database (CDD), Public Safety Canada, 2018). Reliance solely on command and control approaches to FRM is not effective in promoting flood resilience; it does not address the multiple contributors to flood risk and is ill-equipped to cope with uncertainty and change.

The limitations of a command and control approach to managing flood risk have been known for a long time. Indeed, much of the historical and contemporary debate on how flood risk should be managed can be traced back to the work of Gilbert White in 1945 (Macdonald et al., 2011). White considers that numerous human ‘adjustments’ are required to reduce the harmful impacts of flooding on society, including moving out of areas of flood risk, structural protection, emergency management, infrastructure design, regulation of land-use and financial support for flood recovery (White, 1945). In addition, White also argues for the need for continual learning and evolution of flood management strategies, the need for science to extend beyond academia and be used to benefit society, and the importance of a holistic, multi- and trans-disciplinary approach to understanding flooding (Macdonald et al., 2011).

In line with, and significantly influenced by Gilbert White, research on flood resilience and FRM is increasingly turning to strategic and adaptive management concepts (de Bruijn et al., 2007; Schanze, 2006). This conceptualisation of FRM is based on three underlying principles. *First*, a diversity of approaches is pursued including policies that are proactive in reducing risk and preparing for flooding and reactive in order to cope with and recover from flood events, that address the multiple-sources of flood risk, and that promote planning across multiple policy domains (e.g., Gilissen, 2016; Mileti, 1999; White and Haas, 1975). *Second*, FRM is coordinated and integrated across multiple scales and multiple stakeholders, and acknowledges the differing priorities, perspectives, capacities, goals, and objectives present (eg, Butler and Pidgeon, 2011; Hegger et al. 2016b; Pahl-Wostl et al., 2008;). *Third*, FRM is flexible and evolutionary in order to cope with differing contexts, uncertainty, and change over extended timescales (Olmstead, 2014; Pahl-Wostl et al., 2005).

1.3.2 The practice(s) of flood risk management

There has been a proliferation of international, national, regional and local FRM strategies. At the global level, the World Meteorological Office and Global Water Partnership promote and support the concept of IFM, espousing an approach to FRM that is inclusive of multiple stakeholders, integrated across multiple government levels, and adaptive and flexible (WMO, 2009). At national and regional levels, especially over the past ten to 20 years, numerous FRM strategies have been developed, often in response to major floods. The European Union EU floods directive, for example, was implemented in 2007 in response to the increasing cost of flooding to member nations, particularly the major floods in 2002 of the Danube and Elbe river basins, which affected several member states (European Union, 2019). Subsequently, all 28 EU member states have carried out flood risk assessments and developed some sort of FRM strategies and plans. The federal government of New Zealand developed a national FRM strategy in 2008, in response to major flooding in 2004 (New Zealand Government, 2008). In the State of California, all 58 counties have experienced at least one devastating flood over the past 20 years, leading to a state-wide government review of FRM (State of California, 2013).

International, national and regional strategies incorporate various principles of strategic and adaptive management to manage flood risk. National and regional strategies in New Zealand, England, Germany, Scotland and the United States, for example, all include a diverse range of measures to help reduce flood risk, including the renaturalisation of floodplains and river corridors, insurance programs, land-use planning, innovative building design, construction and maintenance of water control structures, and public engagement and education (e.g.: Lancashire County Council & Blackpool Council, 2013; Landesregierung Nordrhein-Westfalen, 2015; Masterton District Council, 2011; Perth & Kinross Council, 2016; Reclamation District 2092 and Stanislaus County, 2014). The coordination of interests and integration across scales is also evident in many FRM planning approaches, with particular emphasis on the watershed, catchment, or river basin as the appropriate scale for planning and encouraging the collaboration and coordination of multiple stakeholders (e.g.: Environment Agency, 2011; European Union, 2007; Lancashire County Council & Blackpool Council, 2013; Landesregierung Nordrhein-Westfalen, 2015; Perth & Kinross Council, 2016; Reclamation District 2092 and Stanislaus County, 2014). In England, for example, FRM planning occurs at two levels, characterized by collaborations between national and regional scales of government to create river basin flood management plans, and between regional and local governments to produce local FRM plans (Environment Agency, 2011; UK Local Government Association). Several national and regional FRM strategies also increasingly acknowledge that effective FRM requires the engagement and inclusion of multiple stakeholders in the planning process. For example, in New Zealand the need to represent traditional indigenous values in FRM planning is emphasized, and the importance of public engagement and risk education forms a prominent part of many strategies (e.g.: Environment Agency, 2011; Landesregierung Nordrhein-Westfalen, 2015; New Zealand Government, 2008; State of California, 2013). Finally, there is also evidence of the recognised need for flexibility and evolution in FRM policy and practice; the EU Floods Directive, for example, requires member states to incorporate climate change projections into flood mapping and flood risk management planning (European Union, 2019), and several jurisdictions across New Zealand engage in scenario planning to help prepare for different potential climatic and social conditions (New Zealand Government, 2016).

The governance arrangements through which these concepts are integrated differ between countries, which may influence the extent to which FRM strategies are successful in increasing flood resilience. In Europe, the EU Floods Directive (European Union, 2007) ensures that the same high-level principles are applied across the 28 member states. Member states are free to implement the Floods Directive how they see fit, and different governance models are used across the bloc. In England, for example, strategy and guiding principles are set at the national level, which are then implemented by regional and local level authorities (Hartmann and Spit, 2016). In Germany, the national government provides guidance and underlying principles of best practice (LAWA, 2010), but each state has significant autonomy over how they develop FRM plans, as they have the devolved responsibility for implementing the EU Floods Directive (Hartmann & Spit, 2016). Several models of governance exist within Germany as a result, including hierarchical and centralised structures, voluntary collaborations between municipal governments, water management agencies and other stakeholders, and formal collaborations between public bodies and private industries called 'Water Cooperatives' (Hartmann and Spit, 2016).

As in Germany, responsibility for FRM in the United States is held primarily at state level (Tullos, 2018). The United States federal government does not provide any strategic guidance on managing flood risk, but does significantly influence state, regional and local FRM planning through the National Flood Insurance Program (NFIP). The NFIP, introduced in 1968, requires state, regional or local governments to invest in the repair and maintenance of aging defence structures to maintain eligibility for flood insurance (Tullos, 2018). At the state level, there can be significant differences in governance arrangements for FRM. For example, California follows an IWRM model, which integrates flood management with water resource and land-use management at the river basin scale, leading to collaborative planning across multiple jurisdictions. In comparison, in North Dakota guidance on floodplain management primarily focuses on how to maintain eligibility for the NFIP (North Dakota State Water Commission, 2016. Page 2), which is implemented in the City of Fargo through floodplain development regulation and the construction of water management structures that are designed to lower the probability of floods impacting the city (City of Fargo, 2012).

The above examples from practice show that strategic and adaptive concepts are acknowledged in many FRM policies and practices internationally. The extent to which these strategies are contributing to increased flood resilience, however, is unclear. The international disaster database (EM-DAT) at least shows that flooding continues to incur significant financial cost to nations, many of which have clearly adopted many of the concepts considered to support flood resilience in FRM strategies (Fig 1.2).

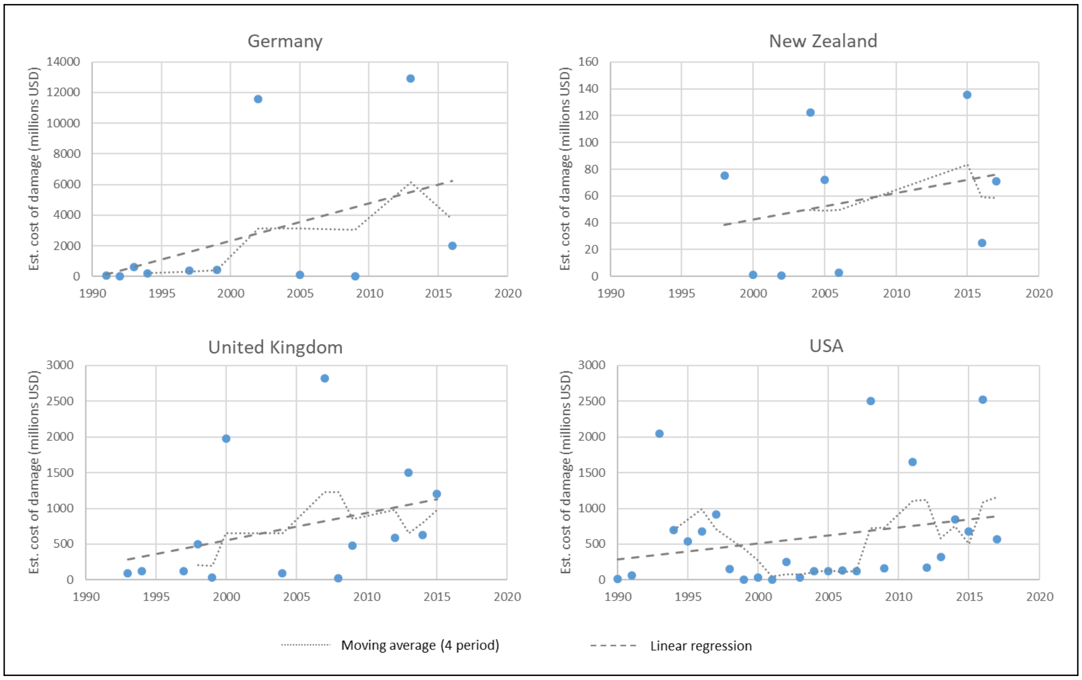

Figure 1.2 Estimated damage costs from extreme flooding 1990-2018 (Source: EM-DAT, 2019)

1.4 Research purpose

The scholarly literature on FRM clearly identifies that a diversity of policy approaches, their coordination and integration across multiple interests and scales, and flexibility and evolution in the design of FRM initiatives are pre-requisites for flood resilience. These concepts are present in the language of many FRM strategies and policies across the globe, including Canada. There is limited research, however, investigating if and how these principles are evident in FRM practice, and the barriers to and opportunities for translating these principles to practice for improved flood resilience. This thesis seeks to explore this gap by examining how the practice of FRM, including FRM governance, speaks to the underlying principles essential to flood resilience.

As such, the **purpose** of this thesis is to *examine the relationship between FRM research, practice, and policy implementation and the challenges and opportunities to achieve flood resilience*. The applied focus of this research is on Canada's Prairie Provinces – a region that has experienced increasingly frequent and severe, flood events and one that exemplifies many of the complexities of FRM. This is accomplished through the following objectives of:

i) examining current academic thought and trends on how flood management relates to flood resilience;

ii) investigating the extent to which institutional arrangements for FRM facilitate or constrain flood resilience; and

iii) exploring how the flood experiences and risk perceptions of decision makers influence FRM policy preferences, and how these preferences might facilitate or constrain flood resilience.

In more simple terms, this research can be conceptualised as exploring how the academic, governance and decision environments contribute to the implementation of the three principles that underlie strategic and adaptive FRM into practice. In theory, these environments should support the translation of the three principles into practical FRM outcomes, and act as a bridge from theory to practice (Fig 1.3).

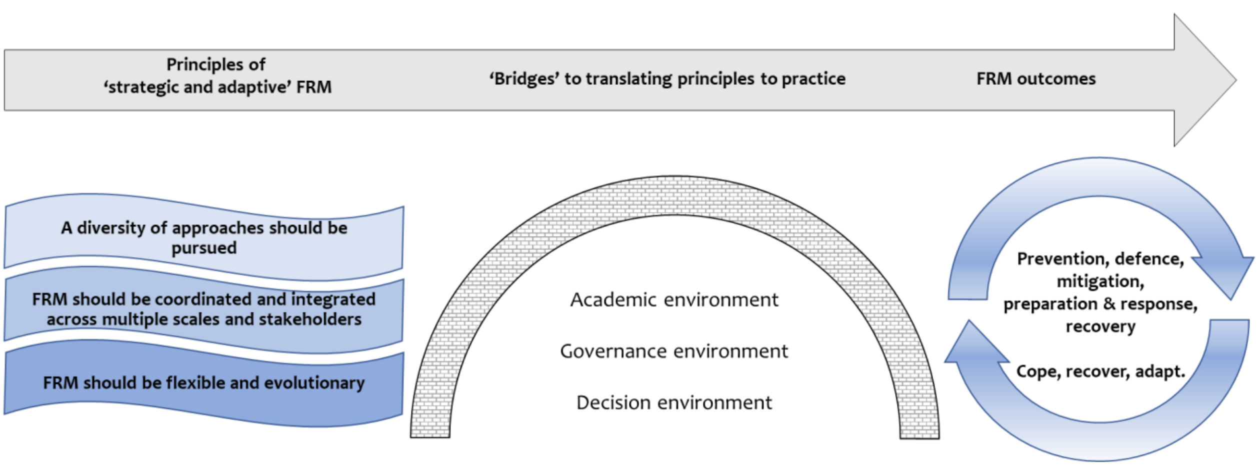

Figure 1.3 Conceptualisation of research project.

1.5 FRM in Canada's Prairie Provinces

This thesis focuses on Canada's Prairie Provinces of Alberta, Saskatchewan, and Manitoba as a case study of FRM governance. The study region encompasses a substantial land area of approximately 1.8 million square kilometres and contains a diversity of landscapes including mountains, foothills, prairies, and boreal forest. Numerous water features of international and national importance are present in the region, including the North and South Saskatchewan Rivers, the Red Deer River, the Red River, the Athabasca River, the Assiniboine River, Lake Athabasca, and Lake Winnipeg. Spring floods are a common occurrence in the region and their severity is influenced by antecedent soil moisture conditions, snow cover, rainfall, and the timing and speed at which air temperatures rise above freezing (Buttle et al., 2016). Flooding also irregularly occurs as a result of extreme and unseasonal precipitation events (Buttle et al., 2016).

Flooding in the Prairie Provinces poses a risk of significant harm to the regional economy, public health, property, and infrastructure in the region. The extent of harm is significant in the Canadian context: since 2010, 16 out of 42 flood disasters recorded in the Canadian Disaster Database (CDD, Public Safety Canada, 2018), including three of the five most costly floods, occurred in the Prairie Provinces. Alberta, Saskatchewan, and Manitoba have also received a disproportionate amount of disaster relief payments from the federal government in relation to flooding compared to other Canadian provinces (OPBO, 2016).

There are over 1,000 local governments representing major cities, smaller urban centres, rural areas, Indigenous communities, and resort villages in Manitoba, Saskatchewan, and Alberta. Each of these levels of government engages in FRM to a certain extent. The Canadian federal government's main roles in FRM are as a funding agency supporting activities at the provincial and municipal levels, the development of best-practice guidelines, the provision of data, and public education on flood preparedness (Chapter 3). Policy instruments at the federal level that influence FRM include the *Emergency Management Act*, the *Emergency Management Framework for Canada* and the *National Disaster Mitigation Strategy*. These instruments broadly seek to reduce the financial and physical harm to Canadians from flooding and other natural disasters. The federal government also provides advisory guidance such as the national building codes, risk-based land-use guidance, and the emergency preparedness guide (National Research Council Canada, 2015;

Public Safety Canada, 2012; Struik et al., 2015). The federal government provides funding to flood-affected communities primarily through the Disaster Financial Assistance Arrangements (DFAA). Funds can also be mobilized to flood victims through the National Disaster Mitigation Program (NDMP) and the Building Canada Fund, which supports key infrastructure for the public good (Infrastructure Canada).

In Canada, the provinces have significant autonomy over managing their natural resources (Bakker and Cook, 2011). All three provinces in the study area have Acts of government that set out legal duties with respect to emergency management, water resource management, and land-use planning (see Chapter 3, Table 3.3). Policies concerning FRM largely fall under the mandates of emergency management agencies, water resource management agencies, infrastructure departments, environmental agencies, and planning departments. Numerous strategies, programs, and policies for reducing flood risk have been implemented across Manitoba, Saskatchewan, and Alberta (see Chapter 3, Table 3.3) and each province has its own programs for providing financial support to individuals and communities affected by major flood events. These include, for example, Alberta's Watershed Resiliency and Restoration program and Saskatchewan's Erosion Control Assistance Program. In Manitoba, various community and individual flood protection programs support the construction of flood defences in areas recently exposed to flooding; in Alberta, the Community Resilience Program performs a similar function. Each province also has a dedicated emergency measures agency that coordinates emergency response during major flood events.

Responsibility for land-use planning and development controls in each province is devolved to the municipal governments, although land-use planning standards for delineating areas at high risk of flooding are set by the provincial governments. Municipal governments are responsible for implementing these provincial land-use planning standards, commonly doing so through municipal development plans, or regional development plans that include multiple local jurisdictions. Municipalities also have responsibility for emergency preparedness planning, again implementing standards and guidelines set at the provincial level. All levels of government provide a variety of flood preparedness and flood risk information to the public, indicating that individuals also have some responsibility for reducing their own flood risk through awareness and preparedness. Homeowners may also have access to overland flood insurance, which has been available to Canadians since 2015; however, this may not be affordable to those living in high risk areas, areas that have experienced repeat flood events, or in areas where the flood risk is unknown or hard to determine (Sandink et al., 2016).

Strategic and adaptive management concepts are evident in current FRM policies in Canada, and in the Prairie Provinces (Sandink et al., 2010; Chapter 3). The federal National Disaster Mitigation Program (NDMP) and the Emergency Management Framework for Canada (Public Safety Canada, 2017), programs for disaster mitigation, for example, cite the four pillars of emergency management, mitigation, preparation, and response and recovery as fundamental principles on which emergency management and disaster mitigation should be founded. Acts of government relating to land-use planning, emergency management, water, and municipal government in each of the three provinces also support multiple approaches to managing flood risk (see Chapter 3, Table 3.2). Like many other jurisdictions around the world, FRM policy instruments in the prairie region appear to acknowledge the principles of strategic and adaptive management and resilience; however, there is limited evidence of formal coordination and collaboration in practice – either within or among jurisdictions. Further, although strategies and policies for different aspects of FRM exist, there is no national FRM strategy, there are no provincial FRM strategies, and there is little evidence of comprehensive, integrated, FRM plans at any scale.

1.6 Thesis structure

This thesis is presented in **manuscript-style format** and is comprised of five chapters including the introduction. Chapters 2 to 4 present the body of the research and is made up of three manuscripts, each aligned with a specific thesis research objective:

Manuscript 1 (Chapter 2): Morrison, A., C. J. Westbrook, and B. F. Noble. 2017. A review of the flood risk management governance and resilience literature. *Journal of Flood Risk Management* 11(3): 291-304.[1]

This manuscript sets the academic context of flood risk management as it relates to flood resilience. It does so by exploring the key focus and gaps in FRM and flood resilience scholarship by investigating *what* is researched in the context of flooding, FRM, governance, and resilience. This Chapter asks and answers: *What has been the focus of scholarship on FRM governance and resilience? What are the dominant lines of inquiry? What are the key gaps in knowledge and understanding?*

Manuscript 2 (Chapter 3): Morrison, A., B. F. Noble, and C. J. Westbrook. 2018. Flood risk management in the Canadian Prairie Provinces: Defaulting towards flood resistance and recovery versus resilience. *Canadian Water Resources Journal* 43(1):33-46. [2]

This manuscript turns to FRM practice on the Canadian prairies, examining whether current policies, instruments and practices enable resilience, as espoused by FRM scholarship, or default toward the traditional practices of flood resistance and recovery. This Chapter asks and answers: *What is the current state of FRM policy and practice in the Prairie Provinces, and does it support flood resilience?*

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[1] Alasdair Morrison is the major contributor and lead author of the manuscript. Bram Noble and Cherie Westbrook were co-supervisors for this study and provided useful feedback on the manuscript content and structure.

[2] Alasdair Morrison is the major contributor and lead author of the manuscript. Bram Noble and Cherie Westbrook were co-supervisors for this study and provided useful feedback on the manuscript content and structure.

Manuscript 3 (Chapter 4): Morrison, A., C. J. Westbrook, and B. F. Noble. 2019. Flood risk management in Canada's Prairie provinces: An analysis of decision-maker priorities and policy preferences. *Environmental Management*. Under review.[3]

The third manuscript focuses on the FRM priorities and preferences of decision makers, examining how these relate to the concepts and principles considered to support flood resilience. This Chapter asks and answers: *What are decision makers' priorities for FRM policy in the Prairie Provinces and, based on those priorities, is Western Canada moving in the direction of flood resilience?*

The thesis is concluded with Chapter 5, which presents a synthesis of the manuscripts and a discussion of the outstanding challenges identified by the research to improving flood resilience with respect to the existing structures and processes of government, and the FRM policy preferences of stakeholders.

[3] Alasdair Morrison is the major contributor and lead author of the manuscript. Bram Noble and Cherie Westbrook were co-supervisors for this study and provided useful feedback on the manuscript content and structure.

2. A REVIEW OF THE FLOOD RISK MANAGEMENT GOVERNANCE AND RESILIENCE LITERATURE[4]

2.1 Preface

Resilience is key to managing complex social-ecological systems and reducing vulnerability to uncertainty and unexpected change. Yet, flood risk management (FRM) has emerged largely from a culture of resistance. Scholarship on how 'good governance' can promote resilience to flooding has increased substantially over the past few decades. Thus, practical guidance for improving FRM to enhance resilience to floods *should* be available from recent scholarship; however, there has been no analysis of the focus of FRM resilience scholarship in terms of governance or the key gaps in knowledge to improve resilience to flooding. This paper examines current academic thought and trends on how flood management relates to flood resilience. Specifically:

- *What has been the focus of scholarship on FRM governance and resilience? What are the dominant lines of inquiry? What are the key gaps in knowledge and understanding?*

This Chapter is published in the *Journal of Flood Risk Management*, a leading international journal in the field of FRM (Impact factor: 2.483):

- Morrison, A., C. J. Westbrook, and B. F. Noble. 2017. A review of the flood risk management governance and resilience literature. *Journal of Flood Risk Management* 11(3): 291-304. doi:10.1111/jfr3.12315.

This Chapter demonstrates that:

- There is a divide in FRM scholarship between the physical and social sciences, even when addressing resilience.
- FRM governance research is siloed from practice and policy, limiting the transfer of knowledge between scholars and practitioners.

[4] The research paper that this chapter is based on was accepted for publication in late 2016. It is acknowledged that more literature relating to the subject matter has been published since this time that is not captured here. More recent literature is captured in the introduction to this dissertation (Chapter 1).

- Most research addressing tools for FRM are focused on physical modelling, with limited attention to social dimensions.
- Most scholarship focused on tools are within the scope of specific disciplines, with limited attention to frameworks for integration.
- There is limited, applied research on governance frameworks and how to organize institutions, people, and information for building flood resilient societies.

Overall, this Chapter shows that notwithstanding an increase in FRM governance and resilience research, much of it is carried out in silos, which seems contradictory to the concepts of resilience and the strategic and adaptive approaches often espoused. There is no clear FRM research agenda, and what constitutes resilience - and more specifically what it looks like in FRM practice - is not clearly defined. A more tightly coupled FRM research-for-policy agenda is required to better direct both research and advances in policy and practice.

2.2 Introduction

Globally, floods are responsible for considerable and increasing economic and social losses (Kundzewicz et al., 2014). In Canada, for example, floods are happening more frequently and are more widespread under a rapidly changing climate (Nastev and Todorov, 2013; Whitfield, 2012). Between 1990 and 2015, 141 flood disasters were recorded in Canada, which were responsible for killing 21 people, evacuation 215,207 people, and costing an estimated CAD $7.9 billion in damages (CDD, Public Safety Canada, 2018). Based on spending in the previous decade, the Canadian Government reports that it expects to pay out, on average, CAD $673 million per year over the next five years in disaster assistance funds (OPBO, 2016). In the United Kingdom, annual flood damage is estimated at £1.1 billion and expected to rise to as much as £27 billion by 2080 under a worst case climate change scenario, with no additional adaptation measures (Foresight, 2004); the maintenance of existing levels of flood defence will require increases in spending of over £1 billion annually (Bennett and Hartwell-Naguib, 2014). In Australia, between December 2010 and January 2011, Western Australia, New South Wales, Victoria, and Queensland experienced widespread flooding that resulted in 37 lives lost and a total cost of over AUD $30 billion to the Australian economy (Garrett, 2011). The increasing frequency and expense of flood disasters like these suggests that becoming more resilient to flooding is likely to be a social and economic priority for many nations.

Historically, efforts to address flood risk have centred on flood resistance rather than resilience (Shrubsole, 2013). The standard response to flood risk management (FRM) amongst developed nations has often been the adoption of resistance-based strategies (Zevenbergen and Gersonius, 2007), meaning attempting to control flood threats with infrastructure and controlling behaviour with laws and regulations (Holling and Meffe, 1996). The aim of resistance-based strategies is to remove, in so far as possible, the threat of extreme variations and to minimise the potential for adverse impacts to society. Although this approach can provide substantial protection against environmental threats such as floods, including minimizing the costs associated with design floods (see Meyer et al., 2012), it does not cope well with uncertainty. A sole focus on resistance to flooding can be costly in terms of human life, property and infrastructure, particularly in those cases when infrastructure or regulatory controls fail to provide adequate protection against surprise events (Dawson et al., 2011; European Union, 2007; FDRP, 1975; Holling and Meffe, 1996; Folke et al., 2002; Park et al., 2013).

