TWENTY YEARS LATER: FLOOD MITIGATION IN THE RED RIVER BASIN

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EXECUTIVE SUMMARY

In its November 2000 report, *Living with the Red*, the International Joint Commission (IJC) made a number of recommendations to governments aimed at reducing, mitigating, and preventing harm from future flooding in the Red River basin. The IJC noted that there is no single solution to the challenge and that comprehensive, integrated, binational approaches must be pursued and implemented.

Since the 1997 flood, governments at all levels have made changes in flood-related policies, funded new programs and modified existing ones, invested in research related to flooding, and supported the establishment of new institutions such as the Red River Basin Commission. Not only major floods such as that of 1997, but also smaller tributary floods have been the focus of attention.

In June 2001, the United States and Canada directed the IJC and the newly created International Red River Board to monitor progress by governments in implementing the recommendations contained in *Living with the Red*, and to provide encouragement for continued cooperative, innovative, and integrated watershed management approaches. In January 2003 the IJC specifically requested the Board to provide a written report on progress. A report indicating substantial progress on many recommendations was prepared and made available to the public through the IJC website.

In 2006, the Red River experienced a significant flood with relatively little urban damage, although costs were incurred for measures such as closing ring dikes. In 2009, a flood occurred that, at Fargo-Moorhead, exceeded those of 1997 and 1897. In the lower basin the 2009 flood was exceeded in the instrumental record only by that of 1997. Although the 2011 flood was very significant in the Assiniboine-Souris basin it did not pose a major threat in the Red River basin. Each flood has its own unique characteristics; for example the 2009 flood was characterized by ice jamming while the 2011 flood featured a record volume.

The flood management measures implemented following the 1997 flood have led to a higher level of preparedness and improved mitigation measures. The basin has become more flood resilient, and this significantly reduced the effects of the 2009 and 2011 floods on the people and communities of the Red River valley.

The International Joint Commission made 28 recommendations to government and endorsed another 30 recommendations of its International Red River Basin Task Force without change. The expenditures to 2016 relating to the IJC recommendations have exceeded one billion dollars. No recommendations have been formally rejected although some are no longer relevant and are unlikely to be implemented.

Some of the key achievements and continuing deficiencies can be summarized under headings of policy, legislation and institutions; preparedness; mitigation; and environment.

Policies, Legislation and Institutions. In 2008 Canada introduced its first national mitigation strategy. The strategy includes a number of priority actions.

Changes in data policies by the Canadian federal government, particularly Environment and Climate Change Canada, and by the Manitoba government have led to a better-informed public.

Manitoba introduced a new designated flood area regulation upstream and downstream of Winnipeg. The province is now basing its regulatory flood on the 1:200 flood rather than the 1:100 flood. The associated elevation and inspection requirements for new structures will reduce future flood damages. The province has also introduced new emergency management legislation and legislation for Red River Floodway expansion.

In the United States, policy changes by the Army Corps of Engineers are aimed at a more integrated basin-wide consideration of projects. The Minnesota Red River Watershed Management Board and its North Dakota counterpart, the Red River Joint Water Resource District, also seek more integrated approaches. The Red River Retention Authority, comprised of members of these two Boards, was formed in 2012 to ensure joint, comprehensive, and strategic coordination of temporary flood water storage projects in the Red River of the North watershed.

Both North Dakota and Minnesota have implemented new state building codes that include flood-proofing measures.

Key institutional developments include the formation of the IJC's International Red River Board, the Red River Basin Commission and the International Water Institute.

Preparedness. Cities such as Winnipeg and Grand Forks have upgraded detailed emergency plans. All communities in the basin now have up-to-date emergency response plans.

Improvements to flood forecasting were carried out following the 1997 flood. Major improvements have been made to data networks; data collection that supports forecasting, such as topographic data; model development; and communication of forecasts. These have occurred in both countries.

The US Federal Emergency Management Agency (FEMA) has instituted a national map modernization program. The program makes current information available in digital, geographic information system compatible form.

Mitigation. Many structural measures aimed at protecting both rural and urban floodplain residents have been completed or at advanced stages of development. Rural protection efforts continue and many high-risk structures have been removed from the floodplain. Major levees such as those for Grand Forks and East Grand Forks are complete. The Red River Floodway (Winnipeg) expansion project is complete. Fargo-

Moorhead measures are under development. Flood protection works have also been developed for many smaller communities. Most individual farmsteads are also protected.

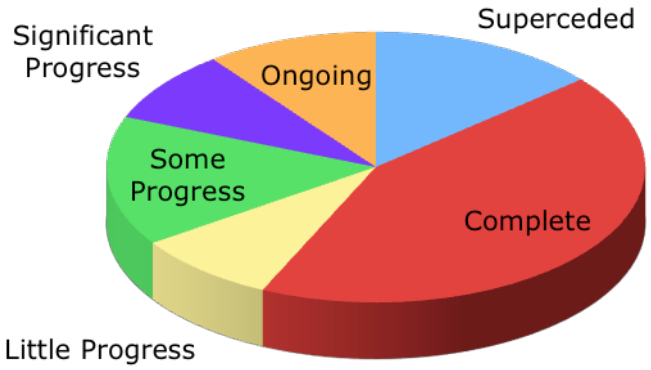
With regard to non-structural measures, the identification of areas at risk in the United States, based in part on information from the 1997 flood, is complete. As indicated previously, Manitoba introduced new floodplain management measures now based on the 1:200-year flood level. All jurisdictions have removed some high risk structures from the floodplain.

The US Army Corps of Engineers is developing a HEC-RAS one-dimensional hydrodynamic model for the Red River that extends up each tributary to the first gauging station. It has also developed HEC-HMS hydrologic models for tributaries in the United States. Local water resource districts/water management boards have completed hydrologic model for each sub-watershed, to locate potential detention sites and to determine potential downstream impacts at the outlet of each sub-watershed.

The Red River Retention Authority obtained federal funding to pursue watershed protection plans within the Red River watershed. Partnering with the Natural Resource Conservation Service, there are 20 plans being developed. Although the main emphasis is to reduce local flood damage, other benefits of any potential projects could also include improvements to water quality and soil health, as well as other benefits.

Environment. The IJC made recommendations concerning biota transfer, groundwater contamination and storage of hazardous goods. Some work has been accomplished in these areas. An area of considerable activity that also arose during the International Flood Mitigation Initiative concerns riparian zones. Riparian conservation reserves have been established as part of the Grand Forks levee project and the Red River Floodway expansion at Winnipeg.

The overall status of the recommendations is shown in the figure below.



The recommendations that have achieved the most success are those that involve construction of a structural measure identified in the IJC report, even if that work requires collaboration at the federal, state or province, and local level. A second group of successful recommendations relate to specific recommendations aimed at a specific agency. Resolving the Canadian vertical datum problem is one such example.

There are some causes for concern nonetheless. The less successful recommendations are those that involve multiple agencies and, perhaps, multiple objectives. These sorts of tasks could be deemed to be more difficult and could naturally be expected to take longer. It may be that public expectations for structural measures override all other post-flood pressures and that those expectations need to be met before proceeding with "softer" projects.

While the Red River basin is unquestionably more flood resilient than it was in 1997, it will still take considerable effort to achieve the level of integration and cohesion on flood management that the IJC envisaged. The mandates and accountability of federal, state/provincial, and local government agencies make it extremely difficult to consider IJC recommendations that imply a degree of collective management or assignment of responsibilities to a third party. This problem is particularly difficult when binational approaches are contemplated. That said, there is currently a high level of interagency and intergovernmental cooperation.

In the almost 20 years since the 1997 flood some matters that were extremely important at the time have been resolved while others can be addressed by today's vastly superior technology. Continued consideration of all the IJC recommendations from *Living with the*

Red is no longer the best approach. Instead the IJC and its International Red River Board can continue to monitor a small sub-set of the original recommendations.

In considering next steps, the International Joint Commission and its International Red River Board may wish to concentrate on a short list of matters concerning Red River flooding. This would include: matters pertaining to the transboundary area, in particular the Roseau and Pembina Rivers; further improvements to flood forecasting methodology; and the development of indicators of basin resiliency. There are also emerging issues such as the burgeoning tile drainage operations in the basin.

Despite the enormous strides made in the past 10 years it is important to keep in mind that floods greater than 1997 have occurred in the past and undoubtedly will occur again. It will be important to maintain the databases and models developed in recent years and to improve them as new information and technologies arise. With continuing high water events since 1997 this task appears achievable. If the Red River basin experiences a decade or more in which no serious flooding occurs, flood preparedness could decline in favour of other priorities.

The apocryphal quote that the Red River basin has two problems, "too much water and too little", has a firm foundation in reality. In attempting to deal with concerns related to flooding, it is important to determine the consequences of any proposed measures during times of drought. Integrated water resources management should be the overarching goal for the basin. This should become the new challenge of “living with the Red”.

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INTRODUCTION

In its November 2000 report, *Living with the Red*, (IJC, 2000) the International Joint Commission (IJC) made a number of recommendations to governments aimed at reducing, mitigating, and preventing harm from future flooding in the Red River basin. The IJC noted that there is no single solution to the challenge and that comprehensive, integrated, binational approaches must be pursued and implemented. In the course of its work, the IJC had also initiated the development of products of continuing utility to the basin, including hydraulic models, high resolution topographic and land use data for flood-prone areas, and a virtual network to link people, information, and the decision-making process.

The IJC study was a response to the 1997 flood. Figure 1 places that flood in context with other floods. The table includes floods from the instrumental record and, in the case of Manitoba, three well-documented historical floods. It is notable that several post-1997 floods appear in the table. The floods are ranked in terms of peak water level, not peak flow.

Table 1. Large Red River Floods

	Location		
Rank	**Fargo, ND**	**Grand Forks, ND**	**Morris, MB**
1	2009	1997	1826
2	1997	1897	1997
3	1897	2011	1852
4	2011	2009	2009
5	1969	1979	2011
6	2006	1882	1861
7	2010	2006	1950
8	2001	2010	1979
9	1989	1996	1996
10	1979	1978	2006

Since the 1997 flood, and in response to the IJC recommendations and others such as those arising from the International Flood Mitigation Initiative (IFMI), significant investments have been made in the basin to better understand flooding along the Red River, to protect communities, and to develop partnerships amongst governments, the private sector, and non-profit organizations to address flood damage and mitigation concerns. Governments at all levels have made changes in flood-related policies, new programs and changes to existing ones have been established, research continues into many aspects of flooding, and new institutions such as the IJC's International Red River Board and the Red River Basin Commission have been established. Not only major floods such as that of 1997, but also smaller tributary floods have been the focus of attention.

In June 2001, the United States and Canada directed the IJC and its newly formed International Red River Board (IRRB) to monitor progress by governments in implementing the recommendations contained in *Living with the Red* (International Joint Commission 2000), and to provide encouragement for continued cooperative, innovative, and integrated watershed management approaches. In January 2003 the IJC requested that the IRRB provide a written report taking stock of what has been accomplished.

One approach to this stock-taking was to conduct an on-line survey of agencies having an interest in flood preparedness and mitigation in the Red River basin. The survey was aimed at providing a consolidated overview of the nature and extent of flood related activities since 1997. In this way the International Red River Board could lend its support and influence towards continued preparedness and mitigation activities in the basin.

The 2003 survey was conducted for the International Joint Commission's International Red River Board by R. Halliday & Associates Ltd. in co-operation with the Canadian Water Resources Association. Funding for the work was made available by the Canadian Departments of Western Economic Diversification and of the Environment. The results are reported in *Flood Preparedness and Mitigation in the Red River Basin* (R. Halliday & Associates 2003).

In 2006 the Red River basin experienced the largest flood since that of 1997. Despite the significance of this flood, there were only minor disruptions and damages were small. This demonstrated a considerable improvement in flood resiliency in the basin since the 1997 event.

In 2009 a flood whose peak water level was second only to that of 1997 in the instrumental record at Morris, MB struck the Red River basin (Macek-Rowland and Gross 2011, Manitoba Water Stewardship 2010, Wazney and Clark 2016). Managing this larger flood proved more difficult than managing the 2006 flood, particularly in upper basin communities such as Fargo and Moorhead, where the 2009 event became the flood of record. The flood peak at Fargo was considered to be a one to two percent (1:100 to 1:50) event (Macek-Rowland and Gross 2011). Hundreds of homes were destroyed and mandatory evacuations were needed in some parts of those cities. At Grand Forks and East Grand Forks the flood was less significant. Water levels, although the fourth highest in the instrumental record, were much lower than in 1997 as the peak flow was only 56 percent of that for 1997. Flood damages in those cities were low on account of structural measures implemented following the 1997 flood.

In southern Manitoba 17 community ring dikes, constructed or improved following the 1997 flood, were activated in 2009. Operation of these ring dykes saved some $700 million in damages (Manitoba Water Stewardship 2010). Although the Red River Floodway protected Winnipeg, some vulnerable riverbank properties were sandbagged. Severe ice conditions in some reaches north of Winnipeg led to record high water levels. The 2009 flood demonstrated the need for additional improvements to the secondary diking system in Winnipeg and for improvements in ice management. Nonetheless, although flood-fighting costs were significant, actual damages were relatively small

compared to what they might have been in the absence of measures taken following the 1997 flood.

In 2008 the IRRB concluded that another examination of the legacy of the IJC's recommendations on Red River flooding would be timely. This examination would also include the establishment of a database compiling the results of actions taken by governments in response to the recommendations. R. Halliday & Associates Ltd. was engaged to perform this work. Representatives of key agencies were contacted in the course of the work. There were two deliverables from the work: a technical report and the text for a public information brochure. The report, *How Are We Living with the Red?,* (R. Halliday & Associates 2009) is available on the International Joint Commission's website.

In 2011 yet another significant flood struck the Red River valley (Manitoba Water Stewardship 2011, Stadnyk *et al.* 2016, Vining *et al.* 2013). This flood generally had peak elevations a little lower than those in 2009. The flood volumes, however, were much larger than those in either 2009 or 1997. On that basis it is likely that the 2011 flood contained the largest volume of any flood in the instrumental record, exceeding that of the 1950 flood.

Flood damages in the Red River basin from the 2011 event were modest. They certainly paled in comparison to those experienced at approximately the same time in the Assiniboine and Souris river basins in Manitoba and North Dakota.

In 2016 the IRRB concluded that a final examination, some 20 years after the 1997 flood, of the IJC's recommendations would be desirable. Once again R. Halliday & Associates was asked to perform the work. Representatives of key agencies were contacted in the performance of the work and some face-to-face meetings were held.

This report summarizes the findings of the study. The results are presented in the context of the emergency planning cycle of preparedness, mitigation, response and recovery. The report includes an Appendix Two that identifies each recommendation made by the International Joint Commission and each recommendation made by the Commission's International Red River Basin Task Force (IRRBTF) that was endorsed by the Commission without alteration. For each recommendation there is a background statement and a status report. In addition to describing the legacy of accomplishments the report also discusses remaining challenges and vulnerabilities.

Acronyms and abbreviations used in this report are defined when they first appear. A complete listing can be found in Appendix One.

LIVING WITH THE RED

In the course of its work the IJC drew 7 conclusions, made 28 recommendations, and endorsed 2 conclusions and 30 recommendations of the IRRBTF without re-statement (International Joint Commission 2000). For the most part the recommendations dealt with

preparedness and mitigation in the basin. In the almost 20 years following the 1997 flood there has been a legacy of accomplishments in many areas such as new legislation, increased interjurisdictional cooperation, improved flood protection measures, enhanced flood forecasting, and increased public involvement. These accomplishments are described later in this section.

The spatial extent of the report is confined to the Red River basin as defined in *Living with the Red*. That is, the Assiniboine River and Devils Lake sub-basins were not included and the report contains no recommendations concerning those basins. The Assiniboine River, in particular its Souris River tributary, is not included in the mandate of the IRRB. Although the Devils Lake sub-basin is part of the Red River basin (and falls within the geographic mandate of the IRRB) it has had no natural hydraulic connection to the Red River in the last millennium. (During very wet weather some water does make its way south from the upper Pembina River basin towards Devils Lake.) After a record low in 1940, Devils Lake rose to a peak in 2011, the highest level in the instrumental record, exceeding the previous high in 1830 (Upham, 1895).

Although it is geologically incorrect, this report uses the expression Red River valley to denote the flat central portion of the Red River basin that takes in the Red River mainstem and its floodplain. For the most part, this is the portion of the basin that appears flooded in 1997 satellite images.

All financial figures are expressed as Canadian dollars for Canada and American dollars for the United States. The exchange rate between United States and Canadian dollars has fluctuated considerably since the 1997 flood. One Canadian dollar has ranged in value from US $1.05 to US $0.65. One Canadian dollar was worth about US $0.90 in June, 2009 and about US $0.75 in December 2016.

Policies, Legislation and Institutions

The IJC made a number of recommendations pertaining to policies, legislation and institutions. These are identified below:

IJC Conclusions	IJC Recommendations	TF Recommendations
1,2,3	9, 12, 15, 20	16, 17, 21

In 2008, Canada introduced its first national mitigation strategy (Public Safety Canada 2008). The strategy included a number of priority actions. It also provided an opening for federal contributions for flood mitigation measures. As a result of several significant floods in the last decade, including two in the Red River basin, there was a greater interest in Canada in reducing flood damages. A *National Disaster Mitigation* program aimed at reducing flood risks and costs was established in 2015. The program received funding of $185 million over five years for projects to be cost-shared equally with provincial governments. The federal government is also examining floodplain mapping issues jointly with the provinces.

Changes in data policies by the Canadian federal government, particularly Environment Canada (now Environment and Climate Change Canada (ECCC)), and by the Manitoba government have led to a better-informed public. Canadian climate, streamflow and sediment data are now available for free download from departmental websites.

Manitoba has introduced new designated flood area regulations based on the 1:200 flood. The associated elevation and inspection requirements for new structures will reduce future flood damages. The province also introduced new emergency management legislation and legislation to support Red River Floodway expansion.

The United States Army Corps of Engineers (USACE) established the National Flood Risk Management Program in 2006 for the purpose of integrating and synchronizing the Corps' flood risk management programs and activities, both internally and with counterpart activities of the Department of Homeland Security's Federal Emergency Management Agency, other federal agencies, state organizations and regional and local agencies. The Minnesota Red River Watershed Management Board and its North Dakota counterpart, the Red River Joint Water Resource District, are seeking more integrated approaches. The Red River Retention Authority, comprised of members of these two Boards, was formed in 2012 to ensure joint, comprehensive, and strategic coordination of temporary floodwater storage projects in the Red River of the North watershed.

Both North Dakota and Minnesota have implemented new state building codes that include flood-proofing measures. Fargo, for example, has changed policy to require floodproofed foundations on any property lower than 41 ft. according to the river gage. That is, about the level of the 2009 flood. This requirement makes flood insurance premiums more affordable. Canada still has not included flood-proofing measures in its model National Building Code.

Key institutional developments include the formation of the International Joint Commission's International Red River Board (IRRB), the Red River Basin Commission (RRBC) and the International Water Institute (IWI, formerly the Red River Basin Institute). The IRRB is an advisory board to the IJC. This 18-person board is co-chaired by representatives from the United States and Canada and is tasked, among other things, with monitoring the status of the IJC’s recommendations pertaining to Red River flooding.

Flood Preparedness

Flood preparedness includes developing a plan for emergency operations, identifying available resources that can be tapped during a disaster, delivering integrated training programs and exercises, and practicing the actions outlined in national, regional or local emergency operations plans. Flood forecasting capability and development of databases to support that capability are a fundamental requirement of flood preparedness. The recommendations pertaining to flood preparedness are shown below.

IJC Conclusions	IJC Recommendations	TF Recommendations
1, 6, 7	8, 17-19, 22, 26	2, 16-19, 26, 30, 35-40, 44, 46, 48, 50

Emergency Plans. Following the 1997 flood North Dakota passed legislation specifically requiring cities, townships and counties to address natural and man-made hazards in their comprehensive emergency plans. Each county must maintain an emergency management organization; cities must maintain an emergency management organization or participate in the county organization. Minnesota Emergency Management has requirements for emergency plans and for exercising these plans.

