MANITOBA 2011 FLOOD REVIEW **TASK FORCE** REPORT

Report
to the Minister of
Infrastructure and
Transportation

April 2013

Executive Summary

The 2011 Manitoba flood was of a scope and severity never before experienced, in recorded history, in this province. High soil moisture at freeze-up, above normal winter snow, additional snow and rain during the spring, heavy summer rains and several severe wind events all combined to form the "perfect storm". In early May, 13 rivers or creeks across the province were at flood stage including the Red, Assiniboine, Souris, Whitemud, Saskatchewan and Pembina rivers. All time record flood peaks were experienced on locations on the Assiniboine River, on the Souris River and a number of smaller waterways. Extremely high lake levels on Lake Manitoba combined with severe winds on May 31 devastated lakeshore communities around the south basin of that lake.

At the height of the flood there were more than 7100 evacuees, primarily from First Nations communities. As this report is being prepared, nearly 2000 still remain out of their homes largely because they are uninhabitable.

The physical strain and the emotional stress was too much for some to bear and the Regional Health Authority of Manitoba established a Psychosocial Flood Recovery Team to help people with issues they were facing.

Three million acres of cultivated farmland went unseeded in 2011. Tens of thousands of cattle had to be relocated. More than 650 provincial and municipal roads were damaged, and nearly 600 bridges, disrupting transportation networks throughout the province. As this report is being prepared, costs associated with flood preparation, flood fighting, repair to infrastructure and disaster payments has reached at least $1.2 billion.

In February of 2012, the Province announced the formation of the Manitoba 2011 Flood Review Task Force. The Task Force was directed to examine many aspects of Manitoba's historic 2011 flood, and to provide an overview to the Province of what happened, what worked and did not work, and what could be done better in the future.

Following is a brief description of the Task Force's findings under each of the nine Terms of Reference. In addition, the Task Force has included a discussion on the unique issues facing First Nations during the 2011 flood. All members of the Task Force participated in the preparation of this report, with individual members responsible for investigating, researching and authoring or co-authoring each of the Terms of Reference.

After an intense and lengthy review of the actions taken by the Province, and others, during the 2011 flood, the Task Force has formulated 126 recommendations. A complete list of these recommendations appears at the end of the Executive Summary.

All time record flood peaks were experienced on the Assiniboine River, Souris River and many smaller streams.

Evaluation of the Operation of Water Control Structures

The operation of the water management structures on Dauphin Lake, Assiniboine River, Lake Manitoba and the main stem of the Red River were evaluated.

Mossy River is the outlet from Dauphin Lake to Lake Winnipegosis, which in turn flows into Lake Manitoba through the Waterhen River. Persistently high lake levels since 2009 had dictated that the structure controlling flows from Dauphin Lake was wide open and outflows were maximized over the entire period.

There was little officials could have done to reduce outflows from the Shellmouth Reservoir or to operate the reservoir differently in 2011. Drawing the reservoir down to a level below the defined minimum late-winter reservoir level was an advantage, maximizing both the storage in the reservoir and the subsequent reduction in flood peaks downstream. However, once the water level reached the crest of the spillway, operators could do no more than to allow the flood to take its course and rely on reservoir storage effects to reduce the peak downstream, relative to the peak inflow into the reservoir.

In 2011, the flow down the lower Assiniboine River was a major concern and it was clear that the Portage Diversion would need to convey substantially more flow than its design capacity. A major effort was made to divert a significant flow down the Portage Diversion without jeopardizing the integrity of both the inlet control structure and the diversion channel itself. Extraordinary efforts were made to increase its capacity largely by raising the dikes on both sides of the channel and reinforcing the drop structures. This required a massive effort given how much flow had to be diverted. The fact that it was successful speaks to the skill and determination of the operating personnel.

The Assiniboine River dikes are an important component of the flood control system both for the city of Winnipeg and the farmland and communities located between Portage La Prairie and Winnipeg. The biggest concern in 2011 was the structural ability of the dikes to contain the expected high flows for extended periods. Failure of the dikes would have been catastrophic for the residents, communities and farmland between Portage la Prairie and Winnipeg.

Even with the increased flow through the Portage Diversion, the amount of flow expected downstream of the diversion put the integrity of the Assiniboine River dikes in jeopardy. The only alternative was to construct a controlled breach that could be used to divert water out of the Assiniboine River as required. This water would then be conveyed across the landscape – through the Elm River to the La Salle River and then to the Red River. The area in the vicinity of Hoop and Holler Bend was chosen. With flows at critical levels on both the Portage Diversion and the lower Assiniboine River, and with Environment Canada forecasts indicating additional rain, the breach was opened on Saturday, May 14. The rain did not materialize, and only a small amount of water actually moved through the breach. The breach was closed on Friday, May 20.

The strategy to construct the breach was entirely reasonable. It is evident that the opening and closing of the breach at Hoop and Holler were carried out as judiciously as possible. To protect the Assiniboine River dikes against any future flood in excess of system capacity, a permanent controlled wasteway should be constructed at an appropriate location along the Assiniboine River downstream of Portage la Prairie.

The Fairford River Water Control Structure (FRWCS) is operated to maintain suitable water levels on Lake Manitoba, the Fairford River, Lake St. Martin and the Dauphin River downstream. Because of persistent high flows into Lake Manitoba, the FRWCS has been kept open effectively from August 2005 until the present. Inflows to Lake Manitoba in 2011 were the highest on record on both the Waterhen River and Portage Diversion. Outflows through the Fairford structure peaked in late July and continued to recede well into 2012. In 2011, levels on Lake Manitoba peaked at 249.05 m (817.11 ft) in mid-July.

It is clear that the water level guidelines for Lake Manitoba and Lake St. Martin were not adhered to in 2011. Despite drawing the water levels down as much as possible in 2010 and in 2011, the high inflows into Lake Manitoba simply overwhelmed the capacity of the FRWCS and the downstream Fairford River channel. Given the design of the structure and the water level objectives established for Lake Manitoba, everything that could be done at the structure to maximize outflows from the lake was done - even at the expense of creating severe water levels on Lake St. Martin.

During the summer of 2011 it was recognized that frazil ice could become a problem on the Dauphin River over the winter of 2011/12, reducing the capacity of the river. To alleviate this problem an emergency channel was constructed from the northeast end of Lake St. Martin to the lower Dauphin River and put into operation on November 1, 2011. If the emergency channel had not been constructed, flows through the FRWCS would have been reduced over the winter period. Lake level simulations indicate that without the emergency channel, levels on Lake Manitoba would have been 0.8 m (2.7 ft) higher going into the spring runoff period and in the summer of 2012 would have been 0.4 metres (1.3 ft) higher than recorded. The simulations also indicate that levels on Lake St. Martin would have been 0.9 metres (2.9 ft) higher over the winter when the lake is high due to frazil ice formations and summer levels would have been 0.5 metres (1.6 ft) higher.

If the FRWCS had been kept open all winter before the 2011 flood, lake level simulations suggest that the peak level on Lake Manitoba would have been only slightly lower. The emergency channel would have lowered the 2011 Lake St. Martin peak level by 0.5 m (1.6 ft). It is apparent that the capacity of the emergency channel is insufficient to provide significant relief in the short term during events like 2011. However, it may have some positive effects for less severe floods. That being said, the emergency channel did in fact meet the Province's objective of lowering both lakes close to the top end of their operating ranges by the end of summer 2012.

Suggested Procedures for Undertaking Flood Mitigation Measures

Sandbags are filled by hand or by using sandbag filling machines. In some cases, enough manpower may not be available to operate the large sandbagging machines. In 2011, some municipalities and others resorted to developing makeshift sandbag filling devices more suited to their situation. These machines should be sized to fit the situation and the number of volunteers available.

During the 2011 flood, some training on erecting sandbag dikes took place in the field, but it was noted by a number of individuals involved in the flood fight at the local level that more training would have been helpful. The Province should develop a handbook providing guidelines for how to select the right type of dike for a particular situation, and the correct way to construct all types of dikes.

An issue which created ill feelings among individuals was the policy of giving preference to permanent residents over seasonal cottagers for the supply of sandbags. The Task Force agrees with this policy.

Aqua Dams and Tiger Dams were used to provide freeboard along the top of larger clay dikes, however this prevented the use of equipment to move along the top of a dike to make emergency repairs and to reinforce the dike. Guidelines for the use of Aqua Dams and Tiger Dams should be put in place.

Used tube-type diking materials provided by the Province for reuse were often found to be defective. An inventory of all tube-type diking owned by the Province should be taken and assessed for condition and repaired for use as necessary.

In November 2010, the Province had the foresight to convene a meeting with contractors to discuss the potential of a major spring flood and to put contractors on notice with regard to the Province's possible requirements. Through a tendering process with larger contractors, accumulating a supply of granular base course and rip-rap began

Many communities did not have the manpower to operate large sandbagging operations.

in February of 2011. The granular material was intended for use in Hesco barriers. Hiring large contractors with significant resources seemed to work well. Many smaller contractors were either hired directly by the Province or as sub-contractors to larger companies.

Aboriginal Affairs and Northern Development Canada undertook a major effort in diking First Nations. Many of the First Nations required financial assistance, engineering expertise and heavy equipment support to reinforce or construct dikes against flooding. An expanded federal financial program was used to complete much of this work. The Province also assisted in diking First Nations communities. In 2011, there was a shortage of prefabricated tube-type diking materials available to First Nations communities.

The flooding of Lake St. Martin was and remains a concern to residents and others. The dike protecting the community was secure during the flood, but many homes were damaged by internal overland flooding. A system had been put in place to pump this water over the dike to the outside. But this action coincided with the commencement of the evacuation of the community and the pumping effort failed.

In general, the Province did a good job of constructing new dikes and raising and strengthening existing dikes both on their own and working with the affected rural municipalities, cities, towns and First Nations.

Flood Forecasting

Given the scope of the 2011 flood and the tools available to the Hydrologic Forecasting Centre (HFC), providing a timely and reliable forecast would have posed a challenge to the most experienced forecasters, let alone a forecast team whose experience ranged from six months to three years. In spite of their limited experience, the HFC was able to identify and effectively communicate the potential risk of flooding as early as December 2010, providing water managers and communities with time to prepare.

The Task Force heard from a number of sources that the inadequacy, or lack, of succession planning within the provincial government was a concern. This was particularly evident in the Hydrologic Forecasting Centre where relatively inexperienced forecasters were required to deal with a flood event far beyond anything they had ever faced. The Province must take steps to address this issue for the future.

The HFC, now part of Manitoba Infrastructure and Transportation, faced many operational and technical challenges. In the beginning, the forecasts were conducted from each individual forecaster's office because they did not have a dedicated operations centre. Then in mid-April, a series of rainfall events in the headwaters of the Souris River, Assiniboine River and the Dauphin Lake area increased flooding concerns over an expanded area and created a significant increase in the need for near real-time data and field measurements. At this stage, the HFC transformed a board room into a temporary operations centre where forecasters could work collaboratively without interruptions, lay out maps and exchange and coordinate information more effectively.

The flood forecasting model being used (MANAPI), is a snowmelt model and is unable to produce reliable runoff forecasts for rainfall events. Most of the largest floods in Manitoba are the result of rainfall on top of, or shortly after, the snowmelt event.

The lack of a data management system for handling large volumes of hydroclimatic (rainfall) data created an immense amount of work for the staff. To gather the data, HFC staff had to visit several Internet climate websites, access the data one station at a time, and finally copy and paste data from each website into EXCEL spreadsheets where it was processed into a usable form. Staff frequently had to start work at 2:00 am to ensure that all data had been gathered and manipulated into a usable format so they could meet the daily flood forecasting deadlines.

Field support in gathering streamflow data during the 2011 flood was described by HFC staff as outstanding. Eighteen water metering crews conducted approximately 5,500 observations to support real-time decisions and verify stage discharge relationships. However, staff identified the need for several additional Acoustic Doppler Meters to reduce safety concerns associated with the use of traditional current meters when conducting streamflow measurement during high flow events.

In their attempts to overcome the obstacles facing them, the HFC forecasters employed a number of initiatives. They developed rainfall-runoff models "on the fly" for sub-watersheds in the Souris, Assiniboine and Red river basins as well as for a number of other streams. A significant number of field staff and other resources were mobilized to provide near real-time data and field measurements as events unfolded. Additional support staff were recruited from other areas of government to help with the forecasts. Consultants were retained to conduct some of the lake level forecasts. The forecasters worked anywhere from 12 to18 hours a day continuously for a period of about 100 days. Eventually, all of these factors in combination with the relative inexperience of the forecasters began taking their toll on the accuracy and reliability of the forecasts.

The problems encountered during the 2011 flood operations are a clear indication that current level of resources in the HFC are inadequate for floods of the magnitude and areal extent of the 2011 event. It is also obvious from the 2011 event that the early development and implementation of the following resources is critical to future operations.

- A full time operations centre which has dedicated computers, telephones, software and other communication equipment as well as adequate room for laying out visual materials.
- A fully functional data acquisition and management system with adequate professional and technical support to develop and maintain the system and to provide data collection and management support to forecasters.
- Provided the above two conditions are met, a complement of four dedicated forecasters should be sufficient to develop, maintain and apply hydrologic forecasting models in the delivery of operational forecasts for the Province, to provide water level forecasts for lakes including wind set-up and wave action forecasts and to develop and maintain automated processes for updating of current conditions reports.

Given the lengthy duration of this event and the personal sacrifice required to provide continuous delivery of an operational forecast, it is believed that overall, the HFC displayed a high level of commitment and professionalism.

Flood Preparedness, Flood Fighting Capacity and Response

Overall, the Province, through the Emergency Measures Organization (EMO) and Manitoba Infrastructure and Transportation (MIT), did due diligence in responding to the 2011 flood. EMO began early stage planning well ahead of the eventual flood. They opened the Manitoba Emergency Coordination Centre in the spring of 2011. It remained open for a total of 103 days of operation. This compares with only 33 days during the 1997 Flood of the Century.

The Task Force heard that EMO just didn't have enough staff in the field, municipal offices and EMO head office to keep up with the demands for service. The Task Force heard many complaints of lack of training provided by the Province's EMO.

The Canadian military played a crucial role in fighting the 2011 flood. They assisted in shoring up dikes in several communities, and provided assistance in producing thousands of sandbags. The military also protected many private homes using aqua dams and tiger tubes.

When it comes to emergency management, the construction industry is not clear on what they can and cannot do before, during and after an emergency event. The construction industry should be involved with EMO in preplanning for an event such as this. The industry also pointed out that it was not included as part of the Manitoba Emergency Coordination Centre (MECC), and perhaps should be.


Canadian military played a crucial role fighting the 2011 flood.

Northern Association of Community Councils (NACC) - struggled before, during and after this 2011 flood event. Lack of resources, training, communication and isolation caused many hardships.

Beyond the regular DFA program, the Province chose to use Manitoba Agriculture, Food and Rural Initiatives (MAFRI)/ Manitoba Agricultural Services Corporation (MASC) programs to administer Lake Manitoba programs to provide enhanced assistance beyond DFA (e.g. The inclusion of secondary residences). This enhanced assistance was in response to the specific circumstances of Lake Manitoba.

There are three full time DFA staff working out of the EMO office in Winnipeg. DFA, at the height of this event hired 68 part time recovery advisers to assist with claims. Training and retention of these individuals appears to be of a concern during this event.

The EMO head office is located on the 15th floor of 405 Broadway Avenue in downtown Winnipeg. Access is difficult and there is a shortage of long-term parking. Easy access to the Manitoba Emergency Coordination Centre by responding departments and emergency management agencies during an emergency event is critical. This unit should be relocated to a more appropriate, accessible and secure location.

Through the consultation process the Task Force heard about difficulties claimants had attending to claims offices, especially those persons who lived in remote areas including First Nations, NACC and farm communities. Many complaints were also heard of MASC/ MAFRI/DFA losing original paperwork. Multiple claims programs cause considerable confusion and stress to claimants across the province.

Who is responsible for First Nations emergency management during events such as the 2011 flood was confusing to those living within the affected areas. Though most interviewed understood the federal government has responsibility, most felt that they were left to look after themselves with little to no assistance from either the federal or provincial governments.

The *Federal Emergency Management Act* states that "First Nations are responsible for developing and implementing plans for their communities. When an emergency occurs or may be imminent within a First Nation, it is the responsibility of the Chief and Council of the First Nation to utilize all available local resources to respond to any situation that results in a present or imminent threat to life, property or the environment in their community. The Chief and Council may declare a state of emergency through a Band Council Resolution and notify Aboriginal Affairs and Northern Development Canada (AANDC) and Manitoba EMO if such a declaration is made. When a First Nation declares a state of emergency it signals its need for assistance."

The federal government, without any formal agreement, placed its responsibility for emergency management on First Nations communities on the Province. These services were provided under the provisions and guidelines of the DFA affecting reimbursement of provincial expenditures on First Nations. There was no standing agreement to do this and it is subject to a case-by-case request from Aboriginal and Northern Development Canada to the Province. The Province may have been placed in a position where it is liable for costs that the federal government may decline to absorb.

Despite the difficulties faced by the Province in several areas in response to the 2011 Flood event, overall the outcome was positive, there was no loss of life and the Province continues to put a great deal of effort into repairing as best as possible the damage left behind after the flood.

Adequacy of Existing Flood Control Infrastructure

The Mossy River Dam has been effective in stabilizing lake levels on Dauphin Lake and preventing very low levels during periods of sustained low runoff. But, it cannot prevent very high lake levels such as occurred in 2011 because of limited channel capacity of the Mossy River, the only outlet from the lake.

On the Shellmouth Dam, any time peak flows are reduced through an increase in reservoir storage, outflows must eventually be greater than inflows to achieve reservoir drawdown through release of water from the reservoir. In most years these outflows can be controlled. However, during high runoff events when the reservoir rises above the crest of the spillway it is not possible to control these outflows and the duration of downstream flooding can be extended. The installation of spillway gates on Shellmouth Dam must be considered.

The Portage Diversion weir and headgate structure, the Portage Diversion channel and associated drop and outlet structures all need to be upgraded. The infrastructure upgrades conducted along the Portage Diversion in 2011 need to be kept and maintained, as a contingency for future large flood events. As well, the Assiniboine River dikes need to be upgraded. In addition, a permanent controlled wasteway at an appropriate location along the Assiniboine River dikes should be constructed.

Outflows through the Fairford River Water Control Structure are limited by the hydraulic capacity of the Fairford River channel. Any increase in outflow capacity from Lake Manitoba would require a similar increase in outflow capacity from Lake St. Martin to prevent surcharging of that lake.

The recommendations of the Lake Manitoba and Lake St. Martin Regulation Review Committee regarding additional outlet capacity requirements for Lake Manitoba and Lake St. Martin, with due consideration for the engineering studies that are being conducted, should be adopted.

A number of alternative schemes were suggested to the Task Force by local residents to reduce or control inflow to Lake Manitoba and thereby reduce or preclude the need for additional outlet capacity from Lake Manitoba and Lake St. Martin. These include:

- a diversion from Lake Manitoba to Lake Winnipeg,
- a diversion from Lake Winnipegosis to Lake Winnipeg, and/or
- an outlet control structure on the Waterhen River to control outflow from Lake Winnipegosis.

These options should be investigated.

The Red River Floodway has proven to be very effective in protecting the city of Winnipeg from flood damages, and the Task Force has no recommendations for additional flood control infrastructure in the Red River Valley.

Environmental Impacts

An environmental consulting firm was contracted to assist the Task Force in its examination of the environmental, social, water quality and human health impacts related to flooding of environmentally sensitive developments such as sewage lagoons, landfill sites and gasoline, oil and farm chemical sites. The impacts to domestic water supplies and the impacts to riparian zones and related erosion were added to the list. Representative sites for each of the items were selected for study.

The effects of flooded lagoons tended to be of a local impact during the flood and of short duration, although potential for medium to long term impacts exists.

The issues related to hazardous materials in the flood zone were focused on the domestic quantities

The 2011 flood still adversely affects domestic water supplies, riparian zones and agricultural land.

that were stored throughout the flooded area. The impacts from these hazardous products has the potential for long term effects. The threat of release may persist for some time and the effects to natural systems and human health are unknown.

Flood issues with landfill sites were only reported on one occasion and a subsequent field visit could not determine the extent of the concern.

A common issue throughout the extent of the 2011 flood was the overall effects of flooding of domestic water systems, including wells and septic fields or holding tanks. Destruction of domestic water systems including flooding of wells and individual wastewater collection systems will impact the surface water quality in local areas for a short duration of time. However, the long term effects to groundwater supplies are unknown.

The loss of the riparian areas leading to severe erosion will produce the most complex impacts over time. While the zones themselves may recover in the medium term, the long term implications to natural ecosystems is unknown. Over the medium term, it is expected that aquatic life will potentially be significantly impacted, although the extent of the impacts is unknown.

The overall environmental impact of the 2011 flood will not be known for many years to come. In the case of Lake Manitoba in particular, measuring the effects of the flood on fish, wildlife and riparian areas over time will be difficult and time consuming. Long-term, on-going monitoring and observations are necessary in order to identify changes that may be happening to the flooded areas over the years.

Throughout the areas surrounding Lake Manitoba that were flooded in 2011 and in the lake itself, debris has accumulated as a result of the flood. Some of the debris contains hazardous materials from private properties. The Province needs to take a proactive role in cleaning the debris from flood-affected areas.