Adaptive approaches, embracing uncertainty, and seeking to accommodate rather than control environmental systems, offer a complementary response to resistance-based FRM. Substantial academic literature on adaptively managing dynamic systems has been available since at least the 1950s (Walters and Hillborn, 1978). Adaptive approaches focus on mitigating, coping with, and recovering from expected and unexpected change through a diverse range of policy and management options. A significant component of adaptation is continuous learning from, and embracing, changing system conditions (Akamani and Wilson, 2011; van Wesenbeek et al., 2014; Zhou et al., 2012). The desire to apply adaptive approaches to environmental management has gained prominence since the late 1970s (e.g. Folke et al., 2002; Grayson et al., 1994; Gunderson, 1999; Holling, 1978; Walters and Hillborn, 1978) and is gradually being adopted into policy and practice (Noble, 2015a).

Flood risk management has also adopted the language of adaptation. The Flood Damage Reduction Program in Canada, for example, acknowledged decades ago the need to move away from sole reliance on large-scale defensive flood control structures towards more diverse and adaptive approaches (FDRP, 1975). More recently, the European Union encoded in law the need for its member states to embrace a more adaptive view of FRM, with the introduction of the 2007 EU Flood Directive (European Union, 2007) identifying the need for not only flood defence and preparedness, but also the capacity to cope with and adapt to flood events. The emergence of more adaptive approaches to FRM does not suggest that traditional, resistance-based approaches are without merit. Rather, improving resilience to the adverse impacts of flood events, and building the capacity to adapt to changing flood conditions, requires a combination of both resistance- and adaptive-based approaches (Schelfaut et al., 2011).

There has emerged, particularly in the past two decades, increased attention on FRM governance and how ‘good governance’ can promote resilience to environmental change (e.g. Borba et al., 2016; Buckland and Rahman, 1999; Carter et al., 2009; Cutter et al., 2000; Dwyer et al., 1997; Levy et al., 2007; Rosner et al., 2014; Smits et al., 2006). At the heart of this scholarship is the notion that flood resilience sometimes means coping with or adapting to flood events and implementing a diverse range of FRM strategies, including resistance-based strategies (Klijn et al., 2008; Schelfaut et al., 2011). This means that increasing flood resilience requires the combination of two, often-contrasting, paradigms of flood resistance and flood adaptation (Park et al., 2013). The differences between these two paradigms represent different theoretical constructs, assumptions, and understandings of the role disturbance plays in integrative human and natural systems, and thus reflect substantially different perspectives on FRM. Multi-disciplinary research initiatives, especially in Europe (e.g., FLOODsite, Flood Risk Management Research Consortium, STARFlood and others) demonstrate a concerted effort to develop resilient approaches to FRM, however, in many cases transitioning to a more diverse set of strategies, policies and actions is constrained by governance institutions that are inherently resistant to change (Pahl-Wostl and Knieper, 2014; Penning-Roswell and Johnson, 2015).

Guidance for improving FRM policy and management to enhance resilience to floods should be available from the scholarly literature. However, there has been no investigation of the state of FRM adaptation and resilience research as it relates to governance, nor of the key gaps in knowledge that need to be addressed to advance resilience to flooding. The purpose of this paper is thus to examine current academic thought and trends on how flood management relates to flood resilience. We do so based on the argument that understanding how the scholarly community relates resilience in FRM research to governance, policy, and actions will help in identifying and prioritizing research needs to enable FRM policy and process improvements. We do this by examining how the scholarly, peer reviewed journal literature has approached the subject of FRM governance and resilience to flooding, the dominant lines of inquiry, and the gaps in knowledge and understanding.

2.3 Methods

Our analysis of the FRM literature focused solely on what resilience scholars are addressing in their research, as represented by the peer-reviewed journal literature. Using the Scopus database (see Baykoucheva, 2010), the search string (TITLE-ABS-KEY (flood*)) identified 178,663 papers addressing some aspect of flooding. Journal papers published up to December 2016 were included, with no lower date limit set. Of these papers, 48,281 included ‘flood’ in the title, suggesting that it was likely a key focus. When resilience and related concepts (e.g., governance, adapt*, resilience, resiliency) were added to refine the search, only 1,245 papers were identified (less than 3%) that speak directly to issues concerning FRM resilience, governance, and adaptation. A seven-step process was then adopted to complete the search process (Fig. 2.1).

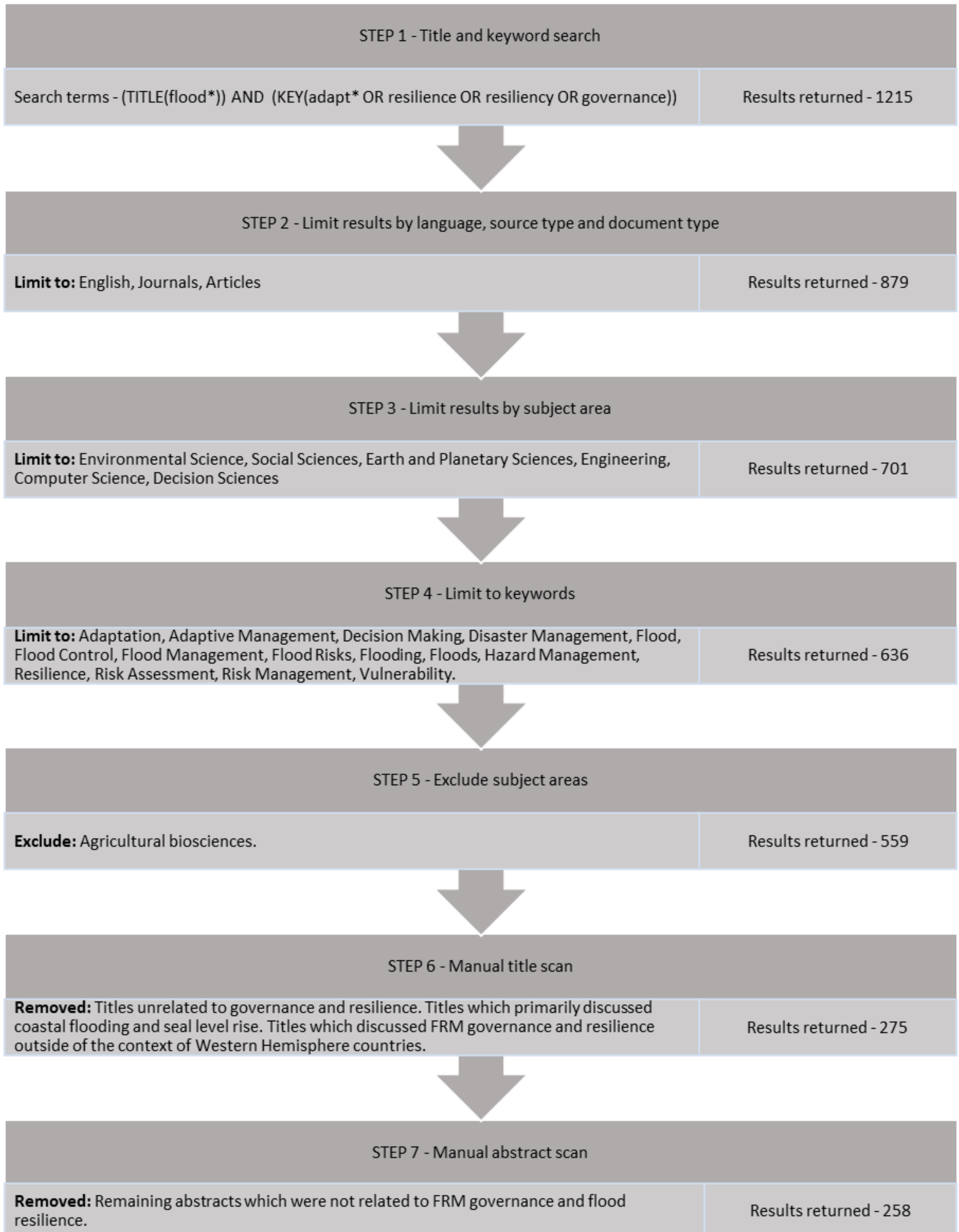

Figure 2.1 Seven step process used to identify FRM governance, adaptation and resilience literature.

The 1,245 papers were screened using the search string "(TITLE(flood*)) AND (KEY(adapt OR governance OR resilience OR resiliency))" to identify papers that are self-identified by the authors as addressing flooding and governance, resilience or adaptation. Of the 982 resultant papers, many were not relevant to the scope of our review - papers such as those addressing biochemistry (e.g. Rivest et al., 2013), human health (e.g. Bei et al., 2013), engineering design (e.g. Ouyang et al., 2015) and plant ecology (e.g. Raymond et al., 2014). The list of papers was then narrowed first to peer reviewed journal articles in English, and then further restricted to subject areas considered most likely to contain research relevant to flood governance and resilience, such as environmental sciences, social sciences and engineering. The results were then filtered to those papers containing keywords linking them to flood governance and resilience (i.e., flood control, disaster management, vulnerability). A title scan showed many papers focused on agricultural technology and soil biochemistry in relation to flooding (e.g., Voesenek and Sasidharan, 2013; Maxwell et al., 2014); the subject area 'agriculture and biological sciences' was thus excluded from the search.

A manual scan was carried out of all remaining papers to further remove less-relevant papers, for example those broadly focused on climate change rather than flooding (e.g., Arnell and Hughes, 2014); papers discussing drought (e.g., Rijke et al., 2014); and papers focused on the ecological effects of flooding on flora and fauna but with no social or policy focus (e.g., Murray et al,. 2012; Scharbert and Borcherding, 2013). Conditions were also set to focus the search on those papers dealing with inland, fluvial, and pluvial flood governance in the western world, including Europe, Australia and the Americas. For this reason, papers focused on coastal flooding and sea level change were also removed.

The final set of papers was thematically analysed (e.g., Braun and Clarke, 2006) using NVivo v.10 qualitative analysis software to code papers into research themes. Topics, for this paper, are defined as specific areas of research, whereas themes are broader subjects that connect one or more specific topics. For example, collaboration and public participation can be considered topics within a broader research theme of stakeholder engagement. This type of coding and classification of research themes, and topics into themes, is inherently subjective and relies on the reviewer's interpretation and knowledge of both the paper and the general subject area. Initial coding was informed by the governance and policy literature on environmental management, focused on broad themes such as ‘governance’, ‘policy’ and ‘theory’, and refined as the coding and analysis progressed.

Papers were coded based on the major topics derived from their abstracts. The complete set of codes across all papers was then reviewed and combined where the topics addressed were similar. This was an iterative process, with abstracts reviewed seven times to ensure that the codes adequately captured the content of the papers, and to further refine the topics and themes. The boundaries between topics and themes were sometimes uncertain. However, we assigned all papers to only one theme, and to only one topic within that theme. The analysis was then repeated to identify papers that addressed more than one theme, and more than one topic within a single theme; to identify connectedness in FRM research; and to account for papers that could not be easily categorized into any single theme during the initial rounds of coding.

We acknowledge the limitations to our results owing to the choice of search terms. Represented in our analysis are only those papers which self-identify as relating to flood resilience based on title, abstract and author-defined key words. Thus, our search omits papers which may contribute to flood resilience knowledge that did not explicitly identify as addressing the topic. Our exclusion of 17 papers relating to coastal flooding due to sea level change, and our focus on studies of westernised countries, means that our results primarily reflect research on surface water systems in developed nations. A comparison of resilience research in FRM for developed versus developing nations, and for coastal versus surface water systems, may provide for an interesting study of its own. Finally, our focus was on understanding the state of scholarly research as presented in journal articles, meaning that we do not capture valuable research that is self-published by multi-disciplinary FRM initiatives, such as the International Centre for Water Hazard and Disaster Risk Management (ICHARM), and the EU’s STARFlood project.

2.4 Results

A total of 258 journal articles were identified that met the search criteria. The first paper addressing flooding in the context of governance and resilience was published in 1987 (Corradini et al; Fig. 2.2). It took another 20 years for FRM resilience research to gain momentum, as 91% of all papers identified (n = 236) were published between 2008 and 2016. Research discussing various aspects of FRM, governance, and resilience are not necessarily limited to this timeframe; however, results do indicate that flooding has only recently been addressed in these contexts. Indeed, we expect that a much larger pool of relevant FRM research exists, research that is published outside of the academic press or does not self-identify as being focused on FRM governance, adaptation, or resilience. The doubling of papers published between 2015 and 2016 could mean more research engagement or it could simply reflect greater adoption of the terminology around FRM governance, adaptation, or resilience.

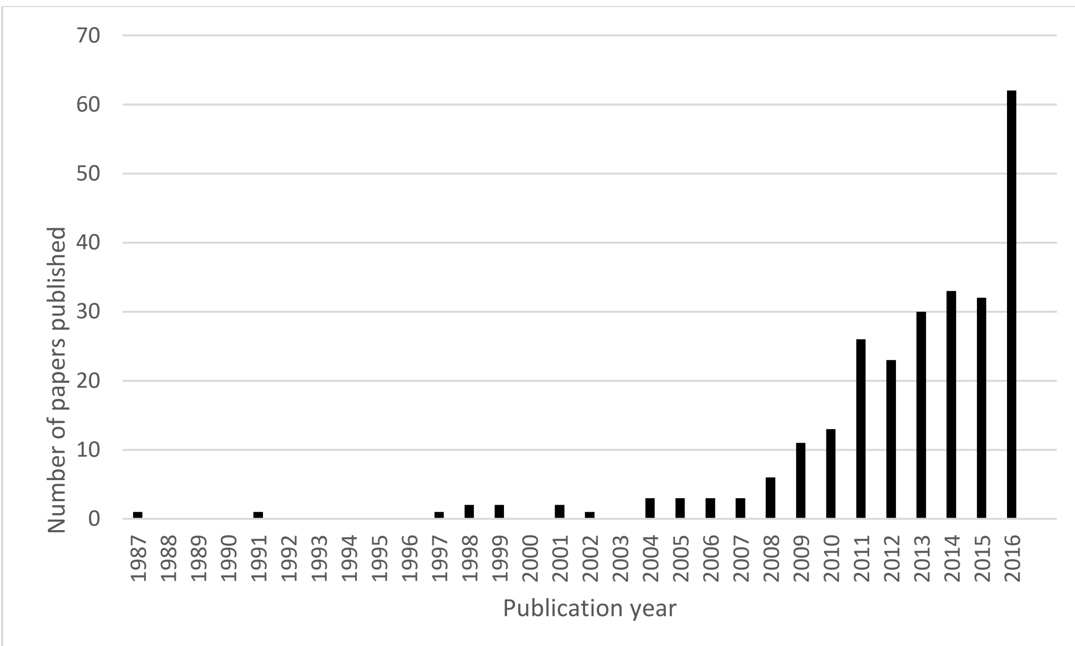

Figure 2.2 Number of papers published annually, 1987 – 2016, on flood risk management governance and resilience.

Table 2.1 Connections between research topics and themes in the flood risk management literature, 1987 – 2016.

Primary theme	Number of papers in each theme (% all papers)	Number of papers per theme that address at least one additional theme	Primary topic	Description of the topic or dominant focus	Number of papers in each topic (% of papers in the theme)	Number of papers addressing each topic that also address:	
						at least one topic from an additional theme(s)	two or more topics from an additional theme(s)
Stakeholder engagement	77 (30%)	30 (39%)	Perceptions and behaviours	Influence of perceptions and behaviours of organisations, groups or individuals about FRM. Examples include changes in perceptions of risk before, shortly after and a long time after a flood event. Perceived responsibility for failure of flood policy.	23 (30%)	6 (26%)	0
			Interplay, collaboration and communication	Role of inter-organisational relationships in FRM. Horizontal and vertical relationships within and across organisations. Communication of knowledge, experience and ideas, and examples of collaboration or effectiveness of collaboration.	23 (30%)	9 (39%)	1 (4%)
			Structures and styles	Structural aspects of governance, such as hierarchical vs. decentralised, panarchy, polycentric, etc., and how FRM functions within these structures and styles.	16 (21%)	6 (37%)	0
			Public participation and public communication	Importance of public participation and engagement in FRM. Methods of engaging and communicating with the public, in particular at-risk communication.	11 (14%)	7 (64%)	0
			Stakeholder roles and responsibilities	Roles and responsibilities of institutions, organisations and stakeholders involved in FRM. What these roles and responsibilities are or should be. How these organisations are, or should be, engaged.	3 (4%)	2 (67%)	0

Table 2.1 (cont.) Connections between research topics and themes in the flood risk management literature, 1987 – 2016.

Policies and action	48 (19%)	26 (54%)	Post flooding studies and analysis	Post-event studies carried out after flood events to analyse the causes, influences and impacts of flooding.	19 (40%)	15 (79%)	2 (11%)
			Opposing paradigms	Policies or policy approaches with regard to command and control or adaptive paradigms. Benefits, limitations and comparisons of policies or actions which are either command-and-control or adaptive.	18 (38%)	3 (17%)	1 (6%)
			Combining paradigms	Policies and actions that combine command-and-control with adaptive paradigms, and proposing strategies that could support both approaches and/ or that imply the use of both approaches.	11 (23%)	8 (73%)	2 (18%)
Research on practice	27 (10%)	20 (74%)	Barriers and solutions	Identification of barriers and proposal of theoretical (untested) solutions for better FRM	17 (63%)	13 (76%)	5 (29%)
			Theory into action	Descriptions of how policies or actions performed during a flood event, including successes and improvements. Development and testing of FRM policies or actions, and learning by experience.	10 (37%)	7 (70%)	1 (10%)
Tools	101 (39%)	29 (29%)	Prediction modeling and forecasting	Climate modelling, climate forecasting, flood flow modeling, and flood extent modelling.	54 (53%)	10 (19%)	0
			Assessment and planning	Tools to assess flood impact and vulnerability, such as impact assessment, cost benefit analysis, vulnerability assessment, and flood risk mapping.	33 (33%)	11 (33%)	1 (3%)
			Policy appraisal and decision making	Tools to help with complex decision-making, and to help identify best-fit policy options to meet varying FRM priorities, such as multi-criteria evaluation tools.	14 (14%)	5 (36%)	1 (7%)
Frameworks	5 (2%)	3 (60%)	Practical or applied frameworks	Frameworks that bring together and apply a range of tools for integrated FRM.	2 (40%)	1 (50%)	0
			Research frameworks	Frameworks that organise different streams of research to address FRM.	2 (40%)	2 (100%)	1 (50%)
			Governance frameworks	Conceptual approaches to organising people, institutions and data for FRM. For example, templates to help assign roles and responsibilities	1 (20%)	0	0

2.4.1 Advances in FRM research

Five key thematic areas relevant to FRM governance for resilience emerged from the coding of the 258 abstracts considered. These themes, described below, are the following: stakeholder engagement, policies and action, research on practice, tools, and frameworks (Table 2.1).

Theme 1: Stakeholder engagement

The theme *stakeholder engagement* includes those papers that discuss organisations and their structures, interactions among stakeholders, and stakeholder perspectives in relation to FRM. A total of 77 papers were identified as primarily addressing FRM stakeholder engagement issues, and these papers were coded into five major research topics. Approximately 30% of papers under this theme addressed individual and group perceptions and behaviours related to flood risk and governance effectiveness and how these influence FRM, and the development and acceptability of FRM strategies and policies (e.g., Ingirige and Wedawatta, 2014; Jeffers, 2014; Thorne, 2014) (Table 2.1). Next, 30% of *stakeholder engagement*-themed papers focused on collaboration and communication; addressing the communication of ideas, experiences and information between organisations; why communication is important; and providing examples of collaborations and the effectiveness of different types of collaborations (e.g., Head, 2014; Osberghaus, 2015; Thaler, 2014). Structures and styles of governance were similarly addressed by 21% of papers. These papers focused on the different styles of governance that have been or could be used in FRM, such as hierarchical, decentralised, polycentric, and panarchy (e.g., Johannesen and Hahn, 2013; Nye et al., 2011; Stevens and Hanschka, 2013). Approximately 14% of papers focused on public participation, addressing the importance of and/or methods of public participation, and the importance of appropriate and effective public communication in FRM processes (e.g., Cashman, 2011; Neuvel and van der Knaap, 2010). Only 4% of papers examined stakeholder roles and responsibilities in relation to FRM governance. These papers addressed how national, regional, and local governments, as well as conservation agencies, businesses, and community interests are or should be involved in FRM.

Theme 2: Policies and action

Policies and action-themed papers discussed or analysed the effectiveness of existing or past FRM policies and actions or proposed alternative policies. The 48 papers in this theme addressed three main topics: separating the paradigms of FRM, combining the paradigms of FRM, and post-flooding studies and analysis. A total of 40% of papers in this theme presented post-flooding studies that analysed specific flood events to assess their financial, engineering, or human impacts (e.g. Coulthard and Frohstick, 2010; Smith and Lawrence, 2014; Wedawatta et al., 2014). An equal number of papers (38%) focused on separating FRM into opposing paradigms; that is, they examined FRM policies and actions within either a resistance- or an adaptive-based approach. These papers set the two approaches as being opposed, either explicitly or implicitly (e.g., Kundzewicz, 2002; Tempels and Hartmann, 2014; Zheng et al., 2014), or focused on specific examples of each paradigmatic approach (e.g. Escaramia et al., 2007; Surminski, 2014). Finally, 23% of papers addressed a combined approach to FRM, wherein the focus was both resistance *and* adaptation. These papers described the combination of approaches in terms of justification, effectiveness, and outcomes for FRM (e.g., Gersonius et al., 2013; van Wesenbeek et al., 2014).

Theme 3: Research on practice

Papers grouped under the *research on practice* theme focused on how FRM governance and policies operate, often proposing or critiquing new or alternative strategies, policies, or options for FRM. The 27 *research on practice*-themed papers focused heavily on barriers and solutions (63%) and less often on how to put principles or theory into action (37%). Barriers and solutions papers concentrated on identifying barriers to successful FRM strategies and proposing potential solutions. Examples of identified barriers include path dependency, where policy approaches have become entrenched through repetition; hierarchical governance, which stifle local decision making (Hasse, 2013; Jeffers, 2013); and differing priorities between stakeholder groups (Butler and Pidgeon, 2011). Theory into action papers focused primarily on case studies of the implementation of FRM strategies, polices or actions, such as the failed implementation of a floodplain restoration project in Germany (Guerrin et al., 2014), and the effectiveness of risk communication procedures as part of a flood risk assessment process on the Sihl River, Switzerland (Buchecker et al., 2013).

Theme 4: Tools

The fourth theme captured 101 papers that focused primarily on FRM tools. *Tools* included programs or prescribed procedures and processes that can be used for forecasting, hydrological modelling, and in aid of FRM planning. These tools generally involved some sort of data input (e.g., property values, hydrological data, stakeholder priorities) to provide information for planning decisions (e.g., risk analysis, seasonal flood risk assessment, economic assessment), and also included mapping applications for flood risk planning and communication. Three topics emerged in this theme, with prediction and modelling tools garnering the most attention at 53% of the papers. These papers developed or proposed, and in some cases demonstrated, specific tools for flood forecasting, flood flow modelling, and flood frequency prediction (e.g., Seo and Singh, 2015; Wang and Liang, 2011; Yazdi and Neyshabouri, 2014). The second most published topic, addressed by 33% of papers, was assessment and planning. This topic examined existing and proposed tools for assessing vulnerability to floods (e.g., Prudhomme et al., 2013) and the potential structural and financial impact of floods (e.g., Veerbeek and Zevenbergen, 2009). Several of these papers sought to support FRM planning processes in practice (e.g., Golz et al., 2015; Zhou et al., 2012). The third topic, policy appraisal and decision making, was addressed by 14% of papers. This focused on tools to appraise policy alternatives, such as real options analysis to assist in mitigation investment decisions (Gersonius et al., 2015; Woodward et al., 2014;, and multi-criteria decision analysis to support FRM decisions in multi-stakeholder environments (Porthin et al., 2013).

Theme 5: Frameworks

The final research theme, *frameworks*, consisted of papers focused on supporting frameworks for FRM research, practice, and policy. Although there were only five papers classified in this theme, they covered three different topics. Two papers addressed practical or applied frameworks, which discussed processes for developing FRM strategy and implementing policies. Gersonius et al. (2012), for example, addressed adaptation processes for resilient flood infrastructure, which sets strategy, monitors performance, and allows for adjustment and response in relation to knowledge gained through monitoring. Sendzimir et al. (1999) examined the use of adaptive environmental management and assessment as a framework for integrated FRM. Research frameworks, concerned with bringing different disciplines together to support more integrated FRM research, accounted for two papers. van Ree (2011) discussed the FloodPRoBE research project, which links infrastructure vulnerability assessment, reliability assessment of flood defences, and the development of new technologies and concepts to advance the effectiveness of flood protection. The governance frameworks topic concerned how organizations, including roles and responsibilities among stakeholders, are structured. The one example of this was van Herk et al.'s (2014) evaluation of the effectiveness of FRM governance frameworks by analysing the interaction and communication among organisations.