Flood preparedness meetings are conducted with state and local officials to update local, state, and USACE Flood Response Plans. These meetings review how flood response is coordinated through the county to the respective State Division of Emergency Management for the allocation of state and USACE flood response resources.

In the United States, the goal of the Silver Jackets program is to develop a state-led interagency team in each American state. Silver Jackets teams bring together multiple state, federal, and sometimes tribal and local agencies to learn from one another in reducing flood risk as well as consequences of other natural disasters. By applying their shared knowledge, the teams enhance response and recovery efforts when such events do occur. In both North Dakota and Minnesota Silver Jackets teams recently completed a pilot project that developed an emergency action plan guidebook template. The template will be the basis of several workshops aimed at the further development of emergency action plans.

Manitoba has rewritten its emergency legislation since 1997. All communities are required to have an emergency response plan. The plans take an all-hazard approach. These plans are submitted to the Manitoba Emergency Measures Organization for review on a four-year cycle. Each community is required to conduct exercises every 14 months. All 198 Manitoba communities have approved plans and all have designated emergency coordinators. In smaller communities these coordinators may be volunteers or shared with an adjacent community.

Public Safety Canada (PSC) administers the Joint Emergency Preparedness Program (JEPP) to assist communities in improving their preparedness capacity for all types of emergencies. Since 1997, PSC has provided funding through the JEPP to enhance “all hazards” response capabilities of several Red River basin communities. Approximately $200,000 is spent on JEPP projects in Manitoba, many of which pertain to the Red River basin, each year.

Databases. Significant improvements have been made in databases in the years following the 1997 flood. These improvements include not only new data but also much improved data distribution. As a result of increased computing power and low-cost storage, institutional capacity to manage large data sets has improved enormously in the

last 20 years. In the current era of big data and Hadoop Distributed File Systems, the data challenges of 20 years ago appear almost quaint.

A lidar-based digital elevation model (DEM) has been prepared for the entire Red River basin in the United States and for the Red River valley in Manitoba through to the Red River delta at Lake Winnipeg. Data in the United States were acquired by the International Water Institute (IWI) and U.S. Geological Survey in 2008 to 2010 as part of the Red River Basin Mapping Initiative. With the exception of a limited length along the lower Pembina watershed, the American and Canadian DEMs have not been stitched together.

American products available are one- and three-metre DEMs, one- and three-metre hillshades, and two-foot contours, plus a tile index map for each county. Since breaklines were not available, the data has not been hydro-flattened. (Hydro-flattening uses software to generate a breakline for shoreline areas in order to "flatten" a body of water's surface elevation thus removing lidar noise and other artifacts.) The Minnesota Department of Natural Resources (DNR) processed the Minnesota data to make it consistent with other lidar data available in Minnesota, including converting it to UTM Zone 15 coordinates and tiling to 3.25 square mile blocks based on 1/16 of a standard USGS 1:24,000 quadrangle.

About 70 percent of all individual residences and businesses in the Canadian portion of the Red River basin have been geo-referenced and the nature of their flood protection works entered into a database. This database does not include structures within ring-diked communities. As well, all groundwater wells (including abandoned wells) in the valley have been inventoried and geo-referenced.

Many layers of spatial data have been made available in GIS-ready formats through federal or state websites. Major efforts have been devoted to creating national spatial data infrastructure that facilitates data sharing among data custodians and users. This requires a common framework data, metadata standards and web protocols. This work is led by the Federal Geographic Data Committee in the United States and Natural Resources Canada in Canada. In addition, the IJC's Data Harmonization Project has produced seamless watershed maps for the basin. The georeferenced data are available to the hydrologic unit level (sub-sub watershed) and have been verified by federal and state or provincial agencies. See http://nhd.usgs.gove/wbd.html and click on "Go to NRCS". The available watersheds are shown in Figure 1.

Other examples of spatial data portals include the Minnesota Data Commons (gisdata.mn.gov), North Dakota's GIS Hub (https://www.nd.gov/itd/statewide-alliances/gis), the Manitoba Land Initiative (http://mli2.gov.mb.ca/), and Agriculture Canada's National Land and Water Information Service (http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226330737632&lang=eng). Basin-specific data can also be found through the Red River Basin Decision Information Network RRBDIN (http://www.rrbdin.org/).Throughout the IJC study there was a marked difference in data availability between Canada and the United States. Organizations such as the U.S.

Geological Survey have had a long history of making historic and current data freely available to users. Since the IJC study of the 1997 flood, ECCC has made its historical hydrometric (HYDAT) and climate data available for download via the internet. Current water level data and streamflow are also available in real time. Manitoba has also taken steps to make its data more readily available, with the Internet being the preferred method of distribution.

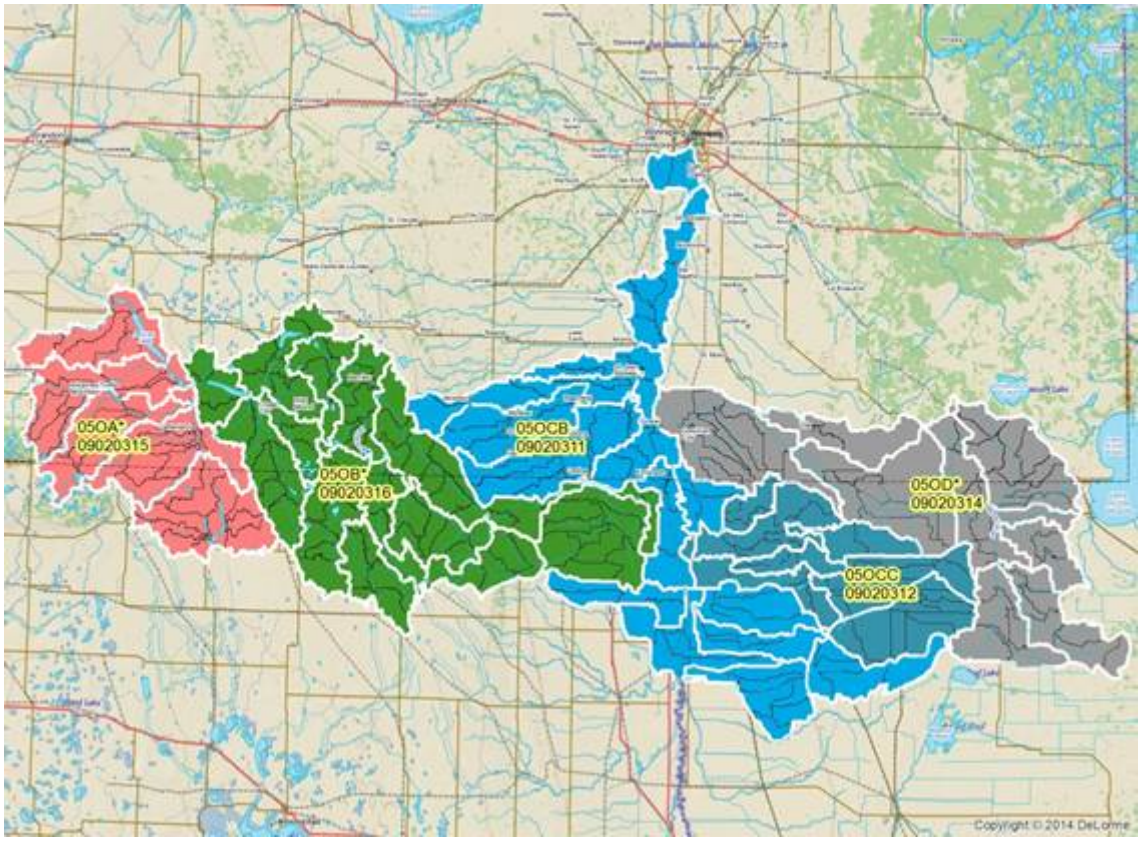

Figure 1. Transboundary Watersheds (IJC 2016).

Flood Forecasting. The US National Weather Service (NWS) carried out significant changes in its flood forecasting methodology shortly after the 1997 flood. Improvements to the Sacramento model were implemented based on the Advanced Hydrologic Prediction System (AHPS). By better quantifying the risks, AHPS had the potential of providing more effective early protection, reducing the number of emergency actions that weren't needed, decreasing the chance of missing emergency actions that are needed, and assisting the USACE with emergency levee freeboard design. In 1999 the NWS implemented the FLDWAV hydraulic model for flood routing. A further 161 cross-sections were added to the model in 2005, bringing the total to 554.

In 2002 Manitoba Water Stewardship implemented a Mike-11 hydraulic model for flood routing in the Manitoba portion of the basin. A decision support system that allowed rural residents to obtain a personalized forecast of spring flood elevations and the emergency measures that are required to protect property was implemented. Maintaining this system

later proved too expensive, and it was discontinued. (As will be discussed later in this report, nearly all rural residents in Manitoba have diked, raised or moved their structures to reduce flood risk.) A similar system has been developed on a pilot scale in Minnesota.

Improvements to the hydrometric and climate monitoring networks were made in both countries. The continuing challenge will be to maintain the expanded networks as operating costs increase. There is still a need for improved snow water equivalent, frost penetration and rainfall data. Since the 1997 flood, snowfall monitoring by ECCC has been reduced and few meteorological observers for the climate monitoring network emain. (Automatic stations tend to produce poor snowfall information.) Since 1997 Manitoba has added 60 weather stations to supplement the ECCC network. More recently Manitoba has incorporated data from the citizen science Community Collaborative Rain, Hail & Snow Network (CoCoRaHS) into its forecast operations. Following the 1997 flood, gauging stations in both countries were improved so that they would withstand high water levels. During the 2009 flood, gauging stations continued to operate throughout the flood; in 1997 maintaining operation was a major problem.

The NWS and Manitoba Infrastructure have both taken steps to increase public engagement in the flood forecasts. A heightened level of collaboration between the two organizations was implemented successfully in 2006 and continues. The challenges of effectively communicating flood forecasts to the public and ensuring the appropriate public response remain.

Forecasting the 2009 flood posed some particular challenges on account of the early snowmelt, which was then followed by several weeks of cold weather. Determining how much snow had melted, how much water lay in temporary storage, and current conditions for soil moisture and frost penetration made forecasting the second peak difficult. In 2016 soil moisture and soil temperature probes were installed at 12 locations in the American portion of the basin as part of a Silver Jackets project.

Red River flood forecasts could be further improved through better determination of winter snowfall, improvements to soil moisture modelling and incorporation of remotely sensed inputs. In general, since 1997 the ability to route flood flows downstream has improved considerably but forecast models have been slow to incorporate detailed hydrological sub-components.

Map modernization. The US Federal Emergency Management Agency (FEMA) has instituted a national map modernization program. The program makes current information available in digital, geographic information system (GIS) compatible form. The Digital Flood Insurance Rate Maps (DFIRM) used in the National Flood Insurance Program replace paper maps and provide greatly enhanced flood-related information.

Although some Canadian provinces have digitized historic flood risk maps, these products are not GIS compatible. In recent years the Canadian government has become concerned about very significant flood damages in various parts of the country. A national floodplain management assessment report in 2014 examined some issues related

to flooding (MMM Group Ltd 2014). The federal government is continuing to work with the provinces on various aspects of flooding in Canada.

Flood Mitigation

Mitigation can be defined as sustained action that reduces or eliminates long-term risk to people and property from natural hazards and their effects. It encompasses a suite of activity by government and non-government organizations, as well as by individuals, aimed at reducing the occurrence or the effects of a disaster. The recommendations pertaining to mitigation are shown below.

IJC Conclusions	IJC Recommendations	TF Recommendations
2-5,	2-7,9,10,11,12,13,14,16	3-7,10-12,15,23,29

In a floodplain management context, policies and regulations identify the floodplain and determine what may be constructed in a floodplain and under what circumstances. Policies and regulations may also cover the construction of flood mitigation measures aimed at reducing flooding or the effects of flooding. These measures may be structural or non-structural in their application.

Structural Measures. Many structural measures have been undertaken in all parts of the basin since 1997. The two largest projects completed were the expansion of the Red River Floodway at Winnipeg and the construction of flood-proofing levees at Grand Forks and East Grand Forks. The proposed Fargo-Moorhead Area Diversion Project, now being developed, will be the most costly project arising from the 1997 flood.

In Manitoba south of Winnipeg, 17 community dikes were constructed or raised. A total of 1,742 homes, farmsteads or businesses were raised, diked or relocated under the terms of a federal-provincial agreement. This represents 95 percent of the eligible structures. During the 2009 flood no farmhouses south of Winnipeg were flooded although some out-buildings were. A further 52 properties were protected after the 2009 flood and two after the 2011 flood.

During the 2009 flood, a number of residential properties on the Red River north of Winnipeg were affected by rapidly rising floodwaters and ice flows, which required the emergency evacuation of residents. In response to these events, the ongoing risk of spring flooding from ice jams along the Red River north of Winnipeg, and the need to reduce the future risk to residents and emergency services workers, the Province and the Rural Municipalities (RM) of St. Andrews and St. Clements agreed to develop a voluntary buy-out program to acquire and remove affected residences. Under the program, approximately $6.1 million dollars was provided to property owners to buy out 17 properties in the RM of St. Clements and four properties in the RM of St. Andrews. The

program costs were shared between Manitoba and the municipalities, on a 90-10 percent basis.

Additionally, the province purchased and removed 42 cottages and homes with Crown land leases in North Breezy Point at a cost of approximately $5.2 million. The Federal Disaster Financial Arrangements Assistance (DFAA) program provided approximately 10 percent towards the North Breezy Point buyouts. As well, roads in the area were raised to the flood of record or ice jam level.

Since 2005, Manitoba has developed a significant ice jam mitigation program on the lower Red River. It involves, ice cutting and breaking 24 km of the Red River ice cover to reduce the effects of ice jamming.

The City of Winnipeg had an extremely close call in 1997. As an interim measure, the Red River Floodway inlet control structure was refurbished, and two notches opened in the east embankment to improve the hydraulic characteristics at the floodway entrance. A preferred option (floodway expansion) for reducing Winnipeg's vulnerability to rare floods was identified and a federal-provincial cost-sharing agreement negotiated. The overall project was estimated to cost $665 million and to provide protection against the 1:700 flood. The floodway expansion project was completed in March 2014 (KGS Group, 2001). The general approach was to widen rather than deepen the existing floodway because of public concerns regarding effects on groundwater wells. *The Red River Floodway Act* (2004) contains provisions related to compensating landowners for artificial flooding caused by floodway operations.

In addition, Winnipeg has made numerous upgrades to improve the reliability of the city's internal flood protection system and to protect it to a water level associated with the legislated Flood Protection Level. Secondary dikes protecting low-lying areas (about 800 residences) on the river side of the primary dikes have been refurbished and a number of new community ring dikes constructed. On-the-land drainage system outfall gate chambers have been constructed to protect these systems during high river levels. The city has 120 km (75 mi.) of primary dikes and 32 combined sewer pumping stations.

In the United States, efforts have been directed to increasing storage in the upper basin and to diking. A co-operative storage project with the USACE, North Dakota State Water Commission, Sheyenne River Joint Water Resources District, and local interests for increasing storage at Baldhill Dam on the Sheyenne River. Two dry dams have been constructed on the Maple River, with the latest project being completed in 2015. (A dry dam allows the river to flow freely and impounds water only during floods.) A Natural Resources Conservation Service *Watershed Protection and Flood Prevention Act* (PL 83-566) project increased storage upstream of Grafton, ND by a dam on the Middle Branch of the Park River. (The act provides technical and financial assistance to states, local governments and tribes for watershed projects.)

The Red River Retention Authority obtained federal funding to pursue watershed protection plans within the Red River watershed. Partnering with the Natural Resource

Conservation Service, there are 20 plans being developed. Although the main emphasis is to reduce local flood damage, other benefits of any potential projects could also include improved water quality and soil health, among other benefits.

The flood protection project for Grand Forks and East Grand Forks consists of 30 miles (48 km) of levees on both banks of the Red River and 3 miles (5 km) of floodwall at East Grand Forks. The East Grand Forks project also protects against the Red Lake River. To accommodate the levee setback and reduce the number of homes and businesses at risk, over 1,000 structures were removed from the floodplain. The project included the stabilization of an existing dam, removal of a former railway bridge, construction of interior flood control features, 24 pump stations, numerous road and railway closures, and two diversion channels. The project cost was $409.3 million. The flood protection level is considered to be 1:250. The project has been certified as providing 1:100 year flood protection in accordance with FEMA's National Flood Insurance Program.

The process by which mitigation projects become certified flood-proofing projects in the United States is an important one. Certification is important to the peace of mind of individual homeowners and, because it affects national flood insurance premiums, is financially important. Certification is accomplished at the request of the local community with engineering aspects being covered by the USACE and administrative aspects by FEMA.

Wahpeton, ND and Breckenridge, MN lie at the confluence of the Bois de Sioux and Otter Tail rivers, the beginning of the Red River. Wahpeton had a close call in 1997 but its emergency levee held. On the other hand, Breckenridge's levees were overtopped twice in 1997, first from the north then from the south. Most of the community was flooded causing damages of $30 million. A flood risk management study of the two communities led to two separate but dependent projects. The Breckenridge project consists of a high-flow diversion channel north of the Otter Tail River and two permanent levee reaches that protect all of the community. The Wahpeton project consists of a permanent levee system and flood easements designed to withstand a 1:125 event. The cost of the Breckenridge project was $45.02 million and the Wahpeton project $21.2 million. Other works completed at Breckenridge include removal or replacement of 132 flood-prone structures, construction of 14 pumping stations, 3.5 miles of dike and 2 miles of floodwall, relocation of lift stations and protection of the water treatment plant. The combined project has prevented nearly $164 million in damages to 2015.

At Fargo about 3,500 feet (1,070 m) of USACE levee and three small cutoff channels were constructed in 1963. For the most part, however, the city depended on emergency earthen and sandbag levees for protection against very large floods, like those in 1997 and 2009. Moorhead in 1997 had no permanent federal flood control project. Analyses following the 1997 flood indicated that it was a 1:70 event at Fargo and that the 100-year flood was about eight percent larger than previously determined. There was, therefore, a need to improve flood protection for both Fargo and Moorhead.

Moorhead made 247 voluntary acquisitions, raised levees, installed gate valves on storm and sanitary sewers to prevent infiltration, installed seals and valves on flood plain houses, and constructed concrete lined storm sewers to convey internal drainage. Total program costs since 2009 have been $105 million with $47 million being spent on infrastructure and the remainder on property acquisition. Some 800 properties remain in the floodplain but are protected by certified levees. At present the city is protected against the 1:100 flood currently being used by FEMA (Zimmermann 2016).

The Buffalo–Red River Watershed District managed a project in Oakport Township (north of Moorhead) including acquisition and removal of a number of flood-prone structures, construction of a levee, and a water control structure in Oakport Slough. Nearly 450 homes are protected to 2009 flood level plus freeboard by a FEMA-certified levee. Sixty property buyouts were necessary on account of slope stability issues. The project cost was $37.5 million, almost all of which was provided by the state (DNR Waters, 2009). This area was annexed by the City of Moorhead in 2015. A project to provide flood protect for the gap between Oakport and the previously protected part of Moorhead is under development.

Fargo has carried out many projects since the 1997 flood and the 2009 flood of record. When all of the projects are complete the city and surrounding urban areas will be able to manage a flood like the 1997 flood with relatively little additional emergency flood protection. Among the projects completed are many miles of levees and floodwalls including an extension of the USACE 4th Street levee and construction of a floodwall to protect the Department of Veterans Affairs hospital. The 2nd Street downtown levee is under construction. Other flood damage mitigation measures that have been completed include the removal of up to 300 flood prone structures, relocation of lift stations, and preventing infiltration into the sanitary system. Over $100 million has been spent on various measures since 1997.