Land Use Policies and Zoning

While provincial flood protection policy requires flood protection to the higher of the 100-year flood level or the flood of record, flood damages continue to occur in Manitoba. The standard response of water managers has been to re-compute the 100-year flood level based on the latest flood or to raise the flood protection level to the flood of record, as was done for Lake Manitoba after the 2011 flood. These new levels determine the Province's flood protection requirements that municipalities must include in their planning documents. This results in uneven flood risk geographically, and has created considerable confusion.

It is the Task Force's opinion that the 100-year flood standard is too low when one considers risk over the longer term. The probability a property in this zone will be flooded sometime over a 50-year period is 40 percent. This risk is considered too high. The 200-year flood may provide an appropriate balance between long term risk tolerance and uncertainty with estimation of flows and levels from limited hydrologic data.

The Lake Manitoba and Lake St. Martin Regulation Review Committee has recommended in its report that the Province establish a five-year pilot project involving the Government of Canada, planning districts, municipalities, conservation districts and First Nations to develop a plan that would define Designated Flood Areas within a watershed. This plan would develop appropriate land use policies and regulations relating to flood control/mitigation including land drainage and incorporate the principles associated with "No Adverse Impact". The Task Force supports this recommendation.

The Task Force also noted that First Nations need the resources to undertake planning for their communities and there is a need to facilitate the development of a collaborative approach to planning between First Nations and adjacent municipalities. A mechanism is needed to ensure drainage systems are designed on a watershed basis, without consideration of administrative boundaries. If an upstream municipality is planning to improve a drain, regulations should be in place to ensure that the downstream municipality or First Nation has adequate capacity to receive the additional flows.

Communications to the Public

Communications by the Province of Manitoba during the 2011 flood was led by Communications Services Manitoba (CSM) within Manitoba Culture, Heritage and Tourism.

The Task Force recognizes that some Manitobans were unhappy with communications related to the flood. Overall, it is the Task Force's opinion that to the Province's and Communications Services Manitoba's credit, they provided Manitobans with a wide and comprehensive communications program throughout this event.

However, the Task Force heard one similar message throughout its travels and consultation.

> *"Communications to the public and emergency management responders needs to be more timely in order to be accurate enough to respond to."*

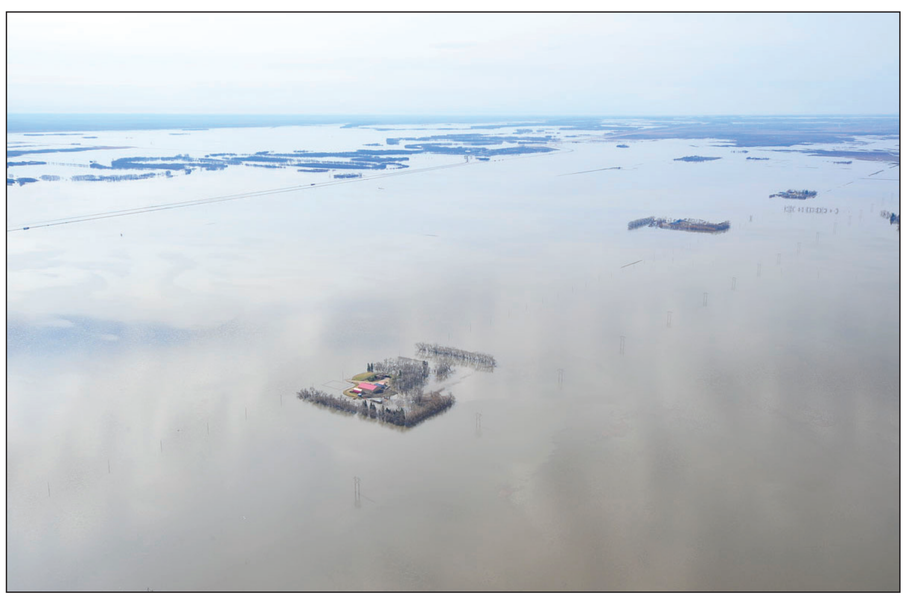
The Task Force feels that, when the Province is under a state of emergency, a public service television channel, radio station or similar media should be dedicated to communicate the details of the emergency at hand to the general public. In the case of a flood event, information provided should include flood bulletins, needs for volunteers, comments on road status and road closures and other relevant information.

The Task Force heard that for some Manitobans, trust became a significant issue. In 2011 the information the government was distributing was changing daily, sometimes hourly, and often coming from different sources. A single spokesperson for the Province would help to instill trust and credibility in the public.

Impacts on Road Networks and Bridges

As of the date this report was prepared, the 2011 flood affected 154 provincial roads and highways, 500 municipal roads, 73 damaged highway provincial structures and 500 municipal bridges. The current estimated value of repairs to bridge sites on the provincial highway network that were impacted by flooding in the Souris and Assiniboine basins alone is $70 million.

Residents, farmers and businesses across Manitoba were impacted in a variety of ways by damage to and closures of flooded roads and bridges. Perhaps the most obvious impact is lost access, but other significant impacts included interrupted delivery of goods and services. Farmers were impacted by being unable to access farmland in some areas or being unable to transport their goods. Many farmers were forced to use alternate routes to gain access to their land which at times put them on major highways. Not only did this increase the travel time between land locations but also caused safety concerns mixing large, slow moving equipment with fast moving traffic.



Many farmers were forced to use alternate routes to gain access to their land, and sometimes had no access at all.

Businesses servicing farmers were unable to reach their clients in some cases causing delays in planting, spraying, harvesting and other similar issues. Children were impacted in many areas due to school bus route detours. Safety issues also came into play when residential traffic, gravel trucks and construction vehicles were forced to share secondary roads.

Many municipalities faced significant financial hardship as a result of the damage caused to roads and bridges by the flood. In addition to the expenses associated with flooded roads, bridges and culvert repairs, municipalities are often faced with costs resulting from the use, or over-use, of soft roads and additional traffic on secondary roads that are used as detours. The costs to repair such “collateral damage” are often not recognized by the Province.

In some cases, the Disaster Financial Assistance (DFA) program required that engineering assessments be conducted before municipalities could proceed with infrastructure repairs or reconstructions. This added costs and caused delays to the process, and in some cases, resulted in recommendations for expensive replacements despite the fact that, from the municipal perspective, less costly options were available. In addition, if a municipality proceeded on its own to repair roads that required immediate attention, it risked losing financial assistance for other claims. If a municipality chose to repair its damaged infrastructure using its own equipment, reimbursement from DFA would only be 65 percent of actual costs. A municipality was not entitled to recover employee costs unless it was considered overtime. As a result, municipalities turned to contractors to do the work instead, because that cost would be fully recoverable. However, contractors were not always readily available.

One method to determine which repair or replacement projects should be funded is to undertake a cost benefit analysis of each project. This must be balanced by considering the importance of such a road or bridge to the municipality. Vital routes must be indentified and given priority.

Consideration must be given to what standards roads and bridges should be repaired or rebuilt. In 2011, some Manitobans had to evacuate not because their homes were below the flood plain, but because their roads would not be able to support emergency vehicles. It is obviously very important that emergency road access be available to all communities at all times.

Too often, the decision is made to repair damaged infrastructure to the same standard it was before the damage occurred. Funding should be invested in remedying the problem, rather than re-establishing the status quo so structures in question can be inundated again during similar floods in subsequent years. With a little extra funding, improvements to the road or structure in question can be brought to a better standard to alleviate the recurring problem instead of having to rebuild it to the old standard repeatedly after each flood event.

Municipalities cannot absorb the burden of upgrading their flood-damaged infrastructure on their own. Instead of investing in temporary solutions, the three levels of government - federal, provincial and municipal - need to work towards a permanent solution.

In some cases municipalities face the opposite problem. There can be a disconnect between the amount of funding available for a repair and the standards which that repair is required to meet. In these scenarios, it may be appropriate to apply a “minimum standard” approach to make decisions on what degree of repair should be undertaken. Standards must be compatible with municipal resources – imposing provincial standards on municipalities is impractical if the municipalities do not have the funds available to comply.

The Task Force believes a comprehensive list of damaged roads and bridges now exists and repairs have been completed, or are underway on many. In recognition of that, there is still much to be done.

First Nations and Flooding

During the course of its work it became apparent to the Mantioba 2011 Flood Review Task Force that First Nations' concerns and issues needed to be dealt with as a stand-alone consideration. There are differences in First Nation governance, relationship to the Crown, history and experience with flooding that requires separate comment on the management of the 2011 flood. Details respecting these issues are found throughout this report in the appropriate sections where First Nations appear to have had a distinct experience relative to their neighbours.

The question of who has the responsibility to do what in relation to First Nations communities and reserve lands seems to have been at the heart of many difficult issues related to the 2011 flood. Jurisdictional problems exist at the federal, provincial and municipal levels.

While jurisdiction is clearly the root of many problems, the Task Force has also become aware of some other key issues for First Nations people deriving from the 2011 flood. Aboriginal people expressed distress over the length of time their communities have been obliged to spend away from their homes. This situation has been difficult for many, and there were concerns expressed that it may have a long-term detrimental impact on the community, particularly in terms of the very young or the very old.

The Task Force recognizes that First Nations communities faced with allocating limited resources are obliged to make difficult choices. Basic needs such as housing tend to be addressed before seemingly less pressing issues like land use planning or flood risk mapping. This has contributed to a situation in which many reserves are ill-prepared to cope with high water.

Aboriginal leaders expressed concern over flood damage to areas of recreational and spiritual significance. Some First Nations communities told the Task Force that water contamination has, in some places, impeded the ability of First Nations people to make use of the waters close to their community without risking boils or skin sores. Such losses may be more significant in the context of remote communities without access to alternative recreational outlets and spiritual gathering areas.

Aboriginal leaders were also troubled over fish and bird kills they believed to be connected to the 2011 flood. In this regard, it is important to recognize the continuing importance of traditional foods in the diets of First Nations people.

Some First Nations communities do not have accounting and management skills necessary to deal with the complexities of large flood protection measures particularly while also coping with personal distress and dislocation of community members.

The Task Force observed first-hand, and heard from a number of First Nations, about the lack of on-reserve drainage. In some instances, the 2011 flood waters did not directly damage houses but water backing up behind dikes flooded basements, soaked crawl spaces and culminated in severe mold problems making houses uninhabitable.

Aboriginal communities have been obliged to a spend long time away from their homes.

The Task Force heard concerns over the effectiveness of emergency management on Aboriginal reserves. The Manitoba Association of Native Fire Fighters played a significant role here, but there seems to be disagreement among Aboriginal people regarding the effectiveness of this organization. The relationship between Manitoba's Emergency Measures Organization (EMO) and on-reserve communities is not clear to all parties. There seems to be a lack of awareness of training opportunities that may be available to Aboriginal people, or some difficulties related to organizing and funding appropriate training.

First Nations have indicated they would welcome the opportunity to collaborate with the broader community on issues related to flooding and water management in general. Further reviews conducted by the Province of issues that involve First Nations and their interests should involve a mandate adequate to encompass the distinctive nature of First Nations' experiences, including geographically and gender balanced representation from affected First Nations communities.

Recommendations

Evaluation of the Operation of Water Control Structures

1. With respect to management of local surface waters and other related infrastructure, the Province develop a regional water management strategy that is both seamless and based on broad consultation among local jurisdictions. These would include municipalities and communities, First Nations communities and the Province, with the Province bringing the Government of Canada into the agreement on behalf of the First Nations.

2. Attention be directed towards providing contextual information to the public about how major water control structures can be operated and reporting on the operational efficacy of these structures on a more routine basis. Operating and other significant information related to the Fairford River Water Control Structure (FRWCS) and the associated fish ladder should be maintained and made available to the public.

3. A condition assessment study of the Fairford River Water Control Structure be conducted, and that its condition and maintenance be monitored on a regular basis.

4. A rehabilitation and preservation plan be developed and funded that allows flood control structures to be upgraded and modernized as required. More investment needs to be made to modernize monitoring and control systems at the Portage Diversion, for example.

5. A formalized process be established to disseminate information in a timely fashion respecting the operations of the flood control structures. This should include more detailed information on expected gate opening and adjustments and the implications on water levels upstream and downstream of the structures.

6. The need for a formalized dam safety review be assessed for each of the structures currently operated by MIT.

7. A study of the diking system on the lower Assiniboine River be conducted to assess the potential implications of its failure, and strong consideration be given to acting on the recommendations arising out of that assessment.

8. Special considerations for providing real-time information be developed for First Nations communities. It is important to indicate when structures are being operated and the expected changes in water levels at key locations.

9. Elected municipal officials of local jurisdictions that are affected by the day to day operation of provincial water management structures be identified and allowance made for local input during severe flood events or when significant deviations from normal operations are expected.

10. The Province embark on a program to assemble more detailed topographic information (LiDAR) generally throughout the province and specifically around Lake Manitoba, Lake St. Martin, Dauphin Lake and along the Assiniboine River.

11. A process be undertaken to re-examine the operating protocols of Ducks Unlimited Canada (DU) structures throughout the province and to hold DU accountable for the integrity and responsible operation of those structures. Dam safety studies should be undertaken for the major structures and the study results should be shared with local stakeholders.

12. A study be initiated to examine the operating protocols at the Shellmouth Reservoir with the objective of enhancing the agricultural productivity of the valley bottom lands by releasing proportionally more water in the spring and subsequently reducing summer flooding without necessarily compromising water supplies later in the year.

13. An examination of the functionality of the Shellmouth Reservoir Regulation Liaison Committee be conducted. Recommended actions include, but are not be limited to the following:
    - maintain the Shellmouth Reservoir Regulation Liaison Committee but reduce its membership to a more manageable number,
    - clarify on a more frequent basis for the members the mandate of the Committee, which is to provide local input to MIT in support of operational decisions, and to report back to the communities and interest groups they represent,
    - prepare an annual report for the public on Shellmouth Dam operations, and
    - continue to provide timely technical information and provide for face to face meetings at least twice annually at times suitable to all members.

14. Provide a more rigorous and transparent accounting of water use on the Assiniboine River downstream of the Shellmouth Reservoir, and provide annual reports on the water supplied and the actual water used within the context of the licensed allocations.

Suggested Procedures for Undertaking Flood Mitigation Measures

15. The Province investigate the use of sandbag filling machines in a variety of sizes to best fit the size of the community and work force.

16. Dikes made of superbags stacked to a significant height be adequately engineered.

17. An inventory of all tube-type diking available in the province be undertaken and the material assessed for condition and usability in an emergency situation.

18. The Province develop a handbook providing guidelines for selecting the right type of dike and the correct way to construct all types of dikes as well as guidelines for placing tube-type dikes along the top of existing dikes for freeboard.

Review of Manitoba's Flood Forecasting System

A number of recommendations have arisen out of this review. They are presented as follows in no particular order of priority, but listed under three general categories. These are political and institutional actions that may require policy decisions and or other departmental inputs, operational actions that should be taken at a departmental level and technical actions that would address science-based issues and forecasting protocols. The recommendations follow.

Political and Institutional

19. The Hydrologic Forecasting Centre (HFC) forecasts for the Red River and the Souris River are comprised of the U.S National Weather Service (NWS) forecast for the Red River at Pembina (Emerson), the NWS forecast for the Souris River at Westhope, and HFC forecast for local drainage areas in the Province. The NWS forecasts are the most important factors in delivery of reliable forecasts for the Red River and Souris River. There is no formal arrangement to ensure this product is of a high quality nor to ensure the continued delivery of this product. Manitoba establish an agreement with NWS to ensure the continued delivery of those forecasts, and that Manitoba arrange for a biennial forecasting workshop/conference with NWS, Saskatchewan and North Dakota forecasters to promote this relationship, develop an understanding of their inter-dependence and evaluate the potential to adopt the same flood forecasting platform.

20. Explore the feasibility of developing a closer relation with meteorologists at Environment Canada (EC) and NWS towards obtaining "best effort" precipitation forecast during flood risk periods.

21. The Province consider having a dedicated, trained spokesperson(s) to deliver forecasts to the media. This (these) person(s) should be intimately familiar with technical terms and understand both the limitations and the potential benefits of a flood forecasting system.

22. The HFC conduct a user analysis to obtain a better understanding of how best to deliver its forecast, develop closer ties and interaction between the forecasters and user groups and develop user-friendly (perhaps graphical) ways of communicating the flood forecasts.

23. Consideration be given to providing prior cross-training to Provincial staff who may be seconded during an emergency to assist in the HFC. Consideration also be given to increasing forecaster salaries and improving the work environment in order to make forecasting a growth position for experienced staff in other areas and to attract qualified forecasters.

24. Document and publish (for public use) all relevant hydrologic and hydraulic data gathered during the flood and incorporate that data in the upgraded flood forecasting protocols. Consider funding an appropriate number of graduate students at the appropriate academic institutions to carry out this work.

25. Since the projections within the Spring Outlook Reports in February amd March are of limited reliability in terms of providing reliable peak water level forecasts, while at the same time potentially creating false expectations, and possibly putting the forecasters credibility into question, the Province consider simply providing a qualitative (high, medium, low) assessment of flood <u>risk</u> rather than flood <u>elevations</u> in these reports.

26. The HFC convert to using the SI system in providing forecasts over an appropriate transition period that is reconcilable with the development of updated forecasting procedures.

Operational

27. Modern flood forecasting operations rely on the collection, transmission, capturing, processing, storage, and quality control of significant amounts of near real-time hydroclimatic data from dozens of sources. Modern flood forecasting also requires frequent and ongoing interaction between members of the forecast team and between forecasters and field staff, data providers, neighbouring jurisdictions, water managers and the public in order to remain on top of rapidly changing conditions, to clarify information and to deliver their forecast effectively and without interruptions. It is recommended that the Province provide the forecasters with dedicated data management systems, computer hardware and software that are external to the managed computing environment and communication devices that are housed in a dedicated space such as an "Operations Forecasting Centre".

28. The HFC add technical support positions to manage the flow of data. Once an Operations Forecasting Centre and integrated data management system with this support staff have been implemented, forecasters should be allowed to focus fully on the development of forecasting tools, optimizing the computer hardware, automating data management and the delivering flood forecasts and current condition reports.

29. The HFC consider forecasting in shifts with a senior forecaster and an assistant always present with adequate technical support so that the previous day's data can be analysed overnight and a forecast prepared by mid-morning to provide the resources on the ground enough time to mitigate upcoming events.

30. The Province acquire at least two additional Acoustic Doppler flow meters to allow field personnel to conduct more timely and accurate discharge measurements during the flood. Ensure that personnel are trained in the use of the equipment. Rent additional equipment as required and/or contract private sector resources as in 2011 to expand capabilities if required.

31. Senior forecasters visit functioning forecasting operations in other jurisdictions to obtain a broader understanding of how best to organize forecast protocols and to meet Manitoba's forecasting requirements.

32. Spring Flood Outlook reports and Flood Reports briefly outline the weather assumptions used rather than stating the generic "favourable" and "unfavourable" conditions.

Technical

33. The MANAPI model, in its current state, is a snowmelt model. Contrary to traditional understanding, most of the largest floods in Manitoba are the result of rainfall on top of, or shortly after, the snowmelt event. The model was last reviewed in 1985. Many developments in modelling procedures have occurred since then. It is recommended that the Province examine other flood forecasting models to determine which model may best meet its forecasting requirements.

34. The Province explore alternative routing procedures that are compatible with more modern flood forecasting software and collect sufficient field data to ensure routing efficacy.

35. The collection of data that is to be used to characterize the spatial distribution of precipitation should be systemized and that systematic approach be maintained to ensure consistency from year to year. The integrity of this system should maintained at all costs.

36. If there is reluctance to adopt an alternative forecasting system, the API approach and the unit hydrograph concept should be refined more rigorously. At least the shape of the unit hydrograph should be decoupled from the historical melt rate.

37. The needs for additional soil moisture measurement sites be identified to fill gaps in the major river basins including North Dakota and Saskatchewan and provide proposals on how this information, especially in other jurisdictions, could be collected.

38. A modernized systematic methodology be established to provide spatial estimates of real time meteorological parameters in salient watersheds to improve the characterization of the precipitation (rain, snow, and snowmelt) in these watersheds. Particular attention should be placed upon the measurement of the winter snowpack. The need to establish an extensive snow surveys program to augment the EC precipitation data and the airborne imagery should be investigated and implemented if required.

39. The forecasting unit carry out an evaluation of the precipitation network for areas for which they have forecasting responsibilities to determine potential gaps in the monitoring of rainfall. Identify and install meteorological stations to support the assessment of rainfall accumulations in salient watersheds within this context.

40. Procedures for the operational forecast be rationalized to reconcile the rainfall runoff modelling component with the flow routing component.

41. Reliance on distributed local ad hoc precipitation monitoring for the systematic operational forecast be minimized. Use only as supplementary data to assist in interpreting the implications of the daily forecasts.

42. Ice-related forecasting methodologies and protocols should be defined explicitly, empirical data that is used to define ice-related water levels should be examined within the context of existing ice hydraulic principles and an explicit criteria for when forecasting should cease in the period after the ice clears should be developed. Historical analogues should be employed to test these forecasting methodologies.

43. The practice of providing one or two decimal points in the water level forecasts places undue expectations on the reliability of the forecast. It is recommended that the inferred precision in the published forecasts reflects the accuracy of these forecasts.