2.4.2 Siloing in FRM research

Of the papers that connected across themes, only 15 (6%) connected their primary theme to two other research themes. None of the papers connected their primary theme to more than two other themes. Approximately 75% of the papers in the *research on practice* theme were connected to at least one other theme. Within individual themes, topics varied in the number of times they connected to other themes (Table 2.2). Within the *stakeholder engagement* theme, for example, the two most common topics, interplay, collaboration and communication, and perceptions and behaviours, were most often studied in isolation. Similarly, within the *tools* theme, prediction modelling and forecasting was the most commonly studied topic, but it also had the fewest connections to other FRM research themes.

2.5 Enduring Issues, Gaps and Opportunities in FRM Research

Siloing is not uncommon in environmental management, especially in fields that have strong scientific, practical and policy components (Morrison-Saunders et al., 2014). Research silos can provide a meaningful opportunity for disciplinary-specific discovery, but they can also stifle progress toward understanding how to effectively manage complex systems with inextricably linked human-environmental interactions (Sheate, 2009). This has been well-argued in the sciences of conservation (Margles et al., 2010), water security (Wheater and Gober, 2013), and environmental assessment (Noble, 2010) – fields of research and practice that have all been hampered, to some extent, by a lack of knowledge integration among the sciences, policy and management fields. Although progress has been made in FRM resilience research, overcoming the siloing of research presents a major challenge to strengthening flood resilience. Below we address how these silos manifest in the subset of the FRM literature we analysed, and we propose directions that may help bridge these divides and aid in the overarching objective of increased resilience to floods.

First, there is a clear divide between the social and physical sciences in FRM research. This was evident in the low connectivity of two key research themes, *stakeholder engagement*, focused on social interactions and FRM governance structures, and *tools*, focused on methods of flood prediction and assessing physical vulnerability. Such thematically-focused research is important for developing an understanding of the many dimensions of FRM, for example social perceptions about flood risk or how to improve flood simulation under increased climate variability, but a more holistic approach to FRM research is needed to truly understand and enhance resilience to floods. The need for interdisciplinary (and transdisciplinary) research is not a novel conclusion (Chin et al., 2014; Harden et al., 2014; Olsson et al., 2014); however, the structure of the many agencies funding research continues to pose a major challenge to more integrative FRM science. In most countries, funding agencies are aligned along traditional disciplines. In Canada, for example, the primary funding agency for scholarly research, Tri-Council, is divided into three bodies: the Natural Sciences and Engineering Research Council (NSERC) – which counts as two of the three – and the Social Sciences and Humanities Research Council (SSHRC). NSERC and SSHRC have limited crossover in scope; NSERC does not support research that integrates a strong social science component, while SSHRC does not support natural science and engineering research (Noble 2015b). Challenges are similar in the UK, where the environment, physical sciences, and arts are separate streams under the Research Councils United Kingdom. Truly integrative work, though often encouraged by most granting agencies, is supported only through a limited number of opportunities, such as the United States National Science Foundation’s (NSF) ‘crosscutting and NSF-wide’ and ‘integrative activities’ initiatives. In order to support greater flood resilience, funding agencies need to provide dedicated programs supporting truly integrative research, that is, research that investigates the complex social-ecological issues surrounding flood resilience that result from the interactions and feedbacks between the physical characteristics of floods, flood risk perceptions, flood tolerance, rapid climate and social change, and FRM policies and actions.

Second, FRM research is siloed from practice and policy; only 7% of the papers in our analysis could be categorized under the *research on practice* theme. This limits the transfer of important knowledge about flooding and resilience between scholars and practitioners and policy makers. As Vogel et al. (2007) state, “policy-makers and managers often indicate that they do not receive the information they need, scientists are frustrated when their information is not being used, and ultimately, communities remain vulnerable in the face of extreme events and environmental changes” (p. 350). Ensuring that FRM science is relevant to, and adopted in, FRM practice and policy making requires a forum for FRM scholars, practitioners, and policy makers at regional and national levels. Such a forum could facilitate mutual learning and work to identify current knowledge gaps and thus collaboratively drive new and meaningful policy, practice, and research opportunities. We suggest the need to step back from the current, independent, and often-individual researcher-led research agendas, and develop a more strategic and integrated FRM research for policy agenda. There has been some recent progress on this, namely the advent of FloodNet in Canada and the Flood and Coastal Erosion Risk Network in the UK. We acknowledge that these networks are relatively new and are thus just beginning to gain momentum at the time of our analysis of the scholarly journal literature. These kinds of networks, however, should play a more prominent role in shaping FRM policy and research agendas elsewhere too.

Third, we found that the majority of research addressing *tools* in the FRM literature focused on physical science tools for use in climate modelling and flood modelling and prediction, with less attention on tools to address the social dimensions of FRM. Progress has been made on understanding and communicating vulnerability to floods and FRM policies (Burch et al., 2010; Lee and Chen, 2011), but our ability to model and integrate the social dimensions of FRM into policy and practice is limited. Better coping with uncertainty and building social-ecological resilience to floods requires tools not only to address the physical attributes and socioeconomic impacts of floods, but also tools that are capable of integrating societal perceptions, priorities, needs, and expectations into FRM policy development and decision processes (see Burch et al., 2010; Clarvis et al., 2014; Godden and Kung, 2011). Multiple social science-based tools and methods found outside of the flood literature hold considerable potential for application to tackle complex FRM problems. Examples of these tools/methods include fuzzy cognitive maps for improving both the engagement of stakeholders and the more effective integration of their perspectives and priorities in decision making (Kontogianni et al., 2012; Strickert et al., 2009);

tools designed to assess and improve the capacity of governance structures to support adaptation to new policies (Pahl-Wostl et al., 2014); tools for trade-off analysis between societal and ecological needs (Daw et al., 2015); and methods for identifying relevant stakeholders in policy decisions and facilitating knowledge transfer (Crona and Parker, 2012). Flood risk management needs tools that can help practitioners access relevant knowledge efficiently, integrate competing knowledge claims into collaborative FRM policy-development processes, and account for and influence the diversity of stakeholder perceptions and behaviours. The development, or adaptation, of social tools to support FRM resilience is a significant research opportunity.

Fourth, we found a tendency for academics to conduct research on FRM tools in disciplinary isolation, and to focus very little attention on frameworks for the integration of tools. Tools for prediction, assessment/planning, policy appraisal, and decision making are often developed without reference to one another, creating a challenge for their adoption in FRM practice. Further, FRM tools developed in isolation are unlikely to perform well in practice where forecasting, assessment, and decision making need to be strongly linked. The consequence of a lack of integration of social and physical aspects of flood risk is that FRM practitioners are forced to rely on a bricolage approach: using the best tools that they can find and combining and adapting them to purposes they might not necessarily have been designed for. This is a common issue in the environmental sciences, and so guidance toward a solution is available from other disciplines. Sheate (2009), for example, discusses how environmental impact assessment, strategic assessment, sustainability assessment, and cost-benefit analysis are essentially different tools for addressing the same greater problem of ensuring environmental protection in the face of development. He argues that the lack of research integration among the experts who develop these tools results in a lost opportunity to integrate different perspectives and identify beneficial or essential connections for tool transference. The important message for FRM scholars is that the advent of integrated FRM tools is likely to yield more rapid advances in our understanding of linked physical and social influences on flood risk. Indeed, there are recent examples of progress. Di Baldassarre et al. (2015) used agent-based modelling to integrate social and physical aspects of flood risk. To advance FRM the development of FRM tools that are integrative and flexible to local or regional flood and governance contexts, greater collaboration across the FRM research community, as well as enhanced collaboration with practitioners, is needed.

Finally, notwithstanding the increasing volume of FRM research, there appears to be very little research focused on the development of supporting frameworks for organising FRM knowledge and expertise either in practice, governance, or in academia itself. Although there is no single agreed upon definition of what constitutes a framework, most literature describes a framework as a means to foster collaboration, share knowledge, determine roles and responsibilities, and provide an arena for continuous learning and policy development and evolution (Clarvis et al., 2014; Cosens et al., 2014; Pahl-Wostl et al., 2013). Our analysis indicates a current lack of the organisational influence and collaborative atmosphere provided by frameworks, with only 2% of the analysed papers focusing on the development or use of frameworks as an organisational influence, and only five papers with a secondary connection to the frameworks theme. Particularly concerning is the limited research on governance frameworks, which involves how best to organize and structure institutions, people, data, and responsibilities for building flood-resilient societies. There is a large body of literature external to FRM research addressing frameworks for environmental governance and public policy. This focuses on the roles and responsibilities, the decision making structures, and the participatory and institutional arrangements appropriate for promoting sustainability, learning, and adaptive capacity in the face of environmental change (e.g. Armitage et al., 2012; Bakker and Morinville, 2013; Westley et al., 2013). How best to introduce these frameworks and concepts into FRM policy and practices needs to play a larger role in the FRM resilience research agenda.

2.6 Conclusions

The findings from this chapter suggest that research self-identifying as relevant to flood resilience is not carried out in a way that incorporates the principles the scholarly literature suggest are underlying a strategic and adaptive approach to FRM. There is diversity in the themes present in the research; however, some themes receive a disproportionate amount of attention compared to others. That this research is often carried out in silos indicates that research lacks coordination and integration across disciplines. A major concern, then, is that research into frameworks for coordinating research, practice, or both is largely missing. There is a clear divide between the research and practice communities, thus it is difficult to see how current trends and approaches to research are evolutionary and responsive to changing conditions and societal needs. There is, therefore, a clear need and opportunity to improve the academic contribution to flood resilience.

The increasing frequency and severity of flood disasters suggests that, without effective and appropriate actions, societies will become more vulnerable to floods. Flooding events are often unpredictable, flood control infrastructure is not always reliable, and societies need to become more resilient to floods. This is not to suggest that flood control structures are not critical to the solution; rather, it suggests that FRM based on resistance needs to be combined with adaptation approaches to understand and enhance resilience to floods. Our analysis of FRM resilience research showed a significant increase in attention amongst the scholarly community, particularly over the last decade, in the areas of FRM stakeholder engagement, policy effectiveness, how FRM governance structures operate, tools to aid in flood forecasting and planning and, to a much lesser extent, frameworks for organizing institutions and supporting FRM implementation. That said, we also observed that FRM resilience research lacks integration, and ways in which to integrate this complex subject are poorly studied; this is, in part, a function of the culture of specialization amongst the academic community (McGraw and Biesecker, 2014; Sheate, 2009). It is a sobering thought that many of the issues that White and Haas (1975) described regarding research into natural hazards in the USA, including a lack of coordination, domination by physical and technical fields, and a research agenda that is not responsive to the needs of the public sector (Mileti, 1999), are present in current research intended to support greater flood resilience.

Flood risk management is a complex challenge and, by definition, comprises many interacting scientific, practical, and political dimensions. Advancing the FRM resilience research agenda requires, at a minimum, interdisciplinary and transdisciplinary research that integrates across the physical and social sciences, supported by government funding programs that transcend the physical-social science boundary. For this research to be influential, a more tightly coupled FRM research-for-policy agenda is needed than is currently the case, to better direct both research needs and policy advances. This means that researchers must not only continue to improve physical science tools for flood forecasting and modelling, but also advance social science tools that aid collaborative FRM policy development processes. We suggest that this is best achieved through the development of collaborative frameworks. Such frameworks would facilitate collaboration both within and between the researcher and policy/practitioner communities and would ensure that the tools developed to support FRM are meaningful in practice, operable across human and natural contexts, and serve to facilitate continuous improvement of FRM governance. Examples of frameworks that aim to facilitate this level of collaboration do exist, including the International Centre for Water Hazard and Disaster Risk Management (ICHARM), the National Water Centre (United States), the National Disaster Reduction Forum (Canada), and the Centre for Research Excellence in Water (Scotland). However, the success of such frameworks and collaborations in building more resilient FRM policies and communities hinges not only on technical skill sets and financial resources, but also on effective dissemination of findings and a more integrative and collaborative FRM resilience research agenda.

3. FLOOD RISK MANAGEMENT IN THE CANADIAN PRAIRIE PROVINCES: DEFAULTING TOWARD FLOOD RESISTANCE AND RECOVERY VERSUS RESILIENCE

3.1 Preface

Flood risk management (FRM) based solely on the resistance, response and recovery policies associated with command and control management is not effective in increasing society's resilience to flooding. This is recognised in current FRM policies in Canada and other countries, which commonly incorporate the language of resilience and strategic and adaptive management. In principle, FRM policy implementation should reflect a move towards a greater resilience. However, the increasing costs of flooding suggest a gap between the resilience concepts represented by contemporary FRM policies and the realisation of those concepts in practice. Key to addressing this gap is greater understanding of the governance institutions, strategies, and policies through which FRM is implemented. However, examples of empirical studies of FRM governance arrangements are not common in the academic literature. This paper investigates the extent to which institutional arrangements for FRM facilitate or constrain FRM resilience; specifically:

- *What are the existing policies that influence FRM in the Prairie Provinces? What are decision makers' experiences of practicing FRM in the prairies? How do the policies presently in place compare to scholarly understanding of flood resilience? What are the experiences of decision makers in the region with responsibility for FRM?*

A shorter version of this Chapter is published in the *Canadian Water Resources Journal,* a leading national journal in the field of water resources and water resource management (Impact factor: 1.547):

- Morrison, A., Noble, B. F., & Westbrook, C. J. (2018). Flood risk management in the Canadian Prairie Provinces: Defaulting towards flood resistance and recovery versus resilience. *Canadian Water Resources Journal/Revue canadienne des ressources hydriques*, *43*(1), 33-46.

This Chapter demonstrates that:

- Although policy instruments appear diverse, poor coordination of FRM resources limits capacity. As such, primarily resistance and response approaches are implemented.
- Prairie FRM governance is highly fragmented and there is no formal coordination of actors, policies or resources between jurisdictions or scales of government.
- That emergency management is generally considered effective, and that there is an appetite for collaboration amongst stakeholders, represents opportunities for improving prairie FRM.
- Academics were not seen by practitioners as fulfilling any significant supporting role to FRM practice.
- There is not enough data to support more effective FRM. Current data management arrangements limit the amount and accessibility of data to support FRM.

Overall, this Chapter shows that the underlying principle of coordination is not present in Canadian prairie FRM. Existing policy instruments suggest that a diverse range FRM policy approaches is present, or at least acknowledged, however, the human, technical, financial and informational resources available to support implementation are not well coordinated, causing a lack of capacity at all scales of management. As a result, FRM tends to default to well-known resistance and recovery approaches. Prairie FRM governance is fragmented and that fragmentation is a root cause of coordination challenges that include unclear and missing roles and responsibilities, policy layering, and policy conflicts. Potentially, coordination challenges could be overcome by implementing a hub and spoke governance architecture. Such an architecture would provide a national level 'hub' agency with a mandate to set strategic FRM objectives and a common approach that would then be implemented through the 'spokes' of regional centres.

3.2 Introduction

The frequency and severity of major flood events is expected to increase globally under changing climatic conditions (Whitfield, 2012; Winsemius et al., 2016; Vitousek et al., 2017), with extreme flood losses expected to more than double in some regions by 2050 (Jongman et al., 2014). In Canada, between 1970 and 1990, more than ten flood disasters were recorded, costing 27 lives, the evacuation of over 34,000 people, and damages of approximately $460 million; between 1990 and 2017, 130 flood disasters were recorded, killing 21 people, evacuating 215,458 people and costing an estimated $8.1 billion (Canadian Disaster Database, Public Safety Canada, 2018). Changes in flood frequency, severity, and timing will have significant implications for flood management, infrastructure, land-use, the insurance industry, and the Canadian economy (El-Jabi et al., 2016).

The traditional approach to flood risk management (FRM) has been to control or manage flood events, typically through flood control structures designed to contain or divert flood waters (Klijn et al., 2008; Shrubsole, 2013), and to control or manage human behaviours through laws and regulations that restrict certain land-uses in flood-prone areas (Morrison et al., 2017; Zevenbergen and Gersonius, 2007). Given the stochastic nature of floods and their increasing severity, coupled with rapidly changing land-uses (Henstra and Thistlethwaite, 2017) and anthropogenic climate change (Vincent et al., 2015), efforts to control floods have proven insufficient for protecting lives and infrastructure (Klijn et al., 2008; Park et al., 2013; Rouillard et al., 2015). In response, scholars and government agencies are lobbying for resilience-based approaches (EU Flood Directive, 2007/60/EC; Gilissen et al., 2016; McEwan and Jones, 2012; Morrison et al., 2017; Rosner et al., 2014). Flood resilience, defined simply as the ability of society to avoid, cope with, recover from, and adapt to flood events (see Shelfaut et al., 2011), is based on a combination of resistance based strategies that seek to prevent or control extreme flood events, and adaptive strategies that focus on mitigating, coping with, and recovering from floods when they occur (Morrison et al., 2017).

There is a growing body of research on resilience across multiple natural resource sectors (Bakker and Morinville, 2013; Clarvis et al., 2014; Cosens and Williams, 2012). A consistent theme is the importance of institutional arrangements – policies and programs and the network of agencies and actor-structure relations responsible for their implementation – as a requisite for creating more resilient social and ecological systems (Clarvis et al., 2014; Cook and Bakker, 2012; Ferguson et al., 2013; UNFCCC, 2014). Significant advances have been made in understanding resilience and how it might be supported through institutional arrangements. However, despite this advancement in knowledge, the formulation of policies, programs, and strategies, the mechanisms for coordinating interests, and the processes for implementation of management actions pose enduring challenges to increasing resilience in practice (Chilima et al., 2013; IFAD, 2017; Lautze et al., 2011; Schmidt, 2013).

Considerable research has focused on understanding the hydrology of flooding (e.g., Fang and Pomeroy, 2008), developing better predictive tools (e.g., de Castro et al., 2013; Ward et al., 2015), and looking back on major flood events (e.g., Ahmari et al., 2016; Shook, 2016; Szeto et al., 2015). Research has also addressed the challenges of fragmented governance, and the need for greater coordination, capacity, and responsiveness (e.g. Gober and Wheater, 2014), but there has been limited detailed analysis of whether and how existing institutional arrangements influence the implementation of FRM and support FRM resilience (Morrison et al., 2017). This paper examines the extent to which institutional arrangements for FRM facilitate or constrain FRM resilience. The focus is on Canada's Prairie Provinces, which have been subject to major flood events of increasing severity in recent years (Gober and Wheater, 2014; Whitfield, 2012), but the policy approaches to FRM, and the reported experiences of those engaged in FRM practice, pose important learning opportunities for other regions and jurisdictions across Canada and, perhaps, internationally.

3.3 Methods

3.3.1 Study area

The study focuses on Canada's Prairie Provinces, Manitoba, Saskatchewan, and Alberta. The costs associated with disaster spending under the federal Disaster Financial Assistance Arrangements (DFAA) program have more than quadrupled over its 45-year history (IBC, 2015), with nearly 60% of all payments due to extreme weather events issued to the Prairie Provinces (OPBO, 2016). The majority of these payments were due to flood events, and the proportion of disaster spending due to flooding on the prairies has increased from 57% over the lifetime of the program to 82% between 2005 and 2014 (OPBO, 2016). A recent special issue of the Canadian Water Resources Journal on floods in Canada highlighted many of the recent major flood events in the prairie region, including their physical attributes, impacts and management responses. In this special issue, Pomeroy et al. (2016), for example, described the 2013 flood events in the South Saskatchewan and Elk River basins, that saw water levels nearing those of the historic events of the late 1800s, and resulted in more than a dozen communities declaring local states of emergency. Flooding of the Bow and Elbow rivers in southern Alberta was described as Alberta's worst-ever natural disaster (Burn and Whitfield, 2016). The Assiniboine River flood one year later, caused by heavy precipitation in mid-summer, resulted in states of emergencies being declared in both Saskatchewan and Manitoba. Ahmari et al. (2016) report that the summer flood was unprecedented in the previous 130 years of observation of the Assiniboine River; similar claims were made about the record flooding of the Assiniboine that occurred only three years earlier (Brimelow et al., 2015).

Flood management in Canada is largely carried out at the provincial level, though municipalities, watershed agencies and the federal government each play a role in FRM policy, program implementation, land-use zoning, and disaster recovery assistance. The Prairie Provinces exemplify the complex, multi-level, multi-actor governance environment (see Gober and Wheater, 2014) through which flood risk is managed in Canada and so provide a good case study for understanding the challenges that exist in implementing policies aimed at resilience.

3.3.2 Data collection and analysis

Data were collected via semi-structured interviews and an analysis of FRM policies and instruments. A total of 60 individuals working in a FRM capacity in the three Prairie Provinces were contacted for interviews, of which 34 participated (Table 3.1). An initial group of participants was identified through organisational websites for people or departments that were likely to be involved in FRM, with further participants identified through a snowballing sampling design (Gifford et al., 2009). Most interviews were conducted over the phone, with a small number carried out in person. Two interviews involved multiple people – one with a group of two, and one with a group of four. Interviews were on average 60 minutes long. One provincial government department requested to provide written responses as they felt it was the best way to coordinate between the four people in their organization engaged in FRM. For confidentiality, the identity of interview participants is withheld in the reporting of results and participants are instead identified as belonging to one of the stakeholder groups and the region in which they work.

Table 3.1 Study participants by stakeholder group and location.

	Federal government	Provincial government	Municipal government	Other stakeholders[1]	**Total**
Non-province specific	4	--	--	7	**11**
Alberta	--	2	5	1	**8**
Saskatchewan	--	2	1	4	**7**
Manitoba	--	5	2	1	**8**
Total	**4**	**9**	**8**	**13**	**34**

[1]Academia, consultancy, non-governmental organizations (NGOs), private business

Interviews were semi-structured based on key themes in the FRM resilience literature (Morrison et al., 2017) and explored the perceived distribution of roles and responsibilities for FRM, how different institutions are involved in FRM, how institutions interact, policy influences, what influences the effectiveness of policy, and what data, information, and knowledge are needed to support effective FRM resilience. Participants were broadly asked the same questions, however, some differences occurred among groups in recognition of their differing levels and types of involvement in FRM. For example, questions to non-government participants about monitoring the effectiveness of FRM policies were less likely to be relevant. Interviews were transcribed and coded using QSR Nvivo v.10 software. Coding was carried out over 7 rounds to identify similar themes raised by multiple interviewees (Table 3.2), and then used to develop a series of broader generic statements describing commonly held FRM perspectives (Braun and Clarke, 2006).

Table 3.2 Thematic coding process applied to interview transcripts

Coding round	Coding activity
Round 1	Open-coding of all interview transcripts
Round 2	Identifying similar codes and developing themes
Round 3	Coding of all transcripts with respect to each theme
Round 4	Open-coding of content coded to each theme
Round 5	Identifying similar codes within each overarching theme to develop sub-themes
Round 6	Coding of all transcripts under each theme and sub-theme
Round 7	Identifying each coded reference as positive or negative

Interviews were supplemented by an analysis of FRM policies and strategies. A web-based search was used to identify flood related policy instruments from federal, provincial and selected municipal government departments. For the purposes of this study a 'policy instrument' is any document intended to influence the practice of FRM, including: acts or legislative requirements; regulations; by-laws that relate to permitting, infrastructure or land-use zoning; funding programs for flood mitigation, preparedness, and disaster recovery; and guidance documents for government departments, businesses, individuals or others on flood preparation or risk management.

The policy search was done prior to the interview process and again following the interviews as participants were asked to identify any policies they were aware of that influence FRM. This two-pronged approach allowed us to review what is available to the public, as well as to capture those key policies that were identified by FRM professionals as influential in practice. Not included in the documents reviewed were any policies that deal with technical aspects of water management, such as storm water treatment operations or reservoir and dam operational guidelines. Although important for how floodwaters are managed, technical operating guidance was considered more relevant to FRM management than governance.

Policy instruments were categorized based on type: strategies, legislation, programs, and guidance and information. Strategies outline a set of guiding principles, set broad goals and objectives, and provide a framework for a coordinated set of FRM programs or actions. Legislation enshrines FRM principles in law, assigning legal responsibility and allowing enforcement of those FRM principles. Programs capture actions and activities that are funded to address well-bounded and specified aspects of FRM, such as erosion control, community defence, or relocation programs. Guidance and information provide standard approaches to FRM and information. Guidance is both technical and lay, such as guidance on flood mapping, building design, or emergency planning, as well as public guidance on flood preparation and recovery. Information includes data that is shared or available for assisting FRM, such as flood maps, hydrological measurements, and other data.

Each policy instrument was then categorized based on its primary focus, using the five FRM approaches described by Gilissen et al. (2016): i) prevention; ii) defence; iii) mitigation; iv) preparation; and v) response and recovery. Prevention seeks to minimise flood risk to people, property and infrastructure. Defence aims to increase resistance to flood waters through structures such as dykes or dams. Mitigation seeks to accommodate flood waters to reduce peak flows, and improve the ability for buildings and infrastructure to cope with floods. Preparation aims to reduce the impact of floods and protect people, property, and infrastructure during an emergency. Recovery seeks to return the socio-ecological system to its pre-flood state. Collectively, these approaches capture the proactive and reactive nature of FRM resilience.