A feasibility study of flood risk management measures for the entire Fargo-Moorhead area began in September 2008. The federal feasibility study covered many structural and non-structural measures including diversions of different configurations and capacities. The plan that emerged from the study is a 20,000 cfs (566 m^3/s) diversion around the west side of Fargo. The 35-mile (56-km) long diversion would extend from Oxbow to Georgetown, have a bottom width of 300 ft. (91 m) and 7:1 side-slopes. The project includes three control structures and two aqueducts, as well as tie-back embankments. It would reduce the level of the 1:100 flood at Fargo by 10 ft. (3 m). The project has been authorized and federal funding of $450 million committed. Local governments' share of the project cost will be met through a sales tax. Part of the project will be constructed using a P3 model and part by the USACE. The estimated cost is $2.1 billion.

The entire city of St. Vincent, MN (across the Red River from Pembina, ND) is in the 100-year floodplain. The city has completed levee repairs and is completing geotechnical and design work on a proposal to raise and partially relocate an existing levee. It is estimated that an additional $2.5 million in state funding will be required to complete construction (DNR Waters 2009, Buffalo-Red River 2016).

A Natural Resources Conservation Service PL 83-566 project was completed for the city of Warren, MN on the Snake River. It consists of an upstream, off-channel impoundment, dikes, and a high flow diversion channel rerouting flood flows around the city, protecting 520 homes and businesses to at least the 100-year flood level (DNR Waters, 2009).

Since the 1997 flood, North Dakota has spent $291,444 on residential/farmstead ring dikes. The state provides a 50 percent share of the cost of such projects up to $40,000. Rural diking projects aimed at protecting individual land holdings have been completed in the Rush River, Walsh County, Richland County and Grand Forks County water resources districts in North Dakota. Renewed interest has been showed in the Maple River, Southeast Cass and Traill County water resources districts. Several communities along the Red River (including Pembina, Drayton, Grand Forks, Fargo, Briarwood, Oxbow, and Wahpeton) took advantage of Hazard Mitigation Grant Program funding following the 1997 flood to purchase and remove homes from the floodplain. The NRCS also was actively involved in funding the construction of farmstead ring dikes.

In Minnesota some $4.5 million has been made available on a 50 percent cost share basis for the construction of farmstead ring dikes. Construction of 265 rural ring dikes protects farmsteads, livestock, machinery and stored agricultural commodities. Since the 2009 flood there has been a renewed interest in farmstead ring dikes, particularly in the upper basin. Small-scale impoundment projects have been constructed in Minnesota. Some of those include the Agassiz Valley, North Ottawa, Brandt-Angus, Euclid East, Riverton Township, Manston Slough, Hay Creek-Norlund projects.

The USACE has completed construction of flood control projects at Cookston and Roseau, MN. A levee project designed by the USACE at Ada, MN is proceeding incrementally with support from the state. Additionally, there are a number of ecosystem restoration projects that have been completed through the Red River mediation process--North Ottawa impoundment, Aggasiz impoundment, and Hay Creek - that have incidental flood damage reduction benefits.

A flood risk management project is being designed for Grafton, ND and funding arrangements are being developed. The cost of a federal project at Drayton outweighs the benefits. Projects are ongoing to increase protection at Valley City and Lisbon, ND. There are also a number of emergency dikes in the United States that have not been certified as flood protection dikes for flood insurance purposes. Neche, ND is one such example, although engineering analysis is currently underway for that project.

Given the recent flooding history on the Red River, structural measures have provided enormous benefits. The levee project at Oslo, MN, for example, cost two million dollars in 1984 and has prevented thirty-one million dollars in damages since, not including the 2009 and subsequent floods. The Red River Floodway at Winnipeg has been estimated to have prevented $40 billion in flood damages since being placed in operation in 1968.

Non-Structural Measures. In its study of Red River flooding, the IJC observed that, unlike the United States, Canada has no continuing mitigation policies or programs. Since that time the Canadian Department of Public Safety has developed a National Disaster Mitigation Strategy (NDMS). The Public Safety Minister and provincial/territorial counterparts approved a National Mitigation Strategy in January 2008. The strategy commits the federal government to using the *Building Canada Fund* (BCF) to support structural mitigation and research. The BCF, administered by Infrastructure Canada, allocated $8.8 billion over seven years to infrastructure projects. The safe and strong communities component includes disaster mitigation. Mitigation projects therefore must compete with a host of other municipal infrastructure priorities. The only Canadian flood mitigation project to receive funding from this program was the Red River Floodway expansion.

A key element of non-structural approaches to floodplain management is the definition of a regulatory floodplain and the institution of regulations for the occupancy of that floodplain. In Manitoba the designated flood area in the Red River valley south of Winnipeg was legislated as that inundated by the 1997 flood. A designated flood area north of the city was instituted following the ice jam problems associated with the 2009 flood. More recently, Manitoba has adopted a province-wide criterion of the 200-year flood as the regulatory flood. The safe building elevation adds 0.6 m (two feet) of freeboard as was the case with previous regulatory floods. In North Dakota and Minnesota the regulatory floodplain is that of the 100-year flood, plus one foot (0.3 m) of freeboard for residential structures.

The 1:100-year flood is considered a reasonable minimum regulatory flood in both the United States and Canada. In its review of the 1997 flood the IJC observed that it would be useful to define a larger flood, the 1:500 flood, and use that flood to assist in locating critical facilities such as schools and hospitals. The 1:500 year flood has been defined for the Red River mainstem, but the water surface elevations and flooded areas pertaining to that flood are not as well known to basin residents as those pertaining to the 1:100 flood.

All jurisdictions have removed at least some severely at-risk structures from the floodplain. Minnesota is committed to acquiring and removing flood damaged or flood prone structures from the floodplain and to protecting remaining structures. Sixty-three of the most vulnerable structures in Manitoba south of Winnipeg were purchased from owners and removed from high hazard areas. Following the ice jam floods north of Winnipeg in 2009, some 200 flood-prone properties were identified as potential buy-out candidates (Free Press, 2009). About 60 of these were purchased.

The USACE is developing a HEC-RAS one-dimensional hydrodynamic model of the Red River mainstem from the headwaters to the international boundary. The model extends up each tributary in the United States to the first USGS gaging station. A HEC-HMS hydrologic model has also been developed for each tributary. The model has been used by the Red River Basin Commission and local boards to examine flow retention strategies.

Under a federal-provincial agreement, a more complex unsteady flow model was developed by the Canadian National Research Council to examine wind set-up and wave uprush in the 'Red Sea' – the 40-km (25-mile) wide floodplain south of Winnipeg. The Telemac-2D model extends from the international boundary to Winnipeg. It was used to calculate the effects of wind and waves at the Red River Floodway inlet control structure and the effects of existing dikes on local water levels. Another Telemac 2-D model was developed with IJC funding and is now being applied to the lower Pembina River basin from Walhalla to the Red River to study the flooding problems in that area.

These models may be used for planning studies for flood control projects. The effects of tributary storage on mainstem flood levels is another application. Such models allow an analysis of tributary peak timing on mainstem water levels, analysis of the effects of various structural measures such as dikes on local water levels, and a determination of the increase in water levels due to encroachment on the floodplain by, for example, fill for residential construction.

Response/Recovery

Response involves the coordinated actions taken during or immediately following a flood when people may have been injured or lives lost, major damage has occurred to public and private property, and essential utilities and supply sources are disrupted. Emergency response takes place at the level appropriate to the emergency. The first line of response is local government, then state/provincial, then federal. Response/recovery recommendations are shown below.

IJC Conclusions	IJC Recommendations	TF Recommendations
	15	25

Following a disaster, the recovery phase attempts to restore all systems to normal or near normal condition. Long-term recovery from a disaster may go on for years until the entire disaster area is completely redeveloped; either as it was in the past or for entirely new purposes that are less vulnerable to disaster. The cornerstone of the recovery process is disaster financial assistance. This alleviates an unreasonable financial burden and is generally provided to help local governments, individuals, full-time farmers, small businesses and some non-profit organizations. There is, off course, a human cost in all disasters and the focus of any recovery program must be to promote community resiliency so that individuals and communities are better able to cope with the next disaster.

For the most part, government agencies charged with response and recovery, have not made major changes as a direct result of the 1997 flood. The emergency plans developed in the years following the 1997 flood have enabled more timely and coordinated responses to disasters. Efforts have been made to deliver financial assistance in a more timely fashion.

The 2008 *Canada-United States Agreement on Cooperation in Comprehensive Civil Emergency Planning and Management* provides a framework for joint response to civil emergencies. Previously, in 2000, an *International Emergency Assistance Memorandum of Understanding* was signed. Other transboundary arrangements followed and, in 2013, the U.S. Congress ratified the *State and Province Emergency Management Assistance Memorandum of Agreement.* This in turn led to the creation in the same year of the *Northern Emergency Management Assistance Compact* (NEMAC) of which Manitoba, North Dakota and Minnesota as well as other northern states and provinces are members.

With the development of NEMAC there is a provision for the possibility of mutual assistance in the Red River basin in managing any emergency or disaster, whether arising from natural disaster, technological hazard, manmade disaster, or civil emergency aspects of resources shortages. The preparation of a NEMAC strategic plan is underway.

Environment

Some IJC and Task Force recommendations apply specifically to the environment. These may also have a bearing on public health and well-being. The recommendations are shown below.

IJC Conclusions	IJC Recommendations	TF Recommendations
4	23	32, 34

Lake Traverse. The risk of biota transfer through the hydraulic connection between the Little Minnesota River and Red River systems at Lake Traverse continues. This is a natural connection between the Hudson Bay and Mississippi basins. The USACE dam safety reconnaissance study for the White Rock Dam, which controls the pool elevation of Lake Traverse during large flood events, has considered the potential for inter-basin flows. Although this is a high priority item from a transboundary perspective, there has been little recent activity. Resolution of the problem is linked to flood control measures for Browns Valley, MN (DNR 2007).

Groundwater. The IJC identified a problem with the contamination of groundwater wells in Manitoba. Since the 1997 flood, an inventory of active and abandoned wells in Manitoba was completed and the wells subject to surface flooding were sealed. Minnesota and North Dakota had regulations concerning abandoned wells in place prior to 1997 (Scherer and Johnson, 2007).

Hazardous Goods. Storage of hazardous goods, even banned substances, in the floodplain was another issue of concern after the 1997 flood. Manitoba does not regulate storage in floodplains. Instead setback distances are contained in Environment Act licences where applicable. Setback distances are contained in codes of practice for various hazardous materials such as fertilizer or petroleum products and these codes of practice are referred to in the appropriate licence.

Prior to the 1997 flood Manitoba based its regulations concerning dikes around sewage lagoons and other hazards on a previously-defined 1:100 flood. The regulations are now based on the 1:200 flood.

The ND Division of Emergency Services (DES) requires yearly reporting to inventory hazardous and toxic chemicals stored across the state. The state does not regulate storage on floodplains but requires a common sense approach. DES has coordinated with ND Department of Agriculture to hold periodic collection and disposal efforts for banned and obsolete chemicals in flood-prone areas under Project Safe Send. Some 91,000 lbs. (40 tonnes) of chemicals were collected in the months following the 1997 flood. A brochure has also been produced on flood-proofing above-ground storage tanks.

The MN Department of Agriculture regulates bulk storage of pesticides and fertilizers. Although the regulations do not contain specific prohibitions or requirements concerning floodplains they do contain requirements relating to surface water runoff protection and containment. The approach of the Minnesota Pollution Control Agency to regulating bulk fuels and lubricants, certain industrial facilities and hazardous waste is similar. The requirements of both these agencies do not generally apply to individual farms.

Lake Winnipeg. The 1997 flood led to a significant loading of nutrients into Lake Winnipeg (Stewart *et al.* 2000). Several programs are aimed at improving scientific understanding of Lake Winnipeg and to reducing nutrient loadings to the lake. In 2003 Manitoba announced a plan to reduce nitrogen and phosphorous loads to Lake Winnipeg to pre-1970s levels. The plan is aimed at protecting riparian growth along the Red and Assiniboine rivers, ensuring appropriate fertilizer application, introducing new effluent regulations, reducing shoreline erosion on Lake Winnipeg, and engaging other jurisdictions in Lake Winnipeg nutrient management. The Province of Manitoba launched the *Save Lake Winnipeg Act* in 2011 and has invested over $100 million in efforts to improve the health of the lake. As a federal contribution to meeting the challenges to the sustainability of Lake Winnipeg ecosystems, $18 million has been allocated to Phase II of the Lake Winnipeg Basin Initiative over the period 2012-2017. Through federal-provincial mechanisms, federal funding will be directed to reduction of harmful algal blooms, improved recreational water quality, restoration of the ecological integrity of Lake Winnipeg, and a sustainable fishery. Federal funding will support research, information and monitoring, and facilitate governance and stewardship (Canada-Manitoba 2011).

In 2014 a Lake Friendly Accord aimed at reducing nutrient loads to Lake Winnipeg was signed by the governments of Canada and Manitoba and by Lake Winnipeg South Basin mayors and reeves. The accord has subsequently been signed by Minnesota, North Dakota and the Red River Basin Commission. The Lake Friendly Stewards Alliance was created as a means of creating additional collaboration on solutions.

During the 1997 flood, a quantity of a banned substance, toxaphene, was released from storage. Manitoba Water Stewardship (now Manitoba Sustainable Development) in partnership with Fisheries and Oceans Canada monitored toxaphene concentrations in

fish tissue for Lake Winnipeg for a number of years. Concentrations have declined since 2002 and have fallen below Manitoba Water Quality Standards, Objectives and Guidelines for both human and wildlife consumers. Monitoring for toxaphene was suspended in 2007.

Riparian Zones. The IFMI process led to a renewed interest in preserving and enhancing riparian zones. Several developments throughout the basin are pertinent. The Greenway on the Red Inc. has been organized to "promote the development of a greenway system on the Red River of the North and its tributaries that mitigates floods and protects people through education and partnerships that enhance the economy, environment and communities of the Red River basin."

Greenway on the Red Inc. is a multi-state and international effort to establish a greenway from Lake Traverse to Lake Winnipeg. The Canadian partner is Rivers West, a Manitoba organization aimed at conserving natural, cultural and heritage resources. The entire Red River in Canada became part of the Canadian Heritage Rivers System in 2007 (Hilderman, Thomas, Frank, Cram, 2005).

The greenway concept would provide multiple on-the-ground benefits through riparian restoration; water quality enhancement; farmer/landowner incentives; community strengthening; and increased recreation, tourism, and economic development. Winnipeg has an on-going program to acquire riverbank property for greenway and park purposes. This sometimes involves the removal of structures (houses and businesses) from the floodplain.

Examples are greenway development in Grand Forks and East Grand Forks, proposals for considerable urban park development along the Red River Floodway at Winnipeg, and the interest in set-back levees for the lower Pembina River. The Dean C. Hildebrand Wildlife Management Area located on the Red River near Drayton provides two miles (three kilometres) of shoreline habitat management. In recent years there has been relatively few additional greenway developments.

The USACE is pursuing several environmental and flood damage reduction projects that protect or enhance the floodplain environment. These include fish passage over existing dams on the Red River and several tributaries; partial restoration of hydrological and floodplain conditions along the lower reaches of Hay Creek in Roseau County; establishment of an urban greenway with the construction of the Grand Forks/East Grand Forks flood control project; and the restoration/ enhancement of floodplain functions along 15 miles (24 km) of the Wild Rice River below Ada through the setback of existing agricultural protection levees and re-meandering of the channelized river.

The Red River Basin Commission has assisted various groups in Minnesota and North Dakota in developing a Red River Conservation Reserve Enhancement Program (CREP). Measures such as buffer strips, wetland restoration, river corridor restoration and setback levees are contemplated. Minnesota has applied these types of programs more than North Dakota.

The Minnesota Mediation Agreement, signed December 9, 1998, is the product of eight months of consensus-based, mediated negotiations by the Red River Basin Flood Damage Reduction Work Group. The agreement is intended as the framework for a new, collaborative approach to implementing both flood damage reduction and natural resource protection and enhancement in the Red River basin in ways that will benefit all Minnesota's citizens. The keys to this new approach are clearly identified goals related to both prevention and reduction of damage, comprehensive watershed planning, early consultation and collaboration on flood damage reduction projects among stakeholders, and a cooperative approach to state-level permitting of those projects.

The Red River Basin Riparian Project, funded by a USEPA grant in 1993, is a land management and water quality project that seeks to improve riparian areas through influencing land management decisions. Eight demonstration sites were established in the basin. Manitoba offers tax reduction measures for landowners in riparian zones as a water quality improvement measure aimed at reducing agricultural runoff.

The Louisville/Parnell Impoundment project in the Red Lake Watershed District controls breakout flows and assists wetland restoration. The project consists of an earthfill structure and three wetlands units.

Winnipeg's standard tender document requires adherence to specified environmental protection measures, as well as best management practices for such things as fuel handling and storage, waste handling and disposal, dangerous goods, emergency spill response, protection of trees, sediment control, etc. Re-vegetation of riverbank and construction of pool and rifle structures on streams are two examples of the types of "compensation" works. These are undertaken to meet the requirements of the federal Department of Fisheries and Oceans (DFO) for flood protection works and associated riverbank works that are considered as "harmful alteration, disruption or destruction of fish habitat".

CURRENT STATUS, CHALLENGES AND VULNERABILITIES

Almost 20 years after the 1997 flood it is evident that much has been accomplished to increase awareness of flood threats in the basin, determine specific flood risks, and mitigate the effects of large floods. This section of the report will provide a status report on each of the IJC Recommendations. It will then go on to discuss the remaining challenges and vulnerabilities.

Status of Recommendations

The IJC made 28 recommendations to governments in *Living with the Red* and endorsed and did not restate a further 30 Task Force Recommendations. In framing its recommendations the IJC stated not only what should be done but also who should do it, and sometimes when it should be done. The IJC also drew seven Conclusions and

endorsed a further two Conclusions by the Task Force. All of these have been accepted, some with qualifications, and the status of that acceptance has not changed.

Making an overall determination of progress on some recommendations is also confounded by, in some cases, differing achievements in each country. A five-point scale has been used to identify progress. The scale used in defining progress on the recommendations is as follows:

- Superseded. This applies to a few recommendations that have been overtaken by events or otherwise no longer relevant and are no longer being pursued.
- Little or No Progress. This applies to cases where a required policy decision does not appear to have been made, where no discernable progress has been reported, or perhaps where meetings have been held but to little effect.
- Some Progress. This applies where there has been activity to meet the recommendation but significant impediments remain before the recommendations can be completed. This includes cases where policies directions are clear but where substantial financial impediments remain.
- Significant Progress. This applies where the completion of the recommendation can be reasonably foreseen.
- Complete. The recommendation appears to have been accepted and implementation is essentially complete. In cases where completion is immanent a completion year is given.
- Ongoing. The recommendation will live forever and is being pursued.

Table 2 summarizes the progress on the IJC recommendations, while Figure 1 illustrates the progress. Each recommendation is covered in more detail in Appendix Two. Needless to say the status represents a value judgment by this writer.

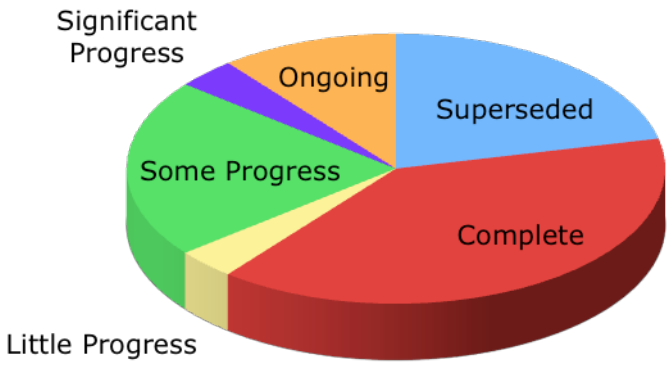

Figure 1. Status of IJC Recommendations.