44. Since it appears that the forecast flood level ranges are based on the expectations of realizing a certain amount of future precipitation, and there does not appear to be any effort to report on how potential errors in the modelling assumptions could contribute to the forecast range, it is recommended that the HFC develop an understanding of the contribution of the potential variability in the adopted model parameters to the magnitude of the forecasted water level range.

Flood Preparedness, Flood Fighting Capacity and Response

Emergency Measures Organization

45. The Province increase the Emergency Measure Organization’s (EMO) full time staff to be better able to deal with present and future emergency management events, training, exercising and mitigation projects.

46. EMO enhance its strategic provincial annual training program with a goal that training be mandatory for all newly elected officials trained in emergency management. This would also include programs oriented to First Nations communities.

47. EMO develop a comprehensive training program that would instruct municipalities, First Nations communities and individuals on how to make sandbags, how to operate machinery and how to properly build flood protection dikes.

48. EMO and Manitoba Infrastructure and Transportation (MIT) develop a strategic program aimed at stockpiling dike building construction material around the province in known flood prone areas with the view toward using this material for other projects once the flood threat has passed.

49. EMO ensure ICS (Incident Command System) training/awareness in all emergency management (EM) training programs.

50. EMO develop an EM data base to be utilized by all partners involved in the EM response.

51. EMO's after-action report should be released in a more timely fashion.

52. EMO consider the development of a provincial "reserve" group, trained to supplement the EM office with its demands during EM events.

53. EMO consider the development of an advisory committee made up of flood victims and responders to look at the response to this flood and future EM events, outside of DFA issues, to assist EMO with its strategic planning.

54. EMO work with universities, organizations, individuals and industry, assisting them with federal and provincial support with their flood mitigation projects.

55. EMO develop an EM training program for the construction industry involved in EM response. This would include management and "on the ground" workers.

56. EMO invite a representative from the construction industry to join their monthly EM meetings and be part of the operational command centre during EM events.

57. EMO, jointly with MIT, host a conference for the construction industry involved in flood response and include items such as training availability, expectations, cooperation and coordination during EM events, tender process, permit issues and call out procedures.

58. EMO establish an on-site training program for isolated, Northern Association of Community Councils (NACC) communities specifically, that would assist them in mitigating and managing future events.

59. EMO develop an advance "Disaster Response Team" to assist municipalities at very short notice during these events.

60. EMO develop a training program that is tailored to rural, smaller centres versus larger municipalities that have more resources.

61. The Emergency Management Organization's head office, located on the 15th floor of 405 Broadway in downtown Winnipeg needs to be relocated to an appropriate location that meets the operational and administrative needs and accessibility of its staff and EM partners.

Disaster Financial Assistance Program

62. The Province take immediate steps to increase the number of DFA's full time employees within the Emergency Measures Organization.

63. The EMO/DFA office develop an easy to understand and use communications package that can be sent out to elected officials, First Nations, business, farmers and individuals.

64. The EMO/DFA office develop a DFA education/training program that is delivered province-wide, not just in Winnipeg, and set training targets and goals as part of EMO's annual program initiatives.

65. EMO undertake a comprehensive review of the provincial and federal DFA program and how it was implemented in 2011, and how can it be done better in future. Develop an easy to understand and comply-with program for individuals.

66. EMO establish a mental health component as part of its strategies and programs within DFA.

67. The Province encourage the federal government to enhance its DFA program within First Nations communities and work more cooperatively with the Province in assisting with DFA/First Nations programming.

68. The DFA/recovery programs should remain within EMO, or an appropriate government department, having control over all compensation programs, provide one-stop shopping for all claimants, reducing confusion.

69. EMO develop a one-window consent information/application/assessment form that can be utilized by agencies, alleviating multiple forms/paper work.

70. EMO consider developing a DFA advisory group made up of those administering the program and those who have been directly affected by disasters and have utilized the program, to assist both sides in understanding and developing training and communications programs to assist in future EM events.

71. EMO, through its DFA programs, develop a communications plan that explains all aspects of the assistance payments, reasons for and outstanding balance issues, when distributing payments to clients.

First Nations

72. The Province strongly urge the federal government (AANDC) to develop a national strategic, overall emergency management plan that would encompass all of their responsibilities in administering and operationalizing their EM plan within the province. This would include all aspects such as mitigation (in Manitoba, flood mitigation is of particular significance), strategies, training, exercising, communications and resources to accomplish these goals.

73 The leadership of Manitoba First Nations communities make emergency management programs within their communities a priority, including the establishment of full time emergency management coordinators, training and exercising programs. First Nations leadership should also address the issue of province-wide First Nations EM mitigation strategies within First Nations communities with the federal government/AANDC.

Adequacy of Existing Flood Control Infrastructure

74. Examine and adopt means to accommodate any impact on hydrology of global warming and climate change when planning, designing and implementing future water use projects.

75. Investigate the feasibility of developing storage on the major tributaries that contribute runoff to Dauphin Lake including the Valley River, Vermillion River, Ochre River and Turtle River.

76. Investigate the feasibility of developing a second controlled outlet from Dauphin Lake into Lake Winnipegosis. Local residents suggest that a possible location for this additional outlet channel would be east of, and parallel to, the Mossy River.

77. Investigate alternative means to prevent or reduce flood damages on the Assiniboine River below Shellmouth Dam:

- Continue to pursue the installation of spillway gates on Shellmouth Dam, but examine and quantify the flood control benefits and assess any impact on other uses served by the reservoir.
- Investigate the merits of a buy-out of flood-prone valley bottom lands downstream of Shellmouth Dam, which would increase the operational flexibility of Shellmouth Dam and eliminate future downstream flood damages and liability.
- Investigate the feasibility of constructing dikes along the margins of the Assiniboine River below Shellmouth Dam to reduce future flood damages on flood prone valley bottom lands and increase operational flexibility.

78. Continue to work with the Province of Saskatchewan to better understand the impact of agricultural drainage on the hydrology of the Assiniboine River, and to identify and control drainage activities in both Saskatchewan and Manitoba.

79. Retain and maintain the upgraded dikes along the Portage Diversion channel, as a contingency for future large flood events. Upgrade drop structures and bridge crossings where necessary.

80. Upgrade the outlet structure on the Portage Diversion channel where it enters Lake Manitoba, to improve the hydraulic performance during passage of the design flow.

81. Investigate means to reduce damages which result from spills through the wasteway (fail safe) on the Portage Diversion:

- Raise both the east embankment and the crest elevation of the wasteway.
- Acquire any additional land control that may be required to accommodate spills through the wasteway.

82. Upgrade and modernize the Portage Diversion headgate structure.

83. Examine the feasibility of developing additional storage on the Assiniboine River (such as the Holland Dam) upstream of Portage la Prairie, which would reduce the frequency of operation and the magnitude of diversions through the Portage Diversion, provide water supply benefits in the region and reduce the reliance on Shellmouth Dam for low flow augmentation in the lower Assiniboine River.

84. Examine the feasibility and effectiveness of developing storage on tributaries to the Assiniboine River.

85. Develop and implement a program to upgrade the Assiniboine River dikes between Portage la Prairie and Headingly. The optimal design capacity should be determined from detailed engineering studies now underway.

86. As one component of a properly engineered dike system, determine the optimum location and capacity of a permanent controlled wasteway (either north or south of the Assiniboine River), and construct such a structure to pass Assiniboine River flows in excess of the combined capacity of the Portage Diversion and Assiniboine River channel and dikes. The facility should be sized with due consideration of the potential flood risks/benefits and the capacity of the landscape to accommodate the design flow through the breach.

87. Adopt the recommendations of the Lake Manitoba and Lake St. Martin Regulation Review Committee regarding additional outlet capacity requirements for Lake Manitoba and Lake St. Martin, with due consideration for the engineering studies that are being conducted.

88. Examine the feasibility of alternative schemes suggested to the Task Force by local residents to reduce or control inflow to Lake Manitoba and thereby reduce or preclude the need for additional outlet capacity from Lake Manitoba and Lake St. Martin:
   - A diversion from Lake Manitoba to Lake Winnipeg.
   - A diversion from Lake Winnipegosis to Lake Winnipeg.
   - An outlet control structure on the Waterhen River to control outflow from Lake Winnipegosis.

89. Identify and better control agricultural drainage activities in tributary basins to the Souris River in Manitoba.

90. Compel Ducks Unlimited Canada to 1) operate its water control infrastructure to provide flood control benefits when necessary and where possible, with local input into the development of appropriate operating guidelines; and 2) develop a long term strategy to decommission structures which no longer meet the needs of the organization and which cannot be transferred to another entity.

91. Require as a condition of its license that Ducks Unlimited include a plan, with funding, for the eventual decommissioning of its water control infrastructure.

92. In concert with local municipalities and individuals, develop an inventory of community and private dikes, determine ownership, and clarify and communicate responsibility for ongoing maintenance and liability.

93. In concert with the Association of Manitoba Municipalities, develop a mechanism to provide technical assistance to local authorities for assessing dike integrity and ensuring that all community and private dikes are constructed and maintained to established industry standards.

94. Continue to monitor and support research to develop tools to better understand and assess the impact on runoff of wetland drainage, and conversely wetland retention and restoration.

95. Consider development of a wetland retention and preservation program with defined goals, possibly in partnership with non-governmental organizations. Such a project could be modelled on the Alternative Land Use Services (ALUS) pilot project.

96. Continue to consult with local stakeholders and interest groups, and attempt to find a water management solution that is in the best interests of all parties affected by closed basins such as Whitewater Lake.

Environmental Impacts

97. Protect the integrity of the province's groundwater supply by instituting an annual water quality monitoring program, and by investigating the various pathways to groundwater contamination that may arise during a flood. Mitigation measures for protecting groundwater supplies in flood prone areas must be investigated and implemented.

98. Establish a water quality monitoring program for surface water to identify any future impacts of hazardous materials in flood zones. Implement an educational program to discourage the storage of these materials on land subject to flooding.

99. Enhance the existing monitoring program for the impacts on fish and wildlife as a result of the 2011 flood , including habitat and physical environment (riparian areas).

100. Establish public consultation procedures and protocols for environmental issues for flood events including public education seminars, news releases and open house events.

101. Implement a program to receive and document public input from First Nations elders and other community members, commercial fishers, lakeshore residents and others to monitor the long-term impacts of the 2011 flood on Lake Manitoba.

102. The Province develop and take a lead role in participating, and supporting local efforts, in a program to remove from Lake Manitoba, its shorelines, shoreline marshes and surrounding areas deleterious and hazardous materials that have accumulated as a result of the 2011 flood.

Land Use Policies and Zoning

103. Develop maps which delineate land subject to flooding for various probabilities of exceedence, and consult with local authorities to ground-truth the results. These maps should be made available through the Internet for convenient use by the public and local administrations for zoning purposes and for developing flood mitigation projects.

104. Implement clear policy measures to ensure future development does not knowingly occur on land subject to flooding without appropriate mitigation. Possibilities include:

- the development of mechanisms through district planning boards to prevent future developments below the FPL, and
- expansion of Designated Flood Areas into regions that experience chronic flooding of developed properties.

105. Develop and adopt a uniform Flood Protection Level (FPL) throughout the province. Such a standard should strike a balance between long term risk tolerance, the economic damages resulting from flooding, the economic costs of building to higher FPLs and the uncertainty in the estimated FPLs due to limited hydrologic data.

106. Permit local developers and institutions to adopt a risk-based approach for determining a higher standard of flood protection where appropriate, to be implemented locally where justified from a benefit-cost analysis or where facilities are of a critical nature. The minimum standard would be enacted through regulation and the higher risk-based approach would be at the discretion of the authority or proponent investing in the new capital works.

107. Engage the Government of Canada and First Nations in a process that will lead to improved planning and coordination among municipalities and First Nations.

108. Accept and implement the recommendation from the Lake Manitoba and Lake St. Martin Regulation Review Committee that the Province establish a five-year pilot project involving the Government of Canada, planning districts, municipalities, conservation districts and First Nations to develop an Integrated Watershed Management Plan within the Lake Manitoba or Lake St. Martin basin. The plan would define Designated Flood Areas within the watershed, develop appropriate land use policies and regulations relating to flood control and mitigation including land drainage and incorporate the principles associated with “No Adverse Impact”.

109. Encourage Public Safety Canada to develop a new program to financially support proactive flood mitigation works by the provinces, as a more cost effective alternative to ongoing, and often repeated, payments of compensation for flood damages through existing programs.

Communications to the Public

110. The Emergency Measures Organization (EMO), in concert with Communications Services Manitoba (CSM) establish a training program specific to CSM and EMO requirements for emergency management events.

111. A 24-hour dedicated television channel, and perhaps a radio service, be established to provide up-to-date information on flood conditions, forecasts and outlooks, road closures, as well as contact information for the public during an emergency.

112. The Province develop an information program to increase awareness among Manitobans regarding the value and usefulness of the toll-free 511 road conditions information line and website during an emergency.

113. A protocol be established to improve communication between the Province and affected municipalities and First Nations communities during an event such as the 2011 flood.

114. The Province take steps to ensure communications to the public and emergency management responders is accurate and disseminated in a more timely fashion to allow those “on the ground” to respond to the situation appropriately.

115. Designate a credible, skilled and knowledgeable spokesperson(s) to provide a “one face” approach to communicating information to the public in a language the public can understand.

Impacts on Road Networks and Bridges to Businesses and Public Access

116. The Province review its five-year Highway Capital Plan in light of the 2011 flood and the fast-tracking of certain pieces of vital infrastructure and roadways. A five-year plan of reconstruction be developed and published by the Province in consultation with local municipalities involved.

117. Identify key transportation routes and protect them so that commerce can continue uninterrupted during a flood.

118. Review the possibility of providing flood-proof emergency access to communities that could be affected by flooding.

119. Jurisdictional issues among federal, First Nations, provincial and municipal authorities be resolved so that roadway and drainage infrastructure on First Nations can be addressed.

120. The Province recognize all the costs incurred with road/culvert/bridge reconstruction required due to alternate route usage (detour) when major roadways are closed due to the flood.

121. The Province continue to study and monitor the effects of the 2011 flood on all affected provincial roads and bridges, and be prepared to address any additional costs that may arise as a result of the flood.

122. Consult with local officials before making decisions on the permanent closure of provincial roads or non-replacement of bridges.

123. Review, with the Government of Canada, alternative options with Disaster Financial Assistance’s policy of replacing structures to the standard that existed prior to the flood as opposed to making permanent improvements to these structures to mitigate damages in the long term.

124. Review, with the Government of Canada, a policy to allow municipalities and First Nations communities who are completing repair works on infrastructure damage due to flooding using their own equipment and staff, to be reimbursed at the same rate as contractors who would be conducting similar work.

125. Decisions made by the Province regarding the closing or decommissioning of provincial infrastructure that would impact a particular municipality be communicated to local officials in a timely manner to allow them to review the situation, examine the municipal perspective on the decision and prepare a response.

First Nations and Flooding

126. Future reviews conducted by the Province of issues that affect First Nations communities must include a mandate adequate to encompass the distinctive nature of First Nations' issues, including geographically and gender balanced representation by members of affected First Nations communities.

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Acknowledgements

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Metric Conversion Table

The description of the hydrologic events that occurred in 2011, and the corresponding flood analysis, was undertaken largely on the basis of hydrologic data provided by Environment Canada. These data are gathered and reported using the conventional SI "International System of Units" that is used throughout Canada. Manitoba Infrastructure and Transportation uses the British system of units, termed "US Customary", to maintain historical consistency and to be compatible with neighbouring jurisdictions in the US. The data in all the graphs, figures and tables contained in this report have been presented in SI units. Both SI units and US Customary units are provided throughout the text when quantifying a particular hydrologic characteristic. In all cases the US Customary values have been derived from the SI values using conventional conversion factors. In some cases, rounding errors and the need to adopt an ergonomic value preclude the exact conversion. In cases of discrepancies, the SI value is numerically correct.

The following table summarizes the most frequently used quantities in this report and provides the conventional factors to convert from SI to US Customary units.

To Covert From:	To:	Multiply By:
Area		
square kilometres (km^2)	square miles ($mile^2$)	0.3861
hectares (ha)	acres	0.4047
square metres (m^2)	square feet (ft^2)	10.76
Flow Rate or Discharge		
cubic metres per second (m^3/s)	cubic feet per second (cfs)	35.31
Length		
millimetres (mm)	inches (in)	0.03937
metres (m)	feet (ft)	3.281
kilometres (km)	miles	0.6214
Volume		
cubic metres (m^3)	cubic feet (ft^3)	35.31
cubic decametres (dam^3)	cubic metres (m^3)	1000
cubic decametres (dam^3)	acre-feet (acre-ft)	0.8106

Acronyms

AMC	Assembly of Manitoba Chiefs
AANDC	Aboriginal Affairs and Northern Development Canada
ANA	Aboriginal and Northern Affairs (Manitoba)
ALUS	Alternative Land Use Services
BRAP	Building and Recovery Action Plan
CWS	Conservation and Water Stewardship (Manitoba)
CSM	Communications Services Manitoba
DFA	Disaster Financial Assistance (Provincial) or; Designated Flood Area
DFAA	Disaster Financial Assistance Arrangement (Provincial and Federal)
DND	Department of National Defense
EC	Environment Canada
EM	Emergency Management
EMO	Emergency Measures Organization
EOC	Emergency Operations Centre
FPL	Flood Protection Level
FRO	Flood Recovery Office
FRWCS	Fairford River Water Control Structure
GIS	Geographical Information System
GO	Growing Opportunities (MAFRI rural offices)
HFC	Hydrologic Forecasting Centre
HSPF	Hydrologic Simulation Program Fortran
ICS	Incident Command System
LMFAP	Lake Manitoba Flood Assistance Program
LiDAR	Light Detection and Ranging (Remote sensing system)
MANAPI	MANitoba Antecedent Precipitation Index (Model)
MAFRI	Manitoba Agriculture, Food and Rural Initiatives
MANFF	Manitoba Association of Native Fire Fighters
MASC	Manitoba Agricultural Services Corporation
MECC	Manitoba Emergency Coordination Centre
MEP	Manitoba Emergency Plan
MFS	Manitoba Family Services
MIT	Manitoba Infrastructure and Transportation
MWC	Manitoba Water Commission
NACC	Northern Association of Community Councils
NGO	Non-Governmental Organization
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NWS	National Weather Service (U.S.)
ODM	Office of Disaster Management
OFC	Office of the Fire Commissioner
PFRA	Prairie Farm Rehabilitation Administration
PR	Provincial Road
PTH	Provincial Trunk Highway
RCMP	Royal Canadian Mounted Police
REM	Regional Emergency Manager (EMO)
RO	Regional Office
SCO	Southern Chiefs Organization
SLURP	Single Linear Unit Reservoir Parametric
SSARR	Streamflow Simulation and Reservoir Synthesis
TOR	Terms of Reference
MWS	Manitoba Water Stewardship
WSC	Water Survey of Canada

1. Introduction

1.1 Background

The 2011 Manitoba flood was unprecedented in scope and geographic extent. High soil moisture at freeze-up in the fall of 2010, above normal snowfall during the winter of 2010/2011 and additional snow and rain during the spring all contributed to the problem. On top of the already serious situation, heavy summer rains and severe wind storms added to the crisis. While the severity of the flood varied from location to location, its sheer size and duration was such that managing it was an enormous challenge.

It was obvious in the fall of 2010 that there was the potential for significant spring flooding throughout the province. Manitoba Water Stewardship issued its first spring flood outlook for 2011 on January 24th. It indicated the potential for flooding was high for much of Manitoba. It also warned that localized overland flooding could be expected in most of central and southern Manitoba. The second outlook, released a month later, was similar, but added that additional snowpack in the southern Red River basin could result in higher flood levels on the Red than predicted earlier.

Although the 2011 flood on the Red River was the fifth highest on record as recorded at Emerson, it caused relatively little damage primarily due to the flood protection infrastructure that had been put in place over the decades, and most notably since the 1997 Flood of the Century. However, the rest of the province did not fare as well.

In early May, 13 rivers or creeks across the province were at flood stage including the Red, Assiniboine, Souris, Whitemud, Saskatchewan and Pembina rivers, as well as several smaller rivers. All-time record flood peaks were set on the Assiniboine River at Brandon in early May and a little later at Portage la Prairie. Water levels on the Assiniboine stayed high until early August. The river was in flood stage for about 100 days.

Records were also established on the Souris River. After the spring peak on the Souris in the second week of April, there were two more peaks at both Souris and Wawanesa as river levels responded to individual rain storms. The highest peak was in early July. The water level at Melita was higher than the previous record peak in 1976.

Records were set on Elgin Creek and Oak Creek in western Manitoba, and on the Waterhen River which conveys water from Lake Winnipegosis into Lake Manitoba. The Qu'Appelle River, which enters the Assiniboine River from Saskatchewan at St. Lazare also established a new record for flow. Lake levels on Dauphin Lake were the highest ever recorded.

In 2011, inflows to Lake Manitoba from both the Waterhen River and Portage Diversion were the highest on record. The annual runoff volume on the Whitemud River into Lake Manitoba in 2011 was the largest ever recorded. Extremely high lake levels on Lake Manitoba combined with severe winds on May 31 devastated lakeshore communities around the south basin of that lake.

In 2011, flood volumes were the highest on record at the Portage Diversion.