3.4 Results

Results are presented below in three sections: i) policy instruments and their approach to FRM; ii) the division of FRM roles and responsibilities as perceived by interview participants; and iii) commonly expressed strengths and challenges to current FRM across the Prairie Provinces.

3.4.1 FRM policy instruments

There were 65 FRM provincial and federal policy instruments identified that apply to the Prairie Provinces. Ten of these are strategies, 14 are legislative instruments, 19 are programs, and 22 are guidance and information documents (Table 3.3). Of the five broad approaches to FRM identified by Gilissen et al. (2016), the two most common instruments were preparation and response (43%), and prevention (40%). Defence was addressed by 32% of policy instruments, mitigation by 25%, and flood recovery by 23%.

Individual FRM policy instruments often address different approaches, with 40% of instruments addressing three or more of the five approaches. The most common FRM approaches identified were flood prevention and flood preparation. Legislation was most strongly concerned with i) enabling flood prevention (64%) via Acts that support land-use planning and the relocation of people and property from areas of high flood risk; and ii) flood defence (36%) via the construction and maintenance of water control structures. Of the programs identified, most were focused on flood defence (58%), mitigation (42%), or both (31%). Guidance and information instruments tended to focus primarily on flood prevention (26%) and flood preparation and response (46%).

Table 3.3 Flood risk management policy instruments applicable in Canada's Prairie Provinces by type, owner and approach.

Policy instruments (n=65)	Owner	Flood Prevention	Flood Defence	Flood Mitigation	Flood Prep. & response	Flood Recovery
		FRM approach supported				
Strategies (n=10)						
An Emergency Management Framework for Canada	F	x	x	x	x	x
National Disaster Mitigation Strategy	F	x	x	x	x	
Resilience and Mitigation Framework for Alberta Floods	AB	x	x	x	x	
Land-use framework	AB	x				
Water Security Agency 25-year plan	SK	x	x	x	x	
Manitoba Emergency Plan & Flood Annexe	MB				x	x
Area Structure Plans (AB)	M	x				
Inter-municipal Development Plans (AB)	M	x				
Municipal Development Plans	M	x				
Emergency response plans	M				x	
		8	**4**	**4**	**6**	**2**
	Owner[1]	**Flood Prevention**	**Flood Defence**	**Flood Mitigation**	**Flood Prep. & response**	**Flood Recovery**
Legislation (n=14)						
Municipal Government Act	AB	x				
Water Act	AB	x	x	x		
Emergency Management Act	AB				x	x
The Planning and Development Act	SK	x			x	x
Provincial Drainage Regulations	SK		x	x		
Statement of Provincial Interests Regulations	SK	x				
Water Security Agency Act	SK	x	x	x		
The Emergency Planning Act	SK				x	x
Designated Flood Areas Regulations	MB	x				
Dyking Authority Act	MB		x			
Emergency Measures Act	MB				x	x
The planning Act	MB	x				
Water Resources Administration Act	MB	x	x			
Land-use bylaws	M	x				
		9	**5**	**3**	**4**	**4**

Table 3.3 (cont.) Flood risk management policy instruments applicable in Canada's Prairie Provinces by type, owner and approach.

	Owner[1]	Flood Prevention	Flood Defence	Flood Mitigation	Flood Prep. & response	Flood Recovery
Program (n=19)						
Building Canada Fund	F		x			
National Disaster Mitigation Program	F		x	x		
Growing forward 2	F			x		
Disaster Financial Assistance Arrangements	F				x	x
Flood Hazard Identification Program	AB	x	x	x	x	
Provincial Mitigation Program	AB		x	x	x	
Agricultural Watershed Enhancement Program	AB			x		
Alberta Community Resilience Program	AB		x	x		
Erosion Control Program	AB		x			x
Floodway Relocation Program	AB	x				
Watershed Resiliency and Restoration Program	AB		x			
Disaster Recovery Program	AB					x
Emergency Flood Damage Reduction Program	SK				x	
Provincial Disaster Assistance Program	SK					x
Erosion Control Assistance	SK		x	x		
Rural Water Control Assistance	SK		x	x		
Community Flood Protection Program	MB		x			
Disaster Financial Assistance (program)	MB					x
Individual Flood Protection Program	MB		x			
		2	**11**	**8**	**4**	**5**

Table 3.3 (cont.) Flood risk management policy instruments applicable in Canada's Prairie Provinces by type, owner and approach

	Owner[1]	Flood Prevention	Flood Defence	Flood Mitigation	Flood Prep. & response	Flood Recovery
Guidance and information (n=22)						
National Building Codes	F	x				
National Flood Mapping Guidelines	F	x			x	
Risk Based Land-use guidance	F	x				
Water Survey of Canada Flood Information	F				x	
Emergency preparedness guide	F				x	
FRM Guidelines for the Location of new Facilities	AB	x				
Guidelines on extreme flood analysis	AB	x			x	
Stormwater Management guidelines	AB		x	x		
Flood Choices for Albertans	AB	x				
Flood hazard map application	AB	x				
Alberta Municipal Recovery Toolkit	AB					x
Personal and Family Preparedness	AB				x	
Nine steps for Emergency Plan Development	SK				x	
Flood Information	MB				x	
Flood Recovery	MB					x
Preparing for a flood	MB				x	
Health and Safety	MB				x	
Evacuation	MB				x	
Managing Stress	MB					x
Prepare	MB				x	
Recover	MB					x
Respond	MB				x	
		7	**1**	**1**	**12**	**5**

		Flood Prevention	Flood Defence	Flood Mitigation	Flood Prep. & response	Flood Recovery
Total number of documents - 65	**Total**	**26**	**21**	**16**	**28**	**15**
		40%	**32%**	**25%**	**43%**	**23%**

3.4.2 FRM roles and responsibilities

Many stakeholders are involved in FRM, including government departments and agencies at the federal, provincial, and municipal levels, as well as non-government organizations. For example, Public Safety Canada and Infrastructure Canada are federal ministries responsible for administering various flood funding programs; Environment and Climate Change Canada and Natural Resources Canada are federal ministries engaged in hydrological and meteorological data collection and the development of FRM guidance; and the Department of National Defence is a federal ministry that provides emergency response measures to flood-affected regions. Provincially, there are multiple departments and agencies involved in land-use planning, emergency preparedness and response, water management, infrastructure design, and public health and safety in the Prairie Provinces of Canada. At the municipal level, depending on the size of the municipality, governments are engaged in setting land-use bylaws, and flood emergency preparedness and response. External to government, organizations such as watershed agencies, conservation groups and land developers also play a role in flood management and protection measures at local and regional scales, although their roles are less well defined.

Thirty different FRM roles and responsibilities were identified by study participants, and assigned to one or more of three levels of government, as well as to organizations external to government (Table 3.4). Fifteen of these roles and responsibilities were identified by more than 25% of participants. The most frequently identified roles and responsibilities broadly reflected matters relating to FRM implementation, funding, and information management. The most prominent role, identified by 68% of participants, was the development, implementation and enforcement of land-use planning – said to be a municipal responsibility. The second most frequently identified role was the provision of funding for flood mitigation, response and recovery, identified by 62% of participants – consistently identified as a federal responsibility. The implementation of FRM initiatives (e.g. flood mitigation projects; construction and maintenance of water control structures) was the third most identified, by 56% of participants, and believed to be a shared responsibility of provincial and municipal governments. Interestingly, participants from municipal governments did not assign this responsibility to themselves, indicating that they may not see themselves as on the front lines of policy implementation.

Table 3.4 Perceived ownership of flood risk management roles and responsibilities, reported by number of participants assigning the role or responsibility.

		Number of participants assigning the role to Federal, Provincial, Municipal, or Other stakeholder groups (total n=34)[1]			
FRM roles and responsibilities identified by study participants	Total	Federal	Provincial	Municipal	Other
Developing, implementing and enforcing land-use planning.	23	0	6	**17**	0
Provision of funding for FRM mitigation, response and recovery.	21	**17**	4	0	0
Implementation of FRM policies and actions	19	0	**9**	**10**	0
Assess flood hazards and flood risks.	17	5	**9**	3	0
Public and stakeholder education on flood risk.	15	2	6	1	6[2]
Support municipalities with technical expertise, flood fighting and other FRM resources.	13	0	**13**	0	0
Coordinate policy and action across jurisdictional boundaries.	12	**9**	2	0	1
Data collection and dissemination.	12	7	5	0	0
Ensure emergency preparedness.	12	0	1	**11**	0
Provide national guidance and standards	10	**10**	0	0	0
Research and development of practice, tools, alternatives or FRM related science.	10	**7**	1	1	1
Development of an FRM Strategy.	10	6	3	1	0
Flood forecasting.	10	2	**8**	0	0
Oversight and enforcement of FRM policies and actions.	9	5	4	0	0
Coordination of emergency response.	9	0	**9**	0	0
Provide emergency support when required	5	5	0	0	0
Responsible for First Nations FRM.	5	4	1	0	0
Administer federal funding programs.	5	0	5	0	0
Regulate drainage.	5	0	2	3	0
Develop provincial guidance and standards.	4	0	4	0	0
Coordination between levels of government, ministries or departments.	3	0	2	1	0
Responsibility for major rivers.	2	1	1	0	0
Water resource management.	2	0	2	0	0
Support government to reduce the financial and human burden	2	0	0	0	2
Translate science for practical use.	2	0	0	0	2
Support provinces and municipalities through a central resource of expertise.	1	1	0	0	0
Watershed management within province.	1	0	1	0	0
Coordination of evacuation of First Nations.	1	0	0	0	1
Responsible drainage.	1	0	0	0	1
Determine socially acceptable levels of risk.	1	0	0	1	0

[1]Bold indicates most frequently identified key roles and responsibilities. [2]Most commonly associated with non-governmental stakeholders.

Perceived responsibility for the assessment of flood hazards and flood risk appears to be split between different levels of government, and into different activities. The role of the federal government was self-described as being to “set the context, [and] provide or facilitate the provision of flood plain maps.” Provincial participants associated this responsibility with financial support from the federal government for flood risk mapping. Provincial governments were commonly assigned the role of producing flood mapping in order to support municipal flood planning and individual flood risk awareness. At the local level, municipal governments were considered to be responsible for carrying out flood risk assessment. Interviewees perceived a fairly clear distribution of responsibilities relating to the assessment of flood hazards and flood risk; however, there is evidence to suggest that these roles and responsibilities are not necessarily acknowledged or being carried out effectively by the organisations that participants assigned to them. This is particularly evident at the municipal levels where participants noted that flood mapping was often unavailable and that it can appear that “no one is actually responsible for flooding”, but also at the provincial level where some participants considered federal support to be insufficient. These results highlight that overlapping and unacknowledged responsibilities, are resulting in challenges to carrying out flood risk assessment at the local level

Public and stakeholder education on flood risk, identified by 44% of participants, was not clearly associated with any single stakeholder group. Approximately 18% equally assigned this responsibility to each of the provincial government and other stakeholder groups, whereas federal participants did not identify this as a federal responsibility. Provincial participants who identified public education as an FRM responsibility generally recognised it to be held at the provincial level. When public education was assigned as a responsibility to ‘other’ stakeholders, this was most often stated in terms of individuals, businesses, or communities being responsible for understanding their own contributions to flood risk. For example, one municipal participant discussed the role of local businesses in reducing flood risk: “Within the city…we have a partnership arrangement between the municipal government…[and] roughly 40 to 45 different businesses and agencies that are working towards educating the public about emergency preparedness issues.”

Responsibility for the development of FRM strategies was most often associated with the federal government. There was a desire from several participants for greater strategic involvement in FRM from the federal government. For example, as one provincial participant expressed, “It would be nice to have a portion of the federal government that is plugged into [FRM], on a regular basis, not only with money, but with a certain amount of interactions. Maybe some kind of strategy, but also a part of federal government civil service that would interact with us on a regular basis.” A municipal participant echoed this sentiment: “As a municipal employee, what I'm looking for is some clear direction, clear regulations, or guidelines from a higher government authority whether that's the province or the federal level.” There were also calls from participants from the ‘Other’ group for the federal government to take a more strategic role in FRM, such as having a federally established common goal comprised of big picture objectives to support provincial level regulation, along with the enactment of risk-reducing measures. Although responsibility for FRM strategy development was most often assigned to the federal government, federal government participants themselves did not identify this as an FRM role.

There were also some notable roles and responsibilities rarely assigned. Except for emergency response, roles that involve coordination of actors were not clearly assigned to any level of government. Only 9% identified coordination of strategies, goals, policies and actions between government levels, ministries and departments to be anyone’s responsibility. Coordination of data and information exchange between researchers and practitioners, such as the research needs of practitioners or data needs of researchers, was also unclear, with only 6% of participants assigning responsibility.

When asked to consider if FRM roles and responsibilities are clearly defined, participants’ answers could broadly be categorised in three ways. First, 11 participants, primarily municipal (4) and ‘other’ (5) stakeholders, indicated that roles and responsibilities are not clearly defined, overlap, or are missing. As one municipal participant described, “You have a bunch of different provincial agencies that are handling water…The same as [there are] federal agencies and departments that are handling water. There's no clear mandate when it comes to water management when it comes to all of those characters.” As such, several participants expressed that clarification of roles and responsibilities would be beneficial for FRM. Second, eight participants (3 municipal, 2 provincial, and 2 ‘other’), noted that in some cases roles and responsibilities are well defined, but gave qualifying statements, particularly in terms of emergency management. As one municipal participant noted, “From an emergency management point of view…it’s very clearly stated in [provincial] legislation what our responsibility is when it comes to people.” Third, three participants (2 provincial, 1 ‘other’) considered that roles and responsibilities are, in fact, well defined, but not performed adequately. Results suggest that roles and responsibilities for FRM are not always clear, especially to those working at the municipal level or to ‘other’ stakeholders external to governments.

3.4.3 Perceptions of how FRM governance supports practice

Participants perceived there to be both strengths and challenges to FRM in the Canadian prairies. The prevalence of these perceived strengths and challenges within the group of interviewees is synthesised in Table 3.5. Examples of some representative or common observations shared by study participants are presented in Table 3.5a and Table 3.5b. Emergency response was perceived as working effectively and a major strength in current institutional arrangements. One provincial participant, for example, explained that the provinces “work with communities [and] municipalities to ensure that they have an emergency plan which is broad enough to include and address flooding.” As a result, emergency response plans are common in municipalities. Provincial level emergency management plans were also considered a strength as they clearly define roles and responsibilities in an emergency. The accessibility of federal and provincial funds during and after an emergency also contributed to the perceived effectiveness of emergency response and recovery. One provincial respondent spoke appreciatively, for example, about how they “haven’t been restricted to funding what’s covered in the program profile.” Specifically, the Disaster Financial Assistance Arrangements (DFAA) was referenced by participants as being a significant source of financial support. According to interview participants, current institutional arrangements facilitate the effective implementation of emergency procedures through preparation, coordination of action, and the guarantee of finance, particularly from the DFAA.

Despite general agreement that emergency management functions effectively, several participants made statements that contradict this perception, particularly with respect to how prepared municipalities are for major flood events. For example, after being involved in a test of city level response to a major disaster, an 'other' interviewee described this perceived limitation: "The idea was to…test out, the inter-agency operability that exists [within the city], between [emergency] plans. It showed very quickly the limitations of all the agencies to actually cope with such a catastrophe." A municipal participant echoed this view in respect to smaller municipalities in considering that many are not prepared for an emergency: "There are a lot of municipalities from an emergency response point of view that are no way prepared or in a readiness state." These dissenting views were significantly outweighed by positive statements about emergency management (Table 3.5), but nonetheless caution against overconfidence.

Table 3.5 Key strengths and challenges to FRM expressed by FRM participants

	No. of participants making supporting statements	Total no. of supporting statements identified	No. participants making dissenting statements	Total no. of dissenting statements found
Ability to manage and recover from floods is a strength of current FRM	13	22	3	5
Commitment to collaborative action is a strength of FRM	31	122	16	24
Conflicts between policy goals and policy implementation are a challenge	29	114	2	2
Inconsistent focus on FRM is a challenge	20	54	0	0
Availability and coordination of resources is a challenge	33	168	18	29

Another reported strength of FRM in the region is a strong commitment to collaborative action in addressing flood risk. Most commonly, interviewees gave examples of collaboration through data sharing. This occurs through both formal and informal arrangements between stakeholders. Participants spoke of informal data sharing opportunities through friendships and professional relationships built at conferences, workshops and other networking events. One provincial participant described specific formal arrangements that exist between government agencies: "We work with department agencies that provide data for us for doing forecasting [and]…we have a contract with [Water survey of Canada] in which they operate a number of hydrometric stations that are essential for flood forecasting."

Collaboration was also identified as an important and common part of accessing funding for FRM. A commitment to cost sharing of FRM projects was identified as important to supporting municipal level FRM, as municipalities often do not have the financial capacity to fully fund local flood risk reduction projects. As one municipal participant put it, "We've seen really good support from the province, so they are helping us in getting our funding applications in and setting out priorities." Similarly, there is cost-sharing between the provincial and federal governments to support larger scale FRM programs for which provincial governments may not have the financial capacity. One provincial participant provided the example of the federal government contributing to the provincial government's community, individual, and emergency flood protection programs, which support the building, improvement, and maintenance of major protective structures.

A further often identified area of collaboration was through river basin councils, watershed groups, and similar organisations. For example, one municipal participant described the value of watershed organisations in making more efficient use of resources and coordination of local actors, "We're involved in the [local] watershed association. We can… pool our resources to determine what the best ways to set up regional flood management structures are. And then it also allows us to pool our resources and dollars towards projects too." The value of these watershed scale organisations to supporting FRM was noted by participants in all three provinces.

Positive statements indicating that there is a commitment to collaborative action outweighed statements that contradict this perception by approximately five to one (Table 3.5). However, these dissenting statements are important as they suggest ways in which the benefits of collaboration are reduced. For example, partnerships can fail when there is no clear leadership role assigned. As one 'other' participant explained, "When you're setting up a meeting, everybody's willing to show up. But…the coordinating thing, it takes an entity to organise it, keep notes, circulate it and then keep on top of it…if you don't have that one group that keeps pushing things along, it can fizzle out." Another interviewee from the group of 'other' participants suggested that a lack of clarity of roles and responsibilities limits the effectiveness of collaborations between government levels, and that there is "a lot of finger pointing. The provincial and federal governments have been able to play off of one another, saying, that's someone else's problem." This participant clarified that their perception was that these levels of government were, in fact, collaborating, albeit ineffectively. Additionally, it was identified that poor communication between provincial jurisdictions and government departments can result in partnerships not achieving their potential. A municipal participant offered this anecdote:

> "There's the Memorandum of Understanding that's been signed by the provinces…some good work has been done on the part of legislators on both sides of the border. But…at the last [municipality association] conference I was at, I had [met] with some people from the [provincial government]. They didn't know about [the MOU]."

Table 3.6a Perspectives on the strengths of current flood risk management roles and responsibilities.

Key strengths	Supporting statements from interviewees
Ability to manage and recover from flood events: ▪ Emergency response is effective. ▪ Response and recovery is well funded. ▪ Emergency preparedness is improving.	▪ We've always concentrated on response, and we do that really well. We have a clear emergency management procedure…It identifies lead roles and responsibilities of all partners within the province. ▪ It's a well-rehearsed cycle of processes each year in flood season. It's all coordinated through a lead organisation which brings all the stakeholders together. ▪ Generally, when you get into an emergency, you know spending control is going to be lifted…haven't had the experience where we've been limited in what we can do to protect life and safety by lack of financial resources. ▪ We have increased the activities that we undertake from a preparedness standpoint. Municipal emergency response plans are now a legal requirement and are now much more common in municipalities than they were 20 years ago. ▪ Provinces are providing guidance on response plan development, ensuring that municipalities are aware of roles and responsibilities and resources that are available.
Commitments to collaborative action: ▪ Collaborations between river basin organisations, watershed groups, and conservation districts. ▪ Cost sharing of FRM project funding. ▪ Data sharing.	▪ The watershed group incorporates planning and advice on a watershed wide scale. It is a beneficial collaboration of municipal and provincial governments, conservation groups and other stakeholders. We can pool our technical and financial resources to plan on a more regional scale. ▪ Municipalities get a lot of support from the province, they really try to help us and push forward our projects and collaborate on our funding proposals. The Province has a grant program to support community and individual flood protection. Then there's the disaster financial assistance program. ▪ Government organisations do try to work together…We [watershed organization] have a contract with all of our partners which determine how we'll handle the sharing of information and data. ▪ A lot of the data we get is shared more informally through professional contacts. I know some people in the provincial government who might have data I need; they know I might have data they need.

Table 3.6b Perspectives on the challenges of current flood risk management roles and responsibilities.

Key challenges	Examples of statements from interviewees
Conflicts between policy goals and policy implementation: ▪ Financial resources are biased towards response and recovery. ▪ Conflict of interest exist between prevention of flood risk and economic development. ▪ Conflicts exist between regulatory regimes. ▪ Funding can be hard to access	▪ We [municipalities] see a lot of support for emergency relief after the fact, when we haven't been able to get our hands on funding related to the prevention of flooding…we saw hundreds of millions of dollars in this area for emergency flood relief, but we feel that if we had seen a fraction of that to go towards prevention, the recovery costs would have been much smaller. ▪ Municipal governments are dependent on property taxes and thus have an incentive to allow development in flood prone areas where often they can collect higher taxes. ▪ We [municipalities] are trying to mitigate for increased drainage in the neighbouring province, but because we have very restrictive regulations here, it is very difficult. We are trapped between a lack of regulation and inflexible regulations. ▪ A $20 million event is what is needed to trigger disaster financial assistance federally. In a rural municipality, it's easy to have significant damage that is under $20 million. ▪ It can be hard to convince governments to invest in mitigation to address flood risk when there are obvious immediate needs in health care, and education.
Inconsistent focus on FRM: ▪ Uncertainty of financial support for mitigation. ▪ Policy cycles make long term FRM planning difficult. ▪ Policy windows influence resources available for FRM policy and action.	▪ We [province] need to say that there's going to be annual funding available to help improve flood protection levels or help in understanding that flood risk. But the NDMP is a 4-year program. We don't know what will be there after that. ▪ The time horizon over which policy is expected to make a difference is extremely important and it needs to also have time to unfold. But we are not good at planning in cycles that are longer than election cycles. ▪ When resource are only available after a flood, it becomes hard. What we end up doing is band-aid fixing issues when a disaster occurs, because that's the funding that's available to us. Rather than working towards mitigation efforts, which is what we should be doing.
Availability and coordination of resources: ▪ FRM knowledge and expertise is too widely distributed to be used in the most effective manner. ▪ Existing tools for FRM are inadequate. ▪ Lack of data to support decisions, assess risks, and enforce legislation. ▪ Data is not coordinated	▪ Human resources are spread over three provinces, three levels of government and many departments and organisations. ▪ Municipal authorities often don't have a technical background and cut backs in provincial and federal departments mean that the support for effective FRM isn't there. ▪ Those of us working in FRM are split up and under-resourced and have a great deal of difficulty doing a good job, despite our best efforts. ▪ We have some unique geography. And while there are tools that are available out there, that are being exploited in other countries, we're not sure how well we could use them or what their effectiveness would be in Canada. ▪ We need data on our hazards, the hydrology, meteorology, topography. We need the data of where are our elements at risk, people, property and infrastructure. But we don't really have this. ▪ During a flood, we needed cadastral data and GIS datasets that were held by another department. Although they were willing to share it, they had to sanitise some of the data, such as people's names and personal information, which took too long to organise. ▪ There is no leadership or coordination of data gathering. As a result, we end up with many groups saying, "well, I'm going to have to start collecting my own data," and then these data failed to get merged.

Participants also identified some enduring challenges (Table 3.5; Table 3.6b), including potential FRM policy conflicts. Economic development policy within municipal governments was often seen as conflicting with efforts to reduce flood risk. The major FRM responsibility attributed to municipalities was developing and enforcing land-use planning to reduce flood risk; however, this was perceived as conflicting with the generation of tax revenues upon which municipalities are reliant for the provision of public services. A provincial respondent expanded on this conflict: "Municipalities generate the bulk of their income from property taxes, and that's…affected by property values. Water is attractive and often increases property values significantly. That often [conflicts] a lot with respect to flood risk management." A lack of oversight from either the federal or provincial government compelling municipalities to enforce good land-use planning practices was often seen as exacerbating this conflict between economic priorities and FRM. However, some participants did note that provincial governments have started to take a more active role in regulating land-use planning in Alberta and Manitoba.