Table 2. Status of IJC Recommendations

Recommendations from IJC Report		Status
1	The federal governments should convene a meeting of senior federal, provincial and state officials in 2002 to undertake policy discussions and an examination of the 1997 flood, with emphasis on review of emergency plans, evacuation procedures and mitigation measures underway.	Super-seded
2	The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.	Complete
3	The city, province and the Canadian federal government should cooperatively develop and finance a long-term flood protection plan for the city that fully considers all social, environmental and human effects of any proposed flood protection measures and respects both the needs of Winnipeg and the interests of those outside the city who might be affected by such a plan.	Complete
4	The government of the United States, in cooperation with the cities of Fargo and Moorhead and the states of North Dakota and Minnesota, should expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo–Moorhead area.	Signif. Progress
5	The government of the United States, in cooperation with the cities of Grand Forks and East Grand Forks and the states of North Dakota and	Complete

Recommendations from IJC Report		Status
	Minnesota, should ensure that the planned flood protection works are promptly and expeditiously completed.	
6	The government of the United States, in cooperation with the cities of Wahpeton and Breckenridge and the states of North Dakota and Minnesota, should expedite approval and implementation of flood protection plans to reduce the risk of flooding at Wahpeton–Breckenridge.	Complete
7	The province of Manitoba and city of Selkirk should expedite studies of flood-risk potential in the Selkirk area.	Complete
8	To improve resiliency in the basin, governments should support enhanced research into the various social dimensions of the flood, including economic, psychological, public health and sociological impacts.	Little Progress
9	Governments at all levels should ensure that in the development of flood mitigation strategies for the basin the needs of small communities, individual isolated farmsteads and agriculture are not overlooked.	Complete
10	Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide necessary resources for the group, and act to achieve a solution.	Some Progress
11	Governments should develop a binational integrated approach to mitigation initiatives at all political levels, based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the overall national framework.	Some Progress
12	The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.	Some Progress
13	Governments should use, at a minimum, the 100-year (1 percent) flood as the basis for floodplain regulations and revise their estimates of the 100-year flood levels based on 1997 and new data that become available.	Complete
14	State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.	Ongoing
15	Within the current context of Canada–United States cooperation for civil emergency planning and management, governments should develop more detailed bilateral emergency planning and management arrangements with specific adaptations to Red River flooding.	Complete
16	Development of the digital elevation model for the Red River basin, with high resolution in appropriate high flood risk areas, should be pursued and completed through collaborative initiatives of federal, state, provincial and local governments.	Complete
17	Federal, state and provincial governments should develop and implement a binational agreement to establish an appropriate network of hydrological and meteorological stations and data exchange for floodplain management and flood forecasting in the Red River basin.	Super-seded

18	The governments should authorize the Commission to establish a binational Red River Flood Forecasting Liaison Committee under the International Red River Board to improve interjurisdictional coordination and to help ensure that clear, understandable and compatible forecasts are issued to the public.	Super-seded
19	As a long term priority, government agencies responsible for flood-forecasting and mitigation measures should develop basin-wide models rather than separate but coordinated models for each country.	Super-ceded
20	The Canadian government should review its data and information management policies to ensure that topographic, hydrometeorological, and other flood related data collected under government programs are made available without restrictions or conditions that limit their accessibility.	Complete
21	Governments should ensure that progress continues in building a binational, virtual network linking the people, data, and models for the Red River basin.	Super-seded
22	Federal, state, and provincial governments should work with basin organizations to complete in a timely manner the development of a prototype decision support system and establish a cooperative mechanism for coordination and funding its further development and implementation.	Super-ceded
23	Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from the Red River basin. Governments should also ensure that potentially hazardous materials are not stored in the 500-year floodplain, although reasonable quantities of such substances could be maintained in the floodplain for immediate use.	Some Progress
24	Flood protection projects focus not only on reduction of flood damage but also on protection and enhancement of the floodplain environment.	Some Progress
25	Governments immediately take steps, on a binational basis, to begin development of a comprehensive flood damage reduction plan for the Red River basin.	Some Progress
26	Governments at all levels should undertake the following measures: [eight items]	Ongoing
27	Governments should assign the following functions to the International Joint Commission for implementation by the International Red River Board: [eleven items]	Complete
28	The federal governments, in cooperation with the state and provincial governments should work with the Commission and its International Red River Board, as well as with existing and emerging bilateral organizations, to ensure that appropriate arrangements are in place to coordinate and implement measures for flood preparedness and mitigation activities and to implement recommendations of the Commission.	Ongoing

In several cases the IJC endorsed recommendations from its Task Force without re-stating them. The status of these recommendations is shown in Table 3 and illustrated in Figure 2. Each is discussed in more detail in Appendix Two.

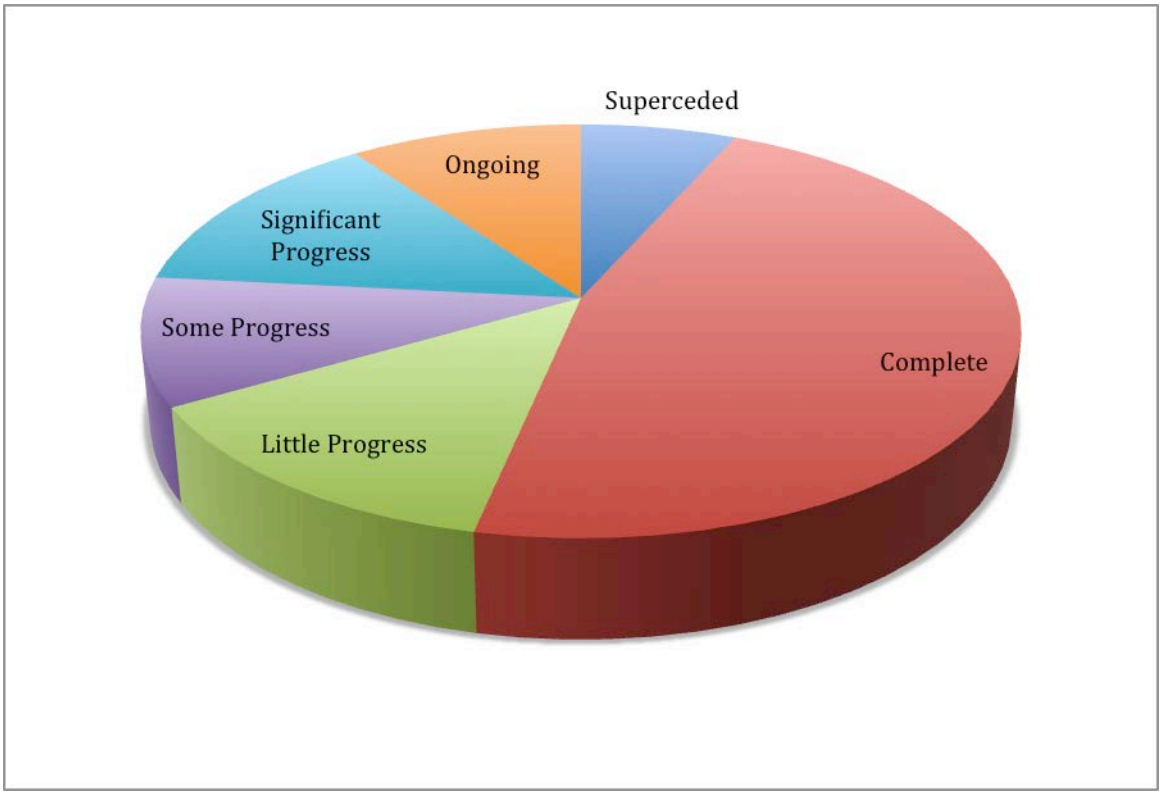

Figure 2. Status of Task Force Recommendations Endorsed by the IJC.

Table 3. Status of Task Force Recommendations Endorsed by the IJC.

Recommendations from IJC Task Force		Status
2	Future ice jam information from the entire basin should be incorporated into the CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.	Little Progress
3	Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program.	Complete
5	Based on results from hydraulic model studies, modify the east embankment of the Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity.	Complete
6	The west dike should be raised to allow a water level elevation of 778 feet at the Floodway inlet structure with appropriate freeboard.	Complete
7	The primary diking system should be raised where economically feasible to the elevation specified in existing legislation.	Signif. Progress
10	Modifications to the sewer and land drainage systems should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.	Signif. Progress

Recommendations from IJC Task Force		Status
11	The city of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual.	Complete
12	Operating rules for new flood control measures should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules.	Signif. Progress
15	The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and floodproofing critical facilities.	Some Progress
16	Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas.	Complete
17	The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.	Little Progress
18	Federal, state, provincial and local governments in the Red River basin, in conjunction with the private sector, should continue to develop, refine and implement effective strategies to improve the disaster resiliency in both communities. Efforts should be made to increase public awareness of flood risks throughout the basin.	Ongoing
21	The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.	Little Progress
25	Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding.	Some Progress
26	Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin.	Little Progress
28	Given the transboundary nature of the basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process as well	Some Progress
29	Changes in the road network and diking system in the Lower Pembina Basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences.	Complete
30	The virtual database and decision support system prototype that the Task Force has begun to develop for the Pembina Basin should be continued by relevant agencies in Canada and the United States.	Super-seded
32	Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.	Ongoing
34	Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels.	Complete

Recommendations from IJC Task Force		Status
35	Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods.	Ongoing
36	New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988.	Complete
37	For consistency and accuracy data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and reported along with the data.	Complete
38	U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts in the year 2000 to discuss Red River basin datum issues and develop a long-term transition plan.	Super-ceded
39	All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modelling activities.	Complete
40	Data providers should remain responsible for maintaining and replicating the data sets.	Complete
44	The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority.	Complete
46	Confirm the flood peak reduction findings of Chapter 3 for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mistinka, Wild Rice and Maple Rivers.	Complete
48	Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models.	Complete
50	Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available.	Signif. Progress

As can be appreciated from Tables 2 and 3, there has been significant attention paid to implementing the recommendations to governments made by the IJC. The expenditures since the 1997 flood exceed one billion dollars on flood mitigation works alone. Additional expenditures continue be made. No recommendations have been formally rejected but some have been overtaken by events or essentially ignored.

Table 4 illustrates the change in the status of recommendations in the last eight years. The largest change over that period was in completed Task Force recommendations. This success is less important than one might assume as much of the change can be attributed to a single albeit, important, decision. That is, a decision in Canada to adopt a new gravity-based vertical datum. Also, given that almost 20 years have passed since the 1997, it now seems appropriate to label a few more recommendations as ongoing tasks.

Table 4. Status of Recommendations

Status	IJC Recommendations		Task Force Recommendations	
	2008	2016	2008	2016
Superseded	4	6	1	2
Complete	7	11	6	14
Little Progress	3	1	4	4
Some Progress	8	6	10	3
Significant Progress	4	1	9	4
Ongoing	2	3		3

The recommendations that have achieved the most success are those that involve construction of a structural measure identified in the IJC report, even if that work requires collaboration at the federal, state or province, and local level. A second group of successful recommendations relate to specific recommendations aimed at a specific agency. Resolution of the Canadian vertical datum issue is an example. A third group of recommendations are those regarding binational approaches to resolving Red River flooding issues. These are complex and difficult and will be discussed in the following section.

Challenges and Vulnerabilities

Based on the effects of the 2011 flood it is clear that the mainstem communities and individual farmsteads of the Red River basin are able to withstand a very significant flood without extensive damage. Flood protection at Fargo remains to be completed and some very small communities do not have economically feasible structural measures. During a major flood there will still be interruptions in business on account of transportation and other disruptions, agricultural losses still take place, and the cost of preparing for very large floods remains significant. Even in those instances, developments such as raising two lanes of PTH 75 between Winnipeg and Emerson MB and improvements to bridge crossings mean that transportation connectivity during a major flood has improved. In effect the basin has been ‘hardened’ to withstand the 1997 flood or, in the cases where 1:100 year flood is larger than the 1997 event, the 1:100 flood. This is a remarkable achievement, but could more be accomplished?

The ultimate goal of floodplain management in the Red River basin must be to make the people, infrastructure and institutions of the basin as resilient as possible in the face of damaging floods. One certainty is that, at some time in the future, the basin will experience a flood that is larger than the present-day 1:100 year flood. Such a flood could take place on the mainstem or on one or more tributaries. In addition, climate change could magnify present-day variability and could lead to increased ice jam floods, either in the spring or fall, and to summer rain-driven floods. Preparing for previous floods is wise, but may be insufficient.

The City of Winnipeg could be taken as an example. Although the 2011 flood on the Red River posed little threat, record high flows in the Assiniboine River and Souris River led to a significant threat, one that challenged flood operations in the city.

It will take considerable effort to achieve the level of integration and cohesion on flood management that the IJC envisaged. This integration is difficult because individual agencies are confined by their mandates. Processes akin to the IFMI process but dealing with a short list of issues could be required (IFMI, 2000). Significant interagency and intergovernmental cooperation will be needed. It is fortunate that residents of the basin and their political leaders are still seized by the flooding issue. If the Red River basin experiences a decade or more in which no serious flooding occurs, flood preparedness could decline in favour of other priorities.

The IJC recommendations that have achieved relatively little success are those that involve multiple agencies and, perhaps, multiple objectives. It could be that these sorts of tasks could be deemed to be more difficult and could naturally be expected to take longer. It could also be said that public expectations for structural measures override all other post-flood needs and that those expectations being largely met, there is little interest in proceeding with "softer" projects.

At this juncture, one could argue that some IJC recommendations have been overtaken by events and focusing on the recommendations as a way forward would not be the most productive means of achieving flood resiliency in the Red River basin. As an example, there are a number of IJC recommendations aimed at improving data availability and hydraulic model development in the basin. These were drafted at a time when lidar information was rare and expensive, Canada had ridiculous policies on making taxpayer-funded data available to users, and two-dimensional hydrodynamic models ran more slowly than real time. Currently modellers have the capacity to deal in terabytes of data, lidar and other large datasets are ubiquitous, and computer capacity has grown enormously. Modelling challenges remain, but they are not the same challenges of 20 years ago. The suite of recommendations related to modelling and decision support are therefore not as relevant as they were when they were originally drafted.

Despite the progress on meeting the spirit, if not the letter, of the IJC recommendations some items that are worthy of attention remain and other matters have arisen. Tables 5 and 6 identify those recommendations where the IJC and its IRRB should continue to be engaged.

Table 5. IJC Recommendations Requiring Continued Attention.

Recommendations from IJC Report		Status
4	The government of the United States, in cooperation with the cities of Fargo and Moorhead and the states of North Dakota and Minnesota, should expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo–Moorhead area.	Signif. Progress
8	To improve resiliency in the basin, governments should support enhanced research into the various social dimensions of the flood, including economic, psychological, public health and sociological impacts.	Little Progress
10	Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide necessary resources for the group, and act to achieve a solution.	Some Progress
12	The Canadian federal government should establish a national flood mitigation strategy, or a broader natural disaster mitigation strategy, and support it with comprehensive mitigation programs.	Some Progress
26	Governments at all levels should undertake the following measures: a. Develop and implement comprehensive, multi-faceted plans for concurrently reducing flood damage and protecting and enhancing the natural environment; b. Ensure ongoing institutional support and full multi-jurisdictional participation in further development and maintenance of the Task Force's legacy products; c. Implement the Commission and Task Force recommendations designed to ensure basin-wide flood preparedness and community resiliency; d. Promote a culture of flood preparedness and flood resiliency in the basin; e. Enhance technology and monitoring systems to provide early warnings and early action in the face of impending major floods; f. Ensure binational coordination of flood forecasting and communications of forecasts to the public; g. Provide opportunities for multi-jurisdictional problem solving and the exchange of best practices information; and h. Integrate floodplain management activities into the broader field of watershed and basin management.	Ongoing

As indicated earlier in this report, flood protection measures for Fargo and Moorhead are in the process of being implemented. The IRRB should continue to report on progress to the IJC.

While there is a considerable body of knowledge related to human dimensions of natural disasters, very little research that is specific to the Red River basin has been carried out. For the most part Red River floods are slow to rise and slow to recede. The human response to flooding can be different from that related to sudden onset events. Understanding the human dimensions of Red River flooding could lead to improvements

in both response and recovery. Agencies represented on the IRRB could facilitate such research.

The IJC should continue to devote attention to the resolution of the long-standing lower Pembina River flooding issue. In general, because of the transboundary nature of the Pembina and Roseau rivers, any matters pertaining to these tributaries are fundamental to the work of the IRRB and to the IJC itself. At present the IJC's data harmonization project and the modelling work carried out in recent years allow any scenario that could lead to a resolution of the problem to be examined in detail. One cautionary note is that any solution may be effective in some but not all years. The IJC should continue to use its good offices to support a solution to this long-standing problem.

One particular impediment to a resolution is the advent of lawsuits among various jurisdictions. Lawsuits tend to inhibit the free exchange of information and have a profound effect on the ability or willingness of parties to reach consensus on a course of action that could resolve the issue in question.

While the Canadian federal government is working towards a national disaster mitigation strategy, it has been slow to fund structural and non-structural mitigation programs. The inclusion of monies in the 2017 federal budget specifically directed to disaster mitigation is therefore welcome.

Recommendation 26 commends eight wide-ranging activities to governments, several of which are covered, at least in part, in other recommendations. Two of these relate directly to flood forecasting. Flood forecasting is another area where significant improvements have been made immediately following the 1997 flood but where more work is needed. Forecasting in the Red River basin requires a cumulative hydrological understanding incorporating antecedent precipitation, blowing snow, snow accumulation, infiltration into frozen soils, spring energetics, spring precipitation, and fill and spill mechanisms. A failure in understanding any one of these processes will lead to forecast failure.

Forecasting is transitioning from using point data to using spatial data. The existence of high quality lidar data in the Red River valley has led to a much enhanced capacity to predict flood extent. The use of remotely sensed data, such as snow water content from natural gamma measurements has a long history in the Red River basin. Currently several satellite-based platforms can provide measures of snow water equivalent or soil moisture, for example Wang and Russell (2016). As well, NOAA's Snow Data Assimilation System (SNODAS) provides best possible estimates of snow cover and related variables. Developing these opportunities could lead to significant forecast improvements.

The floods of 2009 and 2011 indicated that there are still issues related to flood forecasting that could be examined. The 2009 flood, which was the second largest in the instrumental record for much of the basin and a record flood at Fargo-Moorhead, served two purposes. First, it enabled agencies and individuals to evaluate the degree to which measures taken following the 1997 flood achieved their objectives. In general one can say that these measures have been successful. Second, every flood has its own unique

characteristics. The 2009 flood helped illuminate areas where more work is needed, such as ice jamming (Lindenscmidt K-E *et al.* 2011). The spatial extent and duration of the 2011 flood, again, brought different challenges.

A further flood forecasting challenge relates to summer flooding. For decades flooding in the Red River basin has been associated with spring runoff. Since about the mid-1990s, however, summer floods have become more common. The heavy soils of the basin tend to retain moisture and when that moisture is augmented by a series of heavy summer rains flooding can ensue. Forecasting a rapid onset rain-driven flood presents quite different challenges for forecasters.

Climate change may also lead to increased frequency of freeze-up ice jams. Again forecasting methodology requires improvements to handle such jams.

Another worthy area of activity relates to data visualization, in many fields, not just flood forecasting. In the era of big data, data visualization methodologies provide an enormous opportunity to assist both water resources professionals, and non-professionals in the general public.

Table 6. Task Force Recommendations Requiring Further Attention.

2	Future ice jam information from the entire basin should be incorporated into the USACE CRREL Ice Jam data base so that ice jam problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.	Little Progress
15	The 500-year flood should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis for siting and flood-proofing critical facilities.	Some Progress
17	The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.	Little Progress
21	The Canadian federal government should include in the Disaster Financial Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.	Little Progress
26	Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin.	Little Progress
32	Any modification to existing operating plans or physical structure related to Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.	Ongoing

Incorporation of information related to ice jams in the USACE Cold Regions Research and Engineering Laboratory (CRREL) database represents an opportunity for the Red River basin. There is a likelihood that ice jam flooding will increase with climate change.