1.2 Impacts

1.2.1 Physical and Economic Impacts

As a result of the flood, there were three million acres of cultivated farmland left unseeded in 2011, and that problem spilled over into the spring of 2012 in many areas. Tens of thousands of cattle had to be relocated, and some even sold, because of flooded pasture land. The largest numbers were from the area around Lake Manitoba and Lake St. Martin, the most productive cattle-producing region of the province. While relocation of most of the cattle was a temporary measure, some cattle remain on rented acreage elsewhere. Much of the hayland in the area around Lake Manitoba has been severely impacted by the flood, and may take years to become productive again.

The 2011 flood affected 154 provincial roads and highways and 500 municipal roads, and damaged 73 provincial highway structures and 500 municipal bridges. The costs of repairing and replacing damaged infrastructure are enormous. Many municipalities faced, and are still facing, significant financial hardship as a result of the damage caused to roads and bridges by the flood.

Residents, farmers and businesses across rural Manitoba were impacted in a variety of ways by damage to, and closures of, flooded and damaged roads and bridges. Businesses servicing farmers were unable to reach their clients in some cases causing delays in planting crops, spraying and other issues. Children were impacted in many areas due to school bus route detours. Safety issues also came into play when residential traffic, gravel trucks and construction vehicles were forced to share either secondary roads or roads that had been temporarily raised. Business owners who were required to use detours to service their clients faced losses due to considerably increased travel time for both them and their customers.

At the time this report was prepared, costs associated with flood preparation, flood fighting, repair to infrastructure and disaster payments has reached $1.2 billion.

1.2.2 Human Impacts

At the height of the flood, there were more than 7100 evacuees, primarily from First Nations communities. Most had been moved to Winnipeg. Nearly 2000 still remain away from their homes, largely because their homes are uninhabitable. Moving to an urban setting from their familiar surroundings on Aboriginal reserves immersed these evacuees in an entirely different social and cultural environment. While some individuals found opportunities in this situation, it has been very distressing for others. The Task Force heard concerns that the evacuation may have a long-term detrimental impact on First Nations communities, particularly in terms of its impact on the very young or the very old.

According to First Nations people, effects of displacement included culture shock, negative effects on social relationships and personal well-being and loss of time in school for students. There were also difficulties derived from media stories that reflected negatively on displaced First Nations people.

Across the province, the physical strain and the emotional stress and anxiety of preparing for the flood, fighting it, losing property and having to leave homes and communities behind was too much for some individuals to bear. Emotional and financial strain, the fear of long term economic issues and family breakdowns are examples of the issues some families were experiencing. After the flood, the processes involved with having to apply for assistance were very stressful for many. Regional Health Authority Manitoba established a Psychosocial Flood Recovery Team to help people with some of the issues they were facing. While this provided some assistance, more needs to be done. A more comprehensive program to help individuals deal with stress and emotional issues during an emergency should be developed.

Although the flooding in 2011 was devastating, much can be learned through a thorough review of the action undertaken previous to, during and after the flood.

2. The Manitoba 2011 Flood Review Task Force

2.1 Background

On February 8, 2012, largely in response to the flood of 2011, the Province of Manitoba announced four initiatives to help improve the Province's ability to fight floods and manage water in the province. The Lake Manitoba and Lake St. Martin Regulation Review Committee was established to advise the Province on the appropriate interim regulatory ranges for those lakes and operating guidelines for the Fairford River Water Control Structure and for the Lake St. Martin channel. A flood mitigation study for the Lake Manitoba watershed to be conducted by an independent consultant was also announced. The Province also indicated its intent to initiate a province-wide surface water management strategy that will work to ensure a coordinated approach on water management to prevent or reduce flooding of agricultural, industrial and residential land. These three initiatives are either completed or underway.

At the top of the list was the formation of the Manitoba 2011 Flood Review Task Force, an independent body established to examine many aspects of Manitoba's historic 2011 flood. The Task Force was directed to gain an understanding of the issues surrounding the flood, and to provide an overview to the Province of what happened, what worked and did not work, and what could be done better in the future.

2.2 Terms of Reference

Through its Terms of Reference, the Task Force was mandated to examine and make recommendations in nine key areas.

1) **The operation of provincial flood control infrastructure and ancillary works, including the Red River Floodway, Portage Diversion, Shellmouth Reservoir, Assiniboine River dikes, Hoop and Holler controlled breach and the Fairford Dam, to determine whether established rules of operation were followed, determine their role in reducing the overall impact of flooding and provide suggestions for operational improvements.**

2) **Suggested procedures for undertaking flood mitigation measures such as sandbagging, emergency dikes and the appropriateness of such actions.**

3) **The accuracy and timeliness of the Province's flood forecasting efforts, giving particular attention to the current state of flood forecasting practices, capabilities and technologies, and co-ordination with other jurisdictions.**

4) **The level of flood preparedness, flood fighting capacity and response by the Province, the cities of Winnipeg and Brandon, other municipal governments and individual citizens in dealing with the flood.**

5) **The adequacy of existing flood protection infrastructure and the need for additional works.**

6) **The environmental, social, water quality and human health impacts related to flooding of environmentally sensitive developments such as sewage lagoons, landfill sites and gasoline, oil and farm chemical storage sites.**

7) **Land use policies and zoning criteria relative to areas of the basin that are vulnerable to flooding.**

8) **Adequacy of communications to the public about information such as flood forecasts, emergency response, disaster recovery and flood mitigation programs.**

9) **Impacts on road networks and bridges to businesses and public access.**

2.3 Task Force Members

Several Task Force members are from flood affected communities or were themselves impacted by the 2011 record flood. Others bring experience and perspectives from other jurisdictions.

David Farlinger P. Eng – Chair

David Farlinger is a civil engineer with extensive experience in two principal areas, energy and water. Much of Mr. Farlinger's water-related work involves bringing diverse interest groups to a common understanding. In 1997, he was appointed Chair of the Manitoba Water Commission charged with conducting a review of the actions taken by government during the 1997 Red River Flood of the Century. He has also chaired the Lake Winnipeg Shoreline Erosion Advisory Group in 1998 and the Lake Manitoba Regulation Review Advisory Committee in 2001. He has served as a technical advisor to the Manitoba Clean Environment Commission with respect to licensing the construction of the 200 MW Wuskwatim dam project and the expanded Red River Floodway.

Louis Allain – St. Laurent resident

Louis Allain is a long-time resident of the community of St. Laurent and a victim of the 2011 flood. He was president of St. Laurent's Community Development Corporation for over 10 years and is now Executive Director of CDEM, the Economic Development Council for Manitoba's bilingual municipalities.

David Andres P. Eng – Northwest Hydraulic Consultants Ltd.

David Andres is a civil engineer specializing in surface water engineering in cold regions. He is a graduate of the University of Manitoba and has spent almost 40 years practicing in western and northern Canada in three main sectors – government, research and consulting. His work is focused primarily on water management and flood related issues on lakes and rivers. At present Mr. Andres is a principal at Northwest Hydraulic Consultants Ltd. in Edmonton.

Kam Blight – Reeve of the Rural Municipality of Portage la Prairie

As reeve of the rural municipality that includes the Assiniboine River, Hoop and Holler Bend, the Portage Diversion, Delta and St. Ambroise, Reeve Blight has dealt with flood disaster management first hand. Coordinating with disaster management officials from across Canada has provided Reeve Blight an in-depth working knowledge of flood disaster response and how it impacts a community.

Darryl Jackson – Mayor of Souris

Darryl Jackson has been a resident of Souris, Manitoba since 1980. A pharmacist by profession, he has been mayor of the Town of Souris since 2005. Mayor Jackson co-authored a resolution at the 2011 Association of Manitoba Municipalities (AMM) convention in Brandon asking AMM to lobby the Province to establish a comprehensive water strategy for southwest and central Manitoba, as has been done for the Red River basin.

Rhonda Kirkness – Fisher River Cree Nation

Rhonda Kirkness is an employee of Fisher River Cree Nation as an executive assistant responsible for government issues. She is a certified professional trainer with the Indigenous Leadership Development Institute and serves on the scholarship committee of the Aboriginal Financial Officers Association of Canada. Ms. Kirkness has been involved in a range of community leadership initiatives including the National Cree Gathering 2011, the Aboriginal Women's Leadership Manitoba Training pilot project and the Empowering Indigenous Youth through Governance & Leadership group.

Craig MacLaughlan – Consultant, EMO and policing

Craig MacLaughlan served as the CEO/deputy head of the Nova Scotia Emergency Management Office (EMO) for five years, during which time the EMO established itself as a leader in emergency management across Canada and strengthened Nova Scotia's emergency management system. Mr. MacLaughlan previously served as a member of the Royal Canadian Mounted Police for 30 years, including serving as the RCMP's Superintendent in charge of all major events, disasters and major investigations in Nova Scotia. Mr. MacLaughlan and his family have returned to take up residence in rural Manitoba and he is now President of MacDot Consulting Ltd.

Shannon Stunden Bower Ph.D – University of Alberta

Shannon Stunden Bower has a Ph.D. in Geography from the University of British Columbia. She is the author of Wet Prairie: People, Land, and Water in Agricultural Manitoba, as well as a number of articles addressing the history of water management in southern Manitoba. Dr. Stunden Bower grew up in Winnipeg, in a flood-vulnerable house along the Red River.

Ron Woodvine P. Eng – Agriculture and Agri-Food Canada

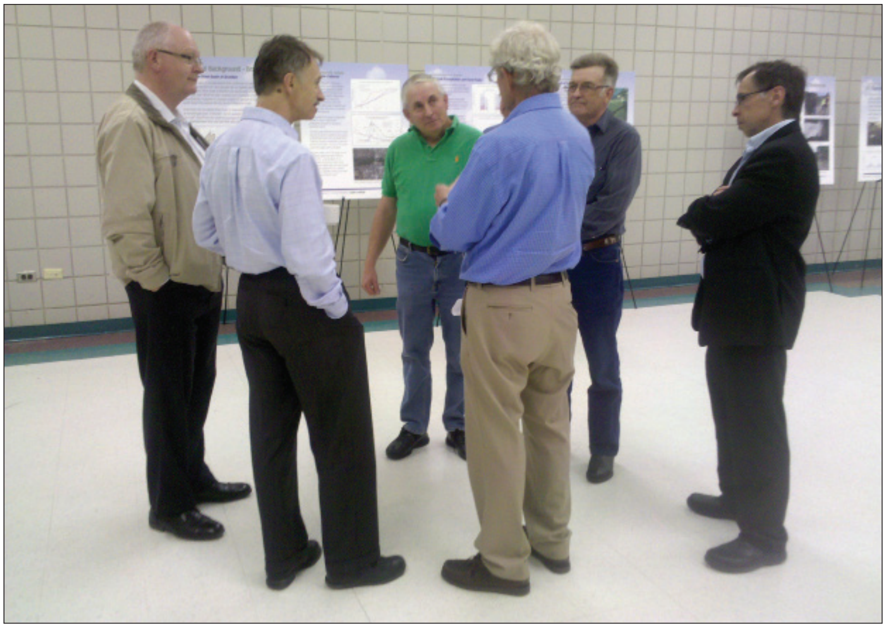
Ron Woodvine has practiced as a hydrologist and water resource engineer with the Prairie Farm Rehabilitation Administration (PFRA) and Agriculture and AgriFood Canada in Regina since 1975. During that time, he has worked closely with colleagues in federal and provincial government agencies and in the private sector on many flood studies in the Canadian Prairies, including in Manitoba.

2.4 Public Consultation Process

The Task Force had a mandate to consult extensively and broadly with Manitobans related to its Terms of Reference. The consultation process began in May 2012 and continued through October of that year.

The Task Force met with more than 45 municipalities, First Nations and stakeholder groups throughout the flood-stricken areas. It also heard presentations at its regular meetings from government agencies involved with fighting the flood, technical experts, First Nations groups, the construction industry and others.

In addition to the Task Force meetings, comments were solicited through several other methods. These included feedback forms at public open houses and on the Task Force's web site, and developing an email sign-up list that was used to disseminate information and for requesting feedback.
Eleven public open houses were held, with over 450 people attending. Several of these open houses were held jointly with the Lake Manitoba and Lake St. Martin Regulation Review Committee. Approximately 100 feedback forms were completed by attendees of the open houses, and approximately 40 additional submissions were received through either mail, email or the online feedback form. The majority of these submissions were received from individuals, but submissions were also received from organizations and municipalities.



Eleven public open houses were held in June through September.

Some of what the Task Force heard was also collected through several surveys that the Task Force made available on its web site. A wide range of information was gathered during the consultation process, with many different perspectives and opinions. These comments and ideas were invaluable to the work of the Task Force. While the Task Force appreciates the effort made by the public to attend meetings and open houses, to fill in submission forms and to respond to surveys, it recognizes that many people who are satisfied with how the 2011 Manitoba flood was handled may have chosen not to participate in the consultation process. A complete description of the consultation process is presented in Appendix A, What We Heard.

2.5 Report Preparation

All Task Force members participated in writing this report. Lead responsibility for the individual sections of the report was designated to one or more of the members. Section leads undertook research and writing in the areas for which they were responsible. While all members of the Task Force were given the opportunity to review report drafts at various stages of completion, variation in style and approach remains evident from section to section.

Some of the Task Force Terms of Reference required an intensely technical and scientific response, while others were addressed in a more qualitative manner. The data contained in this report was extracted from, or provided by, a variety of sources such as Manitoba Infrastructure and Transportation, Environment Canada, Manitoba Agriculture, Food and Rural Initiatives and others. This report has taken a year to research, investigate, develop and prepare, and is a reflection of the effort put forth by each member of the Task Force.

Appendices to this report are available under separate cover.

3. Hydrological Characteristics of the 2011 Flood

3.1 Background

The genesis of the 2011 flood is directly related to Manitoba's location with respect to the topographic and physiographic setting of the western Prairies. Manitoba is at the downstream end of three main river systems (Figure 3.1) that drain the prairie and boreal plains regions of western Canada and north central United States. These are the Saskatchewan River, the Assiniboine River and the Red River. Runoff from these large basins ultimately accumulates in Lake Manitoba and Lake Winnipeg, before continuing on its way eastward and northward through the Nelson River system to Hudson Bay.

The elevations of the rivers and lakes that convey flows across Manitoba vary from west to east and from north to south. Lake Winnipeg, the most downstream large body of water, is at a nominal elevation of 217.6 metres (m) or 713.9 feet (ft). This is about six m (20 ft) lower than the Red River at Winnipeg, due mainly to the difference in water levels across the falls at Lockport. The level of Lake Winnipeg is also about 26 m (85 ft) lower than the level of Lake St. Martin which itself is only four m (13 ft) lower than Lake Manitoba. Most of the difference in elevation between Lake Winnipeg and Lake Manitoba occurs along the relatively steep gradient of the Dauphin River. For additional perspective, the water level on the Assiniboine River at Portage la Prairie averages about 256.0 m (839.9 ft), or some eight m (26 ft) higher than Lake Manitoba and almost 33 m or about 110 ft above the level of the Red River at Winnipeg.

Figure 3.1: Major drainage basins that contribute runoff into Manitoba. The outlet of Lake Winnipeg represents about 65 percent of the total area that drains into Hudson Bay through Manitoba. The Saskatchewan and Red rivers contribute about 25 and 10 percent respectively of the annual flow volume that passes through the lake.

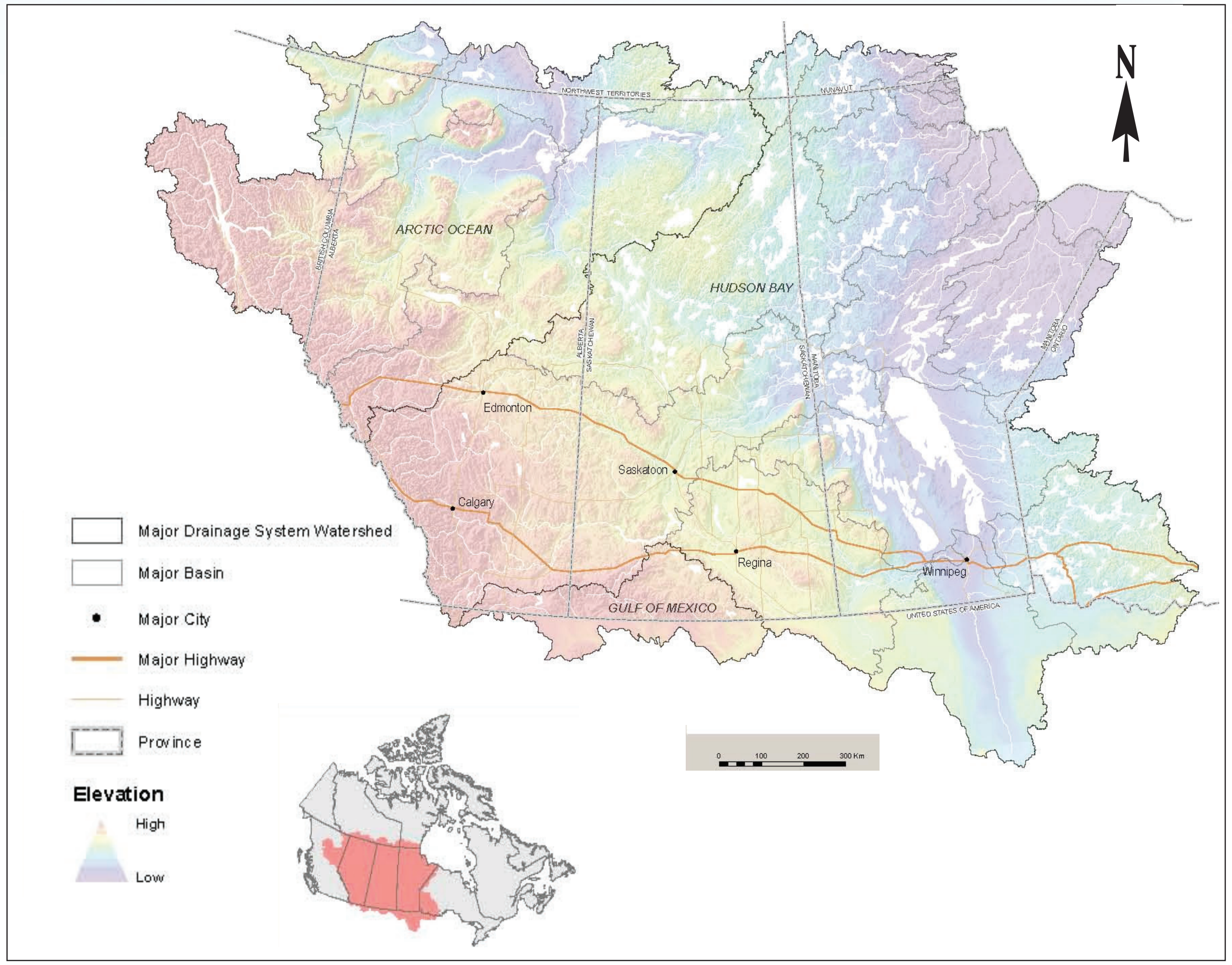
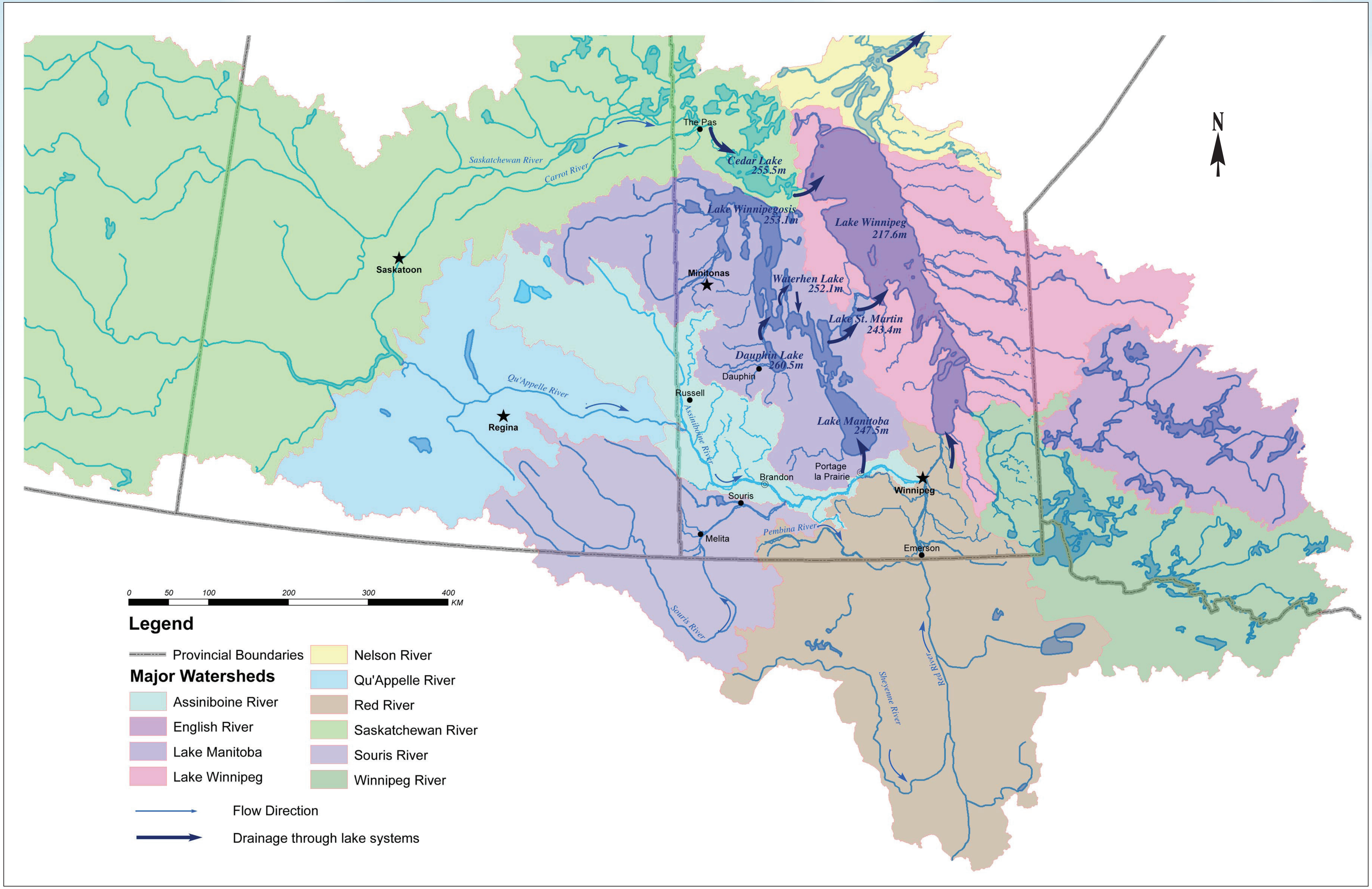


Figure 3.2 Spatial runoff patterns in the Red River and Lake Manitoba drainage systems. All the runoff eventually finds its way into Hudson Bay after passing through Lake Winnipeg.