The different regulatory regimes that exist between government jurisdictions and departments was identified as second source of policy conflict. These conflicts were seen by some participants as reducing capacity to manage flood risk. A municipal participant living close to a provincial border gave a practical example of how the FRM options have been limited as a result of two different provincial regulatory regimes: "We have a very restrictive conservation arm of the government here. And being able to up culverting and up bridges…is not an easy thing to get licensed…We are completely trapped between the wild west of drainage in Saskatchewan, and the Iron curtain of drainage in Manitoba." Conflicting regulations were also noted between government departments with mandates relating to water management. For example, a municipal participant expressed frustration with differing messages coming from provincial government departments when attempting to implement a FRM project, posing the question, "Why are two parts of the government helping us and one part of the government throwing up every road block possible?" However, one provincial participant explained that since 2013, "we're taking a larger view of mitigation when we look at any project…making sure that it doesn't have negative effects upstream or downstream." showing that, at least in some areas, attempts are being made to reduce inter-jurisdictional conflict.

A third policy conflict was identified in relation to how the federal government carries out its role as a funder of FRM. Federal funding for FRM was said to be heavily biased towards response and recovery, both in terms of the amounts of money available, and the timescales over which it is secured. For example, one municipal participant explained that in 2011 and 2013, the municipality "saw hundreds of millions of dollars" for emergency flood relief, but that, "if we had seen a fraction of that to go towards prevention the rest of that money wouldn't have been needed." This financial bias towards recovery is exemplified by the disparity between the two primary federal sources of FRM funding, the Disaster Financial Assistance Arrangements (DFAA) designed to support disaster recovery, and the National Disaster Mitigation Program (NDMP) designed to promote disaster mitigation. An 'other' participant made the observation that over the next few years the federal government expects to disburse an estimated $900 million annually through the DFAA and $40 million annually through the NDMP, a distribution of funding that, to this participant, "just doesn't make sense." There was also frustration expressed that the DFAA does not effectively support improvements to damaged infrastructure, making it more resilient to future flooding.

Participants also expressed concern that support for FRM is irregular, with more financial and political resources available after major events or with certain governments. The participants described policy windows – after a flood event, there is greater awareness of flood risk and resources are more readily available – and frustration that, after time, this support disappears. For example, in one provincial participant's experience, "as a result of some significant floods, 2005, 2010, 2013, it was recognised that something needed to be done and significant funding was approved for mitigation…but, the further away you get from a significant event, the less desire there is [to] spend the money on mitigation." Time bounded funding programs, such as the 5-year NDMP, were also said to cause variations in the financial resources available over more extended time periods. When these policies reach the end of their lifespan, they may be continued, reformed, or scrapped. A municipal participant described how this creates challenges for FRM planning: "We're looking at a lot of different options, but I think that we're limited in what we can do…I think that we've identified some of the options that we have, and now our biggest fight is getting funding or continuing to get support to actually pull them off." Another factor that participants identified as influencing support for FRM was constant competition for funding with other policy areas, such as healthcare or education, that may be seen as more important outside of periods of flooding.

The availability and coordination of human, technical, and informational resources emerged as a final and most prevalent challenge to effective FRM. Capacity constraints were recognised by participants as existing at all levels of government and in the private sector. Within local governments, there is often a lack of technical capacity to support FRM planning. For instance, one municipal participant explained that “we aren't educated in these sorts of events…I think that the human resources to deal with these sorts of things is absolutely something that we are…shy in.” A provincial participant explained that there is some reliance on the private sector to overcome gaps in technical expertise but, even then, there are capacity gaps. Technical capacity challenges were also perceived at the federal level, with one participant noting in relation to flood mapping that “at the federal level, the resources applied to mapping have decreased significantly because of the federal budget being slashed.” The tendency of people to move jobs or retire was another factor identified as contributing to a lack of technical expertise. It was also suggested by one ‘other’ participant that the lack of resources available for FRM itself leads to a loss of FRM expertise: “[The public sector] has a huge problem retaining people. After a big flood, most people quit. Because they’re burnt out. They’ve been overworked.”

Participants also perceived that the technical expertise that is available is spread too thinly and unevenly for the effective and efficient management of flood risk. For example, one ‘other’ participant noted that in granting agencies, “often, the emergency, or the high risk isn't recognised. There's definitely challenges in building the case to those granting agencies, because there aren't the technical staff [in the granting agencies].” Another issue perceived with the current distribution of expertise was duplication of effort. As one ‘other’ participant described it: “Every province is re-inventing the wheel…Instead of having one large critical mass, there’s little penny packets spread across from region to region to region.” This concept of a lack of a critical mass was also linked to challenges in innovating new tools, approaches, and policies to improve FRM strategies. The existing relationship between academia and practice was also identified as stifling innovation. An ‘other’ participant outlined this issue: “We do not have anybody who can take scientific tools developed by academics and support them. There has to be training, the tools have to be updated, they have to be developed and fixed. We don’t have an organisation that can do that in Canada.”

The impact of this at the local level was succinctly expressed by one municipal participant: “I've not seen much come out of the academic community of value.” Expertise is thus effectively siloed, exacerbating capacity challenges and preventing progress towards more effective FRM.

Given the general lack of technical capacity and a limited ability to innovate, it is perhaps unsurprising there was a general consensus that FRM tools currently available to decision makers are inadequate. One significant challenge to producing more accurate flood forecasts is that the methods and models available are often not appropriate to the hydrometric context of the Canadian prairies. As an ‘other’ participant suggested, “It’s based on rainfall. And it’s statistically and hydrologically invalid in western Canada because our floods have been snow, not rainfall. We are using science from…old methods from Europe or the United States.” The accuracy and availability of flood maps is also often seen as a challenge, recognised by participants at all levels of government, several of whom specifically mentioned the difficulties of working with outdated maps. A municipal participant highlighted the problem with using out of date maps for planning: “The provinces do really a good job of mapping it, but that mapping is for the most part based on historic information…but…in ten years the environment changes and more logging and activities happen in the mountains, flood events continue to look different, flooding more area and having a worse effect.”

Some important tools were perceived to be missing in current FRM practice, in particular tools to support risk assessment and decision making. A provincial participant considered that “what's lacking is a solid narrative, quantitative risk assessment methodology. So that we can truly get a handle on where our priority needs are.” An ‘other’ interviewee suggested the need for a decision support system “so that all the stakeholders can weigh the costs and benefits of flood risk management.” Communication tools were a clear exception to the general perception that existing tools were inadequate, especially social media and email. Social media was often identified as an effective method of providing public information during an emergency, and email was seen as an effective way of communicating with homeowners about flood risk issues, especially with seasonal residents who live elsewhere for much of the year.

Current informational resources and the way in which data is gathered and managed was also perceived as a significant challenge for FRM practice. Almost all participants expressed that there is not enough data available to support FRM decision making. The coverage of the hydrometric network across the study area was noted as a concern due to the lack of hydrometric stations and, consequently, a lack of information. However, in one ‘other’ participant’s view, an effective hydrometric network is present in Alberta, where “the provincial government operates weather stations in the mountains in the north and in the prairies. So, Alberta actually has excellent coverage of meteorological data.” Other evidence supports that data availability is not uniformly poor, with more data available for more populated areas and less data available in less populated areas, such as the prairies. This is supported by a municipal participant’s observation that “in our county the river goes across eight townships of land, and there is probably only effectively four miles of it that’s flood risk mapped. That’s just because that’s the most heavily populated part, but there are lots of other people that live on the river.”

Interviewees perceived several other factors limiting the availability or accessibility of data to support FRM decision making. An ‘other’ participant communicated that there is a absence of “a clear leader who is stepping up and doing all of the data collection at a very high level and making it readily available.” The lack of a comprehensive centralised database of information supporting FRM was considered to be a major obstacle to understanding where flood vulnerabilities exist across Canada. Difficulties accessing and using data was also identified by participants. One provincial participant discussed the importance of inter-organisational coordination to data accessibility: “We had cadastral data and GIS datasets, but it was being maintained by another department. When we needed it during the flood of 2011, the other department, it wasn't that they weren't willing to give it to us, but they had to sanitise some of the data, such as people's names and personal information.” So, similar to the technical expertise available for FRM, data to support FRM practice is also effectively siloed.

3.5 Discussion

Results suggests that, in principle, FRM across the Prairie Provinces embraces a diversity of policy approaches – prevention, defence, mitigation, preparation, and response and recovery (Gilissen et al., 2016) – reflecting one of the basic requirements for flood resilience (Rouillard et al., 2015; van Herk et al., 2015). However, results also revealed considerable challenges to implementing this diverse policy agenda, including lack of clarity of roles and responsibilities, policy conflicts, limited capacity, and limited data availability, which, collectively, biases FRM towards reactive solutions. Given international FRM experience, this is not unexpected. Challenges with conflicting and fragmented policy, policy instruments that do not adequately support FRM goals, limited capacity, and no overall coordinating FRM strategy has been reported to be problematic elsewhere, including Sweden, the Netherlands, Belgium, France, and the United Kingdom, to name a few (Ek et al., 2016; Hegger et al., 2016a; Rouillard et al., 2015).

Government institutions, processes, and how they are coordinated have considerable influence on flood resilience (Clarvis et al., 2014). Currently in the Prairie Provinces, FRM is characteristic of fragmented governance, where many organisations with differing priorities are involved in managing the same resource but where no one regime is dominant, and of policy layering, where policy goals and instruments are added to existing ones, incrementally, often in an ad-hoc way over time (Rayner and Howlett, 2009). Provinces are the primary authority for FRM in Canada, but in practice the policies and responsibilities are distributed across complex, multi-departmental, multi-scalar systems of government including federal programs and agencies, provinces, and more than 1,000 municipal governments. The environment produced is one typified by mismatched priorities, goals, capacities, and resources across levels of government, jurisdictions, and departments (Bakker and Cook, 2011; Cook, 2014; Gober and Wheater, 2014), and higher FRM financial costs (OPBO, 2016).

For example, federal FRM funding policies do not always match the FRM priorities of provincial and municipal governments, skewing FRM actions towards response and recovery objectives. There are three major federal funding streams in Canada which, in principle, support FRM: the DFAA aimed at public safety through response and recovery; Building Canada Fund (BCF), which finances infrastructure projects aimed at the public good; and the NDMP, which supports disaster prevention and mitigation. Although the BCF could be used to fund flood prevention and mitigation projects, to the knowledge of the interviewees it has not yet been used to do so. The typical way federal funds support FRM is as an insurer in the event of flood damage, financing the restoration of local infrastructure to pre-flood conditions using DFAA resources. There is a perception that DFAA is the main source of federal funding for FRM, even though it is not designed to be applied proactively. The more recent introduction of the NDMP, focused on prevention and mitigation, may further discourage the use of BCF for flood mitigation and defence;

however, NDMP functions in more of an investigatory manner, trying to understand what is required to support effective prevention and mitigation. Thus, it is not, in its current form, an appropriate source of support for major proactive flood mitigation projects. Mismatched FRM policies and priorities are exacerbated due to limited coordinating influences such as strategies, frameworks, or organisations established to deal holistically with FRM; different aspects of FRM are often sub-sets of other policy areas, such as infrastructure design or land-use planning. The result is constraints on the implementation of FRM policies or initiatives that go beyond defence structures or damage recovery.

Evidence from this study suggests that the challenges to FRM may not be insurmountable, and there are lessons to be learned from certain FRM strategies that can be transferred to other aspects. For example, emergency management was considered by interviewees to function effectively. Emergency management in Canada is comprised of a coordinated strategy that spans all three levels of government (federal, provincial, municipal) and, in the event of an emergency, defines clear roles and responsibilities and establishes the management procedures and processes and provides the necessary resources. This is representative of an incident command system, or a hierarchical command structure, and pre-planned framework, that is put in action during an acute emergency event (Moynihan, 2009) to ensure coordination and cooperation of the many actors involved in emergency response. This approach has proven useful in other countries beyond emergency response. For example, van Herk et al. (2015) explains the transition of Dutch FRM from a focus on structural defence to a "room for the river" as being attributed in large part to a dedicated strategy with clearly distributed roles and decision making power. Indeed, responses from interviewees suggest that there is an appetite for coordination and cooperation between FRM stakeholders in the Prairie Provinces, but that currently no single agency is perceived as having either the mandate or capacity to facilitate this.

An FRM strategy and distributed, but better coordinated, FRM oversight is needed for the Prairie Provinces. This may require the establishment of a new governance architecture for FRM in Canada. A hub and spoke model of governance may be appropriate as it has the potential to address the fragmentation challenges observed in prairie province FRM, as well as support the diversity of strategies, coordination across multiple interests and scales, and flexibility and evolution in design of FRM initiatives considered necessary for flood resilience. In this architecture, a national 'hub' could be responsible for FRM strategy and setting out broad principles and overarching policy direction, thereby reducing fragmentation challenges. Regional centres could be the 'spokes', responsible for adapting and rolling out the inter-provincial strategy through more localised FRM plans, thus maintaining flexibility to account for local needs. Similar models have successfully supported the development of coordinated national, regional and local flood risk management planning in England and other countries in Europe (Boezeman et al., 2013; Environment Agency, 2011; UK Local Government Association). In fact, there is precedent within the Prairie Provinces for applying a hub and spoke governance architecture for managing major social-ecological threats. In response to severe drought and the Great Depression in the 1930's, the federal government of Canada established the Prairie Farm Rehabilitation Administration (PFRA) (Arbuthnott and Schmutz, 2013; Marchildon, 2009). The PFRA was a federal body, headquartered in Regina, SK, with 22 district offices throughout the three Prairie Provinces. Until it was phased out between 2008 and 2013, the PFRA was mandated to assist rural and agricultural communities in the prairies in recovering from and minimising exposure to drought. Particular activities of the PFRA included research and promotion of soil and water conservation strategies, financial assistance, coordination of expertise and resources, and coordination of irrigation and drainage activities (Arbuthnott and Schmutz, 2013; Marchildon, 2009). Historians view the PFRA as one of the few effective federal interventions in response to one of the greatest social-ecological crises Canada has faced (Marchildon, 2009).

Of course, the solution to fragmented water governance is not simply to create more centralised, hierarchical systems (Gober and Wheater, 2014; Hegger et al., 2016a; Lemos and Agrawal, 2007). At the same time, localised or fragmented organisations are often ill-equipped to deal with system-wide and transboundary problems, or lack the capacity, strategy, and authority to deal with uncertain, complex, or surprise events (Craig, 2008; Gober and Wheater, 2014). Thus, any agency mandated to develop and implement FRM strategy should not be led by any one government level, department, or other organisation, but instead take the form of a boundary organisation (e.g. Guston, 2001). Boundary organisations bring together stakeholders around complex, multi-scalar, multi-jurisdictional and multi-stakeholder issues (Guston, 2001; Prager, 2015). For example, the success of the Dutch Delta Committee in achieving a major change in policy direction for the protection and sustainable development of the Dutch coastline in the face of social and climate change was in large part attributed to the Committee taking the form of a boundary organisation (Boezeman et al., 2013). Other examples of the success of boundary organisations in improving management outcomes can be found in energy policy, agricultural management, and conservation (Hisschemöller and Sioziou, 2013; Prager, 2015; Sarkki and Heikkenen, 2013). Given the complex and distributed governance arrangements in the Prairie Provinces, and the associated challenges to achieving more effective FRM, boundary organisations hold significant potential for gathering and making more efficient use of existing knowledge, expertise, and other FRM resources to promote greater accountability between stakeholders.

A major challenge in implementing any new governance architecture is that there are pre-existing mandates, policies, structures and processes. Imposing new structures without adequate acknowledgement and integration of those existing structures may recreate and exacerbate issues of policy layering, policy conflicts, and duplication of effort (Rayner and Howlett, 2009). Rather than impose new agencies, then, it may be more appropriate to adapt existing ones. Within the study region there are pre-existing organisations that could potentially form the 'hub' and 'spokes' of the proposed governance architecture. For example, the Prairie Provinces Water Board (PPWB) could provide a foundation for the FRM 'hub'. The PPWB was established in 1948, through a joint agreement between Alberta, Saskatchewan, Manitoba and Canada to recommend the best use of interprovincial waters and water allocations between the provinces. Its primary mandate is to ensure that transboundary waters are equitably apportioned and protected in accordance with a master agreement, but it also provides an important forum for information exchange and promoting cooperation in water management (PPWB, 2012). Board members are senior officials engaged in water resources administration in each of the provinces, with additional members from the federal government – a co-location arrangement that provides the opportunity for mutual learning (Feldman and Ingram, 2009).

Watershed scale organisations are also present within the region, which could potentially form the regional 'spokes' of the proposed governance model. These are generally independent organisations with a mandate to monitor watershed health and to facilitate collaborative planning, education, and stewardship activities (Government of Alberta, 2003; Government of Manitoba, 2016a; WSA, 2012). A major advantage of adapting these existing agencies is that they already engage many of the stakeholders relevant to FRM such as the federal government, Alberta Environment and Parks, the Saskatchewan Water Security Agency and Conservation Manitoba, NGOs, agricultural lobbies, and other private industries and citizens. However, for these existing organisations to adopt an FRM role would require an expansion of existing mandates and significant investment. New legislation would likely be required at the national level and in all three provinces to ensure national and regional agencies have legal authority to support the implementation of an FRM strategy rather than function purely as an advisory body, a criticism levelled at the Canadian Council of Ministers for the Environment (CCME) (Cook, 2014).

Evidence from other countries in the world, as well as within Canada and the Prairie Provinces, suggest that developing and implementing a national FRM strategy through a hub and spoke architecture has the potential to coordinate national, regional, and local interests, reduce policy layering and fragmentation, and enhance capacity at all scales of government.

3.6 Conclusion

A recent analysis of trends in Canada's climate indicate significant increases in winter and spring temperatures, increased April streamflow, and an earlier start of the spring high-season flow (Vincent et al., 2015). Coupled with changing land-use, increasing urbanization of watersheds, and floodplain development, the frequency and severity of major flood events is likely to increase. Adapting to floods through resilience-based FRM policies and initiatives, rather than relying solely on flood defence structures or disaster recovery programs, is the most appropriate long-term solution. The scholarly literature suggests that in order to increase resilience to flooding, FRM needs to adopt the three fundamental principles of a diverse FRM policy approach, coordination across multiple interests and scales, and flexibility and evolution in the design of FRM initiatives.

Results of this research show that FRM policy instruments in the Prairie Provinces are diverse, and include prevention, defence, mitigation, preparation, and response and recovery approaches to FRM. However, coordination is clearly lacking in the region, despite the best efforts of those involved, and flood resilience is inherently challenged by institutional fragmentation. The lack of strategic oversight, clarity of FRM roles and responsibilities, and coordination of resources results in policy layering and competing mandates, indicating that there is poor integration of FRM activities across government scales and among stakeholders. As a result, rather than evolving and becoming more flexible, FRM in the Prairie Provinces tends to default toward flood resistance and/or recovery. The prairie region needs an overarching FRM strategy and boundary organisations to coordinate roles and responsibilities for the specific purpose of flood resilience, rather than solely coordinating flood emergency response and recovery. This requires an agency with the mandate to manage FRM policy instruments, and clearly allocate decision making authority amongst the multiple levels and layers of FRM governance.

More broadly, this research supports calls for a national overarching strategy in Canada (Pomeroy et al., 2016). However, this research also shows that any new national, regional or local FRM strategy must be cognisant of the particular challenges, successes, and resources that are present. Otherwise, there is risk of recreating the problems we wish to solve, repeating previous mistakes, and failing to take advantage of successes. A fundamental part of any national strategy, in Canada or elsewhere, therefore, is to first understand how existing governance arrangements influence the practice of FRM at national, local, and regional levels.

4. FLOOD RISK MANAGEMENT IN CANADA'S PRAIRIE PROVINCES: AN ANALYSIS OF DECISION-MAKER PRIORITIES AND POLICY PREFERENCES

4.1 Preface

If the aim of flood risk management (FRM) is to increase society's resilience to floods, a multi-scalar and diverse policy approach that addresses flood prevention, defence, mitigation, preparation and response, and recovery is required. To prevent issues of fragmentation and policy conflicts, flood resilience also requires that FRM strategies and policies are coordinated across scales, between jurisdictions, and between FRM mandates. Decision makers and the FRM policy choices they make play a key role in flood resilience. This paper explores how the flood experiences and risk perceptions of decision makers influence FRM policy preferences, and how these preferences might facilitate or constrain flood resilience. Specifically:

- *What are decision makers' priorities for FRM policy in the Prairie Provinces and, based on those priorities, is Western Canada moving in the direction of flood resilience?*

This chapter has been submitted to the *Environmental Management* journal, a leading international journal in the field of environmental management and decision making (impact factor: 2.177).

This chapter demonstrates that:

- The FRM priorities of decision makers are similar across the Prairie Provinces. Policy preferences, however, differ between provincial jurisdictions, presenting challenges to a coordinated approach to FRM.
- In some regions, strong preferences for a single policy approach present a challenge to progressing greater flood resilience.
- Coordinating FRM policies across policy domains and making FRM policy flexible to changing circumstances are of low priority to decision makers.
- There is a need to find effective ways of influencing decision makers' perceptions of the effectiveness of FRM strategies.
- Decision makers' FRM policy preferences are influenced by flood experiences and risk perceptions.

Overall, this chapter shows that pre-existing policy preferences, flood experiences, and flood risk perceptions can present challenges to realising strategic and adaptive management principles in FRM practice. These findings have implications for the scholarly discourse on the role of governance structures and processes in promoting greater flood resilience. Effective means of influencing policy preferences are needed as part of any strategic FRM governance approach, otherwise transitioning from a historic flood resistance approach to one of resilience will remain challenging.

4.2 Introduction

Flooding has become more frequent and more severe across the globe (Kundzewicz et al. 2014), a trend that is expected to continue with changing climate and land-use patterns (Jongman et al., 2014; Whitfield, 2012; Winsemius et al., 2016). This is especially the case in western Canada, where many communities have been severely impacted by major flood events (Morrison et al., 2018). The scholarly discourse calls for a shift in flood risk management (FRM) away from a solely resistance-based approach, driven by protection, response and recovery (Gilissen et al., 2016; de Bruijn, 2004), and a move towards resilience-based FRM (Klijn et al., 2008; Shrubsole. 2013; Zevenbergen and Gersonius, 2007). Resilience broadly refers to the ability of a system to resist, absorb, adapt to, and recover from change (Brand and Jax, 2007). A resilience-based FRM approach is thus one that focuses on the ability of society to resist, cope with, adapt to, and recover from flood events. Flood resilience implies that it is society's risk from flooding that needs to be managed rather than simply the hazard of flood waters (European Union, 2007; Shanze, 2006; Vojtek and Vojtekova, 2016). Although the language of resilience is becoming more common in FRM policy and strategy (Morrison et al., 2018), escalating costs of floods in western Canada and in other regions of the world (Buttle et al., 2016) suggest that achieving policy agendas that support resilience remains a formidable challenge.

Flood risk is the result of complex interactions between climate, landscape, hydrology and society (Hümann et al., 2011; Singer, 2007). The governance of flood risk often involves multiple jurisdictions, multiple levels of government, and multiple stakeholders (Seher et al., 2018; Thaler et al., 2016). To adapt and cope with flood events, FRM requires a combination of policies or strategies that are applicable to various physical causes of flooding and to flood events of different magnitudes. These policies or strategies also have to operate at different spatial scales, within different jurisdictional boundaries, and at different levels of government (van Herk et al., 2015). Numerous factors influence how FRM policy is developed and implemented: for example, immediate reactions to major flood events through policy windows (Pahl-Wostl et al., 2013); the security of FRM funding in the short- versus long-term (Morrison et al., 2018); and the coordination between jurisdictions and governments (Hegger et al., 2016a). As a result, there is unlikely to be a blanket solution that is acceptable across all stakeholders or jurisdictions (Brunner, 2010).

Policy setting to support increased resilience to floods is a multi-criteria problem. There are multiple approaches to FRM from resistance, prevention, and mitigation preparation to response and recovery, and there are multiple criteria against which policy choices must be evaluated. These policy choices are made by decision makers and actors with a range of priorities, flood experiences, and perspectives. Determining appropriate FRM policies requires a realistic appraisal of a range of viable options based on often-competing values and management objectives, and an understanding of the factors that influence FRM policy preferences. Multi-criteria decision analysis has been used to support policy development in complex areas of natural resource management (Sizo et al., 2016; White and Noble, 2012), including FRM (Lyu et al., 2018). However, these exercises often use a panel of 'experts' to identify the 'best' solution to a problem based on their expert knowledge. Although expert guidance is important in developing science- and knowledge-based policies, it alone does not guarantee that those policies will be effectively implemented (Gober and Wheater, 2014). Understanding the factors that influence policy implementation is an important aspect of FRM policy development, but there is little evidence of this being done in practice.