Providing information that may assist researchers in the future may be useful in managing ice jam floods in the basin.

The 500-year flood has been defined throughout the basin. While information concerning the basic regulatory flood, 1:100 in the United States and 1:200 in Manitoba, is widely available, this does not appear to be the case for the 1:500 flood. Providing information on this larger flood could promote long-term resilience. It could be noted that even extreme events do occur. The 2011 flood on the Souris River was roughly a 1:500 event.

The lack of flood-proofing information in Canadian building codes leads to increased flood damages. Improvements to the national model code would be a good first step to resolving this problem. The IJC, ECCC and the province of Manitoba could use their good offices to support this change.

In general, the Canadian Disaster Financial Assistance Arrangements encourage the reconstruction of flood-damaged structures, even in the case of repetitive flooding. Permitting property buy-outs would lead to more appropriate uses of vulnerable floodplain lands.

Flood resilience tends to be a theoretical concept but some attempts are being made to operationalize it. For an example see Szoenyi *et al.* (2016). The key message is to develop resilience before an event takes place. The IRRB or perhaps the RRBC may wish to actively pursue resilience measures in the Red River Basin.

Finally, the level terrain and low slope of the Red River valley mean that opportunities for biota transfer exist between the Gulf of Mexico and Hudson Bay basins near Lake Traverse. A continuing challenge will be to minimize that risk, especially when modifications to structures are undertaken.

In the last 20 years there has been an enormous increase in tile drainage in the Red River basin. While tile drainage has unquestionable effects on crop yield and water quality, the effects of tile drainage on flooding are complex, sub-basin specific, and vary with soil type. It is unlikely that tile drainage has any effect on large floods in the Red River basin but may have an influence, positive or negative on smaller floods.

The Red River Basin Commission has recently updated its *Long Term Flood Solutions* report and the U.S. Army Corps of Engineers is working on a *Comprehensive Watershed Management Plan* that will include flooding issues. Today these are likely to be more relevant to the contemporary basin than the IJC recommendations contained in *Living with the Red*. In the future it is important that the IJC and its IRRB continue to assist in seeking a solution to the lower Pembina issue. In addition the IRRB should monitor developments pertaining to Fargo-Moorhead flood protection. Other recommendations in *Living with the Red* could be deemed to be concluded.

The apocryphal quote that the Red River basin has two problems, "too much water and too little" has a firm foundation in reality. In attempting to deal with concerns related to

flooding, it is important to determine the consequences of any proposed measures during times of drought. Integrated water resources management should be the overarching goal for the basin.

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APPENDIX ONE

Acronyms and Abbreviations

AHPS	Automated Hydrologic Prediction System (USNWS)
BCF	Building Canada Fund
CoCoRaHS	Community Collaborative Rain, Hail and Snow Network
CD-ROM	Compact Disk - Read Only Memory
CRREL	Cold Regions Research and Engineering Laboratory
CREP	Conservation Reserve Enhancement Program
DEM	Digital Elevation Model
DES	Division of Emergency Services (North Dakota)
DFA	Designated Flood Area (Manitoba)
DFO	Department of Fisheries and Oceans (Canada)
ECCC	Environment and Climate Change Canada (formerly Environment Canada)
EERC	Energy & Environmental Research Center (UND)
FEMA	Federal Emergency Management Agency (United States)
FGDC	Federal Geographic Data Committee (United States)
GPS	Global Positioning System
GRT	Greenway on the Red Trust
IFMI	International Flood Mitigation Initiative
IJC	International Joint Commission
IRRB	International Red River Board (IJC)
IRRBTF	International Red River Basin Task Force (IJC)
IWI	International Water Institute (Tri-colleges)
JEPP	Joint Emergency Preparedness Program (Canada)
Lidar	**Li**ght **d**etection **a**nd **r**anging
MB	Manitoba
MEMO	Manitoba Emergency Measures Organization
MN	Minnesota
ND	North Dakota
NDMS	National Disaster Mitigation Strategy (Canada)
NOAA	National Oceanic and Atmospheric Administration (United States)
NRCS	Natural Resources Conservation Service (United States)
PRBAB	Pembina River Basin Advisory Board
PFRA	Prairie Farm Rehabilitation Administration (Canada)
PREMAC	Prairie Region Emergency Management Advisory Committee
PSC	Public Safety Canada
RM	Rural Municipality (Manitoba)
RRBB	Red River Basin Board (now RRBC)
RRBC	Red River Basin Commission
RRBDIN	Red River Basin Disaster Information Network
RRWRC	Red River Water Resources Council (now RRBC)
SNOTEL	SNOw TELemetry
TIC	The International Coalition (now RRBC)

UNET	Unsteady NETwork
US	United States of America
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USNWS	United States National Weather Service
WET	Water Education for Teachers

APPENDIX TWO

Status of IJC Recommendations

IJC Recommendation 1: Senior Officials Meeting		
The federal governments should convene a meeting of senior federal, provincial and state officials in 2002 to undertake policy discussions and an examination of the 1997 flood, with emphasis on review of emergency plans, evacuation procedures and mitigation measures underway.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: While the governments have been responsive to many IJC recommendations, there is still a need for additional cross-border co-ordination and co-operation on matters such as data enhancement and model development. A senior officials meeting was seen as one step in this process.		
Progress to Date: No single meeting of senior officials was held. One outcome from the International Flood Mitigation Initiative process was to draw governors of Minnesota and North Dakota together with the premier of Manitoba to discuss matters pertaining to flooding. This led to the signing of a Memorandum of Understanding in November 2000. The RRBC has organized further meetings of senior elected officials from the three jurisdictions. In April 2004 the governors of North Dakota, Minnesota, and South Dakota, and the premier of Manitoba signed a Memorandum of Understanding for Flood and Drought Mitigation on the Red River.		
Related Recommendations:		
References: IFMI 2000. *International Flood Mitigation Initiative for the Red River Basin.* Final Report and Executive Summary. The Consensus Council, Bismarck.		
Date: February, 2009		**Revised:**

IJC Recommendation 2: Design Flood for Winnipeg		
The design flood used as the standard for flood protection works for Winnipeg should be the highest that can be economically justified or, at a minimum, the flood of record, the 1826 flood.		
Category: mitigation	**Location:** Manitoba	**Status:** complete
Background: The city of Winnipeg had an extremely close call in 1997 when recorded flows exceeded the design capacity of the Red River Floodway by about 10 percent.. Shortly after the flood the Red River Floodway inlet control structure was refurbished and two notches opened in the east embankment to improve the hydraulic characteristics at the Floodway entrance. A federal-provincial study examined options for improving flood protection for Winnipeg and identified two feasible options: expansion of the existing Red River Floodway and a detention structure at Ste. Agathe. A preferred option (Floodway expansion) for reducing Winnipeg's vulnerability to rare floods was identified. The expanded floodway will provide protection against a 1:700 year flood, a rarer event than the 1826 flood, which is considered to be a 1:300 year flood.		
Progress to Date: Floodway expansion is complete. For additional information concerning the floodway expansion project, see IJC Recommendation 3.		
Related Information: The 1997 flood was deemed to be a 1:100 year flood at Winnipeg. The large number of inhabitants of the city and the importance of the city to the provincial economy led to the IJC recommendation. The IJC, while agreeing that the Ste. Agathe option would provide the required flood protection level for Winnipeg, considered that this option would not meet tests of public acceptability.		
Related Recommendations: 3-7, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: KGS Group 2001. *Flood Protection Studies for Winnipeg*. A report to the Government of Canada, Manitoba Conservation and the City of Winnipeg. KGS Group, Winnipeg, MB. Blais, E-L, S. Clark, K. Dow, B. Rannie, T. Stadnyk, and L. Wazney 2016. Background to flood control measures in the Red and Assiniboine River Basins. *Canadian Water Resources Journal* **41**:1-2 31-44.		
Date: February, 2009		**Revised:** April 2016

Recommendation 3: Flood Protection for Winnipeg

The city, province and the Canadian federal government should cooperatively develop and finance a long-term flood protection plan for the city that fully considers all social, environmental and human effects of any proposed flood protection measures and respects both the needs of Winnipeg and the interests of those outside the city who might be affected by such a plan.

Category: mitigation	**Location:** Manitoba	**Status:** complete

Background: The city of Winnipeg had an extremely close call in 1997. In its study of the flood the IJC recommended that the city be protected against floods at least as great as that of 1826. A federal-provincial study examined options for improving flood protection for Winnipeg and identified two feasible options: expansion of the existing Red River Floodway and a detention structure at Ste. Agathe. The federal and provincial governments agreed that the Red River Floodway be expanded to provide protection against the 1:700 year flood. (The 1826 flood is considered to be a 1:300 year flood.) The initial cost-sharing agreements for Floodway expansion were signed in 2003.

During the IJC study and other subsequent studies of flood protection for Winnipeg, there was considerable public concern about the social, environmental and human effects of enhancing Winnipeg's flood protection. This related, in particular, to the upstream effects of floodway operation and the possible effects downstream where the floodway channel rejoins the Red River.

Progress to Date: Construction on the floodway expansion project began on September 23, 2005 was completed in March 2014 at a cost of $627 million, $38 million under budget. The cost was shared equally between the federal and provincial governments. In addition, the City of Winnipeg has made improvements to its secondary dikes, which protect about 800 homes, and constructed outfall gate chambers for the land drainage system.

The capacity of the floodway was increased from 1700 m^3/s to 4000 m^3/s. *The Red River Floodway Act*, 2004 contains provisions related to compensating landowners for artificial flooding caused by floodway operations.

Related Recommendations: 2, 4-7, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29

References:

KGS Group 2001. *Flood Protection Studies for Winnipeg*. A report to the Government of Canada, Manitoba Conservation and the City of Winnipeg. KGS Group, Winnipeg, MB.

Manitoba Floodway and East Side Road Authority 2014. *2013 Annual Report*. Manitoba Floodway and East Side Road Authority, Winnipeg, MB.

Blais, E-L, S. Clark, K. Dow, B. Rannie, T. Stadnyk, and L. Wazney 2016. Background to flood control measures in the Red and Assiniboine River Basins. *Canadian Water Resources Journal* **41**:1-2 31-44.

Date: February, 2009		**Revised:** April 2016

IJC Recommendation 4: Flood Protection Measures – Fargo-Moorhead

The government of the United States, in cooperation with the cities of Fargo and Moorhead and the states of North Dakota and Minnesota, should expedite the study of flood risk potential and implement plans for flood protection measures for the Fargo–Moorhead area.

Category: mitigation	**Location:** North Dakota, Minnesota	**Status:** significant progress

Background: At Fargo about 3,500 feet (1,070 m) of USACE levee and three small cutoff channels were constructed in 1963. For the most part, however, the city depended on emergency earthen and sandbag levees for protection against very large floods, like those in 1997 and 2009. Moorhead in 1997 had no permanent federal flood control project. Analyses following the 1997 flood indicated that the 1997 flood was a 1:70 event at Fargo and that the 100-year flood was about eight percent larger than previously determined. The 2009 flood was deemed to be a 1:50-1:100 event. There was therefore a need to improve flood protection for both Fargo and Moorhead.

Progress to Date: Moorhead has acquired and moved 20 flood-prone structures, raised levees, installed gate valves on storm and sanitary sewers to prevent infiltration, installed seals and valves on homes, and constructed concrete lines to storm sewers to convey internal drainage. The city is deemed to be protected against the current 1:100 flood. Fargo has removed about 300 flood prone structures, constructed levees and made other improvements such as relocating lift stations.

A feasibility study of flood risk management measures for the entire Fargo-Moorhead area began in September 2008 and the project was authorized in 2014 and received new start construction funding in 2016. The required Minnesota EIS was released in May, 2016 and deemed to be adequate. The proposed project consists of a 20,000 cfs (566 m^3/s) North Dakota diversion with upstream staging. The plan includes a 30-mile (48-km) long diversion channel levee/floodwall features in Fargo and Moorhead, control structures on the Red and Wild Rice rivers, a gated diversion inlet structure, aqueducts on the Sheyenne and Maple rivers, ring levees around the communities of Comstock, MN and Oxbow/Hickson/Bakke, ND, and other features. It is currently in the preconstruction engineering and design phase. It will be implemented using a public-private partnership model. The estimated project cost is $1,912,261,000.

Related Recommendations: 2-3, 5-7, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29

References:

Lokkesmoe, K. 2007. "Disaster Recovery Following the 1997 Spring Floods in Minnesota." *Water Resources Impact*, November.

Sisco, G. and T. McAdams (eds.) 2001. *Flood Damage Reduction: What Minnesota has Done and Still Needs to Do.* Minnesota Department of Natural Resources, St. Paul, MN.

US Army Corps of Engineers 2016. *Red River of the North*, Corps of Engineers Fact Sheet. US Army Corps of Engineers, St. Paul, MN.

Date: February, 2009		**Revised:** August 2016

IJC Recommendation 5: Flood Protection for Grand Forks and East Grand Forks		
The government of the United States, in cooperation with the cities of Grand Forks and East Grand Forks and the states of North Dakota and Minnesota, should ensure that the planned flood protection works are promptly and expeditiously completed		
Category: mitigation	**Location:** North Dakota, Minnesota	**Status:** complete
Background: The cities of Grand Forks and East Grand Forks were devastated by the 1997 flood. In East Grand Forks only 27 residential properties experienced no damage. Temporary levees were overtopped and the cities evacuated. Flood damages were estimated to be $3.6 billion. Many houses and other buildings were total losses. The 1997 flood was determined to be a 1:210 event at Grand Forks.		
Progress to Date: The flood protection project consists of 30 miles (48 km) of levees on both banks of the Red River and 3 miles (5 km) of floodwall at East Grand Forks. To accommodate the levee setback and reduce the number of homes and businesses at risk, over 1000 structures were removed from the floodplain. The project included stabilization of an existing dam, removal of a former railway bridge, construction of interior flood control features, 24 pump stations, numerous road and railway closures, and two diversion channels. The total project cost was $409,300,000 with a federal share of $203 million. The flood protection level is considered to be 1:250.		
Related Information: The project has been certified as providing a 1:100 level of flood protection in accordance with FEMA's national flood insurance program. This benefits householders protected by the levee by significantly reducing flood insurance premiums. The project has recreation features including 24 miles (39 km) of trails and channels.		
Related Recommendations: 2-4, 6-7, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Lokkesmoe, K. 2007. "Disaster Recovery Following the 1997 Spring Floods in Minnesota." *Water Resources Impact*, November. Sisco, G. and T. McAdams (eds.) 2001. *Flood Damage Reduction: What Minnesota has Done and Still Needs to Do.* Minnesota Department of Natural Resources, St. Paul, MN. US Army Corps of Engineers 2009. *Red River of the North*, Corps of Engineers Fact Sheet. US Army Corps of Engineers, St. Paul, MN.		
Date: February, 2009		**Revised:** April 2016

IJC Recommendation 6: Flood Protection Measures – Wahpeton-Breckenridge		
The government of the United States, in cooperation with the cities of Wahpeton and Breckenridge and the states of North Dakota and Minnesota, should expedite approval and implementation of flood protection plans to reduce the risk of flooding at Wahpeton–Breckenridge.		
Category: mitigation	**Location:** North Dakota, Minnesota	**Status:** complete
Background: Wahpeton, ND and Breckenridge, MN lie at the confluence of the Bois de Sioux and Otter Tail rivers, the beginning of the Red River. Wahpeton had a close call in 1997 but its emergency levee held. On the other hand, Breckenridge's levees were overtopped twice in 1997, first from the north then from the south. Most of the community was flooded causing damages of $30 million. A flood risk management study of the two communities led to two separate but dependent projects. The Breckenridge project consists of a high-flow diversion channel north of the Otter Tail River and two permanent levee reaches that protect all of the community. The Wahpeton project consists of a permanent levee system and flood easements. The flood protection level is considered to be 1:125. The estimated cost of the Breckenridge project is $45.02 million and the Wahpeton project $21.2 million.		
Progress to Date: The diversion at Breckenridge was completed in 2005 and operated for the first time in the summer of 2005. Other works completed at Breckenridge include removal or replacement of 132 flood-prone structures, construction of 14 pumping stations, 3.5 miles of dike and 2 miles of floodwall, relocation of lift stations and protection of the water treatment plant. The Wahpeton project began in 2003 with interior flood control features. Levee construction was completed in 2012 and a seepage cut-off in 2014. The local sponsor will have completed the removal of levee encroachments in the zoo in 2016. The combined project has prevented nearly $164 million in damages through 2015.		
Related Recommendations: 2-5, 7, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Lokkesmoe, K. 2007. "Disaster Recovery Following the 1997 Spring Floods in Minnesota." *Water Resources Impact*, November. Sisco, G. and T. McAdams (eds.) 2001. *Flood Damage Reduction: What Minnesota has Done and Still Needs to Do.* Minnesota Department of Natural Resources, St. Paul, MN. US Army Corps of Engineers 2016. *Red River of the North*, Corps of Engineers Fact Sheet. US Army Corps of Engineers, St. Paul, MN.		
Date: February, 2009		**Revised:** April 2016

IJC Recommendation 7: Flood Risk Studies – Selkirk		
The province of Manitoba and city of Selkirk should expedite studies of flood-risk potential in the Selkirk area.		
Category: mitigation	**Location:** Manitoba	**Status:** complete
Background: Although Selkirk experienced some flooding of water front properties in 1997, its susceptibility to ice jam flooding has been known for many years. Prior to 1997, the flood protection level at Selkirk was considered to be the 1:160 year flood. Subsequent analysis indicated the flood protection level was about 1:100. Residents in the Selkirk area believed they may be affected by downstream impacts of Red River Floodway expansion. There was therefore a need to quantify the flood risk and consider mitigation measures.		
Progress to Date: The province has confirmed that the present infrastructure provides 1:100 year flood protection. Studies have confirmed that water levels will only increase marginally for the 1:700 flood downstream of the outlet structure. The design of the Red River Floodway expansion includes bank erosion protection of the river bank opposite the outlet structure. The province purchased four Amphibex AE-400 amphibious excavators and three ice cutting saws for use in the Selkirk area and other locations where ice jams are a concern. This new equipment was used in 2009 for the first time with partial success. Experience with that flood led to a $4.4-million buyout of flood prone properties near Breezy Point, St. Andrews and St. Clement.		
Related Recommendations: 2-6, 9-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Fleming, Sandford. 1880. Documents in Reference to the Bridging of Red River. *Report and Documents in Reference to the Canadian Pacific Railway, Appendix No. 16.* Ottawa. Wazney, L. and S. P. Clark 2016. The 2009 flood event in the Red River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* **41**:1-2 56-64.		
Date: February, 2009		**Revised:** July 2016

IJC Recommendation 8: Socio-economic Research		
To improve resiliency in the basin, governments should support enhanced research into the various social dimensions of the flood, including economic, psychological, public health and sociological impacts.		
Category: preparedness	**Location:** basin	**Status:** little progress
Background: Many floodplain residents experienced some degree of collective trauma in recovering from the 1997 flood. This human toll was particularly evident in the flooded area immediately south of the Red River Floodway inlet. Further research concerning the human aspects of flooding and recovery from flooding is required.		
Progress to Date: Although some social and economic studies are being undertaken at universities such as the University of Minnesota using government and other funding concerning topics raised by the 1997 flood, the level of funding support, and hence the research effort, is still modest.		
Related Recommendations: 17-19, 22, 26 and TF 2, 16-19, 26,30, 35-40, 44, 46, 50		
References: Shrubsole, D. 2001. The Cultures of Flood Managements in Canada: Insights from the 1997 Red River Experience. *Canadian Water Resources Journal*. **26**:4 461-479		
Date: February, 2009		**Revised:**

IJC Recommendation 9: Flood Mitigation Strategies for Small Communities		
Governments at all levels should ensure that in the development of flood mitigation strategies for the basin the needs of small communities, individual isolated farmsteads and agriculture are not overlooked.		
Category: mitigation	**Location:** basin	**Status:** complete
Background: Many small communities and individual farmsteads were affected by the 1997 flood. In the United States some small communities may be protected by non-federal levees but the exact level of protection was unknown.		
Progress to Date: In Manitoba south of Winnipeg 17 community dikes were upgraded or constructed and 1742 homes, farmsteads or businesses were raised, diked or relocated under a federal-provincial agreement. This represents about 95 percent of the eligible structures. The ring dikes were estimated to have saved $600 million in damages in the 2009 flood. Further diking was carried out in four communities downstream of Winnipeg following the 2009 flood. A call for applications for the individual flood protection program following the 2009 flood drew 52 applicants while one following the 2011 flood drew only 2 applications. Increased storage has been added to Baldhill Dam on the Sheyenne River and two dry dams have been constructed on the Maple River in North Dakota. North Dakota raised funding support level for rural ring dikes to 50 percent in 2001. Minnesota has supported the construction of 225 rural ring dikes. Small-scale remediation projects have been constructed in Minnesota. In general, all farmsteads desiring flood protection by raising or ring diking have been protected. The USACE completed construction for a Cookston and Roseau, MN flood control projects. Major levee and floodwall improvements for Pembina, ND have been implemented to enable the community to maintain FEMA accreditation. At Grafton, ND recurrent flooding along the South Branch and mainstem of the Park River, a Red River tributary, has caused significant problems. A flood control project having an estimated cost of $52.7 million is being designed and funding arrangements are being developed. USACE studies for projects at Drayton, ND and Ada, MN showed that benefits were insufficient to meet guidelines for federal projects. The Ada project is being developed incrementally with the support of the State of Minnesota. Projects are ongoing at Lisbon and Valley City, ND. Some small North Dakota communities such as Fort Ransom do not have the financial capacity to undertake projects. Neche has some flood protection from old emergency levees. Engineering analysis of that situation is underway.		
Related Recommendations: 2-7, 10-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Manitoba Water Stewardship 2010. *Manitoba 2009 Spring Flood Report*. Manitoba Water Stewardship, Winnipeg, MB. Sisco, G. and T. McAdams (eds.) 2001. *Flood Damage Reduction: What Minnesota has Done and Still Needs to Do.* Minnesota Department of Natural Resources, St. Paul.		
Date: February, 2009		**Revised:** August 2016

IJC Recommendation 10: Lower Pembina River Basin Flooding

Federal government agencies, in cooperation with the state of North Dakota and the province of Manitoba, should establish a consultative group to work with local interests, including the Pembina River Basin Advisory Board, to resolve the lower Pembina River flooding issue, provide necessary resources for the group, and act to achieve a solution.