Near the north end of Lake Winnipeg there is about a drop in water levels of 38 m (125 ft) across Grand Rapids from Cedar Lake to Lake Winnipeg, while there is only a three m (10 ft) difference in water levels on the Saskatchewan River between The Pas and Cedar Lake. The nominal water level of Dauphin Lake is 260.5 m (854.7 ft) which is about seven m (23 ft) above the level of Lake Winnipegosis, which in turn is about six m (20 ft) above the level of Lake Manitoba. Figure 3.2 provides a map of these salient lakes and waterways, along with their respective elevations and Table 3.1 summarizes typical water elevations along the lakes and waterways.

Table 3.1: Water elevations along salient lakes and waterways.

Water Body	Nominal Elevation (m)
Saskatchewan River at The Pas	258.5
Cedar Lake	255.5
Dauphin Lake	260.5
Lake Winnipegosis	253.0
Waterhen Lake	252.1
Assiniboine River at Portage la Prairie	256.0
Lake Manitoba	247.5
Lake St. Martin	243.5
Red River at Winnipeg	223.5
Lake Winnipeg	217.6

Runoff volumes and subsequent lake levels vary over time in response to changing precipitation patterns. But because the overall system is so large, it takes a sequence of dry or wet years to produce a dramatic change in runoff and consequently to adversely affect lake levels and/or flood peaks. The 1930s, early 1960s and early 2000s are examples of dry periods. Wet periods with above average flood peaks occurred in the mid 1950s, late 1970s and the late 2000s. Annual flows on the Waterhen River (Figure 3.3) and peak flows on the Red River (Figure 3.4) provide a good representation of the cyclic nature of these runoff patterns.

Figure 3.3: Historical annual runoff volumes - Waterhen River. These runoff volumes reflect the year to year variation in the levels of Lake Winnipegosis.

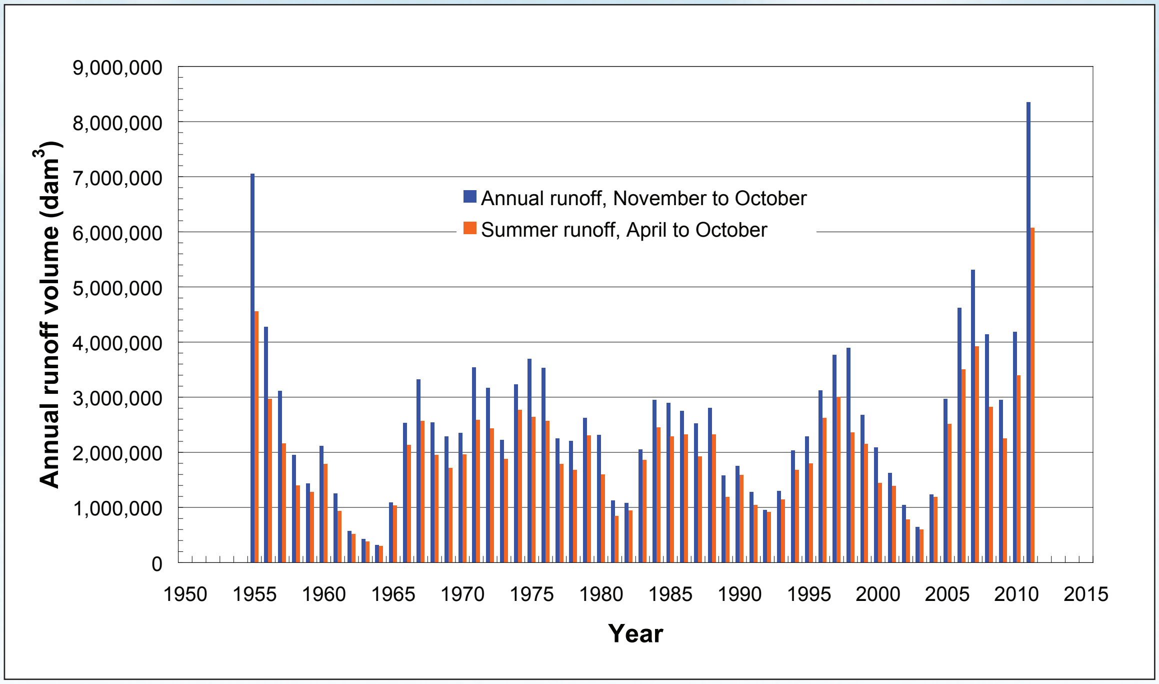
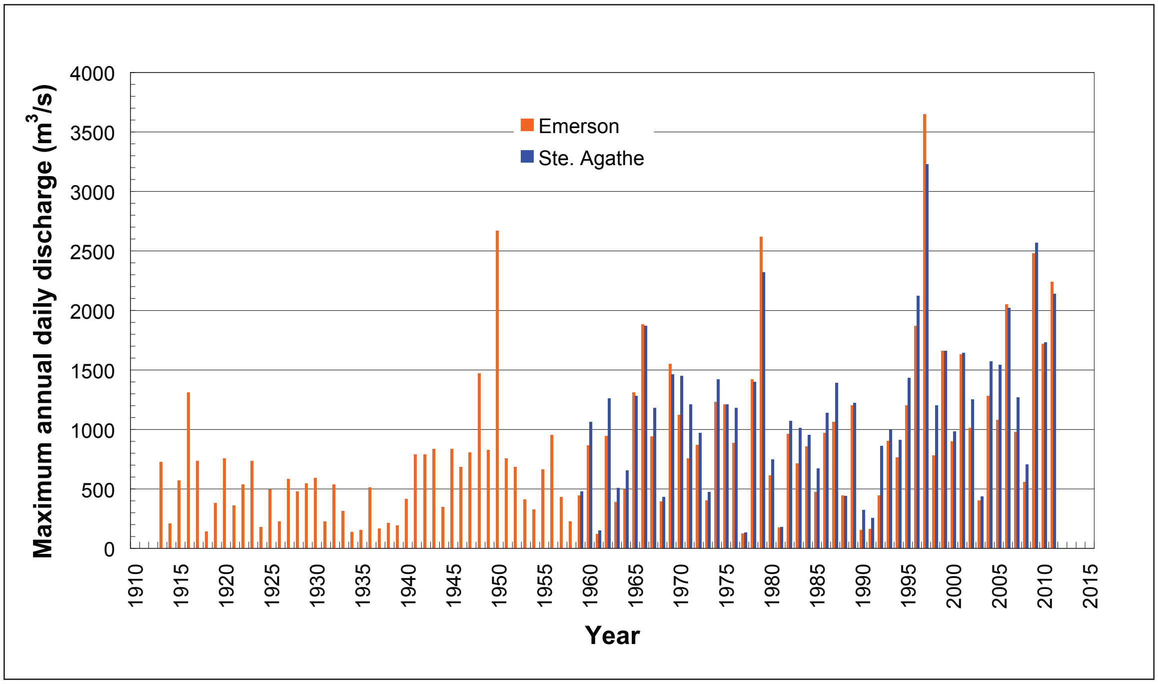


Figure 3.4: Historical flood series on the Red River at Emerson and Ste. Agathe. A 30-year cycle between wet and dry periods may be inferred from the flood peaks.



The manifestation of runoff and related flooding is a complex hydrologic process that depends on a number of factors. These include the physiographic characteristics of the region, the amount of precipitation (either snow or rain) that is available to be converted into runoff and the amount of storage available on the landscape (generally defined on the basis of antecedent moisture levels) that could limit how much of the precipitation actually runs off. While the physiographic characteristics are more or less the same from year to year (not withstanding the effects of land drainage), year to year variability in the precipitation and antecedent moisture levels can have dramatic effects on runoff volumes, river flows and subsequent flood levels.

3.2 The 2011 Flood

Appendix B contains a detailed description of the hydrologic characteristics of the 2011 flood at locations defined in the Terms of Reference provided to the Task Force. The scope was limited to areas where there was significant flood management infrastructure (dikes, control structures, etc.). These areas included the Saskatchewan River at The Pas, Dauphin Lake, Assiniboine River, Lake Manitoba and Lake St. Martin, the Souris River and the Red River. The hydrological and meteorological data used in the analysis was provided by Environment Canada. The 2011 hydrological data referred to in the following discussion should be considered provisional as the finalized data was not available at the time of the analysis. Furthermore, although the statistical analysis is based on accepted hydrologic practice, the interpretation of the flood severities will depend on the choice of frequency distributions and how the historical data is interpreted.

Figure 3.5: Prairie antecedent precipitation (August to October, 2010/11 inclusive) as a percent of normal. Antecedent moisture levels prior to the 2010-11 winter were well above average in Manitoba and Saskatchewan.

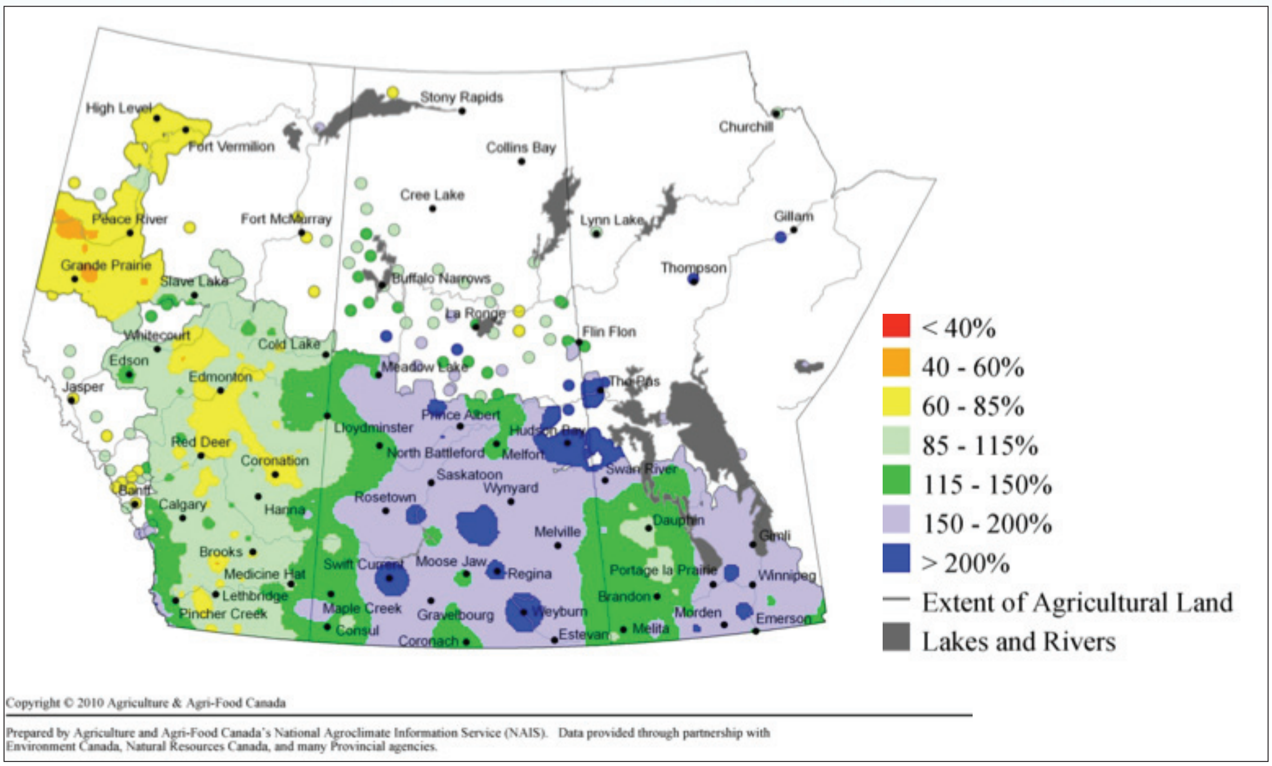
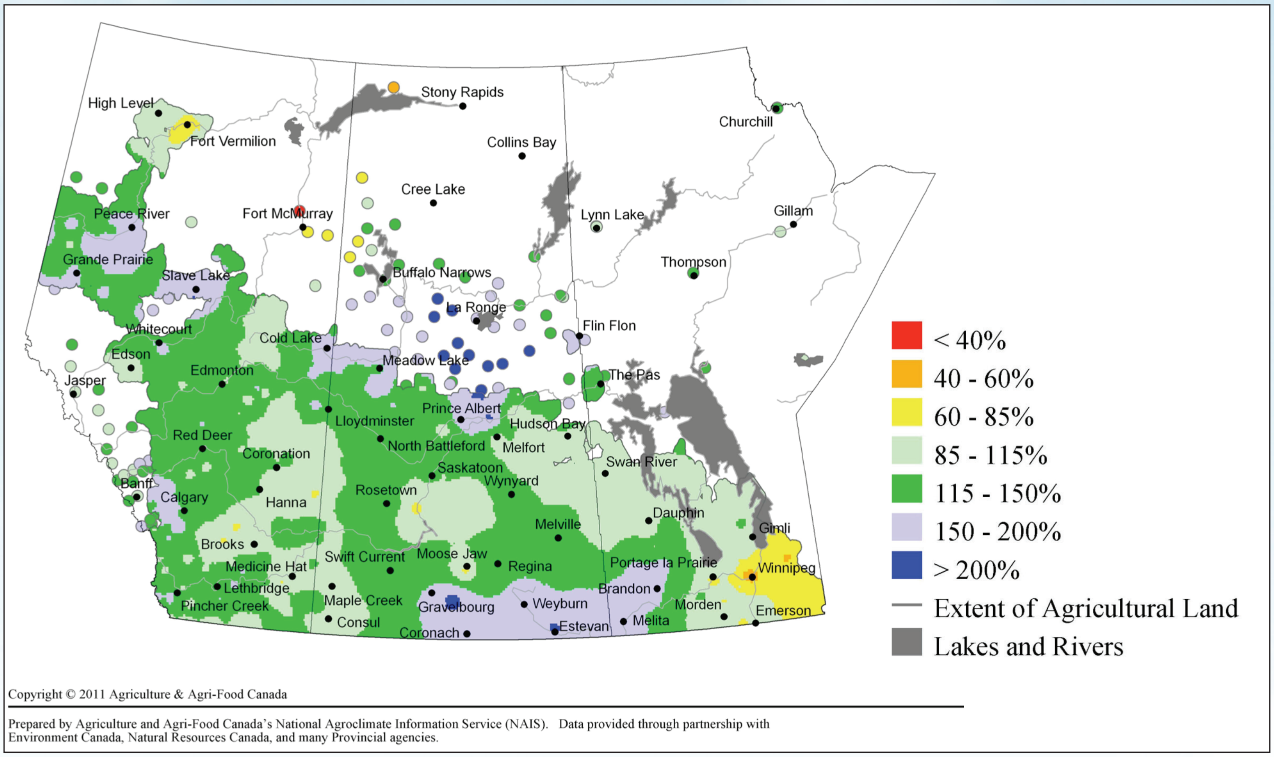


Figure 3.6: Prairie summer precipitation (May to June, 2011 inclusive) as a percent of normal. Summer precipitation west of the Red River ranged from just below normal to almost twice the amount normally experience.



In 2011, the antecedent conditions, the winter snowpack and summer rains all combined to produce one of the largest floods ever experienced in Manitoba. Falling within a somewhat wet cycle, 2011 was preceded by a very wet fall in 2010 when precipitation averaged between 150 and 200 percent of normal over a wide area in Manitoba and Saskatchewan (Figure 3.5). This produced extremely high regional antecedent moisture conditions whereby soil moisture levels were 100 to 250 percent of normal, or 1.5 to 2.5 times the long term average. Added to this, the winter snowpack was relatively high, varying geographically in the range of 90 to 130 percent of normal. Finally, after all that, unprecedented rainfall volumes were experienced in the region throughout the months of May, June and July when some areas received rainfall amounts that were 350 percent of normal (Figure 3.6).

It was clear in early January that Manitoba was in for relatively severe snowmelt flooding, given typical melt rates, and there was concern about both localized and general flooding. However, what was not so clear, and could not have been at any time during the spring and summer, was the amount of rain the region would receive, and the effects that rain would have on the intensity and duration of the summer flooding.

The most severe flooding occurred along the Souris and Assiniboine rivers (Figures 3.7 and 3.8), and around Dauphin Lake, Lake Manitoba and Lake St. Martin. The Red River was spared because the expected runoff from North Dakota did not materialize. Furthermore, runoff from the small tributaries between Emerson and Winnipeg also did not appear to be significant, even though many watersheds in southern Manitoba experienced record floods. Flood flows on the Saskatchewan River at The Pas (Figure 3.9) were also relatively benign likely due to the extensive storage in Cumberland Lake upstream in Saskatchewan, although some of the larger tributaries such as the Carrot River were affected by backwater from the Saskatchewan River. Much of the landscape south of the Saskatchewan River in the vicinity of The Pas was, and still is, saturated.

Figure 3.7: Historical flood peaks on the Souris River at Westhope and Wawanesa. The 2011 flood peaks are the highest on record by a huge margin – even exceeding those experienced in 1976.

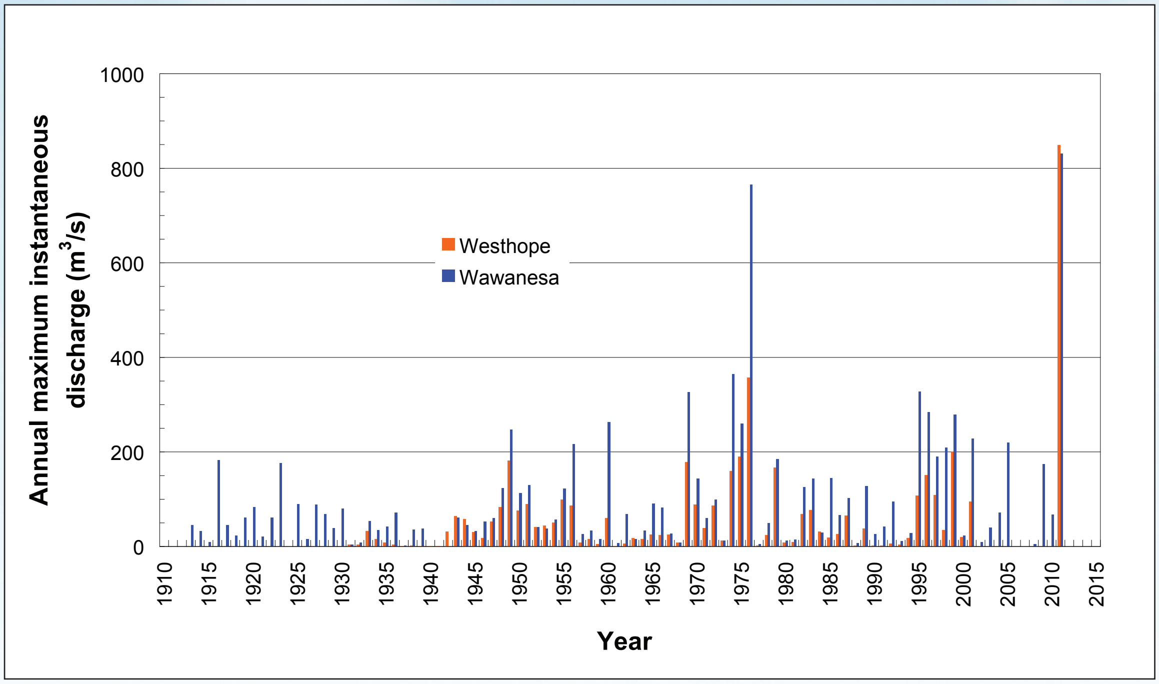
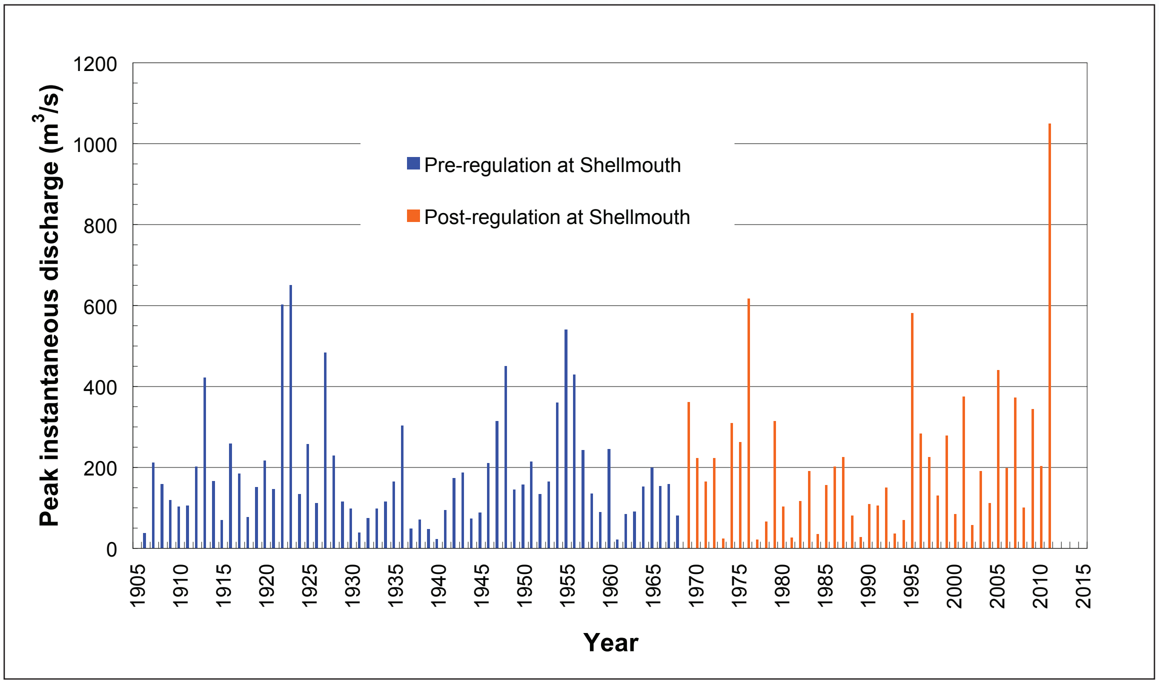


Figure 3.8: Peak Flows on Assiniboine River at Brandon for period of record, 1906-2011. The flood peaks after regulation would typically be lower than those prior to regulation due to managed storage in Lake of the Prairies.