Western Canada has a varied geography, multiple jurisdictions, and multiple levels of government with diverse FRM roles and responsibilities. It is a region subjected to regular severe floods, with more frequent and severe flooding expected in the future (Buttle et al., 2016). Resistance-based FRM is currently practiced in the region (Morrison et al., 2018). Flood recovery in Canadian communities is primarily supported through federal and provincial government disaster assistance, and private insurance coverage, the extent of which varies by province and provider (Sandink et al., 2016). What has not yet been addressed is whether western Canada is moving in the direction of resilience-based FRM. To better understand the future direction of FRM, we analysed FRM decision makers' preferences about competing FRM policy alternatives, the implications of these preferences in furthering flood resilience, and the opportunities and constraints to more resilient FRM policy development. The approach and lessons learned should be relevant to understanding the development and implementation of FRM policies and strategies in regions and jurisdictions in Canada and elsewhere.

4.3 Study Area and Methods

Our study focuses on three western Prairie provinces: Manitoba, Saskatchewan and Alberta. The region is comprised of three provincial governments, numerous municipal governments, major cities and smaller urban centres, Indigenous lands and reserves, and resort villages and rural municipalities. The geography is diverse, including mountains, foothills, boreal forest, large expanses of prairie, inland deltas and terminal basins. FRM is largely carried out at the provincial level through various provincial policies and policy instruments; yet these policies and instruments are not necessarily aligned with more local or municipal FRM objectives and priorities. Local powers, roles and responsibilities for FRM, for example, are generally limited to land-use planning, emergency preparation and response planning, and disaster recovery, limiting the local influence over FRM policy (Morrison et al., 2018). However, the impacts of flooding are most acutely experienced at the local level.

Several major floods have recently been experienced in the study area, including the South Saskatchewan and Elk River basin floods in 2013 (Pomeroy et al., 2016), the Bow and Elbow River floods in Southern Alberta in 2013 (Burn and Whitfield, 2016) and the Assiniboine River flood in Manitoba in 2014 (Ahmari et al., 2016). These floods have been some of the worst recorded in the region, having had profound impacts on communities (Ahmari et al., 2016; Pomeroy et al., 2016) and among the most expensive in Canadian history. The variety of contexts, experiences, and priorities, as well as the way FRM decision making is structured in the Prairie provinces, make this region valuable to understanding the relationship between policy preferences at the local level, the distribution of decision-making authority, and FRM policies and strategies aimed at resilience.

4.3.1 Data collection

Data were collected using a survey of FRM decision-makers (i.e. policy makers, planners, managers) with various FRM roles and responsibilities using a multi-criteria design. The survey was administered online using the Voxco web-based survey platform. The survey consisted of three parts. First, participants were presented with a set of criteria for the evaluation of FRM policy alternatives (Table 1). The criteria represent common considerations when making FRM policy decisions, such as the cost of implementing or maintaining a policy or action, climate variability and uncertainty, safeguarding public health, and public acceptance of policies. The criteria were developed based on a review of academic and policy literature which propose or use indicators to assess the effectiveness of FRM, climate change adaptation, sustainability, and similar policies and plans to determine context appropriate criteria (e.g. Bozza, 2015; Cutter et al., 2010; Qin et al., 2008; Scottish Environment Protection Agency, 2015). To minimize bias, criteria were identified prior to FRM policy alternatives (van Huylenbroeck, 1995). Participants were asked to weigh criteria, pairwise (Saaty, 1980), on a reciprocal scale from 1 (i.e. the two criteria are of equal importance) to 9 (i.e. criterion i is strongly more important than criterion j), or 1/9 (i.e. criterion j is strongly more important than criterion i), based on the relative importance of the criteria in the design or implementation of FRM policy or strategy. The purpose of criteria weighting was to determine their relative importance (i.e. priorities) in FRM policy decision making.

Table 4.1 Proposed FRM policy evaluation criteria.

Criteria	Description
C1	Minimising the immediate, *up-front costs* of the design and implementation of a FRM program or strategy
C2	Minimising the *ongoing costs* associated with the operation or maintenance of a FRM program or strategy
C3	Ensuring that a FRM strategy is flexible enough to cope with long-term, changing climatic circumstances
C4	Ensuring that a FRM program or strategy is consistent with other government flood management plans, policies, programs or land-use zoning priorities
C5	Minimising the risk to health and life resulting from flood events
C6	Minimising the loss of and promote restoration of ecosystem services which help to mitigate flooding
C7	Minimising the financial impacts associated with flood events (e.g. response, damage and recovery) when they occur
C8	Minimising the inconvenience to communities / residents associated with implementing, maintaining or enforcing a FRM program or strategy

Second, participants were presented with eight FRM policy options or alternatives (Table 4.2). The alternatives are not comprehensive, but illustrative of a range of strategies from compensation for flood loss to different measures of flood avoidance or resistance (Gilissen et al., 2016). Emergency preparedness and response was not included amongst the policy alternatives as emergency preparedness was considered to be a fundamental part of all FRM strategies and not a negotiable policy choice. Alternatives were identified based on existing FRM strategies, plans and policies from both within the study area and from other jurisdictions, as well as research on FRM policy (Government of Alberta, 2014a; Government of Manitoba, 2003; Qin et al. 2008; Scottish Environment Protection Agency, 2015). Participants were presented with each criterion and asked to score how effectively each of the policy alternatives met or satisfied the criterion. Participants were asked to distribute a total of 80 points across the eight FRM policy alternatives based on how effective they considered the alternative to be in meeting the criterion. Points could be distributed between as many or as few policy alternatives as considered appropriate, with the only requirement being that all 80 points are assigned.

Table 4.2 Proposed policy alternatives.

Policy alternative	Description
A1	Relocation of people, property and businesses out of areas of high flood risk.
A2	Construction of large-scale protective dykes, dams and/or floodways. (Increasing flood defence measures that contain and move flood waters away from the population.)
A3	Construction and coordination of agricultural drainage control networks, which help to attenuate peak flows from agricultural run-off.
A4	Restoration of wetlands and re-naturalisation / revegetation of river corridors
A5	Provision of private flood insurance schemes. (Insurance industry responsible for determining flood risk, with governments providing oversight to ensure consistency and fairness.)
A6	Development and provision of national standards for constructing and retrofitting buildings in high flood risk areas. (Standards developed collaboratively by federal, provincial, municipal and private sector.)
A7	A dedicated government-funded financial reserve to assist property owners rebuild after damaging floods.
A8	Proactive mitigation fund for community led flood risk management plans. (Provision of annual, long term funding by government(s) for the development and maintenance of community led flood risk management plans and strategies.)

Third, participants were asked supplementary questions: first to determine the province in which they work and the type of organisation they work for, and second to gather information about their experiences with flooding and perceptions of flood risk. Responses to these questions were used to explore any underlying factors in FRM policy preferences. For example, participants were asked about how recently they had experienced flooding, and their perceptions about the effectiveness of existing flood protection. Other questions related to the severity of floods experienced, frequency of floods experienced, and opinions on how flood risk or severity might change over the next ten or 25 years.

Decision-makers in municipal governments across Alberta, Saskatchewan and Manitoba were primarily targeted as participants, but also included were representatives of provincial governments and watershed groups. Indigenous administrations were invited, but no participants identified themselves as representing a First Nations administration. Online municipal government directories and a search of municipal websites were used to identify potential participants. A total of 830 potential participants were emailed with a short description of the study and invited to complete the survey. A total of 102 completed surveys were returned, 14 from provincial government agencies, 81 from municipal governments, and six from watershed organisations. Of the respondents, 52 were in Alberta, 35 in Saskatchewan, and 14 in Manitoba. The survey response rate was lower than expected given the targeted focus on decision makers (Baruch and Holtom, 2008) and considering the salience of the topic (Sheehan, 2001). A pilot test showed that the survey required up to 60 minutes to complete. This may have adversely affected response rates (Sheehan, 2001), whereby only those with a particular interest in the topic or with a direct involvement in FRM decision making participated.

4.3.2 Data Analysis

Data from participants' paired comparisons of FRM policy evaluation criteria (Table 4.1) were used to derive criteria weights and ranks following the analytical hierarchy process (Saaty, 1980). Unweighted FRM policy preference scores were derived from participants' evaluations of the effectiveness of each policy alternative (Table 4.2) in meeting the FRM policy evaluation criteria. Criteria weights were then applied to determine weighted FRM policy preference scores for each alternative. Weighted FRM policy preference scores were converted to a Euclidean scale and plotted to show comparative preference for each policy alternative on a scale from 0 to 1, with 0 being least preferred and 1 being most preferred.

Non-parametric and exploratory statistics were used to examine the aggregated results and the results for different groups of participants based on provincial jurisdiction. Two sets of sensitivity tests were carried out to assess the robustness of FRM policy preferences. First, the sensitivity of FRM policy preferences to changing future priorities or conditions (e.g. changing costs of FRM implementation) was tested by adjusting criteria weightings. Second, sensitivity to recent flood experiences and perceptions about future flood risk was tested by grouping participants based on their responses and comparing against the median FRM policy preference scores of all participants.

4.4 Results

4.4.1 FRM policy evaluation criteria importance

The median values (i.e. importance) assigned by decision makers to FRM policy evaluation criteria are shown in Table 4.3. Minimising risk to health and life (C5), was identified as the most important criterion in the design and implementation of an FRM policy. This criterion was weighted approximately double that of the two next most important criteria, minimising the financial costs associated with major floods (C7), and promoting restoration of ecosystem services (C6). Approximately half the stated importance again were the following criteria: ensuring flexibility to cope with long-term climatic change (C3); minimising the inconvenience to people and businesses (C8); and ensuring consistency with other FRM plans and policies (C4). The lowest weighted criteria, considered to be the least important in formulating or implementing FRM policies, were minimising the ongoing costs associated operation and maintenance of an FRM policy or strategy (C2); and minimising the ongoing costs associated with the implementation of an FRM policy or strategy (C1). The relative importance of several criteria were not significantly different, resulting in an overall ranking of criteria for FRM policy development and implementation as follows: C5 > C7 I C6 > C3 I C8 I C4 I C2 I C1, where; ">" indicates a significant difference between criteria based on the 95% confidence interval for median and "I" indicates indifference.

Table 4.3 Criteria weights and 95% confidence interval for all participants (n=102).

		All Participants		
Criterion	Description	Median	95%CI* +/-	Rank
C1	Minimising upfront costs	0.0360	0.0043	8
C2	Minimising ongoing costs	0.0430	0.0072	7
C3	Allows flexibility in FRM strategy	0.0752	0.0109	4
C4	Ensures consistency with other FRM plans and policies	0.0585	0.0087	6
C5	Minimises the risk to health and life	0.3354	0.0370	1
C6	Minimises loss, promotes restoration of ecosystem services	0.1290	0.0140	3
C7	Minimised the financial costs associated with major floods	0.1463	0.0167	2
C8	Minimise the inconvenience caused by implementation to people/businesses	0.0713	0.0169	5

$*95\%CI = median \pm \frac{1.58(H\text{-}spread)}{\sqrt{n}}$

Based on the 95% confidence interval the median values of several criteria are not significantly different, resulting in an overall ranking of criteria as follows: C5 > C7 I C6 > C3 I C8 I C4 I C2 I C1, where; ">" indicates a significant difference between criteria based on median weights and "I" indicates indifference.

4.4.2 FRM policy preferences s

The preferred FRM policy identified by participants was the relocation of people, property and businesses out of areas of high flood risk (A1) (Table 4.4). This was followed by the construction of large-scale defensive structures (A2), restoration of wetlands and renaturalisation of river corridors (A4), construction and coordination of agricultural drainage networks (A3), and having a proactive mitigation fund for community-led FRM plans (A8). The least preferred FRM alternatives were the development and provision of national standards for flood resilient construction and retrofitting of buildings (A6), a financial reserve to fund recovery from major floods (A7), and the provision of private flood insurance schemes (A5). The Willcoxon test for difference indicates no statistical difference ($p > 0.5$) in median preference scores between FRM alternatives ranked 2nd to 5th, resulting in an overall FRM policy preference amongst decision makers of: A1 > A2 I A4 I A3 I A8 > A6 > A7 > A5 (Figure 4.1). Results show that FRM policy options A2, A4, A3 and A8 are competing secondary policy alternatives, following A1 – the preferred FRM policy option.

Table 4.4 Aggregate FRM policy preference scores for all participants.

	A1 W			A2 W			A3 W			A4 W		
Criteria	Median		CI	Median		CI	Median		CI	Median		CI
C1	0.0026676	+/-	0.001372	0.002766	+/-	0.001107	0.003424	+/-	0.001059	0.003341	+/-	0.001312
C2	0.0061141	+/-	0.002202	0.006397	+/-	0.001621	0.005389	+/-	0.001379	0.005936	+/-	0.001471
C3	0.00720587	+/-	0.003345	0.008438	+/-	0.002467	0.008087	+/-	0.001899	0.008765	+/-	0.002776
C4	0.00532047	+/-	0.002973	0.007048	+/-	0.002257	0.006273	+/-	0.002439	0.007168	+/-	0.002136
C5	0.07957429	+/-	0.021005	0.035955	+/-	0.012163	0.019308	+/-	0.006309	0.016582	+/-	0.005313
C6	0.01159247	+/-	0.003966	0.006027	+/-	0.003169	0.017333	+/-	0.004741	0.029184	+/-	0.00787
C7	0.02282623	+/-	0.008368	0.013695	+/-	0.004676	0.009262	+/-	0.003603	0.008587	+/-	0.003442
C8	0.00246652	+/-	0.003481	0.007052	+/-	0.002999	0.007684	+/-	0.002518	0.007128	+/-	0.002285
Sum	0.13777			0.08738			0.07676			0.08669		

	A5 W			A6 W			A7 W			A8 W		
Criteria	Median		CI	Median		CI	Median		CI	Median		CI
C1	0.00135097	+/-	0.000922	0.002698	+/-	0.000845	0.001288	+/-	0.000748	0.004267	+/-	0.001204
C2	0	+/-	0.000629	0.003508	+/-	0.001271	0	+/-	0.000756	0.004307	+/-	0.001717
C3	0	+/-	0.000873	0.005357	+/-	0.001922	0.003649	+/-	0.001386	0.007766	+/-	0.002012
C4	0	+/-	0.00084	0.006147	+/-	0.00231	0.00346	+/-	0.001267	0.007101	+/-	0.002002
C5	0	+/-	0.001736	0.015296	+/-	0.005997	0	+/-	0.003497	0.015387	+/-	0.007146
C6	0	+/-	0.000496	0	+/-	0.001863	0	+/-	0.001304	0.008058	+/-	0.003202
C7	0.00124797	+/-	0.002677	0.009154	+/-	0.003358	0.007178	+/-	0.003988	0.015464	+/-	0.005152
C8	0	+/-	0.001368	0.003248	+/-	0.002558	0.002155	+/-	0.001857	0.006145	+/-	0.00371
Sum	0.00260			0.04541			0.01773			0.068495		

Results show that policies A2, A4, A3 and A8 represent a group of competing secondary policy options, following A1.

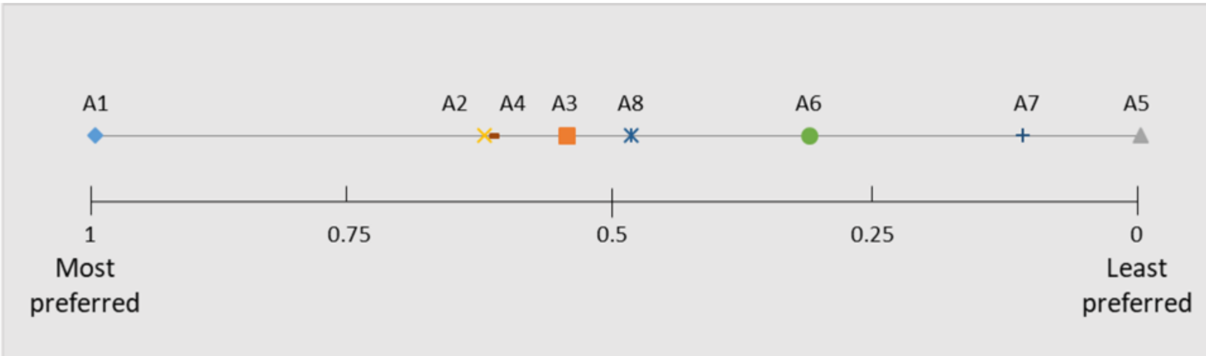

Figure 4.1 Scaled policy preference scores for all 102 participants.

Note: The symbols (A1 - , A2 - , A3 - , A4 - , A5 - , A6 - , A7 - , A8 -) are used to help visually differentiate between alternative scores and used consistently throughout the figures.

4.4.3 FRM policy evaluation criteria importance by province

The relative importances' of the proposed FRM criteria in making policy choices were similar across provincial jurisdictions, with minimising the risk to health and life (C5), minimising the financial impact of flood events (C7), and minimising loss and promoting restoration of ecosystem services (C6), consistently ranked 1st, 2nd and 3rd respectively (Figure 4.2).

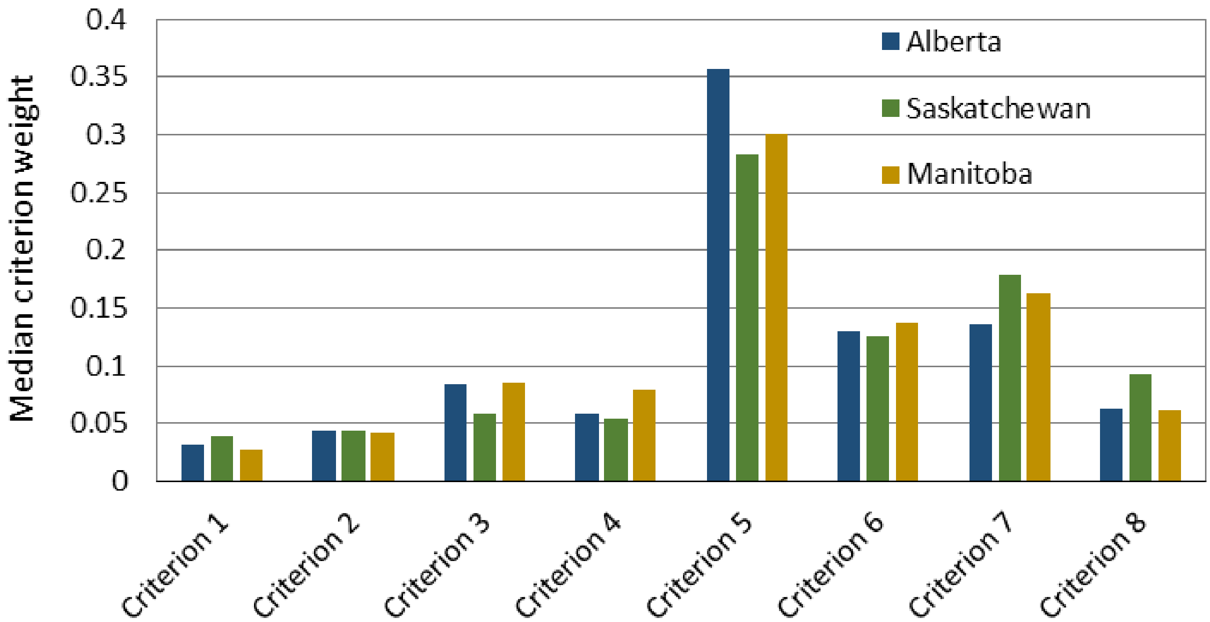

Figure 4.2 FRM criteria weightings (priorities) by provincial jurisdiction.

The importance placed on ensuring that an FRM policy or strategy is flexible enough to cope with long-term changing climatic circumstances (C3), ensuring that an FRM policy or strategy is consistent with other government initiatives, policies, programs, or land-use zoning priorities (C4), and minimising inconvenience to communities/residents (C8), varied across provinces, but these criteria were consistently ranked either 4th, 5th, or 6th. Based on the 95% confidence interval of median weights (Table 4.5), C3, C4 and C8 are not statistically different in all three provinces, indicating that they are of equal importance in the design and implementation of FRM policies. In each province, minimising the risk to health and life (C5) was clearly the highest priority. In Alberta, minimising the financial costs associated with major floods (C7) and minimising the loss of, or promoting the restoration of, ecosystem services (C6) ranked 2nd and 3rd, are statistically indifferent, and competing secondary priorities. In Saskatchewan, the 2nd ranked criterion, C7, is statistically different from the 3rd ranked criterion, which suggests that it's a clear secondary priority in FRM decision making processes. In Manitoba, criteria weightings ranked 2nd to 8th are indifferent, suggesting that there is no clear 2nd order priority, with C7 and C6 equally important.

Table 4.5 Criteria weightings by provincial jurisdiction.

	Rank														
Participant group	R1		R2		R3		R4		R5		R6		R7		R8
Alberta (n=52)	C5	>	C7	/	C6	>	C3	/	C8	/	C4	/	C2	/	C1
Saskatchewan (n=35)	C5	>	C7	>	C6	/	C8	/	C3	/	C4	/	C2	/	C1
Manitoba (n=14)	C5	>	C7	/	C6	/	C3	/	C4	/	C8	/	C2	/	C1

4.4.4 FRM policy preference by province

Results indicate clear differences in FRM policy preferences based on provincial jurisdiction (Figure 4.3). In Alberta, the 1st ranked FRM policy, relocation (A1), scores significantly higher than the 2nd ranked alternative, renaturalisation (A4). A1 is almost twice as preferred to A4 by Albertan participants. In Saskatchewan, A1 also ranks 1st; however, no statistical differences were found between A1 and A2, A3, A8 and A4, suggesting a suite of competing FRM policy options. In Manitoba, the 1st ranked FRM policy, construction of major defensive structures (A2), scored significantly higher than the group of secondary competing alternatives, A1, A3 and A4.

Alberta participants tend to favour a prevention-based approach to FRM by removing people from risk; Manitoba participants tend to favour a protection-based approach by controlling the flood hazard; and Saskatchewan participants do not tend to favour any single approach to FRM. The results also show that the development of national standards (A6), a dedicated government-funded financial reserve to assist property owners to rebuild after damaging floods (A7), and the provision of private flood insurance schemes (A5), consistently ranked amongst the least preferred FRM policy options in all three provinces.

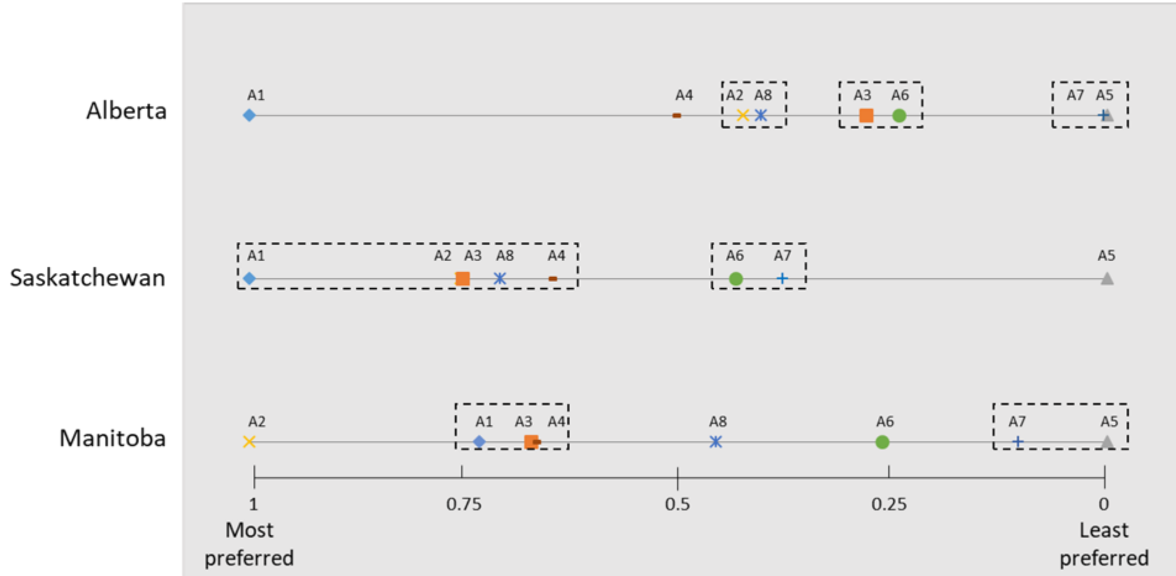

Figure 4.3 Scaled FRM policy alternative preference scores by provincial jurisdiction. Dashed boxes represent statistical indifference between alternative preference scores. For example, for Alberta A2 is indifferent to A8. A3 is statistically different from A8, but indifferent from A6. Significance was determined for $p < 0.05$ using a Mann-Whitney u-test.

4.4.5 Sensitivity analysis of FRM policy preferences by scenario

FRM policy preferences were tested for sensitivity to different future scenarios. These scenarios are represented by increasing or decreasing the importance (weight) of FRM evaluation criteria and reassessing the rankings of FRM policy alternatives (Table 4.6). For example, scenario S1 suggests an increased priority is placed on reducing the upfront and ongoing costs of FRM. This change is reflected by a significant increase in the relative weights of C1 and C2 (both cost minimization criteria) in FRM decision making, and the remaining criteria weights adjusted in proportion. When criteria weights were adjusted to represent increased priority, they were raised to match the highest value from the original weightings (i.e. 0.33). When criteria weights were adjusted to represent reduced priority, they were reduced to match the lowest value from the original weightings (i.e. 0.04). All remaining criteria weights were adjusted proportionately. Eight scenarios were developed for testing the sensitivity of decision makers’ FRM policy preferences.