Category: mitigation	**Location:** Pembina basin	**Status:** some progress

Background: For more than 50 years unilateral road and dike building on both sides of the international boundary has been a source of tension among basin residents and between the governments of North Dakota and Manitoba. Certain levees along the lower Pembina River have been deemed to be illegal and have been removed. Manitoba has cost-shared with North Dakota some improvements to drainage through the road-dike that parallels the international boundary. The road dike currently is under litigation between various interests in Pembina County and the RM of Rhineland and Manitoba.

Progress to Date: A report in 2004 reviewed the lower Pembina basin flooding issue and made recommendations concerning an examination of flood measures protecting Pembina and Neche, flood-proofing of rural farmsteads, and further study of spring and summer floods. In 2008 the USACE and the State of North Dakota began developing a HEC-RAS model of the lower Pembina basin and the Red River. The model has been calibrated and verified to the 2006 and 2009 floods.

The IRRB endorsed the formation of the Lower Pembina River Task Team in January 2008. The objective of the Task Team is to oversee technical work to determine methods to minimize flooding on the lower Pembina River and adjacent watersheds. The work included the development of the Telemac-2D hydrodynamic model of the lower Pembina River by the Canadian National Research Council. The Task Team indicated the goal for future solutions should be that flooding should be no worse than existing conditions in Manitoba and no worse that natural in North Dakota.

Related Recommendations: 2-7, 9, 11-14, 16 and TF 3-7, 10-12, 15, 23, 29

References:

Faure, T. and R.W. Jenkinson 2012. *Simulation of Flood Scenarios on the Lower Pembina River Flood Plains with the Telemac2D Hydrodynamic model – Phase 3*. Natural Research Council, Ottawa, ON.

Halliday, R., R. Bowering and R. Gjestang 2004. *Lower Pembina River Flooding*. A Report to the International Red River Board. Winnipeg

Lower Pembina Flooding Task Team 2012. *An Exploratory Analysis of mitigation Measures for the Lower Pembina Basin.* Report to the International Red River Basin Board. Lower Pembina Flooding Task Team

U.S. Army Corps of Engineers 2009. *Red River of the North,* Corps of Engineers Fact Sheet. U.S. Army Corps of Engineers, St. Paul, MN.

Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 11: Mitigation Strategy for the Basin		
Governments should develop a binational integrated approach to mitigation initiatives at all political levels, based on a comprehensive mitigation strategy for the entire basin. In the United States, the strategy should be integrated within the overall national framework.		
Category: mitigation	**Location:** basin	**Status:** some progress
Background: Red River basin residents have a right to expect that governments at all levels will show leadership and work together to reduce the damaging effects of flooding. The United States has a framework for dealing with flooding and flood damages through instruments such as the National Flood Insurance Program, statutory programs of the USACE, and other instruments. Canada does not, and depends on *ad hoc* post event programs.		
Progress to Date: The Red River Basin Commission has developed a natural resources framework plan that includes aspects of flood mitigation. More recently the RRBC Forecast Working Group on Networks has reported on forecast networks, particularly in the United States portion of the basin. The RRBC does have representatives from all levels of government but the process itself is not government led.		
Related Recommendations: 2-7, 9-10, 12-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Red River Basin Commission 2005. *Red River Basin Natural Resources Framework Plan.* Red River Basin Commission, Moorhead, MN. Red River Basin Commission 2015. *A Red River Basin River Forecast Data Network Integration and Stabilization Program.* Report by the Forecast working Group. Red River Basin Commission, Moorhead, MN.		
Date: February, 2009		**Revised:** September 2016

IJC Recommendation 12: National Mitigation Strategy – Canada		
The Canadian federal government should establish a national flood mitigation strategy, or a broader disaster mitigation strategy, and support it with comprehensive mitigation programs.		
Category: mitigation	**Location:** Canada	**Status:** some progress
Background: Flood mitigation in Canada tends to be event driven. With the demise of the federal-provincial flood-damage reduction program in 1990 there is no common program or framework tying activities together. Some provincial governments continue to update flood risk maps, conduct hydrological and hydraulic studies, and construct mitigation works. These programs, however, are often a response to a specific event.		
Progress to Date: The Public Safety Minister and his provincial/territorial counterparts approved a National Mitigation Strategy in January 2008. Mitigation programs to support the strategy are yet to come. The strategy committed the federal government to using the *Building Canada Fund* (BCF) to support structural mitigation and research. Thus far, the only flood mitigation program to receive funding from this program is the Red River Floodway expansion. More recently, a National Disaster Mitigation program aimed at reducing flood risks and costs was established in 2015. The program allocates $183 million over five years for projects to be cost-shred equally with provincial governments. The federal government as well is working with the provinces on a renewed floodplain mapping program.		
Related Recommendations: 2-7, 9-11, 13-14, 16 and TF 3-7, 10-12, 15, 23, 29		
References: Infrastructure Canada 2007. *Building Canada*. Infrastructure Canada, Ottawa, ON. Public Safety Canada 2008. *Canada's National Mitigation Strategy*. Public Safety Canada, Ottawa, ON.		
Date: February, 2009		**Revised:** July 2016

IJC Recommendation 13: Regulatory Flood		
Governments should use, at a minimum, the 100-year (1 percent) flood as the basis for floodplain regulations and revise their estimates of the 100-year flood levels based on 1997 and new data that become available.		
Category: mitigation	**Location:** basin	**Status:** complete
Background: Communities and individuals need to understand the flood risks they face and need to be assured that flood risk information is up-to-date. The 100-year (1:100) floodplain extent is one such measure. A 500-year floodplain definition is useful for design of critical infrastructure or where flooding may be deemed unacceptable.		
Progress to Date: All American jurisdictions have defined the applicable 100- and 500-year floods. In North Dakota and Minnesota the states have adopted a safe building elevation of the 100-year flood elevation plus one foot. In Manitoba south of Winnipeg, the province has adopted a safe building elevation and regulatory level of the 200-year flood plus 0.6 m. This is higher than the 1997 flood elevation.		
Related Recommendations: 2-7, 9-12, 14, 16 and TF 3-7, 10-12, 15, 23, 29		
References:		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 14: Floodplain Management Regulations		
State, provincial and other appropriate authorities should review the effectiveness of and compliance with the floodplain management regulations in the basin and take steps as needed to improve enforcement.		
Category: mitigation	**Location:** basin	**Status:** ongoing
Background: The 1997 flood pointed out the need to enforce or improve regulations aimed at reducing flood damages in the Red River basin. The need to enforce regulations pertaining to building codes, zoning and other matters was identified.		
Progress to Date: More than 400 cities and counties in Minnesota enforce floodplain zoning ordinances that state no new buildings shall be placed in the path of floodwaters and that buildings experiencing substantial flood damage shall be removed. The required safe building elevation is the 1:100 level plus one foot of freeboard. Ninety percent of Minnesota jurisdictions participate in the National Flood Insurance Program. North Dakota defines the 1:100 floodway on the basis of a one-foot rise criterion and does not allow structures in the floodway. Structure in the floodway fringe must be flood-proofed. Manitoba uses the 1997 level plus 0.6 m as a safe building elevation. The province has a two-step inspection process, once after the foundation is built and again when the project is completed, to ensure compliance. A detailed review of flood damages in 2009 to houses and other structures constructed since 1997 would useful in demonstrating the effectiveness of the post-197 regulations. The fact that the 2011 flood caused very little damage in the Red River basin is an indicator that current regulations are reasonably effective.		
Related Recommendations: 2-7, 9-13, 16 and TF 3-7, 10-12, 15, 23, 29		
References: North Dakota 2007. Chapter 61-16.2, Floodplain Management, in *Century Code*. State of North Dakota, Bismarck, ND. Sisco, G. and T. McAdams (eds.) 2001. *Flood Damage Reduction: What Minnesota has Done and Still Needs to Do.* Minnesota Department of Natural Resources, St. Paul, MN.		
Date: February, 2009		**Revised:** August 2016

IJC Recommendation 15: Binational Civil Emergency Planning		
Within the current context of Canada–United States cooperation for civil emergency planning and management, governments should develop more detailed bilateral emergency planning and management arrangements with specific adaptations to Red River flooding.		
Category: response, recovery	**Location:** basin	**Status:** complete
Background: The Canada-United States Agreement on Cooperation in Comprehensive Civil Emergency Planning and Management provides a framework for joint response to civil emergencies. The likelihood of continued Red River flooding makes specific binational arrangements for the basin desirable. One early mechanism for this is the Prairie Region Emergency Management Advisory Committee (PREMAC). In 2000 an *International Emergency Management Assistance Memorandum of Understanding* was signed. Other transboundary arrangements followed and, in 2013, the U.S. Congress ratified the *State and Province Emergency Management Assistance Memorandum of Agreement*. This in turn led to the creation of the *Northern Emergency Management Assistance Compact* (NEMAC) of which Manitoba, North Dakota and Minnesota as well as other provinces and northern states are members		
Progress to Date: With the development of NEMAC there is provision for the possibility of mutual assistance in the Red River basin in managing any emergency or disaster, whether arising from natural disaster, technological hazard, manmade disaster or civil emergency aspects of resources shortages. The preparation of a NEMAC strategic plan is underway.		
Related Recommendations: TF 25		
References: The NEMAC website www.nemacweb.org contains detailed information.		
Date: February, 2009		**Revised:** September, 2016

IJC Recommendation 16: Digital Elevation Model		
Development of the digital elevation model for the Red River basin, with high resolution in appropriate high flood risk areas, should be pursued and completed through collaborative initiatives of federal, state, provincial and local governments.		
Category: mitigation	**Location:** basin	**Status:** complete
Background: The 1997 Red River flood occupied a floodplain that was as much as 40 km-wide in southern Manitoba. Modelling flood paths through this flat landscape requires high resolution digital elevation models (DEM). The IJC study funded the development of lidar-based digital elevation models for a portion of the Red River floodplain from Winnipeg to Ste. Agathe and for the lower Pembina basin.		
Progress to Date: The entire Red River basin in the United States has lidar coverage obtained in 2008-2010 and one-, two- and three-metre DEMs are available. The DEMs meet FEMA standards. The project was carried out by the International Water Institute in co-operation with federal and state agencies. In Manitoba a lidar DEM has been prepared for the entire Red River floodplain from the international boundary to Winnipeg and from Winnipeg to the Red River delta. The Canadian and United States DEMs have not been stitched together except for the lower Pembina basin.		
Related Recommendations: 2-7, 9-14 and TF 3-7, 10-12, 15, 23, 29		
Date: February, 2009		August, 2016

IJC Recommendation 17: Flood Forecast Data		
Federal, state and provincial governments should develop and implement a binational agreement to establish an appropriate network of hydrological and meteorological stations and data exchange for floodplain management and flood forecasting in the Red River basin.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: Hydrological and meteorological data are an essential element of flood forecasts. It is essential that the improvements to observing networks carried out following the 1997 flood be maintained and that information sharing continue to improve. A binational agreement was seen as the best way to accomplish this.		
Progress to Date: The hydrometeorological monitoring network has been improved considerably since 1997, and data are routinely shared between forecast agencies in both countries and among other interests. The monitoring activity is not supported by any basin-specific binational agreement, however. As costs of network operation increase, additional pressure is put on operating and funding agencies to maintain the present level of service. Environment Canada's abandonment of observer-operated climate stations and the current poor quality of snowfall data makes snow monitoring more difficult.		
Related Recommendations: 8, 18-19, 22, 26 and TF 2,16-19,26,30,35-40,44,46,48,50		
References: Red River Basin Commission 2015. *A Red River Basin River Forecast Data Network Integration and Stabilization Program.* The Red River Basin Commission, Forecast Working Group. Fargo, ND.		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 18: Flood Forecasting Liaison Committee		
The governments should authorize the Commission to establish a binational Red River Flood Forecasting Liaison Committee under the International Red River Board to improve interjurisdictional coordination and to help ensure that clear, understandable and compatible forecasts are issued to the public.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: There is a long-standing and successful bilateral arrangement for sharing flood forecasting information in the Red River basin. A more formal interjurisdictional coordination would be useful.		
Progress to Date: This recommendation pertaining to the establishment of a Flood Forecasting Liaison committee under the aegis of the IRRB has not been implemented. Flood forecasting agencies have taken steps to improve coordination and dissemination of forecasts. The 2009 and 2011 floods demonstrated well-established coordination/communications between all government agencies concerned with flood issues. Daily conference calls provide opportunity to learn and share information. Both the Red River Basin Commission and the IRRB have worked to facilitate improved linkages among agencies involved in flood forecasting.		
Related Recommendations: 8, 17, 19, 22, 26 and TF 2,16-19,26,30,35-40,44,46,48,50		
References: Red River Basin Commission 2015. *A Red River Basin River Forecast Data Network Integration and Stabilization Program.* The Red River Basin Commission, Forecast Working Group. Fargo, ND.		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 19: Basin-wide Models		
As a long-term priority, government agencies responsible for flood forecasting and mitigation measures should develop basin-wide models rather than separate but coordinated models for each country.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: Although the forecast models used in the Red River basin share datasets and are calibrated to provide similar results at the international boundary, a basin-wide problem merits a basin-wide model.		
Progress to Date: The USACE is implementing a HEC RAS one-dimensional hydrodynamic model for the Red River mainstem that extends up each tributary to the first gaging station. An HEC HMS model has been developed for each tributary. The National Weather Service has implemented a detailed FLDWAV model one-dimensional model for the Red River mainstem and the lower Sheyenne River. The model extends into Manitoba to the City of Winnipeg. These models can be used for evaluating flood mitigation measures. It is extremely unlikely the flood forecast entities, the National Weather Service and Manitoba Water Stewardship, would support a common forecast model on account of the administrative complexities and the need to demonstrate due diligence to their respective governments.		
Related Recommendations: 8, 17-18, 22, 26 and TF 2,16-19,26,30,35-40,44,46,48,50		
References:		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 20: Canadian Data Holdings		
The Canadian government should review its data and information management policies to ensure that topographic, hydrometeorological, and other flood-related data collected under government programs are made available without restrictions or conditions that limit their accessibility.		
Category:	**Location:** Manitoba	**Status:** complete
Background: Following the 1997 flood there were a number of roadblocks pertaining to Canadian data that inhibited the development of a common searchable database for the basin. Government data holdings tended to be inaccessible, access to internal computer networks constrained by security requirements, and cost-recovery policies made access expensive. This placed public safety in jeopardy by constraining public and agency access to data.		
Progress to Date: This recommendation was directed at Canadian data management policies. Policy decisions have now been taken by the Canadian and Manitoba governments that have significantly improved access to Canadian data. Improved access to data holdings has taken place through programs such as Natural Resources Canada's GeoConnections and the Environment Canada's Water Survey of Canada's data portal. Environment Canada's Meteorological Service has also improved access to meteorological and climate data. Similarly, Manitoba Water Stewardship has improved access to its data holdings.		
Related Recommendations:		
References:		
Date: February, 2009		**Revised:** July, 2016

IJC Recommendation 21: Binational Virtual Network		
Governments should ensure that progress continues in building a binational, virtual network linking the people, data, and models for the Red River basin.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: Work on a distributed (or virtual) database linking flood-related data holdings across the basin led to conceptual plan for a decision support system linking both data and models.		
Progress to Date: Several measures have been introduced to continue the work on a binational virtual network linking people, data and models for the Red River basin. One has been the RRDDIN project, supported for the most part by the USACE. There have also been significant agency-level initiatives aimed at making data, tools and model output more available. Manitoba created a decision support system linking forecast water levels, cadastral data and sandbag requirements. It proved too expensive to maintain and was wound down. (Almost all the dwellings in the Manitoba floodplain were flood-proofed following the 1997 flood therefore reducing the need for this sort of information.) Minnesota has implemented a similar pilot project. Improvements in data acquisition and distribution since the 1997 flood call into question the need for any formal activity aimed at enabling data sharing. The RRDDIN project never did extend into Manitoba and its continuing need is in some doubt. That said, the ready availability of standardized metadata continues to be a problem.		
Related Recommendations: 8, 17-19, 22, 26 and TF 2,16-19,26,30,35-40,44,46,48,50		
References:		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 22: Decision Support System		
Federal, state, and provincial governments should work with basin organizations to complete in a timely manner the development of a prototype decision support system and establish a cooperative mechanism for coordination and funding its further development and implementation.		
Category: preparedness	**Location:** basin	**Status:** superceded
Background: Work on a distributed (or virtual) database linking flood-related data holdings across the basin led to conceptual plan for a decision support system linking both data and models.		
Progress to Date: As indicated for Recommendation 21 there have been some developments related to decision support systems.		
Related Recommendations: 8, 17-19, 26 and TF 2,16-19,26,30,35-40,44,46,48,50		
References:		
Date: February, 2009		**Revised:**