Difficulties on the Souris and Assiniboine rivers appear to be the result of very high runoff in Saskatchewan, both during the spring period and later in the summer. The portions of these basins in Saskatchewan had been subjected to very high precipitation for at least two years prior to 2011 and they were primed to produce significant runoff volumes for even marginal rainfall events. While the amount of precipitation received in the May to July period of 2011 certainly had an effect on the runoff volumes and flood severity, the effects of the high antecedent moisture conditions in all the basins cannot be understated.

Figure 3.9: Historical series of measured flood peaks on the Saskatchewan River at The Pas. Post-regulation flood peaks would typically be lower than those prior to regulation due to storage in Tobin Lake.

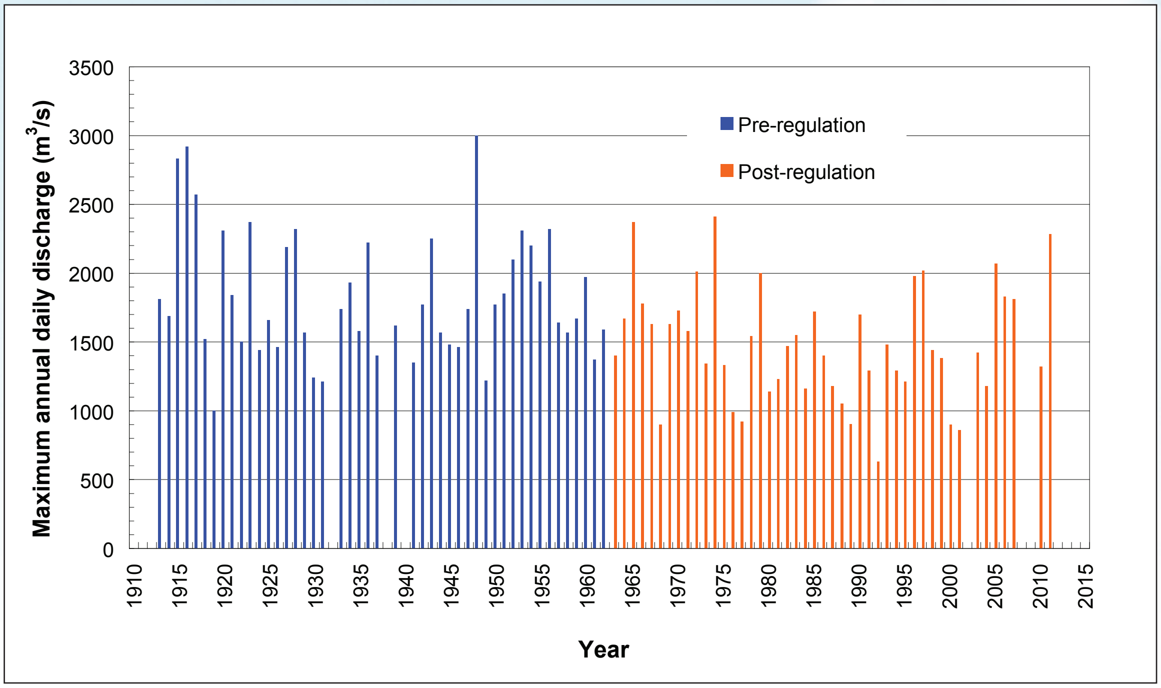


Figure 3.10: Historical record of daily water levels on Dauphin Lake. The 2011 peak water level exceeded the 1974 record high level.

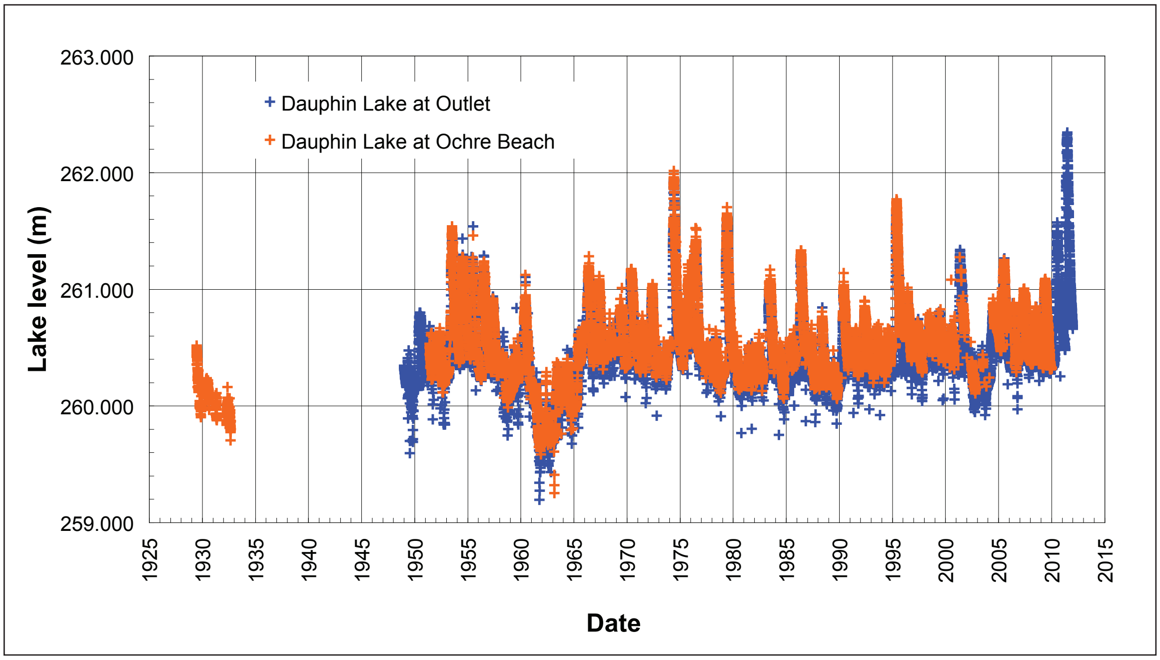


Figure 3.11: Water levels on Lake Manitoba, 2011. The instantaneous peak levels on any given day are due to wind-related setup and wave effects.

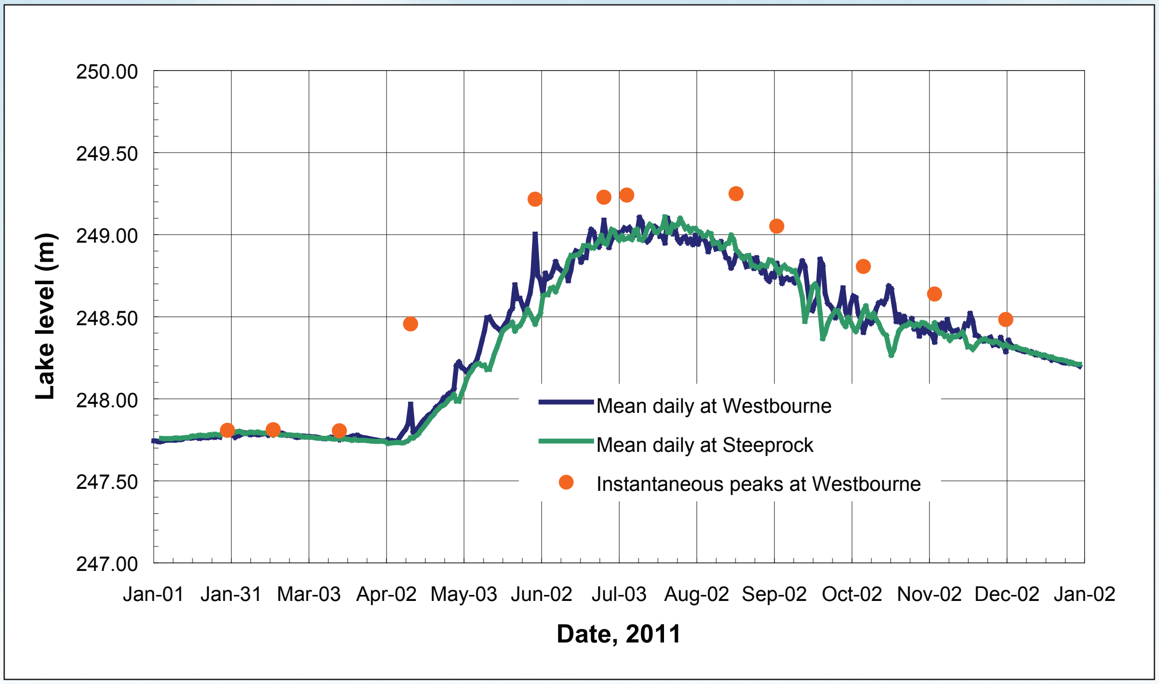
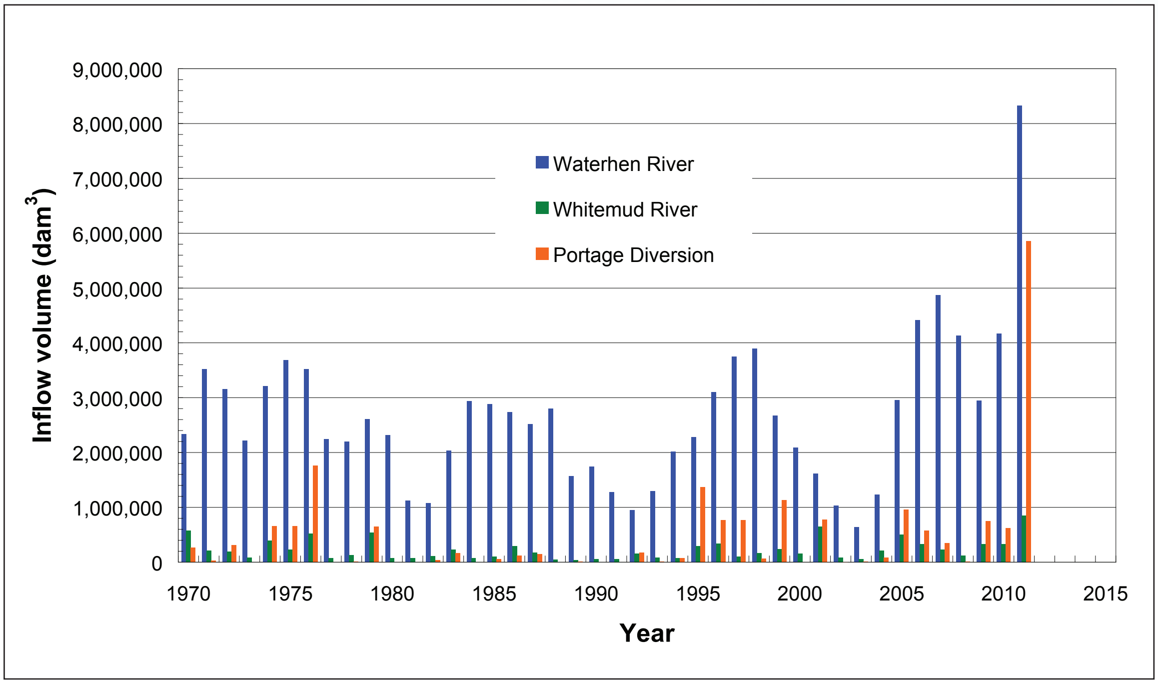


Figure 3.12: Annual inflows into Lake Manitoba since the implementation of the Portage Diversion in 1970. Inflows from the Waterhen River have the greatest effect on lake levels followed by inflows from the Portage Diversion.



Water levels on Dauphin Lake (Figure 3.10) were the highest on record due to large runoff volumes from the Duck Mountain and Riding Mountain, as evident from the Valley River record. Lake Manitoba reached record levels (Figure 3.11) due to high inflows from the Waterhen River and the Portage Diversion (Figure 3.12). High flows on the Waterhen River were due to above average precipitation in 2010 and 2011 which ultimately contributed to high water levels on Lake Winnipegosis. Inflows from the Portage Diversion arose out of the huge runoff volumes produced mostly by the Souris River and Qu'Appelle River basins. Lake St. Martin also experienced record high water levels because of the high outflows from Lake Manitoba at Fairford.

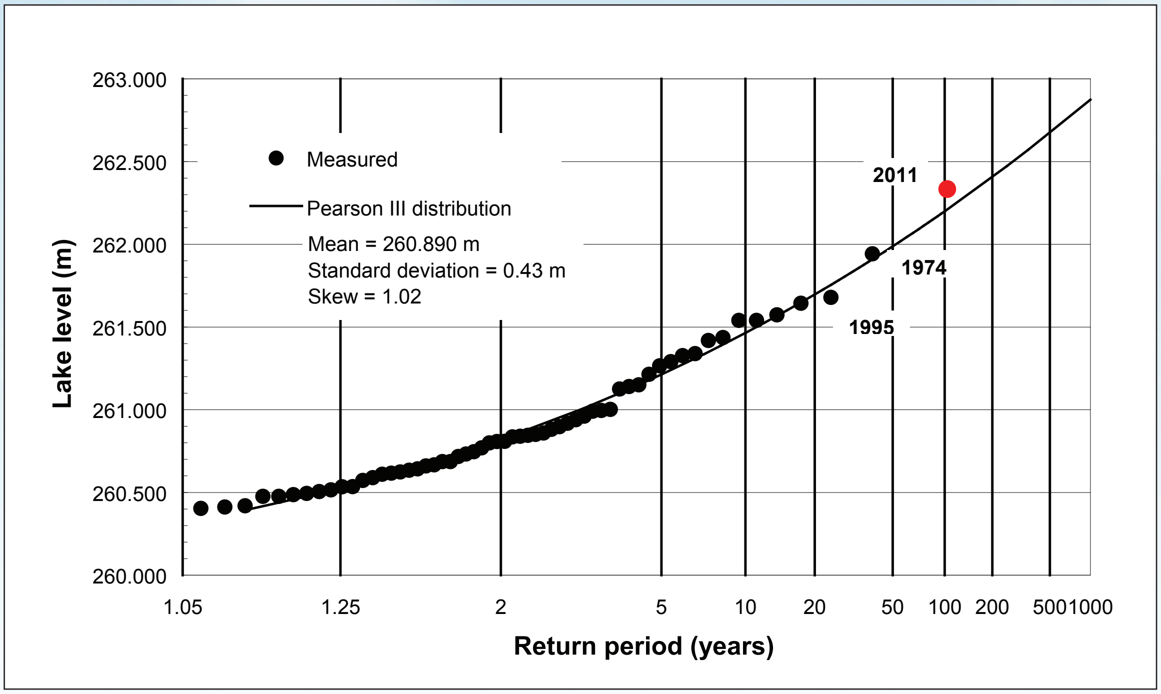
Table 3.2 summarizes the severity of the flood peaks and runoff volumes at selected locations throughout Manitoba. The table provides an indication of the return period of various facets of the 2011 event. As an example, Figure 3.13 illustrates the results of a typical statistical analysis – a water level frequency curve derived for Dauphin Lake on the basis of historical data. At locations such as The Pas and Brandon where flood peaks are important, the table references the peak discharge in 2011. For Dauphin Lake the peak water level is of most interest in interpreting the severity of the event. Lake Manitoba and Lake St. Martin are not included in the table. Due to rigid controls of lake levels on Lake Manitoba, the peak water levels on both lakes are not amenable to a straightforward statistical analysis. This is especially because of confounding effects related to year to year persistence of inflows due to the large storage in Lake Winnipegosis, and lake setup and wave heights due to winds. However, the 2011 flood volumes on the lower Assiniboine River and the Waterhen and Whitemud rivers would be useful in assessing the severity of the 2011 water levels on Lake Manitoba.

Table 3.2: Severity of the 2011 flood at salient locations in Manitoba.

River/Lake	Location	Parameter	Value	Approximate Return Period (years)
Saskatchewan River	The Pas	Peak Discharge	2290 m^3/s	25 (1)
Valley River	Dauphin	Runoff Volume	432 000 dam^3	50
Dauphin Lake	Mossy River Outlet	Peak Water Level	262.33 m	175 (2)
Assiniboine River	Brandon	Peak Discharge	1050 m^3/s	450 (3)
Assiniboine River	Holland	Runoff Volume	11 800 000 dam^3	350
Souris River	Westhope	Peak Discharge	850 m^3/s	500
Souris River	Wawanesa	Peak Discharge	830 m^3/s	350-500
Waterhen River	Waterhen	Runoff Volume	8 350 000 dam^3	250
Whitemud River	Westbourne	Runoff Volume	789 000 dam^3	100
Red River	Emerson	Peak Discharge	2240 m^3/s	25
Red River	Ste. Agathe	Peak Discharge	2140 m^3/s	15

Notes:
(1) *The return period is given for the post-regulation period. If the flood peak was evaluated within the context of the pre-regulation peaks the return period would be about 5 years.*
(2) *May include some wind effects.*
(3) *The return period is given for regulated conditions over the entire flood record as computed by Manitoba Water Stewardship. If the regulated flows are naturalized the 2011 flood peak would have been 1250 m^3/s and it would have had the same 450-year return period. Within the context of the natural flood series, regulation reduced the return period of the 2011 flood to just less than 200 years.*

Figure 3.13: Frequency curve of peak annual lake levels - Dauphin Lake, 1949-2011. The 2011 would have a return period of about 175 years.



3.3 Conclusion

It is clear that the 2011 flood was an extreme event at many locations, and care must be taken to evaluate these floods within the context of what might constitute a reasonable design event. The Souris and Assiniboine rivers were particularly hard hit and both the flood peaks and flood volumes were well above what would be considered in the design of flood management infrastructure. If these floods are meant to be used as a design benchmark it is important to review their genesis in considerable detail and reflect on what precedent such a choice would make. With respect to the flood risks on Lake Manitoba and Lake St. Martin, it is suggested that a rigorous statistical analysis be undertaken to take into account the effects of regulation on the ambient lake levels to provide perspective for the 2011 flood. Also, it is suggested that a probability analysis be carried out to assess the joint probabilities of high ambient lake levels and high wind-related lake setup to develop an understanding of the confounding effects of the winds.

Within the context of the analysis carried out herein, the view is that the 2011 floods in the Assiniboine River basin (including Lake Manitoba and Lake St. Martin) and those in the Souris River basin may be treated as outliers in any statistical analysis. This should be confirmed through statistical analysis and the application of the appropriate criteria for defining what constitutes an outlier.

The Souris and Assiniboine rivers were particularly hard hit, with flood peaks and flood volumes well above the design of flood management infrastructure.

4. Evaluation of Operation of Water Control Structures

The operation of provincial flood control infrastructure and ancillary works, including the Red River Floodway, Portage Diversion, Shellmouth Reservoir, Assiniboine River dikes, Hoop and Holler controlled breach and the Fairford Dam, to determine whether established rules of operation were followed, determine their role in reducing the overall impact of flooding and provide suggestions for operational improvements.