Table 4.6 Scenarios and criteria weights used for sensitivity analysis. Shading indicates highest criteria weight for each scenario.

		Adjusted cirtieria weighting							
Scenario	**Short description**	C1	C2	C3	C4	C5	C6	C7	C8
S0	Original participant weightings	**0.04**	0.04	0.08	0.06	**0.33**	0.13	0.15	0.07
S1	Increased priority to reducing up-front AND ongoing costs	0.33	0.33	0.02	0.02	0.07	0.03	0.05	0.02
S2	Increased priority to coping with changing climate	0.02	0.03	0.33	0.04	0.20	0.08	0.11	0.05
S3	Increased priority for minimising public incovenience	0.02	0.03	0.04	0.04	0.19	0.06	0.08	0.33
S4	Increased priority for coordinating FRM policies	0.02	0.03	0.04	0.33	0.19	0.08	0.09	0.04
S5	Reduced priority for minimising risk to health and life	0.05	0.06	0.11	0.09	0.04	0.17	0.22	0.11
S6	Increased priority for ecosystem services	0.03	0.03	0.05	0.04	0.23	0.33	0.11	0.05
S7	Reduced priority for minimising recovery costs	0.04	0.05	0.09	0.07	0.37	0.15	0.04	0.08
S8	Reduce priority for minimising recovery costs AND risk to health and life	0.06	0.08	0.14	0.12	0.04	0.22	0.04	0.15

Under the eight scenarios tested, the preferred FRM policy alternatives in each province did not change substantially (Figure 4.4). Results suggest that changing FRM priorities do not have a large impact on the FRM policy preferences, although some policy alternatives appear less sensitive to change than others. Relocation (A1) remains the most preferred option amongst Alberta decision makers, with one exception (Figure 4.4): renaturalisation (A4) becomes the most preferred under S8 – whereby both minimising the risk to health and life (C5), and minimising the cost of recovery (C7), are reduced to the lowest priority. Under all other scenarios, renaturalisation (A4) is consistently the second ranked FRM alternative. Although renaturalisation is competitive with other alternatives in several scenarios, it becomes a clearer second choice under three scenarios: S5, reduced priority for minimising the risk to life and health; S6, an increased priority for protection of ecosystem services; and S8, a reduced priority for protection of life and health and a reduced priority for minimisation of recovery costs. Results suggest that Alberta decision maker preferences for FRM policy A1 and A4 remain robust to changes in priorities.For Saskatchewan, sensitivity tests show that relocation (A1) may not be robust to changing priorities (Figure 4.4). The construction coordination of agricultural drainage (A3) appears to consistently score the highest across the eight scenarios. Comparatively, A1 performs inconsistently, showing substantially reduced preference scores under four scenarios, namely S1, S3, S5, and S8. The same five policy alternatives, A1, A2, A3 and A8 remain competitive across all scenarios. However, the construction and coordination of agricultural drainage control networks may be the most robustly preferred FRM policy when considering potential changes in priorities. For Manitoba, the construction of large-scale defensive structures (A2) ranks 1st across all scenarios except S8, where it ranks 2nd (Figure 4). The construction coordination of agricultural drainage (A3) and renaturalisation (A4) rank the most consistently as 2nd and 3rd, doing so under scenarios S2, S3, S4, S5, and S6, and ranking 1st and 3rd under S8. Decision maker preference for A2 appears robust to changing priorities in Manitoba, with A3 and A4 robust secondary alternatives.

Sensitivity analyses also show provincial differences in the ability of FRM policy alternatives to meet specific priorities under changing conditions. For example, under S1, which adds increased priority to reducing the costs associated with FRM, the preference for relocation (A1) declines in Alberta and Saskatchewan but increases in Manitoba. This suggests that relocation is perceived as increasing the cost of implementation and maintenance of FRM strategies in Alberta and Saskatchewan, but as reducing those costs in Manitoba. Under S2, which increases the priority for FRM policies and strategies to be able to adapt to changing climate (C3), preference for A1 increases in Saskatchewan and decreases in Manitoba. Perceptions of how effective relocation is as a policy to adapt to climate change differs. Under S6, preference for the construction of large-scale defensive structures (A2) decreases in Alberta but increases in Saskatchewan. Perceptions differ on the value of major defensive structures in protecting ecosystem services, which help to mitigate flooding (C6). Under S3, preference for the provision of a proactive mitigation fund for community-led FRM plans (A8) increases in Saskatchewan and decreases in Manitoba. This suggests that perceptions of the effectiveness of funding for community level FRM plans in minimising the inconvenience to communities and residents differ between the provinces.

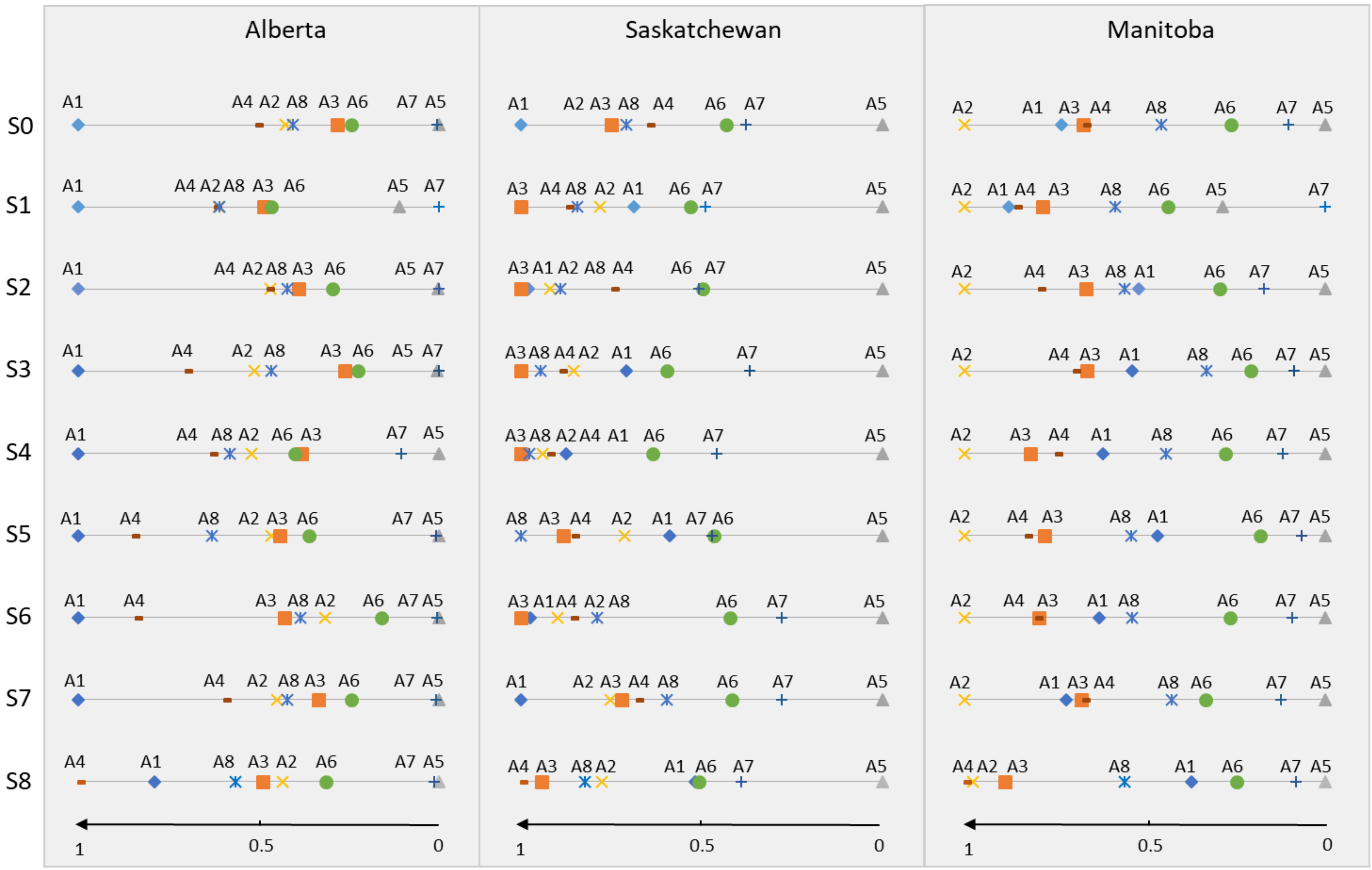

Figure 4.4 Variation in preference scores by scenario, for Alberta, Saskatchewan, and Manitoba.

4.4.6 Sensitivity analysis of FRM policy preferences by flood experiences and perceptions

Median preference scores for FRM policies across all participants were used as a baseline for assessing variation in responses based on recent flood experience and risk perception. For example, when analysing results based on "recency of flooding", median results for participants who experienced flooding within the last two years were compared to the median results for the aggregated group of all participants (Table 4.7). Flood experiences were found to be associated with differences in participants' FRM policy preference scores. For participants who had previously experienced 'high severity' floods the median preference score of A2, the construction of large-scale defences, was lower than for the aggregate group. In contrast, those participants who had experienced 'moderate severity' floods had a higher median preference score for A2 than the overall group. This result suggests that confidence in, or preferences for, constructed defences as an effective risk-reduction policy is influenced by the severity of recent flood experiences. The result also suggests that the severity of flooding has more influence on preferences for A2 than how recent the flooding was; median preference scores for A2 do not change substantially regardless of when flooding was experienced (Table 4.7).

Differences in FRM policy preference scores were also found to be associated with participant's flood risk perceptions. Concerning 'long term risk perception', participants who perceived that the severity of flooding will increase over the next 25 years (S+) (Table 4.7) showed a decrease in preference for an FRM policy based on renaturalisation (A4). In comparison, participants who perceived that flood frequency would increase (F+), but not flood severity, showed a reduced preference for relocation (A1) and large-scale defence structures (A2) and an increased preference for renaturalisation (A4). Perceptions that floods will become more severe over the long term may indicate a reduced preference for renaturalisation as an effective policy alternative, whereas perceptions that flood frequency will increase over the long term may indicate an increased preference for renaturalisation, but a decreased preference for relocation and defence.

The influence of flood experience and risk perception was further analysed by jurisdiction (Figure 4.5). Responses to 'severity of flooding' and 'level of protection' were chosen for analysis as there was substantial variation of median preference scores compared to the overall median.

Each of these groups of responses generally contained a reasonable number of data points (between n=13 and n=42). Numbers for Manitoba are included in Figure 4.5, but the number of observations was too small to allow for any reliable comparisons.

Table 4.7 Variation of scores of participants grouped by flood experience compared to overall average scores.

			Alternatives							
			A1	A2	A3	A4	A5	A6	A7	A8
All (Baseline Score)	Score	n	1	0.627211	0.54866	0.622124	0	0.316712	0.111941	0.487508
Recency of Flooding	<2yrs	23				+ +				-
	2-5yrs	38		-	- -	- -		-		
	5+ years	14		+	+ +	+			+	+
	No floods	24			+	+ +		+	+	+
Severity of flooding	High	32		- -	- -	- -		-		-
	Medium	29		+ +					-	
	Low	13	-			+ +		-		
	Zero	24			+	+ +		+	+	+
Frequency of flooding	High	5		- -	- -	- -		- -	-	- -
	Medium	37								
	Low	32				-				
Short Term Risk Perception	F&S +	60								
	S+	11				- -		-		-
	F+	18	-	+	+ +	+ +				+
	F&S-	10		-	- -	- - -		-	+	-
Long Term Risk Perception	F&S +	62								
	S+	12				- -		-		-
	F+	12	- -	- -	-	+ +				
	F&S-	11		-	- -	- -		-	+	- -
Level of Protection	High	19		+ +						-
	Medium	47		+ +	+ +				-	+ +
	Low	33		- -	-					-

Changes in score of between 0 and 0.1 are considered minimal, changes of between 0.1 and 0.25 are denoted by + or - and considered slight, changes of between 0.25 and 0.5 are denoted by + + or - - and considered substantial, and changes of greater than 0.5 are denoted by + + + or - - - and considered very substantial.

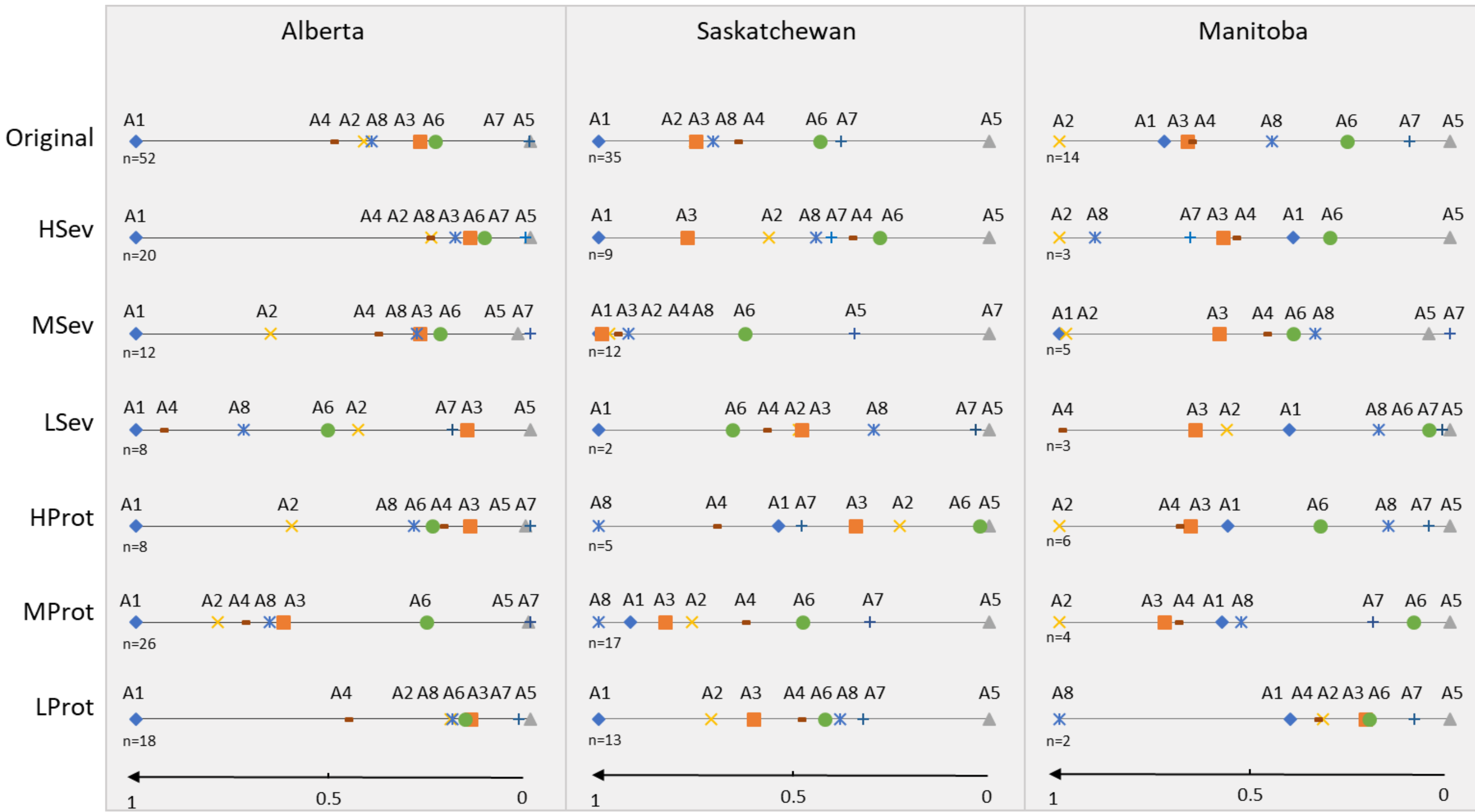

Figure 4.5 Scaled preference scores for participants grouped by flood experiences and perceptions; HSev = High Severity of Flooding; MSev = Medium Severity of Flooding; LSev = Low Severity of Flooding; HProt = High Perceived Protection; MProt = Medium Perceived Protection; LProt = Low Perceived Protection.

The flood experiences and perceptions of Alberta participants did not influence their choice of preferred FRM policy. However, results suggest some connection between participants' flood experiences and perceptions, and FRM policy preferences. For example, participants who experienced high severity floods, and participants who had a low confidence in existing protective structures, showed greater preference for relocation (A1) compared to the overall median response for Alberta. Those with low confidence in protection also showed a much lower preference for constructing defences (A2). For participants who had experienced medium severity floods and participants who had high confidence in defence structures, the preference for constructing defences (A2) was higher than the median. Experience of low severity events was associated with higher than average scores for renaturalisation (A4) and establishment of a community mitigation fund (A8). Participants who had a moderate level of confidence in protective structures showed higher than average scores for A2, A4, A8 and A3. In Alberta, relocation as a preferred alternative was strengthened by high severity flood experience and by low confidence in protective structures. Preference for the defensive approach appears to be strengthened by moderate severity flood experience and high confidence in protection, and weakened by low confidence in protection. Experience with moderate severity floods and moderate confidence in protection appear to increase the perceived effectiveness of several approaches.

In Saskatchewan, participants with experience of high severity events had higher preference scores for A2, A8 and A4 compared to the overall scores. Experience of moderate severity events, by comparison, was found to be associated with an increase in preference for A3, A2, A4 and A8. Moderate confidence in protective structures was found to be associated with an increase in preference for A8. Preference for A8 is higher than the median amongst participants who experienced moderate flooding or feel moderately protected. These results suggest that experience of high severity events increases the perceived value of relocation (A1) and agricultural drainage (A3) and reduces the number of competitive alternatives; that experience of moderate severity floods leads to greater competitiveness of a number of policy approaches; and that where there is at least moderate confidence in protective structures, the funding of community-led strategies (A8) is the most preferred alternative.

4.5 Discussion

The priorities of FRM decision makers are similar across Alberta, Saskatchewan and Manitoba. However, despite similar priorities, participants from the different provinces expressed different preferences for FRM policy. Participants in Alberta had a strong preference for flood prevention through relocation; those in Saskatchewan equally preferred several alternatives, including relocation, improved agricultural drainage management, construction of defences, funding for local mitigation plans, and renaturalisation. Participants in Manitoba had a strong preference for construction of defences. Although the strength of policy preferences changed with changing FRM priorities, the most preferred policies remained fairly consistent under different scenarios. Differences in policy preference were also associated with different flood experiences and flood risk perceptions, specifically, the recency, severity, or frequency of floods experienced; how flood risk was expected to change into the future; and perceptions of the effectiveness of existing flood defences. Several lessons and observations emerge from this research for advancing FRM policy development and implementation in Canada and for FRM policy broadly.

Consensus on FRM priorities across the Prairie region suggests that at least one pre-condition for supporting a resilient FRM policy agenda is present. Shared priorities are considered a pre-requisite for developing integrated/coordinated policy across multiple actors, especially in environmental and natural resource management (Cook, 2014; Rayner and Howlett 2009; Underdaal, 1980). A foundational aspect of developing coordinated and integrated policy is aligning strategic goals prior to developing solutions (through policies and policy instruments) to meet those goals (Rayner and Howlett, 2009). The relatively homogenous FRM criteria weightings across the region suggest that there is some agreement about underlying FRM priorities, primarily the protection of life and health and the reduction of flood recovery costs, at least at the local level. Defined and shared decision-maker priorities are not enough in themselves to improve coordination and integration between actors or increase resilience (Rayner and Howlett, 2009), but they do provide a starting point for developing underlying FRM policy principles, clarifying roles and responsibilities, organisational relationships, and other factors considered to be pre-conditions for resilient policy agendas (Cook, 2014).

Shared FRM priorities across the study area also represent a potential threat to resilience. A diverse policy approach is a pre-condition of resilience (Gilissen et al., 2016), but focusing on a narrow range of priorities may serve to limit diversity. The prioritisation of life and health is not surprising, as loss of life is the most serious impact of flooding and therefore likely to always be seen as a failure of FRM (Cigler, 2007). At the time of this research, FRM within the region appears to be conceptualised primarily as a public safety issue. Current practice suggests that policy is responsive to this conceptualisation; existing provincial policies are primarily focused on defence and response and recovery, while municipal policy is primarily focused on land-use planning (Morrison et al., 2018). Records suggest that public safety is well served by these existing policies. For example, since 1976 there have been 80 floods across the Prairie provinces and six fatalities (CDD, Public Safety Canada, 2018); the incidence of injury and illness resulting from flooding is not reported.

Given the potential threat to health and life that can result from the failure of FRM policy, public safety criteria are always likely to be weighted heavily by decision-makers. But decisions based solely on public safety run the risk that policy choices will favour those alternatives that are perceived to reduce the threat to the public, which may result in FRM strategies that do not address the requirements of resilience. The difficulty in making comparative judgements between human welfare and economic impacts is a notable challenge for FRM (Messner and Meyer, 2006). Nevertheless, existing emergency preparedness and response policy within the study area appears to be effective in protecting public safety. Potentially, reconceptualising the five approaches to disaster management into two streams would allow FRM policies to be developed with a reduced influence of public safety on policy decisions. Flood prevention, mitigation, defence, and recovery are all approaches aimed at reducing the risk from flood events, whereas emergency preparation and response deal specifically with flood events when they occur. Emergency preparation and response are primarily concerned with public safety. Therefore, segregating emergency preparation and response from broader FRM planning, with public safety as an explicit goal, may allow decision-makers to consider policy alternatives with less concern for public safety. This may reduce the pressure on decision makers to make value judgements between financial costs and human lives.

This research showed that, in many cases, participants had significantly stronger preferences for one policy alternative. This presents a challenge to FRM policy diversity, the essence of a resilient FRM policy agenda (Aerts et al., 2008; Gilissen et al., 2016). Participants from Alberta preferred the relocation of people, and property and businesses policy. These can be effective for reducing flood risk (Filatova, 2014). However, the experience gained from the 2013 southern Alberta floods suggests that relocation may not be popular with a substantial proportion of the public. As of June 2014, only 77 out of 250 homeowners eligible for relocation compensation from the provincial government had entered into relocation agreements (Government of Alberta 2013; Government of Alberta 2014b). Alberta's relocation program was a reaction to flooding, but the preference for relocation suggests that the participants find flood avoidance a desirable, proactive risk reducing alternative (Doberstein et al., 2018). The cost of implementation of Alberta's 2013 relocation program highlights the potential financial limitations of a relocation policy; relocating 77 homeowners cost $81 million (CAD); a proactive, province-wide relocation policy is likely to be financially unfeasible, especially considering that major public funding is often only available in the aftermath of flood events (Johnson et al., 2005; Pahl-Wostl et al., 2013; Petak, 1985).

In Manitoba, participants expressed strong preference for the construction of large-scale defences, which mirrors the focus of current provincial policy (Morrison et al., 2018). To date, defensive structures in Manitoba have functioned effectively and have not suffered major failures; however, recent cost estimates of over $1 billion CAD (Government of Manitoba, 2016b) to upgrade existing defence infrastructure to maintain design protection levels highlight the financial risk of becoming dependent on large scale engineered defences (Berkhout, 2002; Burch et al., 2010). Despite significant investment in Manitoba's flood defence infrastructure, the cost of disaster recovery remains high (Ahmari et al., 2016), suggesting that smaller and rural communities remain vulnerable to flooding. This may reflect that the focus of flood defence infrastructure in Manitoba is primarily to protect major population centres and farmland in the Red and Assiniboine River Valleys (Government of Manitoba, 2013). Although community and individual scale defences are funded through Disaster Financial Assistance payments, these projects happen in response to flooding, therefore do not proactively reduce risk, and the associated costs to municipalities of construction and maintenance may risk path dependency and limit local capacities to engage in more diverse FRM (Berkhout, 2002; Burch et al., 2010).

Saskatchewan differed from the other two provinces in that several FRM policy options were equally preferred by participants. Although progressive in theory, equal preference for multiple policy alternatives is not reflected in current provincial policy. Rather, Saskatchewan mainly uses a land-use planning, emergency preparedness, and response and recovery approach to FRM (Morrison et al., 2018). It is not clear why participants in Saskatchewan perceive several policies as equally effective in meeting FRM priorities, but this result suggests that there may be a pre-existing 'openness' to a range of policy alternatives amongst local governments or, alternatively, that none of the policy alternatives presented were preferred. Further study of FRM policy preferences and why several policies are perceived as equally effective in Saskatchewan may provide insights into how greater policy diversity could be promoted in jurisdictions where there are strong biases towards single FRM approaches.

Within the study area, influencing the development and implementation of more diverse approaches to FRM that address prevention, defence, mitigation, preparedness, and response and recovery (Gilissen et al., 2016) is likely to be a significant challenge. Financial assistance, taxation and regulatory pressure are often used to influence water, environmental, climate change, and sustainability policy and can be successful in stimulating local level FRM action (Filatova, 2014). Results of the sensitivity analysis suggest that using policy instruments to manipulate administrative priorities can increase competitiveness of policy alternatives across the study area. This could help with the design of appropriate policy instruments; for example, ring-fencing public funds that are available for different policy approaches so that expensive projects such as major defence structures do not dominate FRM spending, or providing financial incentives to landowners to retain or restore wetlands and riparian corridors. However, at least in Alberta and Manitoba, financial and legal instruments alone might not be enough to overcome the strength of existing policy preferences and make additional policies equally attractive.