IJC Recommendation 23: Hazardous Materials		
Governments should take immediate steps to ensure that all banned materials such as toxaphene are removed from the Red River basin. Governments should also ensure that potentially hazardous materials are not stored in the 500-year floodplain, although reasonable quantities of such substances could be maintained in the floodplain for immediate use.		
Category: preparedness, environment	**Location:** basin	**Status:** some progress
Background: During the 1997 flood a banned pesticide, toxaphene, was released to the aquatic environment. Increased concentrations were detected in fish tissue in Lake Winnipeg. In Minnesota and North Dakota, the state agriculture departments regulate storage of chemicals while in Manitoba this is regulated by the environment department. While the floodplain is not used as the basis for regulations, the regulations do call for set backs from streams and limit quantities stored in certain locations.		
Progress to Date: The US Environmental Protection Agency worked with North Dakota to distribute information on storage of chemicals in flood prone areas. Some 91,000 lbs. of chemicals were collected and removed. The work was accomplished under Project Safe Send, a non-regulatory state-wide program for safe disposal of unusable pesticides. North Dakota has also produced a brochure on flood-proofing of above ground storage tanks,		
Related Recommendations: TF 32, 34		
References:		
Date: February, 2009		**Revised:** November, 2016

IJC Recommendation 24: Floodplain Environment		
Flood protection projects focus not only on reduction of flood damage but also on protection and enhancement of the floodplain environment.		
Category: mitigation	**Location:** basin	**Status:** some progress
Background: Flood mitigation projects provide an opportunity to restore wetlands, enhance fish or wildlife, or otherwise compensate for the effects of human activity in the basin.		
Progress to Date: In addition to building flood mitigation projects in conformance with federal, state or provincial laws, there have been developments that provided additional environmental values as part of a mitigation project. Examples are greenway development in Grand Forks and East Grand Forks, proposals for considerable urban park development along the expanded Red River Floodway at Winnipeg, and the interest in set-back levees for the lower Pembina River. Greenway on the Red was a multi-state and international effort to establish a greenway from Lake Traverse to Lake Winnipeg. The task is about one-quarter complete but little has been achieved in recent years. The Canadian partner is Rivers West, a Manitoba organization aimed at conserving natural, cultural and heritage resources. The entire Red River in Canada became part of the Canadian Heritage Rivers System in 2007.		
Related Recommendations:		
References: Hilderman, Thomas, Frank, Cram, 2005. *Canadian Heritage Rivers System: Nomination Document for the Red River in Manitoba.* Report prepared for Rivers West and Manitoba Conservation, Winnipeg, MB. Rivers West – Red River Corridor Association 2004. *Red River Greenway: A Strategy for Development*. A report by RAS Consulting.		
Date: February, 2009		**Revised:** July, 2016

IJC Recommendation 25: Comprehensive Flood Damage Reduction Plan		
Governments immediately take steps, on a binational basis, to begin development of a comprehensive flood damage reduction plan for the Red River basin.		
Category: mitigation	**Location:** basin	**Status:** some progress
Background: The nature of flooding in the basin means that basin residents will remain at risk until a multifaceted solution is developed for the full range of flood problems. This can best be accomplished on a binational basis.		
Progress to Date: There has been almost no attention devoted to a comprehensive flood damage reduction plan, as such, by government agencies. Individual agencies nonetheless have made enormous efforts to improve flood management in the Red River basin since 1997. The aggregate result of these efforts, while not a plan, represents a significant improvement in flood resiliency in the basin. While it may be a slight exaggeration, a reoccurrence of the 1997 flood now would almost be a non-event. The work currently being undertaken by the RRBC (Recommendation 19) could ultimately contribute to such an overall plan, however.		
Related Recommendations: 11		
References:		
Date: February, 2009		**Revised:** August, 2016

IJC Recommendation 26: Flood Management Measures		
Governments at all levels should undertake the following measures: *a. Develop and implement comprehensive, multi-faceted plans for concurrently reducing flood damage and protecting and enhancing the natural environment;* *b. Ensure ongoing institutional support and full multi-jurisdictional participation in further development and maintenance of the Task Force's legacy projects;* *c. Implement Commission and Task Force recommendations designed to ensure basin wide flood preparedness and community resiliency;* *d. Promote a culture of flood preparedness and flood resiliency in the basin;* *e. Enhance technology and monitoring systems to provide early warnings and early action in the face of impending major floods;* *f. Ensure binational coordination of flood forecasting and communications of forecasts to the public;* *g. Provide opportunities for multi-jurisdictional problem solving and the exchange of best practices information; and* *h. Integrate floodplain management activities into the broader field of watershed and basin management.*		
Category: preparedness, education	**Location:** basin	**Status:** ongoing
Background: Although agencies throughout the basin can carry out the many flood-related tasks within their respective mandates, this transboundary watershed also requires binational approaches to achieving flood resiliency.		
Progress to Date: This recommendation directed eight measures to governments for action. All are long-term and will require sustained activity over many years. The work already initiated meets the intent of the recommendation, but this is a very long-term recommendation. One indicator of success is that the 206 Red River flood was considered a 'non-event' in the basin, except for road closures and restricted access to properties. Nonetheless the 2009 flood, the second largest in the instrumental record (and the largest in the headwaters) demonstrated that large floods can still cause considerable disruption and damage. On the other hand the 2011 flood, the third largest flood in the instrumental record at Morris was uneventful. In contrast the 2011 flood on the Assiniboine River was a significant challenge and did pose a risk to Winnipeg when combined with the Red River flood.		
Related Recommendations: 8, 17-19, 22 and TF 2, 16-19, 26, 30, 35-40, 44, 46, 48, 50		
References: Wazney, L. and S. P. Clark 2016. The 2009 flood event in the Red River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* **41**:1-2 56-64. Stadnyk, T., K. Dow, L. Wazney, and E-L Blais 2016. The 2011 flood event in the Red River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* **41**:1-2 65-73. Blais, E-L., J. Greshuk, and T. Stadnyk 2016. The 2011 flood event in the Assiniboine River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* **41**:1-2 74-84.		
Date: February, 2009		**Revised:** July 2016

IJC Recommendation 27: Functions of the International Red River Board		
Governments should assign the following functions to the International Joint Commission for implementation by the International Red River Board: *a. Monitor progress by the governments (federal, state, provincial, municipal) in implementing the recommendations of the Commission's report on Red River basin flooding, and in maintaining and advancing the work of the Task Force's legacy projects;* *b. Encourage governments to develop and promote a culture of flood preparedness in the Red River valley;* *c. Encourage government efforts to develop and implement a long-term strategy for flood mitigation and emergency preparedness;* *d. Encourage the sharing of accurate and timely transboundary information to support the development of improved flood forecasting techniques and procedures for early flood warnings and to improve communication of flood forecasts;* *e. Provide through the activities of the Board a forum for the exchange of best practices and for other flood-related information on preparedness, mitigation, response, and recovery, to assist in transboundary problem solving;* *f. Promote the application of innovative technologies for supporting flood modelling and mapping;* *g. Monitor the adequacy of data and information collection networks (meteorological, hydrometric, water quality) for flood preparedness, forecasting and mitigation, within the larger context of overall water management needs in the basin;* *h. Monitor potential transboundary effects of flood mitigation and other works in the basin, and encourage cooperative studies necessary to examine these effects;* *i. Encourage governments to integrate floodplain management activities in watershed and basin management;* *j. Interact with all levels of government to help decision makers become aware of transboundary flood-related and associated water management issues; and* *k. Assist in facilitating a consultative process for resolution of the lower Pembina River flooding issue.*		
Category:	**Location:** basin	**Status:** complete
Background: There are many flood-related functions and tasks that need to be pursued by out by government agencies and others. The IRRB can assist this task by assuming some functions for the transboundary area.		
Progress to Date: This recommendation identified 11 flood-related functions that the IRRB should be asked to perform on behalf of the IJC. These are included in the IJC Directive to the Board. The tasks themselves are continuing tasks.		
Related Recommendations:		
References:		
Date: February, 2009		**Revised:** July 2016

IJC Recommendation 28: Coordination and Implementation: Preparedness and Mitigation		
The federal governments, in cooperation with the state and provincial governments, should work with the Commission and its International Red River Board, as well as with existing and emerging bilateral organizations, to ensure that appropriate arrangements are in place to coordinate and implement measures for flood preparedness and mitigation activities and to implement recommendations of the Commission.		
Category: preparedness, mitigation	**Location:** basin	**Status:** ongoing
Background: There is a need for coordinated bilateral action on measures aimed at improving flood resiliency in the Red River basin. This is in addition to measures taken by agencies.		
Progress to Date: There is activity on a number of fronts related to preparedness and mitigation. The approach tends to be agency specific and progress on measures taken by various agencies is reported by the International Red River Board and the Red River Basin Commission.		
Related Recommendations:		
References:		
Date: February, 2009		**Revised:**

Task Force Recommendations

(endorsed but not restated by the International Joint Commission)

Task Force Recommendation 2: Flow Management		
Future ice jam information from the entire basin should be incorporated into the CRREL Ice Jam Database so that ice problems in the basin can be analyzed further. Where feasible, historic ice jams from the Canadian portion of the basin should be entered.		
Category: prepardness	**Location:** basin	**Status:** little progress
Background: Ice jams occur at many locations on the Red River and its tributaries. At times these jams can lead to damaging floods. Systematic documentation of ice jam incidents may encourage additional research specific to the Red River basin.		
Progress to Date: There was a significant ice jam flood on the Red River at Selkirk in 2007. Because of an ice jam north of the city, the crest in 2007 was the highest on record. It exceeded the 1996 crest, also caused by an ice jam, and that of 1997. Ice jamming was also a major factor in the 2009 flood. Intact ice covers persisted at higher than usual flows. Record high water levels were obtained in areas north of Winnipeg. The only historic Red River ice jam added to the CRREL database since 1997 is one at Fargo in April 2005.		
Related Recommendations: IJC **7,**8, 17-19, 22, 26 and 16-19,26,30,35-40,44,46,48,50		
References: Beltaos, S., R. Pomerleau and R. A. Halliday 2000. *Ice Jam Effects on Red River Flooding and Possible Mitigation Methods.* Report for the International Red River Basin Task Force, International Joint Commission. Wazney, L. and S. P. Clark 2016. The 2009 flood event in the Red River Basin: Causes, assessment and damages. *Canadian Water Resources Journal* **41**:1-2 56-64. Lindenschmidt, K-E, M. Sydor, R. Carson, and R. Harrison 2011. Ice Jam Modelling of the Red River in Winnipeg. *Proceedings 16th Workshop on River Ice September 18-22, 2011*. CGU HS Committee on River Ice Process and the Environment.		
Date: February, 2009		**Revised:** July, 2016

Recommendation: TF 3 Communities at Risk		
Communities in the United States portion of the Red River basin should ensure that community-built flood damage reduction projects are certified by FEMA for 100-year or greater protection, or should participate in the Non-Federal Flood Control Works Inspection Program.		
Category: mitigation	**Location:** North Dakota, Minnesota	**Status:** complete
Background: Many communities have constructed dikes and levees under emergency conditions. These structures may or may not meet federal standards. Some emergency levees remain in place after the flood event. When the Federal Emergency Management Agency can accredit a levee as flood-proofing, homes and other structures can be removed from the 1:100 floodplain protected by the levee for National Flood Insurance Purposes.		
Progress to Date: The US Non-Federal Flood Control Works Inspection Program is now known as the Rehabilitation Inspection Program (RIP). The program is administered by the U.S. Army Corps of Engineers. All communities on the Red River mainstem and almost all on the tributaries now or soon will have levees that meet FEMA accreditation standards.		
Related Recommendations: IJC 2-7, 9-14, 16 and 4-7, 10-12, 15, 23, 29		
References:		
Date: February, 2009		**Revised:** September, 2016

Recommendation: TF 5 Winnipeg at Risk		
Based on results from hydraulic model studies, modify the east embankment of the Floodway to improve the performance of the Floodway entrance to lower upstream water levels and increase capacity.		
Category: mitigation	**Location:** Manitoba	**Status:** complete
Background: Winnipeg faces a number of threats from damaging floods. The city was fortunate in 1997; with more severe weather conditions at the time of the peak the existing flood defenses may have failed. Modifications to the east embankment were considered an interim measure pending design of a floodway expansion project.		
Progress to Date: The work on improving the performance of the floodway inlet is complete. Two notches were cut in the east embankment.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-4, 6-7, 10-12, 15, 23, 29		
References: KGS Group 2001. *Flood Protection Studies for Winnipeg*. Report prepared for the governments of Canada, Manitoba and Winnipeg. KGS Group, Winnipeg, MB.		
Date: February, 2009		**Revised:**

Recommendation: TF 6 Winnipeg at Risk		
The west dike should be raised to allow a water level elevation of 778 feet at the Floodway inlet structure with appropriate freeboard		
Category: mitigation	**Location:** Manitoba	**Status:** complete
Background: Winnipeg faces a number of threats from damaging floods. The city was fortunate in 1997; with more severe weather conditions at the time of the peak the existing flood defenses may have been insufficient. This work was considered an interim measure pending design of a floodway expansion project.		
Progress to Date: Modifications to the West Dike as part of the floodway expansion project are 80 percent complete. The work was completed in 2009.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-5, 7, 10-12, 15, 23, 29		
References: KGS Group 2001. *Flood Protection Studies for Winnipeg*. Report prepared for the governments of Canada, Manitoba and Winnipeg. KGS Group, Winnipeg, MB.		
Date: February, 2009		**Revised:** May 2016

Recommendation: TF 7 Winnipeg at Risk		
The primary diking system should be raised where economically feasible to the elevation specified in existing legislation		
Category: mitigation	**Location:** Manitoba	**Status:** significant progress
Background: Winnipeg faces a number of threats from damaging floods. The city was fortunate in 1997; with more severe weather conditions at the time of the peak the existing flood defenses may have been insufficient. This work was considered an interim measure pending design of a floodway expansion project. The total cost of primary dike improvements was originally estimated to be $100 million.		
Progress to Date: Winnipeg continues to improve its primary diking system where feasible. The design of this work has been harmonized with the floodway expansion project.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-6, 10-12, 15, 23, 29		
References: KGS Group 2001. *Flood Protection Studies for Winnipeg*. Report prepared for the governments of Canada, Manitoba and Winnipeg. KGS Group, Winnipeg, MB.		
Date: February, 2009		**Revised:** September 2016

Recommendation: TF 10 Winnipeg at Risk		
Modifications to the sewer and land drainage systems should be optimized and undertaken once the overall plan for Winnipeg flood protection is determined.		
Category: mitigation	**Location:** Manitoba	**Status:** significant progress
Background: Winnipeg faces a number of threats from flooding. Even with an expanded floodway attention must be paid to improving internal drainage within the city.		
Progress to Date: Winnipeg continues to improve its internal drainage system. The design of this work has been harmonized with the floodway expansion project. Some 30 pumping stations have now been upgraded.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-7, 11-12, 15, 23, 29		
References: KGS Group 2001. *Flood Protection Studies for Winnipeg*. Report prepared for the governments of Canada, Manitoba and Winnipeg. KGS Group, Winnipeg, MB.		
Date: February, 2009		**Revised:**

Recommendation: TF 11 Winnipeg at Risk		
The City of Winnipeg should give immediate high priority to the preparation of a detailed emergency preparedness and response manual.		
Category: preparedness	**Location:** Manitoba	**Status:** complete
Background: Although Winnipeg performed well in responding to the 1997 flood, the need for improvements to its emergency plan became evident. Under provincial law all communities are required to have an emergency response plan that is subject to periodic review and testing.		
Progress to Date: A detailed flood emergency manual for the city of Winnipeg has been completed. The city is planning a major upgrade of the manual aimed at operations during a flood of 1826 proportions, roughly a 1:300 event.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-7, 10, 12, 15, 23, 29		
References:		
Date: February, 2009		**Revised:** November, 2016

Recommendation: TF 12 Winnipeg at Risk		
Operating rules for new flood control measures should be designed to accommodate all flow regimes, even those beyond design capacity. The public should be consulted on any proposed new operating rules.		
Category: mitigation	**Location:** Manitoba	**Status:** significant progress
Background: During normal floodway operation, operating rules specify that the upstream water levels be held at or below the elevation that would have occurred in a state of nature. When the design capacity of the floodway is exceeded as in 1997, upstream water levels can be raised above those that would occur naturally. This results in artificial flooding of upstream residents.		
Progress to Date: This recommendation regarding operating rules for mitigation works has been accepted and is being taken into account in Red River Floodway expansion. New floodway operating rules covering four modes of operation were prepared in 2005. A compensation program for properties experiencing higher than natural water levels due to floodway operations was introduced in 2006. Public consultation on operating rules was completed in 2010.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-7, 10-11, 15, 23, 29		
References: Farlinger Consulting Group Inc. and H.N. Westdal & Associates 2010. *Red River Floodway: Public Consultation on the Rules of Operation*. Report to Manitoba Water Stewardship. Manitoba Water Stewardship 2005. *Rules of Operation: Red River Control Structure*. Manitoba Water Stewardship, Winnipeg, MB. Manitoba Water Stewardship 2006. *Implementation and Administration of Compensation Program For Damages Caused by Rule 4 Operation of the Red River Floodway.* Manitoba Water Stewardship, Winnipeg, MB. Manitoba Water Stewardship 2011. *Floodway Operations Report: Spring 2011*. Manitoba Water Stewardship, Winnipeg, MB.		
Date: February, 2009		**Revised:** August, 2011

Recommendation: TF 15 Flood Preparedness and Resiliency		
The 500-year flood (0.2 percent flood) should be defined throughout the Red River basin and used to inform the public of the potential risks of flooding from rare events, including the need to buy flood insurance in the United States, and as the basis of regulations for siting and floodproofing critical facilities.		
Category: mitigation	**Location:** basin	**Status:** some progress
Background: Critical infrastructure such as hospitals, fire stations, etc. should be exposed to minimal flood risks. The 1:500 floodplain is delineated on US National Flood Insurance rate maps and can be used in siting critical infrastructure.		
Progress to Date: The 500-year floodplain is being defined in flood frequency analyses conducted by the USACE, but there is little evidence of regulatory agencies incorporating this floodplain into regulations. The 500-year floodplain has been defined in Manitoba south of Winnipeg as part of the floodway expansion project but is not used in regulations. A 200-year flood is used for regulatory purposes.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-7, 10-12, 23, 29		
References:		
Date: February, 2009		**Revised:** September, 2016

Recommendation: TF 16 Flood Preparedness and Resiliency		
Both North Dakota and Minnesota should consider adopting the new International Building Code that includes requirements for design and construction in flood hazard areas.		
Category: preparedness	**Location:** North Dakota, Minnesota	**Status:** complete
Background: At the time of the 1997 flood the United States model building code was in transition from the Uniform Building Code to the International Building Code. Adoption of the new code was deemed desirable on account of its inclusion of flood-proofing requirements. Both Minnesota and North Dakota adopted new building codes based on the 2000 International Building Code.		
Progress to Date: The North Dakota State Building Code, effective November 1, 2007, adopts the 2006 edition of the International Building Code without appendices. The Minnesota Building Code, adopted July 10, 2007, is also based on the 2006 International Building Code. In both North Dakota and Minnesota, enforcement of the building code is the responsibility of local jurisdictions. Jurisdictions that elect to adopt and enforce a building code must adopt the state building code, but may amend the code further to conform to local needs. In Minnesota such amendments must be more stringent than the state code. In 2008 the Minnesota Building Code became the minimum construction standard throughout the state although it is not enforceable by municipalities unless adopted by local ordinance.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2,17-19,26,30,35-40,44,46,48,50		
References:		
Date: February, 2009		**Revised:**

Recommendation: TF 17 Flood Preparedness and Resiliency		
The National Building Code of Canada should specify design and construction standards for buildings in flood hazard areas such as the Red River basin. Floodplain construction requirements should be incorporated into the Manitoba code when available.		
Category: preparedness	**Location:** Manitoba	**Status:** little progress
Background: Unlike the US model code the Canadian model code contains no information on flood-proofing requirements.		
Progress to Date: No steps have been taken to incorporate flood-proofing information into the Canadian National Building Code. Canadian officials take the view that people should not live in floodplains and therefore should not be encouraged by the inclusion of flood-proofing information in the code. This position ignores the fact that thousands of Canadians do live in floodplains.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2,16, 18-19,26,30,35-40,44,46,48,50		
References:		
Date: February, 2009		**Revised:**