4.1 Background

The Government of Manitoba operates a number of structures that are integral to the water management and flood control in the province. In addition, there are a large number of water management structures operated by Ducks Unlimited Canada whose main functions are to preserve wetlands and/or create water bodies that will support habitat for waterfowl and other related species. These structures are operated and maintained under licence from the Province. Also, there are many locally owned water storage facilities on private and municipal lands that are used to augment water supply and are operated on the basis of local water management objectives. Finally, Manitoba Hydro owns and operates a large number of hydropower installations on a number of large rivers - Winnipeg River, Saskatchewan River, Burntwood River and Nelson River, for example, along with structures that regulate water levels on Lake Winnipeg and South Indian Lake, again, as examples.

There are two categories of water control structures. Passive structures have more or less fixed crest levels and provide local flood control up to an elevation determined *a priori* on the basis of an adopted design elevation consistent with historical flood levels. Examples include the dikes at the town of Souris and along the lower Assiniboine River. Active structures with gates and spillways on existing rivers and lakes, or on man-made reservoirs, such as the Shellmouth Dam, Fairford River Water Control Structure and the Red River Floodway, allow for day to day regulation of water levels upstream of the structures and flows and water levels downstream. This subsequently provides some measure of water level control on lakes and rivers downstream.

The Term of Reference within which this assessment was carried out limited the scope of the review to facilities (dams, dikes, outlet control structures, etc.) that were directly under the control of Manitoba Infrastructure and Transportation (MIT), were within the geographic area most severely affected by the flood and could be proactively operated prior to, or during the flood. Therefore, this assessment is limited to the water management structures on Dauphin Lake, Assiniboine River, Lake Manitoba and the main stem of the Red River. This review identifies salient structures, provides a brief description of the structures and their operational protocols, and determines if these structures were operated optimally during the 2011 flood event.

The following structures were examined within the context of the 2011 flood.

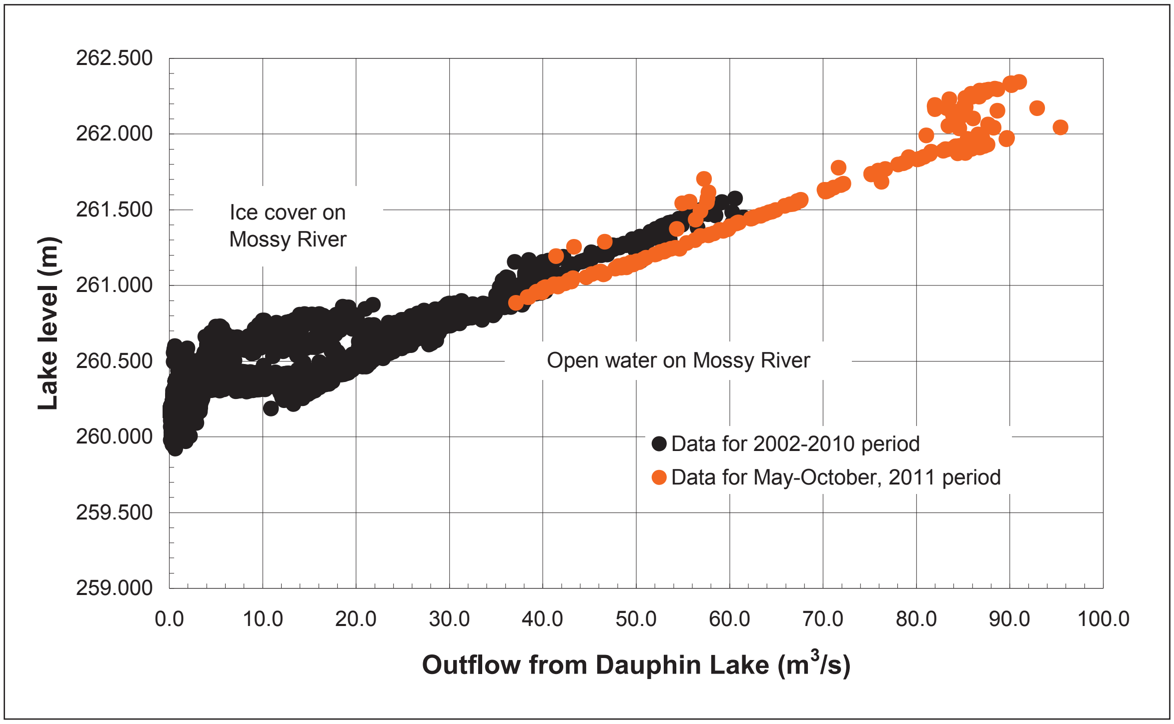
- Mossy River Control Structure at the outlet of Dauphin Lake.
- Shellmouth Dam and Lake of the Prairies Reservoir.
- Portage Diversion, including the gates and the diversion channel.
- Assiniboine River dikes downstream of Portage la Prairie.
- Fairford River Water Control Structure (FRWCS) at the outlet of Lake Manitoba.
- Red River Floodway.

4.2 Mossy River Control Structure

Water levels on Dauphin Lake have been the subject of some controversy since development around the lake was first considered in the late 1890s and early 1900s. Local stakeholders want to see sustainable resource use (including stable agricultural production), an increased recreational capacity and improvements to wildlife habitat around the margins of the lake. Water levels at the low end of the historical range for extended periods adversely affect shoreline habitat and recreation potential. Water levels at the high end of the range cause damage to recreation properties and reduce agricultural production. Within this context, water level extremes are undesirable and the local consensus is to try and manage the lake to a narrower water level range with an upper limit on water levels of 260.54 metres (m) or 854.8 feet (ft). This would be achieved by increasing outflows at high lake levels and reducing inflows during flood events by providing storage in watersheds upstream of the lake.

Several efforts have been made to control lake levels in the last century. In 1964 the Mossy River Dam, a ten bay concrete stoplog structure complete with a fish ladder, was constructed at the outlet of the lake. The structure is operated by the Province, and since 1993 the objective was to maintain water levels below 260.54 m (854.8 ft). The structure has improved the outlet efficiency when lake levels are low and so it works well to increase outflows from the lake during periods of low lake levels to ensure ecological integrity and water supplies along the Mossy River which is a fairly important fishery. However, at high lake levels, backwater effects from the less efficient Mossy River limit its outflow capacity. Figure 4.1 illustrates the relationship between lake levels and flows through the control structure for both winter (ice covered) conditions and summer open water conditions with all the stoplogs removed. Typical outflows in the winter range from 10 to 20 cubic metres per second (m^3/s), or 350 to 700 cubic feet per second (cfs), while the maximum outflow during the summer period likely cannot exceed about 90 m^3/s (3200 cfs).

Figure 4.1: Relationship between flows on the Mossy River and water levels on Dauphin Lake. When the river is ice covered outflows are reduced relative to summer outflows for equivalent lake levels.

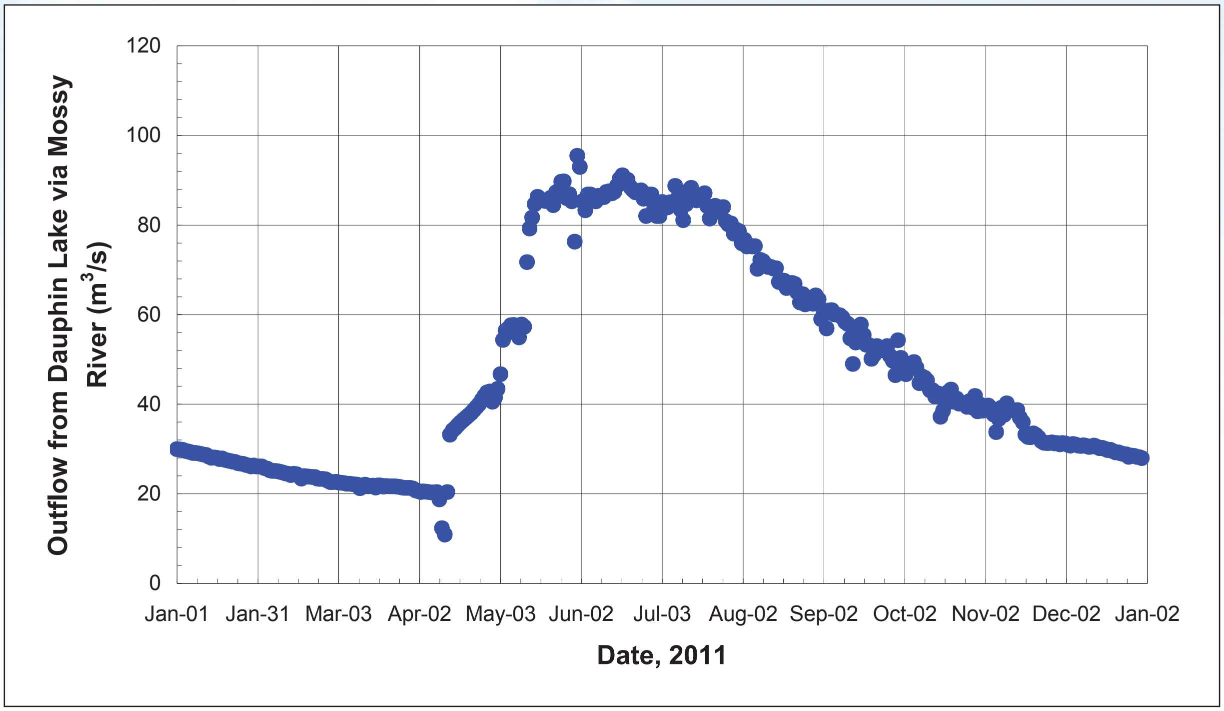


Accordingly, the structure works well enough to mitigate the effects of low lake levels, but it does not meet local performance expectations when lake levels are high. Solutions have been suggested to improve the situation at the structure which include improving the conveyance capacity of the Mossy River and/or constructing an auxiliary outlet channel with an appropriate outlet structure east of the Mossy River to connect the lake to Lake Winnipegosis. Both solutions would be controversial.

4.2.1 Flows and Water Levels in 2011

Outflows into the Mossy River ranged from about 20 m^3/s (700 cfs) in late March of 2011 to maximum of about 95 m^3/s (3350 cfs) in early June (Figure 4.2) that coincided with a nominal maximum lake levels that ranged between 262.0 and 262.3 m (859.6 and 860.6 ft).

Figure 4.2: Outflows from Dauphin Lake via the Mossy River, 2011.



4.2.2 Structure Operations in 2011

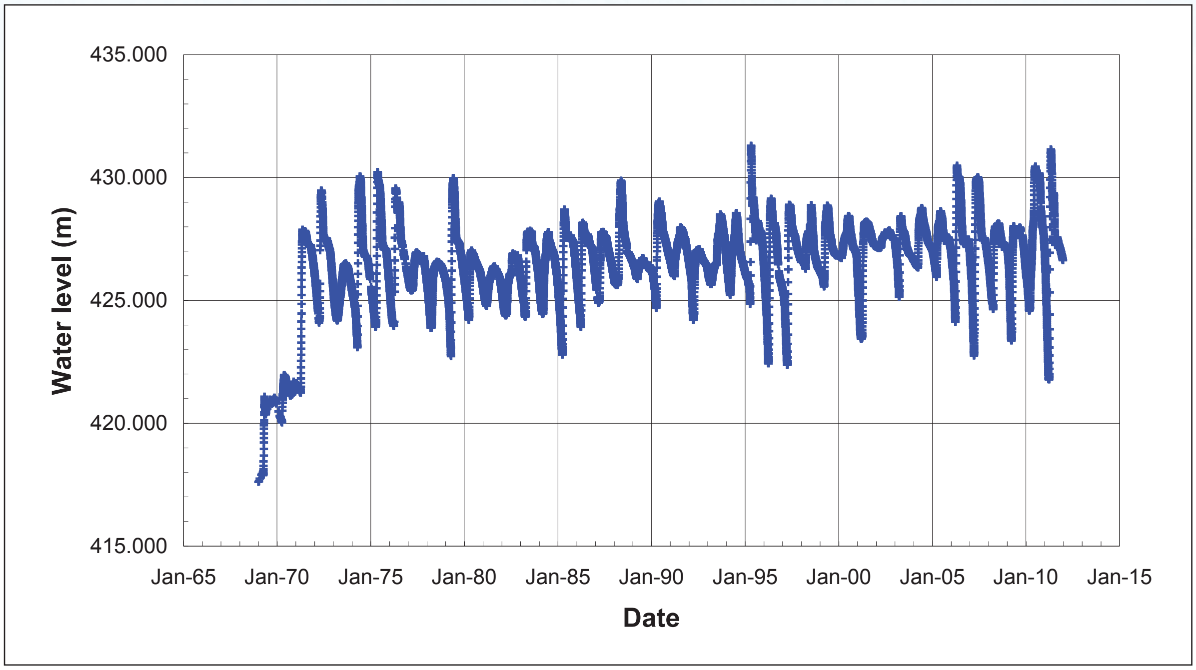
Persistently high lake levels since 2009 and in the period leading up to the 2011 flood had dictated that all the stoplogs in the dam would be removed to reduce lake levels as much as possible. Under this operating condition, flows out of the lake were free to respond to changing lake levels, with the only constraint being the limited conveyance capacity of the Mossy River due to the ice cover in the winter and the channel flow resistance in the summer. The *de facto* result was that outflows were maximized over the entire period before, during and after the flood event. This created more storage in the lake prior to the 2011 flood and thus reduced the peak by as much as possible within the framework of the existing conveyance capacity of the Mossy River.

4.3 Shellmouth Dam and Lake of the Prairies Reservoir

The Lake of the Prairies reservoir was created in 1969 by the construction of the Shellmouth Dam to provide storage for downstream flood control and to supply water to areas along the Assiniboine River. The drainage area above the lake is 17 900 km^2 (6900 $mile^2$). Most of the inflow is derived from the upper Assiniboine River basin (gauged at Kamsack) in Saskatchewan and from the Big Boggy Creek and Shell River basins in Manitoba. The dam that created the reservoir is 1280 m (4200 ft) long and about 21 m (69 ft) high. The lake is about 60 km (38 miles) long and more or less contained within the valley of the Assiniboine River. The surface area of the reservoir is about 60 km^2 (23 m^2) and its total volume is about 480 000 cubic decametres (dam3) or (390,000 acre-ft) which is equivalent to about the average annual inflow volume.

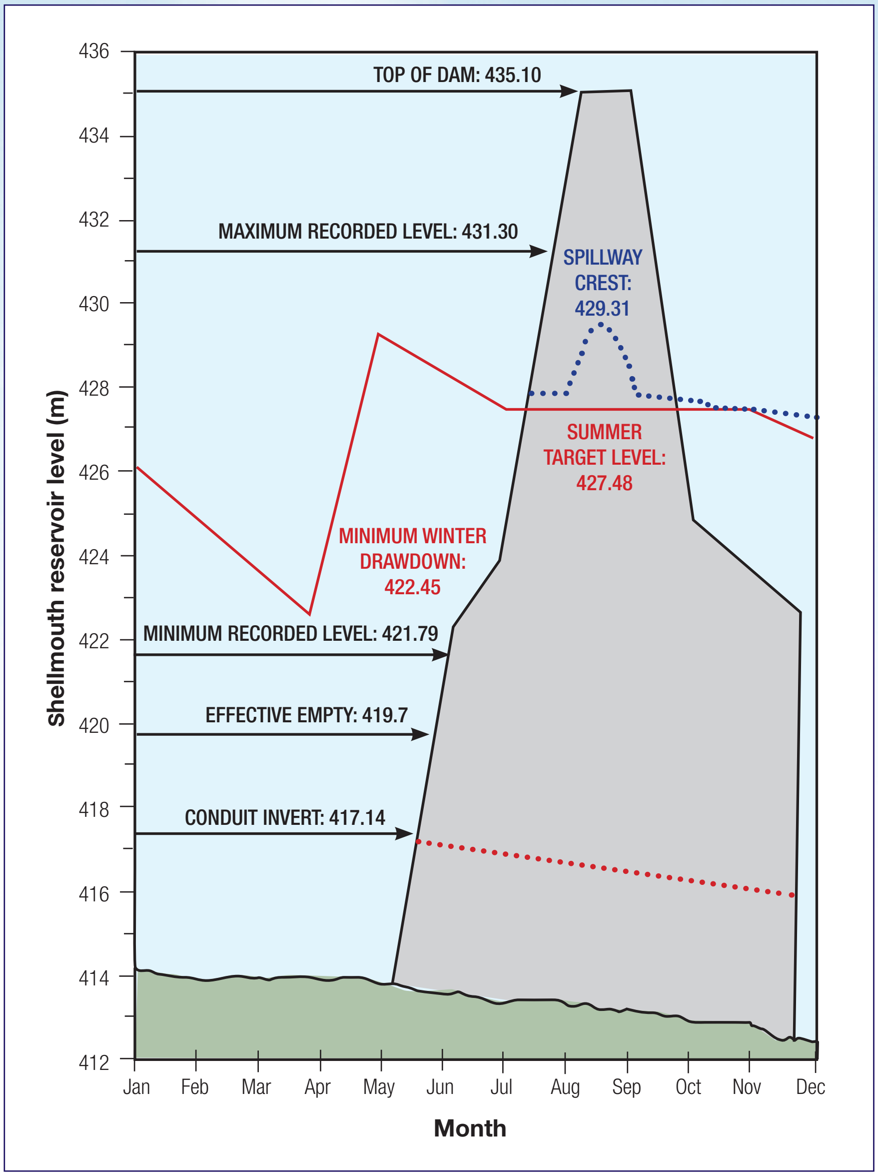
Although Lake of the Prairies reservoir was constructed initially as a flood control and water supply reservoir, and is operated primarily for that purpose, considerations are given also to recreation and environmental concerns. The water levels generally fluctuate within an elevation range of 425 to 430 m (1395 to 1410 ft), except in times of severe inflows when the water levels exceed the upper bound of that range and during periods of severe droughts or when the lake is drawn down to maximize storage with the expectation of experiencing a severe flood – like in 2011. The highest water level on record is 431.3 m (1415.0 ft) on May 3, 1995 (Figure 4.3). As a comparison, the peak water level in 2011 was 431.1 m (1414.4 ft), also in early May. The lowest water level on record is 421.8 m (1383.9 ft). This occurred in late March and early April, 2011 as the water levels were drawn down in anticipation of the 2011 flood.

Figure 4.3: Historical water levels on Lake of the Prairies Reservoir.



The water levels in the reservoir are managed by controlling releases through the gated low level outlet. The low level outlet flows depend on the gate opening and the reservoir level. With the gates totally open, the maximum discharge that can be realized when the reservoir level is just at the crest of the spillway (elevation 429.31 m or 1408.5 ft) is about 165 m^3/s (5800 cfs). Once the water level exceeds the spillway crest level, the flow over the spillway depends only on the reservoir level which in turn depends on the inflows to the reservoir. Control of outflows is lost until the reservoir level drops below the crest of the spillway. Figure 4.4 illustrates some of the salient elevations of the structure. The red line on Figure 4.4 represents typical reservoir levels over the course of the year.

Figure 4.4: Schematic of salient water and structure levels for the Lake of the Prairies Reservoir. The red line represents the target water level in the reservoir throughout the year.



4.3.1 Operating Guidelines

In order to optimize the use of the reservoir for flood control and water supply, and subsequently recreation and fisheries, the operating guidelines have become quite complex. In fact, an elaborate method of forecasting the inflows into the reservoir has been developed. A liaison committee has been established to advise on how to operate the reservoir and to provide information to interested parties with interests upstream and downstream of the reservoir. However, in the case of severe events like 2011 that might tax the capacity of the reservoir, the reservoir operating procedures rest solely with the Province to ensure the integrity of the structure and the safety of local residents.

Over time, as the intended uses for the reservoir have changed or have been expanded, the operating guidelines have been updated. The following description of these guidelines is based on information provided by Manitoba Infrastructure and Transportation (MIT) in 2012.

Winter Operations

Winter operations of the Shellmouth Dam are a balancing act between developing sufficient storage in the reservoir to provide a measure of flood control downstream, maintaining sufficiently high water levels to ensure ecological integrity in the reservoir and keeping enough water in the reservoir to accommodate water needs in the following summer. These objectives need to be met on the basis of the spring runoff volume forecasts and with limited outflow flexibility due to downstream channel capacity constraints and the need to maintain a stable ice cover on the Assiniboine River downstream. The winter operating guidelines are as follows.

- Regardless of the spring runoff forecasts, the normal winter drawdown would be to an elevation of 424.0 m (1391.1 ft) with a minimum drawdown level of 422.45 m (1386.0 ft) unless an extreme event (like 2011) is forecast for the following year. This level should be achieved without the outflow exceeding 42.5 m^3/s (1500 cfs) and without large day to day fluctuations in the outflows.
- To maintain either sufficient storage capacity for flood protection or a sufficient volume for water supply to accommodate back-to-back droughts, the target drawdown level and the corresponding winter outflows are established on the basis of the following:
  - November and December outflows as based on the lower decile spring runoff forecast,
  - January and February outflows are based on the lower quartile spring runoff forecast, and
  - March outflows are based on the upper quartile spring runoff forecast.

Spring Operations

The spring operations focus mostly on minimizing the spring flood peak downstream of the reservoir while maintaining operational integrity at the facility. Maintaining minimum flows downstream is less of a concern. The spring operating guidelines are as follows.