Acknowledging flood experiences and flood risk perceptions in policy development may provide another avenue for influencing policy decisions. The flood experiences and risk perceptions of participants had a similar magnitude of influence on policy preference scores to changes in FRM priorities, underscoring that decision making is not just an analytical process and choices can be influenced by psychological factors (Leiserowitz, 2006). Experiences and perceptions of natural hazards are known to influence the behavioural responses of individuals and can often lead to decisions that actually increase risk (Wachinger et al., 2013). The results suggest that administrative experiences and perceptions influence the policy preferences of decision makers, therefore, the way in which administrators and administrations make decisions in response to flood experiences could either raise or lower flood risk. For example, severe floods and low confidence in the effectiveness of protective structures was associated with an increase in preference for relocation, whereas moderate floods and at least a moderate level of confidence in protective structures was associated with greater preference for large scale constructed defences. The characteristics of decision maker's flood experiences and their perceptions of policy effectiveness may then serve to present one obvious "best" alternative and continually reinforce its value. When this "best" alternative matches that of pre-existing policy preferences, the outcome may be to further entrench single-policy approaches to FRM, further obstructing resilience. The results support the need for greater collaboration between subject-matter experts and decision makers with lay knowledge in policy evaluation and implementation (e.g. Burch et al., 2010; Filatova et al., 2013; Gaddis et al., 2010).

4.6 Implications and Conclusion

This chapter explored FRM policy preferences in the Prairie Provinces of western Canada. The research shed light on the influences and implications of decision makers' FRM priorities and perceptions of policy effectiveness, with respect to adopting strategic and adaptive management principles considered by the scholarly literature to support greater flood resilience. Policy preferences may create a challenge to diverse FRM policy approaches in practice. Policy preferences were found to be heavily biased to a single option in some cases. It was also found that policy preferences were strongly held, suggesting that means of encouraging a more diverse perspective on how to manage flood risk management is needed. The results also highlighted that attempts to coordinate and integrate FRM policy within and between provinces will need to take into account and influence pre-existing policy preferences. Decision makers expressed a comparatively low priority for coordination and integration of FRM policies highlighting another challenge to implementing strategic and adaptive FRM. Similarly, ensuring that FRM policies and strategies are able to cope with climatic and social change was a low priority, and represents a challenge to implementing flexible and evolutionary FRM strategies.

Developing FRM policies that effectively reduce flood risk requires context, both local and regional, to be considered; policies must be able to reduce flood risks at the individual community scale as well as regionally. Decision making that is too centralised can increase flood risk at local levels by not being responsive to the local characteristics that contribute to flood risk. However, simply devolving decision making authority and capacity to local levels can increase flood risk regionally through poorly coordinated, antagonistic, and narrow approaches to FRM. Beyond the implications of how FRM priorities, flood experiences, and flood risk perceptions relate to policy decisions, this research highlights a fundamental need to understand how best to structure governance so that it supports and influences policy decisions that lead to flood resilience.

The findings illuminate some of the challenges that decision maker perceptions of FRM policy can create in achieving more resilient FRM. However, they also highlight the importance of governance structures and processes in supporting more resilient FRM. For example, it was found that existing provincially-set FRM policies may not be those which are perceived to be appropriate at local levels. Policy decisions that are responsive to both local and regional contexts is commonly considered to be a requirement for building flood resilience (Gupta et al., 2013; Seher et al., 2018). The appropriate structure of governance to support both local and regional contexts in FRM and other aspects of natural resource management is an evolving field of academic investigation (Cook, 2014; Gupta et al., 2013; Pahl-Wostl and Knieper, 2014). There are benefits and drawbacks of both centralised, hierarchical structures and more decentralised, polycentric structures (Armitage et al., 2015; Burch et al., 2010; Green et al., 2013); some balance between the two is likely necessary (Huntjens et al., 2011; Pahl-Wostl and Knieper, 2014; Rijke et al., 2013). The contextual nature of FRM, both in terms of the physical hazard and the social structures involved in managing the hazard means that there is no 'ideal' solution for structuring FRM governance and the most effective governance structures are also likely to be contextual in nature.

The results also suggest that governance structures themselves are not enough to support resilience. Also needed is greater understanding of what contributes to stakeholder preferences and how those preferences might be influenced towards policy decisions that support resilience. Both narrow and homogenous preferences and diverse and uncoordinated preferences present a challenge to achieving greater resilience. Therefore, effective means of influencing policy decisions towards those which are more diverse and more regionally appropriate are needed.

Existing decision support tools tend to focus on integrating flood risk assessment into FRM decisions. However, quantifying flood risk does not necessarily change flood risk perceptions (Burch et al., 2010). Potentially, quantification of flood risk to support decision making could lead to justifying existing policy preferences, rather than promoting more resilient policy choices.

Taking advantage of opportunities and overcoming constraints to achieve greater flood resilience requires transitioning from a historically narrow set of FRM policy approaches to greater diversity. Flood risk management decision makers across the Prairie Provinces of Canada continue to have a narrow view of the effectiveness of FRM policies, there are differences between jurisdictions in the types of FRM approach that are seen as effective, and local contexts are not necessarily acknowledged in the current governance structure. Within such a governance environment, policy transition is unsurprisingly challenging. To support policy transition, there is a need to transition existing governance arrangements towards forms that are more effective in coordinating jurisdictions, linking local and regional contexts, and increasing the perceived value of a greater range of FRM policies. Understanding how to achieve this transition necessarily requires an understanding of FRM governance in-situ and underlines the importance of bridging the science-policy divide (Gober and Wheater, 2014).

5. CONCLUSIONS AND SIGNIFICANCE

5.1 Conclusions

The purpose of this thesis is to examine the relationship between flood risk management (FRM) research, practice, and policy implementation and the challenges and opportunities to achieving flood resilience. In doing so, the relationship between FRM research, practice, and policy implementation and how it contributes to flood resilience is investigated. The scholarly literature suggests that to increase flood resilience, FRM needs to adopt three fundamental principles. *First*, a diverse policy approach is pursued that; is both proactive in reducing risk by preparing for flooding, and reactive in order to cope with and recover from flood events; addresses the multiple-sources of flood risk; and promotes planning across multiple policy domains (e.g., White and Haas, 1975; Mileti, 1999; Gilissen, 2016). *Second*, FRM is coordinated and integrated across multiple scales and multiple stakeholders, and acknowledges the differing priorities, perspectives, capacities, goals, and objectives present (eg, Pahl-Wostl, 2008; Butler and Pidgeon, 2011; Hegger et al. 2016b). *Third*, FRM is flexible and evolutionary in order to cope with differing contexts, uncertainty, and change over extended timescales (Pahl-Wostl, 2005; Olmstead, 2014).

Despite a proliferation of research contributing to increased understanding of flooding and the management of social-environmental systems, the impacts of recent flood events suggest that flood resilience is not increasing in the Prairie Provinces of Canada. The science/policy gap has been noted as a challenge to realising concepts such as sustainability, adaptation, and resilience in the management of linked human-environmental systems (Seitz et al, 2011; Kirchhoff et al., 2015). The role of the relationship between science, policy and achieving flood resilience is largely unknown; therefore, the following research objectives were pursued; i) examine current academic thought and trends on how flood management relates to flood resilience; ii) investigate the extent to which institutional arrangements for FRM facilitate or constrain flood resilience; iii) explore how the flood experiences and risk perceptions of decision makers influence FRM policy preferences, and how these preferences might facilitate or constrain flood resilience.

To meet objective (i), I reviewed and analysed themes of research and trends in academic literature that authors self-identified as relating to FRM, governance, and resilience (Chapter 2).

To meet objective (ii), I examined how FRM functions in practice using a case study of the Prairie Provinces of Canada by looking at the main policies that influence FRM, roles and responsibilities for FRM, and stakeholder experiences of the effectiveness FRM in the region (Chapter 3). To meet objective (iii), I investigated the role of stakeholder preferences, experiences, and perceptions in making FRM policy decisions in a complex environment with competing priorities (Chapter 4).

Overall, the research showed that, in the Prairie Provinces of Canada, there is limited evidence that the three principles of strategic and adaptive FRM are being translated into practical outcomes. Challenges within each of the academic, governance and decision environments study represent barriers to bridging the gap from theory to practice (Fig 5.1). The nature and significance of these challenges are discussed in the following paragraphs.

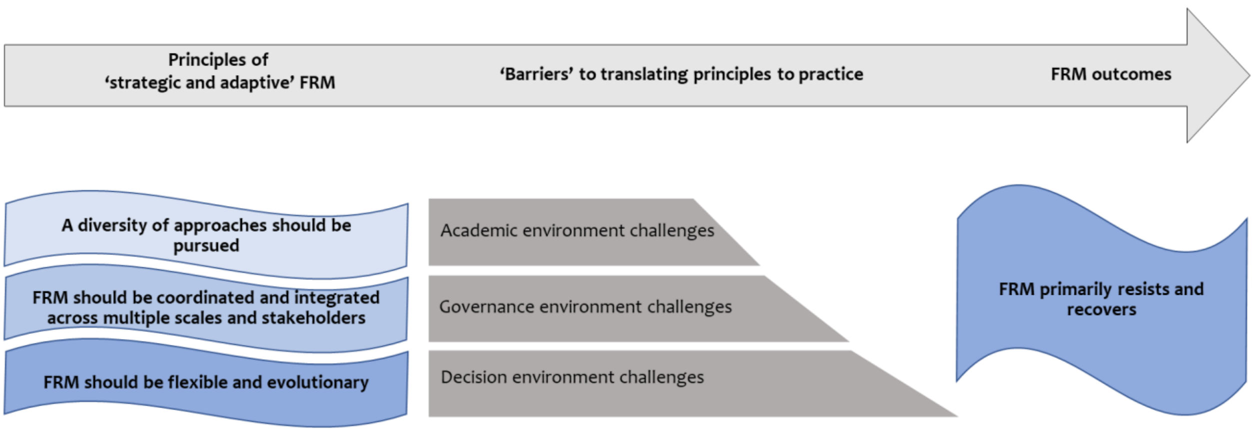

Figure 5.1 Barriers to translating strategic and adaptive FRM principles to practice.

5.1.1 Chapter 2: Scholarly contribution to flood resilience

A lack of coordination of FRM and resilience related research is a contributing factor limiting the effective transfer of scientific knowledge into FRM practice. In FRM practice, the broadly accepted goal is to become more resilient to flooding (Johnson and Priest, 2008) and, ideally, policies and actions align with that goal. However, as is commonly observed in other research fields with scientific, political, and practical components (Morrison-Saunders et al., 2014), FRM governance and resilience related research is often carried out within silos. Rather than starting from an objective to understand flood resilience, research self-identifying as relevant to flood resilience tends to focus on specific components of flood risk then relates those findings to the broader issue of flood resilience post-hoc. For example, the goal of hydrological studies of flooding is generally to understand the hydrological processes that contribute to flooding, and the goal of studies of governance structures is often to understand how the distribution of power influences FRM decision making; both of these endeavours provide knowledge relevant to flood risk and its management, but neither seeks to specifically develop knowledge of 'flood resilience'. Despite understanding that flood resilience requires that FRM strategies acknowledge the complex nature of social-ecological systems, a lack of coordination of research relating to flood resilience suggests that FRM research, as a whole, does not adequately acknowledge the complexity of flooding. The practical applications of FRM research in supporting flood resilience is therefore likely to be limited.

It is recommended that, to better coordinate FRM research in addressing challenges to achieving flood resilience, a research agenda specifically aimed at understanding flood resilience is developed. The results of Chapter 2 suggest at least three foundational characteristics are needed to support a coordinated FRM research agenda that supports flood resilience in practice. First, there is a need for a common understanding of what is meant by 'flood resilience'. Within the FRM literature flood resilience is often explicitly or implicitly considered to be the ability of society to cope with and adapt to flood events (Hegger et al., 2016b; O'Sullivan et al., 2012; Schelfaut et al., 2011), suggesting that there is a general underlying basis for a common definition of flood resilience. In developing a research agenda, it will be necessary to unpack what is actually meant by 'coping' and 'adapting' and how this relates to practical situations. For example, different perceptions of flood risk and physical or financial limitations in mitigating flood waters may lead to different perceptions of flood policy outcomes that constitute coping and adapting amongst stakeholders (Messner and Meyer, 2006; Scheuer et al., 2011). Second, all the relevant knowledge streams that contribute to understanding flood resilience need to be identified and engaged. It is clear from the results of Chapter 2 that research contributing to the understanding of flood risk and its management spans many disciplines, but it is less clear how to apply the knowledge within these disciplines effectively to achieve greater resilience to floods. Third, key challenges and knowledge gaps that create obstacles to achieving greater flood resilience in practice need to be identified. Chapter 2 also found that studies of FRM in practice are not well represented in the literature. This is likely to be a contributing factor in challenges to translating scientific knowledge into practice. These results strongly suggest that, to better support flood resilience, FRM research frameworks are needed to define flood resilience as a research problem, coordinate the many disciplines required to understand and manage flood risk, and link to the real-life challenges of managing flood risk in practice.

5.1.2 Chapter 3: Current state of FRM practice in the Canadian Prairies

Chapter 3 found that the management of flood risk in the Canadian prairies is primarily reliant on land-use planning based on AEP levels, engineered defences, and emergency preparation, response and recovery. FRM policies at national, provincial, and municipal levels are subsumed into discrete policy areas with no overarching strategy or organisation mandated to coordinate actors, policies, and resources around the problem of flooding. As such, FRM implementation in the Prairie Provinces does not display the diversity of policy approaches or the coordination and integration of those approaches across multiple interests and scales considered necessary to support flood resilience (Gilissen et al., 2016; Mileti, 1999: Hegger et al., 2016b). This is despite the presence of a diverse range of policy instruments that cover the five approaches to FRM (prevention, mitigation defence, preparation, and response and, recovery), and despite that research participant's broad acknowledgment of the need for holistic and coordinated FRM strategies to reduce the negative impacts of flooding. There is debate as to whether it is more difficult to change policy ideas or institutions (van Buuren et al., 2016); the case study of FRM in the Canadian prairies suggests that policy ideas have evolved beyond a primarily command and control conceptualisation, but that the governance institutions, structures, and processes through which policies are implemented have not. Similar to other parts of the world, implementing more strategic and adaptive FRM is a major challenge in the Prairie Provinces, even though there is an evident desire to do so (Schelfaut et al. 2011). At the root of this challenge is a lack of coordination of FRM actors, roles and responsibilities, policy instruments, and resources, a known factor that limits the adaptive capacity of governance regimes (Pahl-Wostl et al., 2005). Therefore, when it comes to implementation, policy instruments and resources are arranged in a way that more readily supports historic policy approaches. As a result, prairie province FRM displays characteristics of path dependency (van Buuren et al., 2016), tending to favour the established land-use planning, defence, and response and recovery policies and obstruct greater diversity. This finding highlights that flood resilience is unlikely to result from greater policy diversity alone (Hegger et al., 2016b), but also requires policies that are appropriate to the existing institutional context; that is, resources, policy instruments, and management structures that facilitate the types of policy to be implemented need to be in place (Cook, 2014; Hegger et al., 2016a).

This thesis supports calls for the development of national FRM strategy (Pomeroy et al., 2016) and proposes a hub and spoke governance model for FRM as appropriate for addressing the particular challenges to, and opportunities for achieving greater flood resilience in the Prairie Provinces and Canada. This governance architecture would consist of a national boundary organisation to help set a common purpose and objectives for FRM at all government levels, clearly define and allocate roles and responsibilities, provide a bridge between governments and other stakeholders, facilitate the development of policies and the policy instruments required to implement them, and provide a forum for the sharing of knowledge and experience and the ongoing evolution of FRM strategies. Supporting the national agency would be regional ‘spokes’ to adapt and roll out the national FRM with respect to local contexts. The creation of a national agency is likely to be extremely challenging in itself given the current, extremely fragmented, way in which FRM is governed in Canada; however, such an agency is not without precedent (Arbuthnott and Schmutz, 2013). Opportunities exist to take advantage of existing governance structures and relationships between stakeholders to evolve the institutional arrangements for FRM in a way that more effectively supports the implementation of a greater diversity of policy approach.

Of major importance to flood resilience in the Prairie Provinces, Canada, and globally, is understanding how to transition towards governance arrangements that more readily support strategic and adaptive FRM. Chapter 3 of this thesis demonstrates the value of carrying out empirical studies of FRM governance in-situ to help understand some of these challenges to transition. However, as Chapter 2 demonstrates, empirical research of FRM governance is lacking, leading to a major gap between the knowledge that scholars produce with respect to FRM and resilience, and the needs of FRM in practice. Progress towards flood resilience is likely to remain challenging without first addressing this gap.

5.1.3 Chapter 4: Barriers and potential solutions to integrating strategic and adaptive principles into prairie FRM

Results from Chapter 4 indicate that a combination of decision maker priorities, perceptions, experiences, and preferences is an influencing factor in transitioning to more strategic and adaptive FRM. These findings are novel in linking the flood experiences and risk perceptions of decision makers to the FRM policy preferences, and support the observation that decision making is not just an analytical process, but also has a psychological and experiential component (Leiserowitz, 2006). Three observations from Chapter 4 demonstrate how human factors within institutions can create challenges to achieving greater flood resilience. First, FRM priorities are similar across the three Prairie Provinces. As such, there appears to be significant common ground in the study area, which is considered to be fundamental to supporting a coordinated multi-jurisdictional strategy for FRM (Rayner and Howlett, 2009; Underdaal, 1980). Despite these broadly shared priorities, provincial differences in policy preference highlight the risk of conflicting FRM policies and strategies across the region. Second, in many cases decision makers perceive one policy alternative to be significantly more effective than other alternatives in meeting FRM priorities. This narrow perception of policy effectiveness represents a challenge to achieving greater flood resilience since, in the context of a complex social-ecological issue such as flooding, a mix of approaches is required to be able to respond to contextual differences in physical and social characteristics of flooding (Gilissen at al., 2016; Lin Moe et al., 2007). Policy instruments that aim to influence FRM priorities and the resulting policy choices (Filatova et al., 2014) are therefore, by themselves, not necessarily effective within the case-study area. Third, flood experiences and flood risk perceptions influence how effective decision makers consider different policy options to be in meeting FRM priorities. This finding is significant as it expands on existing understanding of how people's experiences and perceptions relate to flood resilience. Although the influence of perceptions and experiences of natural hazards on the risk reducing behaviours of individuals has been established (Aerts et al., 2018; Brilly and Polic, 2005; Spence et al., 2011), it is not established how these experiences and perceptions influence the choices of individuals with responsibility for FRM policy decisions.

The findings from Chapter 4 provide further insight into the role of context in implementing strategic and adaptive FRM policies. The importance of recognising the physical contexts of climate, hydrology, geomorphology, land-use, and the built environment is broadly acknowledged, as demonstrated in Chapter 2 by the prevalence of research into flood modelling and risk assessment tools to support FRM decision making. The importance of social and institutional contexts, such as stakeholder perceptions and behaviours, roles and responsibilities, and institutional structures and relationships is also acknowledged within the scholarly literature (Ingirige and Wedawatta, 2014; Osberghaus, 2015; Thorne, 2014). However, as Chapter 2 also demonstrated, tools that attempt to integrate these social influences on flood risk into FRM decision-making are an underdeveloped research topic. This is a significant gap in light of the results from Chapter 4 which show; that strong policy preferences are held that do not fit with a strategic and adaptive approach to FRM, and; that the existing financial and regulatory policy instruments may have a limited ability to shift policy preferences towards more strategic, diverse, and adaptive options. Recent scholarly attention to the potential of Agent Based Models (ABMs), which dynamically link social and environmental processes (Matthews et al., 2007), suggests that the need for more effective modeling of flood risk that accounts for complex social-ecological interactions (Haer et al., 2016; Jenkins et al., 2017) has been recognised, at least in some quarters. There is an urgent need to develop similar tools which can be used in practice to integrate the social-ecological complexity of flooding into policy development. Through such tools, a more realistic representation of the potential outcomes of policy choices can be produced and may prove effective in shifting the FRM preferences of both decision makers and other stakeholders towards more strategic, diverse and adaptive options (Burch et al., 2010) and help progress a more strategic and adaptive approach to FRM.

5.2 Significance of research findings

This thesis provides several significant contributions to the scholarly discourse on FRM and flood resilience. The insights of many scientific disciplines contribute to understanding how to manage flood risk and are of fundamental importance to making society more resilient to flooding; however, there is a clear need to coalesce academic knowledge and expertise around a formal understanding of what is meant by ‘flood resilience’, to translate that understanding into clear research objectives, and to develop research frameworks that will support, develop and adapt those objectives in response to practical FRM needs and expanding knowledge. The research presented in this thesis shows the importance of investigating and characterising the particular challenges that emerge from existing governance arrangements within which flood resilience concepts are applied. It is clear that the ways in which governance arrangements influence policy implementation are extremely complex and context specific.

Although this complexity is the source of significant challenges for practitioners seeking to implement resilience concepts within FRM policy, it also presents a significant opportunity for researchers who wish to develop greater understanding of how resilience concepts relate to and can be translated into solutions to real-world problems. The ability to understand and apply resilience concepts in practice is of significant importance given that society is all but certain to experience greater exposure to risk as a result of both societal and climate change. This thesis also contributes to the understanding of flood risk and its management as a social-ecological system. A clear link was found between flood experiences and perceptions and preferred policy response. Implementation of these policies would likely lead to changes in the physical characteristics of flood events, changing how floods are experienced in the future. As with social-ecological systems, the human components of flood risk management, in this case human experience, cannot be considered separately from the greater system from which flood risk emerges. The characteristics of a flood and how that flood is experienced by society influences societal response, which in turn influences the way in which future floods unfold and how they are experienced. Greater understanding of how the physical 'events' of flooding and human experiences and reactions to those events is therefore a significant part of understanding how to influence greater flood resilience.

Overall, the three research chapters highlight that the coordination of researchers, practitioners, decision makers, other stakeholders, resources, and policies and strategies is fundamental to implementing FRM that increases community flood resilience. The case study presented shows evidence of transition towards a more strategic and adaptive approach to FRM in Canada, but also evidence of significant gaps in knowledge obstructing that transition. Strategic and adaptive management requires that policies be treated as experiments to allow continuous learning, improvement and adaptation to change. This thesis demonstrates that the governance environment in which those experiments must be carried out is complex and that there are significant gaps in knowledge of how the functioning of governance systems influences policy implementation and outcomes. True policy experiments are therefore significantly complex undertakings that FRM practitioners are unlikely to have the resources to carry out effectively.

Arguably, though, the academic community does have the resources to treat FRM policy implementation as an experiment; experimentation, identification of knowledge gaps, and research design and methodology are the particular skills in which FRM scholars are trained. However, there is limited evidence that the academic community uses FRM policies as experiments from which to learn. Although Chapter 3 concludes with the need for an agency to address coordination issues in FRM governance, in combination with the findings of Chapters 2 and 4, this thesis concludes that any organisation for coordinating FRM needs not only to coordinate FRM in practice, but also to coordinate FRM science and link the research and policy communities at a fundamental level. Essentially, if policies are to be designed as experiments to allow ongoing learning from and evolution of policy, there needs to be improved collaboration between FRM scholars and practitioners.

5.3 Future research needs

Fundamental changes are needed in the way academics research FRM if their work is to support greater flood resilience. There is a need to research *how* to achieve closer linkages between research and practice. Insight might be found from the successes, challenges and legacies of existing and previous existing collaborative efforts between the science and policy communities, for example, the EU STARFlood program, the Canadian Floodsmart initiative, and the international research initiative, ICHARM.

We need also to determine how these research partnerships can be supported in perpetuity. Change and uncertainty are an omnipresent and fundamental characteristic of flood risk, therefore there is a need to continuously adapt our understanding of FRM to unpredictable change. Inspiration might be found from the UK's Climate Change Act (UK Government, 2008), which required that an independent advisory body, the Committee on Climate Change, be created and mandated to provide objective policy advice to UK governments (Fankhouser et al., 2018).

More specifically, there is a need for more research into factors that influence FRM policy decisions. This research found that political priorities, flood perceptions and flood experiences have *some* influence on policy preferences. However, this is probably just scratching the surface. It is likely that numerous, interacting factors play a role in decision makers' judgements; for example, Burch et al. (2010) found that visual representations of potential flooding scenarios influenced policy choices. In order to influence governments towards policy decisions that support diverse FRM approaches, that are locally and regionally appropriate, that are coordinated across jurisdictions and scales of government, and that are adaptive and evolutionary, both FRM researchers and practitioners need a far greater, and shared, understanding of these influencing factors and how they interact.

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