Recommendation: TF 18 Flood Preparedness and Resiliency		
Federal, state, provincial and local governments in the Red River Basin, in conjunction with the private sector, should continue to develop, refine and implement effective strategies to improve the disaster resiliency in both communities. Efforts should be made to increase public awareness of flood risks throughout the basin.		
Category: preparedness	**Location:** basin	**Status:** ongoing
Background: Continuing public education on flood risks is an important component of improving disaster resiliency. The International Flood Mitigation Initiative, initiated by FEMA and financially supported by Manitoba, was one part of this public education process.		
Progress to Date: Measures undertaken to mitigate the effects of damaging floods in the Red River basin have undoubtedly led to increased resiliency in the areas flooded in 1997. The continuing discussions of floods and flood risks have increased public awareness. Post-1997 flood events, most recently in 2011, have also maintained awareness.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2,16-17,26,30,35-40,44,46,48,50		
References: IFMI 2000. *International Flood Mitigation Initiative for the Red River Basin.* Final Report and Executive Summary. The Consensus Council, Bismarck.		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 21 Flood Preparedness and Resiliency		
The Canadian federal government should include in the Disaster Financial Assistance Arrangements provisions to allow for the permanent removal of structures in areas subject to repeated flooding.		
Category: preparedness	**Location:** Manitoba	**Status:** little progress
Background: The Canadian Disaster Financial Assistance Arrangements financially supports the replacement of a damaged building with one that is identical, except that current safe building elevations and building codes must be respected. There is no provision for compensation for structures subject to repetitive losses through buy-outs.		
Progress to Date: The Canadian Disaster Financial Assistance Arrangements were revised effective January 1, 2008 and the cost-sharing formula was revised effective February 1, 2015. The new arrangements require replacement structures in designated flood risk areas to be flood-proofed and allow some flexibility for additional costs aimed at reducing future damages. They do permit buy-outs of high-risk structures but only if the cost is lower than for repair of the structure. Some Canadian buy-outs following the 1997 and 2009 Red River floods were made using a separate funding arrangement.		
Related Recommendations: TF 15-18, 25-26		
References: Public Safety Canada 2007. *Guidelines for the Disaster Financial Assistance Arrangements.* Public Safety Canada, Ottawa, ON.		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 25 Flood Preparedness and Resiliency		
Recovery, rebuilding, and mitigation expertise and information should be widely shared across the border in advance of flooding.		
Category: recovery, mitigation	**Location:** basin	**Status:** some progress
Background: The international boundary can become an impediment to timely sharing of expertise and wisdom. Having arrangements in place prior to a disaster improves flood resiliency.		
Progress to Date: There is considerable sharing of recovery, mitigation and re-building expertise and information across the international boundary. For the most part, this has been on an informal agency-to-agency basis. The Red River Basin Commission also provides a mechanism for sharing information.		
Related Recommendations: TF 15-18, 21, 26		
References:		
Date: February, 2009		**Revised:** August, 2016

Recommendation: TF 26 Flood Preparedness and Resiliency		
Measures of flood resilience should be developed, and a system should be established to monitor resilience in the Red River basin		
Category: preparedness	**Location:** basin	**Status:** little progress
Background: Although one may subjectively feel that the post-1997 efforts have led to a more flood resilient basin, the improvements in resiliency cannot be quantified, nor can desired further improvements be compared and evaluated. Development of specific measures of resiliency would help this task.		
Progress to Date: The experiences of the 2006, 2009 and 2011 floods provide an indication that resiliency has improved. There has been no activity specifically directed to developing measures of flood resiliency for the basin.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2,16-19, 30, 35-40, 44, 46, 48, 50		
References:		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 28 Lower Pembina Flooding		
Given the transboundary nature of the basin and the potential for federal involvement in funding and monitoring any agreement, federal agencies from both countries should be engaged in this process as well		
Category: preparedness	**Location:** Pembina basin	**Status:** some progress
Background: For more than 50 years unilateral road and dike building on both sides of the international boundary has been a source of tension among basin residents and between the governments of North Dakota and Manitoba. Certain levees along the lower Pembina River have been deemed to be illegal and have been removed. Manitoba has cost-shared with North Dakota some improvements to drainage through the road-dike that parallels the international boundary. The road dike, however, is now the source of litigation between North Dakota and Manitoba.		
Progress to Date: Following the 1997 Red River flood several agencies over a number of years took actions explicitly aimed at contributing to the solution of the problem. The IRRB endorsed the formation of the Lower Pembina River Task Team in January 2008. The objective of the Task Team is to oversee technical work to determine methods to minimize flooding on the lower Pembina River and adjacent watersheds. The work included the development of the Telemac-2D hydrodynamic model of the lower Pembina River by the Canadian National Research Council. The Task Team endorsed the report and indicated the goal for future solutions should be that flooding should be no worse than existing conditions in Manitoba and no worse that natural in North Dakota. It would be correct to state that the technical work accomplished in the basin is now sufficient to accurately evaluate any scenario that could be considered as contributing to the solution of the problem.		
Related Recommendations: IJC 10, TF 29-30		
References: Faure, T. and R.W. Jenkinson 2012. *Simulation of Flood Scenarios on the Lower Pembina River Flood Plains with the Telemac2D Hydrodynamic model – Phase 3*. Natural Research Council, Ottawa, ON. Halliday, R., R. Bowering and R. Gjestang 2004. *Lower Pembina River Flooding*. A Report to the International Red River Board. Winnipeg Lower Pembina Flooding Task Team 2012. *An Exploratory Analysis of mitigation Measures for the Lower Pembina Basin.* Report to the International Red River Basin Board. Lower Pembina Flooding Task Team US Army Corps of Engineers 2009. *Red River of the North*, Corps of Engineers Fact Sheet. US Army Corps of Engineers, St. Paul, MN.		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 29 Lower Pembina Flooding		
Changes in the road network and diking system in the Lower Pembina Basin should be modeled by the hydrodynamic model prior to implementation of any plan to ensure that there are no unintended consequences.		
Category: mitigation	**Location:** lower Pembina basin	**Status:** complete
Background: Flooding in the lower Pembina basin is sensitive to existing roads and dikes. Solutions to the existing problems could involve new construction. Because of the situation, a careful examination of the effects of new works is required.		
Progress to Date: The modelling task described under Recommendation TF 28 is based on up-to-date data on the roads and dikes. There will be a need to confirm that any models used to examine flooding in the lower Pembina basin employ the same configuration of roads and dikes in order to build confidence in the results.		
Related Recommendations: IJC 2-7, 9-14, 16 and 3-7, 10-12, 15, 23		
References: Faure, T. and R.W. Jenkinson 2012. *Simulation of Flood Scenarios on the Lower Pembina River Flood Plains with the Telemac2D Hydrodynamic model – Phase 3*. Natural Research Council, Ottawa, ON.		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 30 Lower Pembina Flooding		
The virtual database and decision support system prototype that the Task Force has begun to develop for the Pembina Basin should be continued by relevant agencies in Canada and the United States.		
Category: preparedness	**Location:** lower Pembina basin	**Status:** superseded
Background: Some effort has been devoted to improving databases and to developing decision support in the lower Pembina basin. More work is necessary to realize the benefits of this effort.		
Progress to Date: As part of its data harmonization project, the IJC has developed a seamless and comprehensive hydrographic dataset for the Red River basin. This includes the stream network, basin delineation, horizontal and vertical datums, and physical features. The work on databases and decision support related to the Pembina River is being continued to some extent by the Pembina River Basin Advisory Board and RRBDIN. Technological improvements since this recommendation was made tend to make this recommendation moot.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 35-40, 44, 46, 48, 50		
References:		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 32 Hydraulic Connection at Lake Traverse		
Any modification to existing operating plans or physical structures associated with Lake Traverse that could increase pool elevation must be accompanied by features that eliminate the southward movement of water into the Little Minnesota River.		
Category: preparedness, environment	**Location:** Minnesota	**Status:** ongoing
Background: Hydraulic connections are one means by which non-native invasive species may be propagated across the major continental river basin divides. The flat terrain and the proximity of the Little Minnesota River in the Mississippi basin to Lake Traverse in the Red River headwaters make this a potential point of transfer. There is a need to consider movement of water in either direction, southward or northward.		
Progress to Date: The potential for biota transfer at Lake Traverse was considered as part of the dam safety study at White Rock Dam. In general, however, there is little progress on this recommendation. A flood protection project for Browns Valley, MN is part of the solution.		
Related Recommendations: TF 34		
References: Minnesota DNR 2007. *Background on the March 13-14, 2007 Flooding in Browns Valley (Traverse County), Minnesota*. Report to the Minnesota Governor's Office. Minnesota Department of Natural Resources, Waters Office. St. Paul, MN.		
Date: February, 2009		**Revised:** September, 2016

Recommendation: TF 34 Lake Winnipeg Water Quality		
Governments should continue to monitor toxaphene in the Lake Winnipeg ecosystem until concentrations decline to pre-1997 levels.		
Category: environment	**Location:** Manitoba	**Status:** complete
Background: During the 1997 flood a banned pesticide, toxaphene, was released to the aquatic environment. Increased concentrations were detected in fish tissue in Lake Winnipeg.		
Progress to Date: Manitoba Water Stewardship in partnership with Fisheries & Oceans Canada monitored toxaphene concentrations in fish tissue for Lake Winnipeg for a number of years. Concentrations have declined since 2002 dropping to within Manitoba Water Quality Standards, Objectives and Guidelines for both human and wildlife consumers. Monitoring for toxaphene was suspended in 2007.		
Related Recommendations: IJC 23 and TF 32		
References: International Red River Board 2007. *Eighth Annual Report to the International Joint Commission.* International Joint Commission, Washington and Ottawa. Stewart AR, GA Stern, A Salki, MP Stainton, WL Lockhart, BN Billeck, R Danell, J Delaronde, NP Grift, T Halldorson, K Koczanski, A MacHutcheon, B Rosenberg D Savoie, D Tenkula, G Tomy, and A Yarchewski 2000. *Influence of the 1997 Red River Flood on Contaminant Transport and Fate in Southern Lake Winnipeg*. A report to the International Red River Basin Task Force. Winnipeg, MB		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 35 Data and Decision Support		
Hydrometric and meteorological data networks necessary for flood forecasting should be improved and maintained in a state of readiness to forecast future floods.		
Category: preparedness	**Location:** basin	**Status:** ongoing
Background: Hydrological and meteorological data are an essential element of flood forecasts. It is essential that the improvements to observing networks carried out following the 1997 flood be maintained and that information sharing continue to improve.		
Progress to Date: The initial task of improving hydrometric and meteorological networks used in flood forecasting has been completed. Maintaining these networks in the long term as operating costs increase remains a challenge. Forecasts could be further improved with additional snow water equivalent, frost penetration and soil moisture data. Environment Canada's curtailment of manned climate observing sites has reduced snowfall data availability.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 36-40, 44, 46, 48, 50		
References: Red River Basin Commission 2015. *A Red River Basin River Forecast Data Network Integration and Stabilization Program.* The Red River Basin Commission, Forecast Working Group. Fargo, ND.		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 36 Data and Decision Support		
New geographically related data collection in the United States should be in accord with the North American Vertical Datum of 1988.		
Category: preparedness	**Location:** North Dakota, South Dakota, Minnesota	**Status:** complete
Background: The United States adopted a new gravity-based vertical datum in 1988. This new datum is naturally compatible with global positioning system output. The previous datum, NGVD 1929, is widely used in the basin and often documents do not specify the datum. Given the flat terrain and the difference between the two datums in the Red River basin, this can lead to potential problems.		
Progress to Date: Data collected by US federal agencies are being collected using the new US vertical datum (NAVD 1988). This is frequently not the case for city and county entities. Canada also has adopted a new gravity-based datum, CGVD2013. The vertical datum is harmonized with that used by the United States and is compatible with Global Navigation Satellite Systems such as GPS. The previous vertical reference system, CGVD28, is still widely used in the Canadian part of the basin. Currently available software makes datum conversion quite straight-forward, provided that data collectors specify the datum used.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35, 37-40, 44, 46, 48, 50		
References: Harkness, R. E. 1999. *Datum Issues in the Red River of the North Basin.* Water Resources Division, US Geological Survey, Bismarck, ND.		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 37 Data and Decision Support		
For consistency and accuracy, data used in models should take into account the differences in data at the border. Because datum conversions can affect data accuracy, any conversions between standards should be noted and reported along with the data.		
Category: preparedness	**Location:** basin	**Status:** complete
Background: The United States adopted a new gravity-based vertical datum, NAVD 1988, in 1988 while Canada adopted a new datum in 2013, CGVD2013. These new datums are naturally compatible with global positioning system output. The previous datums, NGVD 1929 and CGVD28, are still widely used in the basin. Given the flat terrain and the difference between the old and new vertical datums at the international boundary, this can lead to potential problems.		
Progress to Date: There now appears to be a greater likelihood of the datum used in specific projects being reported, but this is not always the case. Conversion algorithms for converting between the former and the new US and Canadian vertical datums are widely available.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-36, 38-40, 44, 46, 48, 50		
References: Harkness, R. E. 1999. *Datum Issues in the Red River of the North Basin.* Water Resources Division, US Geological Survey, Bismarck, ND.		
Date: February, 2009		**Revised:** July 2016

Recommendation: TF 38 Data and Decision Support		
U.S. National Geodetic Survey and the Geodetic Survey of Canada should convene a forum of datum experts in the year 2000 to discuss Red River Basin datum issues and develop a long-term transition plan.		
Category: preparedness	**Location:** basin	**Status:** superseded
Background: The United States adopted a new gravity-based vertical datum, NAVD 1988, as did Canada in adopting CGVD2013. These new datums are naturally compatible with global positioning system output. The previous datums, NGVD 1929 and CGVD28, are still widely used in the basin. Prior to Canada's adoption of its new datum, given the flat terrain and the difference between NAVD 1988 and CGVD28 at the international boundary, this difference may have led to potential problems.		
Progress to Date: With the adoption of new vertical datums in each country the potential problem identified by the IJC has been overtaken by events. The challenge now is to implement the new datum. The IJC's International Water Initiative has provided funding for an international data harmonization project, which includes the Red River basin. The project examines datum issues. The project is now at Phase III focusing on HUC 12s in the United States and sub-sub basins in Canada.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-37, 39-40, 44, 46, 48, 50		
References: Harkness, R. E. 1999. *Datum Issues in the Red River of the North Basin.* Water Resources Division, US Geological Survey, Bismarck, ND.		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 39 Data and Decision Support		
All key data providers in Canada should make available at no cost and with no restriction the data sets necessary for the Red River floodplain management and emergency response, and regional or basin-wide modelling activities.		
Category: preparedness	**Location:** Manitoba	**Status:** complete
Background: Following the 1997 flood there were a number of roadblocks pertaining to Canadian data that inhibited the development of a common searchable database for the basin. Government data holdings tended to be inaccessible, access to internal computer networks constrained by security requirements, and cost-recovery policies made access expensive. This placed public safety in jeopardy by constraining public and agency access to data.		
Progress to Date: Substantial improvements in data availability for both Canadian and American data have been made since the flood. Canadian cost-recovery policies have been changed significantly. More work on making data available by means of the Internet continues to be needed including conversion of paper records and further development of data portals.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-38, 40, 44, 46, 48, 50		
References:		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 40 Data and Decision Support		
Data providers should remain responsible for maintaining and replicating the data sets.		
Category: preparedness	**Location:** basin	**Status:** complete
Background: The Task Force saw the distributed (or virtual) database as the preferred model for data distribution in the basin. The other model was the data warehouse. Having data providers retain responsibility for their data is a necessary pre-condition to development of distributed databases.		
Progress to Date: There is general acceptance of the concept of data providers being responsible for maintaining and replicating data sets, as opposed to this being done by third parties.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-39, 44, 46, 48, 50		
References:		
Date: February, 2009		**Revised:**

Recommendation: TF 44 Hydrologic and Hydraulic Modelling		
The U.S. National Weather Service should implement its Advanced Hydrologic Prediction System in the Red River basin as an early priority.		
Category: preparedness	**Location:** North Dakota, Minnesota	**Status:** complete
Background: At the time of the 1997 flood the NWS had embarked on significant changes in its flood forecast systems. These changes had not been incorporated into Red River forecasts and for much of the United States in 1997.		
Progress to Date: The National Weather Service has implemented the AHPS forecast system and new modelling for the US portion of the basin. A detailed FLDWAV one-dimensional hydrodynamic model for the Red River mainstem was implemented in 1999 and updated in 2005. Further improvements were made by adding additional cross-sections.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-40, 46, 48, 50		
References:		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 46 Hydrologic and Hydraulic Modelling		
Confirm the flood peak reduction findings of Chapter 3 for large floods and examine reductions for smaller floods by implementing distributed models on tributaries such as the Mustinka, Wild Rice and Maple Rivers.		
Category: preparedness	**Location:** basin	**Status:** complete
Background: The Task Force made some basic calculation of the effect of upstream storage on downstream water levels. These calculations could be refined using sub-basin scale distributed hydrological models.		
Progress to Date: The flood peak reduction analysis performed during the IJC studies can be re-examined using a hydrodynamic model of the entire Red River main stem. The USACE has developed a HEC RAS one-dimensional hydrodynamic model for the Red River, extending from the headwaters to Winnipeg. The model extends up each Red River tributary to the first USGS gauging station. The USACE has also developed an HEC HMS hydrologic model for each Red River tributary in the United States. The models allow sub-basin inputs and can be used watershed groups to examine flow reduction scenarios. The RRBC as part of its basin wide flow reduction strategy determined that achieving a 20 percent flow reduction would require an additional 885,000 ac.-ft. of storage in the basin. Gate controlled storage of this magnitude would cost about one billion dollars. The Waffle Project®, based at the University of North Dakota also examined flood peak reduction.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-40, 44, 48, 50		
References: Anderson, C.L. 2010. Basin Wide Flood Flow Reduction Strategy. A Report to the RRBC, Fargo, ND. Kurz, B.A., X. Wang, L. de Silva, S.K. Hanson, M.D. Kurz, W.D. Peck, T. K. Simonsen, E.N. Steadman 2008. *An Evaluation of Basinwide, Distributed Storage in the Red River Basin: The Waffle® Concept.* Energy & Environmental Research Center, University of North Dakota, Grand Forks, ND		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 48 Hydrologic and Hydraulic Modelling		
Conduct surveys of secondary roads, particularly in the central portion of the basin, with differential global positioning systems, and incorporate the results into the hydraulic models.		
Category: preparedness	**Location:** basin	**Status:** complete
Background: Accurate modelling the movement of flood waters in the flat landscape of the Red River valley requires very detailed topographic data. As roads and railways can influence the accuracy of the models, inclusion of this information in the model is important.		
Progress to Date: In the United States the International Water Institute managed a project that developed lidar-based DEMs for the entire Red River basin. The product, based on 2008-2010 data, meets FEMA standards for lidar data. That is, an uncertainty of ±150 mm. In Canada, Manitoba Water Stewardship in collaboration with Agriculture Canada has prepared a lidar-based DEM for the Red River valley. The two DEMs have not been stitched together.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-40, 44, 46, 50		
References:		
Date: February, 2009		**Revised:** August 2016

Recommendation: TF 50 Hydrologic and Hydraulic Modelling		
Measures should be taken to ensure that data supporting the operation of the hydraulic models and model outputs can be made widely available.		
Category: preparedness	**Location:** basin	**Status:** significant progress
Background: Operation of the hydraulic models used in the Red River basin requires a considerable amount of topographic and hydrometric data. As different models are developed they must be calibrated and verified. Using common datasets assists the development of new models and the intercomparison of model results.		
Progress to Date: The data supporting the operation of hydraulic models and the output from those models are generally widely available. There remains a need for the preparation of metadata in accordance with a standard such as the FGDC standard to facilitate this process.		
Related Recommendations: IJC 8, 17-19, 22, 26 and 2, 16-19, 26, 30, 35-40, 44, 46, 48		
References:		
Date: February, 2009		**Revised:** August 2016