- Minimum releases shall be 0.71 m^3/s (25 cfs), regardless of flood conditions downstream, prevailing reservoir levels or projected inflows to the reservoir.
- Maintain outflows below 14.1 m^3/s (500 cfs) until the spring flood has crested at Miniota to minimize flood risks between Shellmouth and Miniota where the channel capacity of the Assiniboine River is the lowest.
- If inflow forecasts indicate that the reservoir level is expected not to exceed 428.70 m (1406.5 ft), maintain outflows below 45.3 m^3/s (1600 cfs), but if reservoir levels are expected to exceed 428.85 m (1407.0 ft) outflows may be increased. Note that the crest of the spillway is at elevation 429.31 m (1408.5 ft).
- If inflow forecasts indicate that reservoir levels may rise to above the crest of the spillway, April outflows may be increased to as high as required to keep the reservoir level below 428.85 m (1407.0 ft), or about 0.46 m (1.5 ft) below the spillway crest. Should the operational period extend into May or June, limit outflows to 56.7 m^3/s (2000 cfs) if possible by adjusting flows through the low level conduit.

Summer Operations

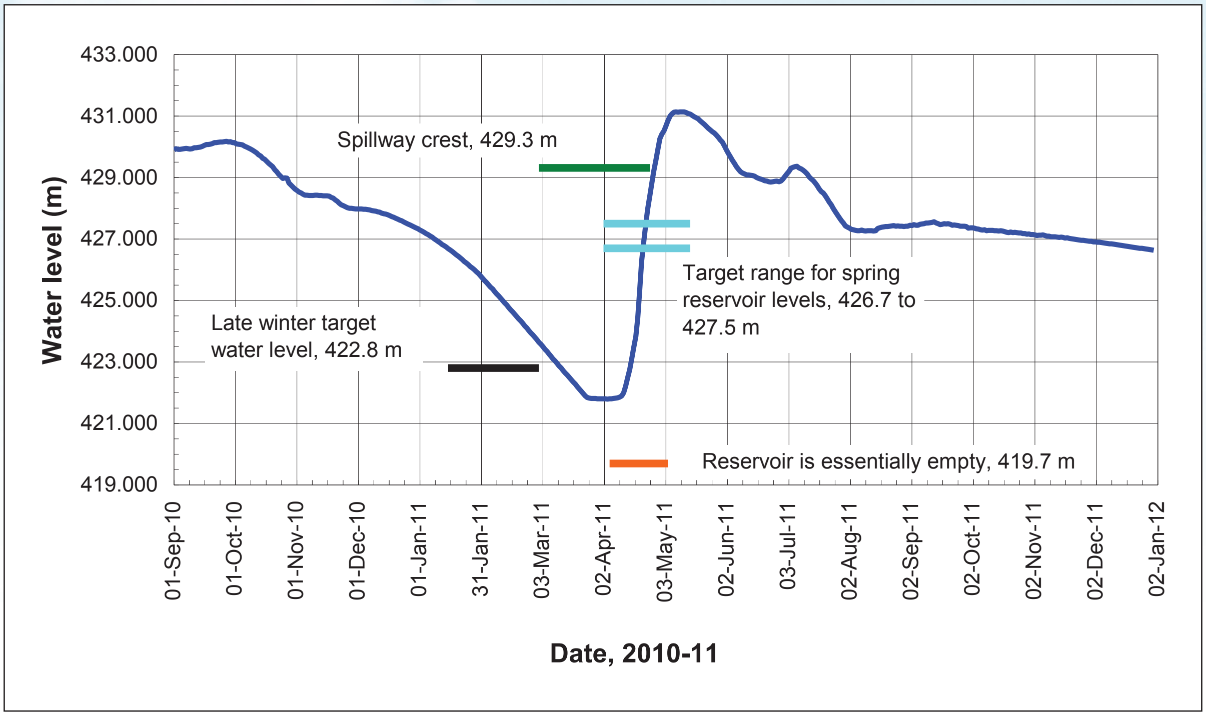
Summer operations are mostly concerned with maintaining reservoir levels within the desired range for recreational purposes and maintaining minimum flows along the Assiniboine River for both water quality and water supply purposes. In some years, like 2011, when summer inflows are significant, the integrity of the structure also becomes a concern. The summer operating guidelines follow.

- The preferred water level range is 426.72 to 427.94 m (1400.0 to 1404.0 ft), and if possible an absolute minimum outflow of 1.4 m^3/s (50 cfs) is to be maintained without allowing outflows to exceed 28.3 m^3/s (1000 cfs). Target minimum outflows for water supply purposes at Brandon and Headingly are 2.8 and 5.7 m^3/s (100 and 200 cfs) respectively. The corresponding reservoir outflow would be adjusted on the basis of tributary inflows between the reservoir and those locations.
- If summer flooding becomes a concern (high reservoir inflows) outflows may be increased to 45.3 m^3/s (1600 cfs) to prevent the spillway crest from being overtopped. Outflows may be increased further if the reservoir level is expected to exceed 429.92 m (1410.5 ft).
- Should the spillway be overtopped outflows should be maintained at 34.0 m^3/s (1200 cfs) if possible by adjusting the gates of the low level outlet until reservoir levels drop to 428.70 m (1406.5 ft), but without allowing river levels to recede by more than 0.091 m (0.3 ft) per day.
- When the reservoir level declines to below 426.72 m (1400.0 ft) reduce outflows to 0.71 m^3/s (25 cfs).
- Should reservoir levels recede to below 423.67 m (1390.0 ft) outflows shall be set in consultation with the Minister and following discussions with stakeholders.

4.3.2 Flows and Water Levels in 2011

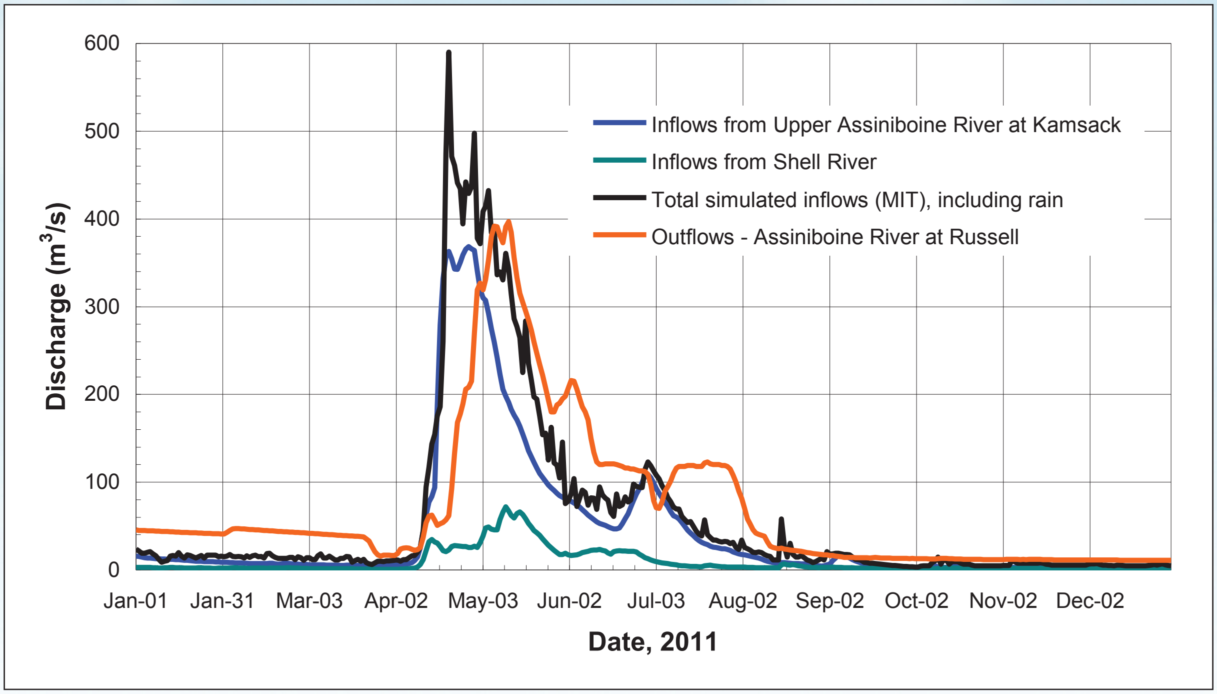
In 2011 the reservoir was drawn down (Figure 4.5) to an elevation of 421.8 m (1383.9 ft) in anticipation of a severe runoff event. This was about one metre or three feet lower than provided for in the operating protocols. Outflows (Figure 4.6) exceeded the 70.8 m^3/s (2500 cfs) criterion on April 22 and water levels rose to the level of the spillway on April 28. During the periods when water levels in the reservoir were below the crest of the spillway and outflows could be controlled by adjusting the gate(s) on the low level conduit, peak water levels in the river near Russell at the old Provincial Trunk Highway 5 bridge were limited to between 410.2 and 410.4 m (1345.8 and 1346.5 ft). This was close to bankfull, but low enough not to produce significant inundation of the floodplain.

Figure 4.5: Water levels on Lake of the Prairies Reservoir, 2010/2011.



Peak inflows into the reservoir were in the 475 to 500 m^3/s (16,800 to 17,700 cfs) range (Figure 4.6) according to MIT simulations after accounting for gauged inflows from the Assiniboine and Shell rivers, for precipitation falling onto the reservoir and for contributions from ungauged portions of the contributing basin. The spillway operated between April 28 and about June 6. In that period the peak outflow from the reservoir was between 340 and 400 m^3/s (12,000 and 14,130 cfs), corresponding to a peak water level in the reservoir of 431.1 m (1414.4 ft). The peak water level at the Water Survey of Canada (WSC) gauge downstream near Russell occurred over a period of about seven days in early May when water levels hovered between 412.2 and 412.3 m (1352.4 and 1352.7 ft).

Figure 4.6: Inflows and outflows from Lake of the Prairies Reservoir, 2011. The simulated inflows provided by MIT reflect precipitation inputs and runoff from ungauged catchments.



Analysis suggests that the peak outflow was about 350 m^3/s (12,360 cfs). After accounting for local inflows between Shellmouth and Russell, the peak at the WSC gauge near Russell was about 420 m^3/s (14,830 cfs). Reservoir storage reduced the peak at the WSC gauge by about 22 percent – equivalent to a water level reduction of about 0.3 m (1.0 ft). The storage provided by Lake of the Prairies reduced the downstream flood peaks and made a significant contribution to the mitigation of flood damages on the Assiniboine River. Peak reductions at Russell amounted to 22 percent and peaks downstream of the Qu'Appelle River confluence were reduced by about 10 percent. Corresponding water level reductions ranged from 0.3 m (1.0 ft) to 4 m (1.3 ft). Table 4.1 summarizes the peak reductions at salient locations along the Assiniboine River.

Table 4.1: Comparison of Assiniboine River flood peaks with and without regulation at Shellmouth. [(1)]

Location	Unregulated Peak Discharge (m^3/s)	Regulated Peak Discharge (m^3/s)	Percent Flow Reduction	Water Level Reduction (m)
Russell	540	420	22	0.55
St. Lazare (downstream of Qu'Appelle River confluence)	920	830	10	
Miniota	970	870	10	
Brandon	1120	1030	9	0.20
Holland/Portage (downstream of Souris River confluence)	1610	1470	9	0.25

[(1)] *Discharge data supplied by MIT.*

With respect to water levels in the Shellmouth area, the adopted channel capacity is 85 m³/s (3000 cfs) at the Russell gauge – equivalent to a water level of 409.5 m (1343.5 ft) as illustrated in Figure 4.7. In 2011, this water level was exceeded in January, February and March (Figure 4.8) when the reservoir was being drawn down, and for about 100 days in April through to July when reservoir levels were above the spillway crest.

Figure 4.7: Assiniboine River rating curve at the WSC gauge near Russell.

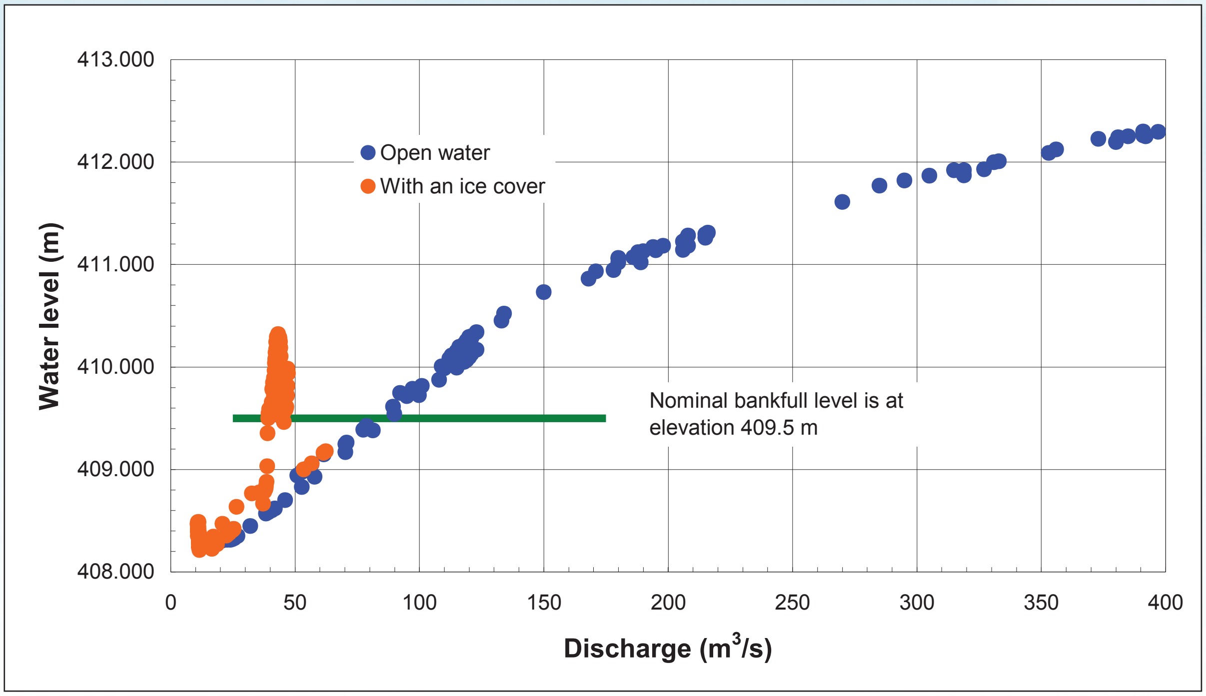
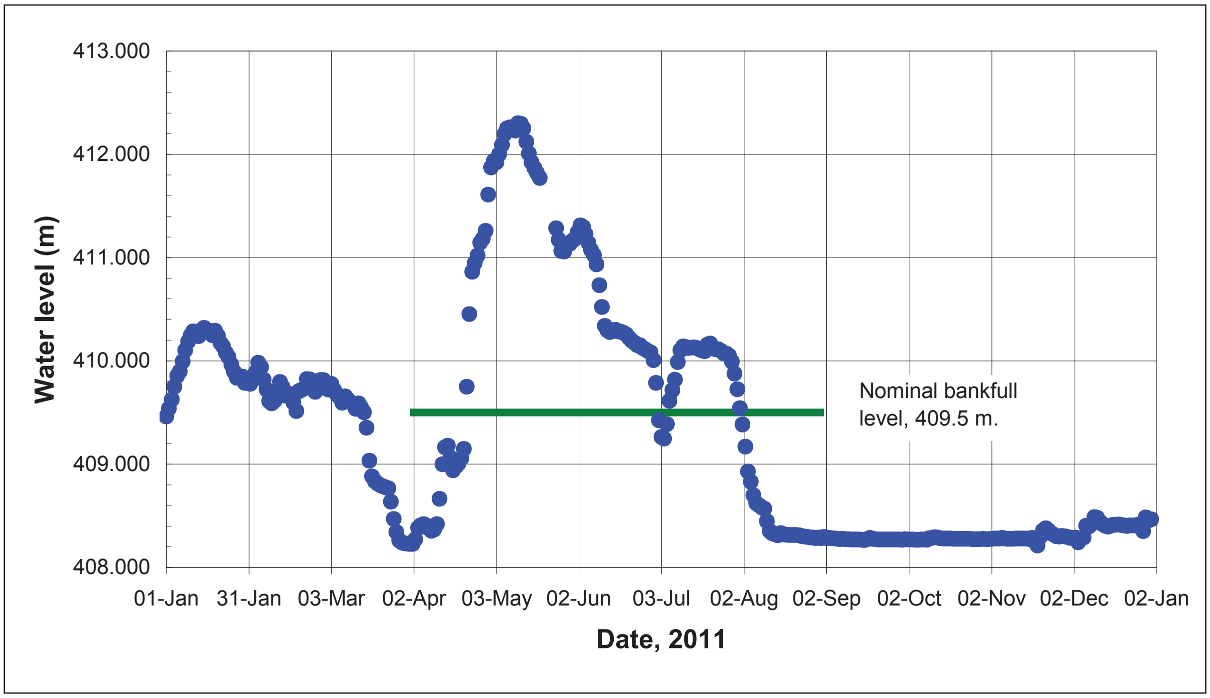


Figure 4.8. Water levels at the WSC gauge near Russell, 2011.



There was little that officials could do to reduce outflows or to operate the reservoir differently in 2011. The foresight to draw the reservoir down to a level below the defined minimum late-winter reservoir level was an advantage given the severity of the 2011 inflows. This maximized both the storage in the reservoir and the subsequent reduction in flood peaks downstream. However, once the water level reached the crest of the spillway, all that could be done was to allow the flood to take its course and rely on reservoir storage effects to reduce the peak downstream, relative to the peak inflow into the reservoir.

4.3.3 The Shellmouth Reservoir Regulation Liaison Committee

The Shellmouth Reservoir Regulation Liaison Committee was formed in 1996 to facilitate communication between then Manitoba Water Stewardship (now Manitoba Infrastructure and Transportation – MIT) and various stakeholders along the Assiniboine River regarding operations at the Shellmouth Dam. The liaison committee is chaired by the Executive Director of Hydrologic Forecasting and Water Management for MIT, and technical support and advice is provided by staff from the department's Hydrologic Forecast Centre. There are currently 16 non-MIT members on the committee representing producers, irrigators, conservation districts and rural municipalities upstream and downstream of the dam, the cities of Brandon and Portage la Prairie, and Manitoba Agriculture, Food and Rural Initiatives.

Stakeholders provide local input regarding watershed conditions and information on the effects of dam operations in their areas of interest, thereby contributing to operational decision-making by MIT. The Terms of Reference include the following duties:

- Evaluate and report on probable local effects of proposed reservoir operation scenarios and river forecasts provided by MIT. Provide opinions via phone, fax, e-mail or during conference calls.
- Provide local information on watershed conditions such as precipitation, soil moisture, snow cover, flooding and drainage to supplement MIT data networks.
- Comment on operations at post-flood meetings held after significant flood events and participate in any workshops on operations.
- MIT will notify members in advance of any significant reservoir operations.
- Members will keep local interests informed of committee activities.
- The Committee will report to the Minister of MIT following significant flood events.

The Task Force heard reports of dissatisfaction from the general public and Committee members themselves regarding the functioning and effectiveness of the Committee and of Shellmouth Dam operation itself. These concerns included:

- too many members on the Committee,
- the Committee rarely meets face-to-face,
- members are unclear of the scope of their mandate,
- certain members are alleged to have undue influence on operational decisions thereby favouring downstream irrigators and recreational interests, and
- there is widespread misunderstanding about the objectives of Shellmouth Dam operation and of its potential to mitigate downstream flood damages.

The Task Force supports the need for a liaison committee to provide local knowledge and information to MIT, but has presented a number of recommendations at the end of this section of the report related to the make-up, mandate and function of the Committee.

4.4 Portage Diversion and Lower Assiniboine River

4.4.1 Portage Diversion

The impetus to construct the Portage Diversion came from the 1958 recommendations of the Royal Commission on Flood Cost Benefit that was struck by the Province of Manitoba. The purpose of the diversion was to shunt excess Assiniboine River flows into Lake Manitoba both to improve the performance of the Assiniboine River dikes by reducing their overtopping risks and to reduce the inflows to the Red River at the city of Winnipeg. The Commission also recommended the construction of the Shellmouth Dam and Reservoir to reduce flood peaks from the upper parts of the Assiniboine River basin, and the Red River Floodway to divert flows around the city of Winnipeg.

The Portage Diversion facility consists of the following.

- A 29 km (18 mile) long diversion channel that outlets into Lake Manitoba with a nominal capacity of 708 m^3/s (25,000 cfs). There is also a failsafe section that allows overflow from the channel westward when flows exceed 425 m^3/s (15,000 cfs). This plays a role in maintaining the integrity of the outlet structure at Lake Manitoba, and preventing overtopping of the east dike along the diversion channel during ice jam conditions. Also, there are three drop structures along the diversion channel that dissipate energy and reduce the effective slope of the channel so that it does not erode excessively.
- A gated diversion structure on the Assiniboine River whose main function is to regulate flows down the lower Assiniboine River and to create a headpond from which water can be drawn off into the diversion channel.
- A gated inlet control structure that regulates how much flow is dispatched from the headpond and into the diversion channel. The maximum nominal operating level of the headpond is 234.39 m (769.0 ft).

For a given inflow into the headpond, a unique set of gate settings on both the diversion structure and the inlet control structure will result in a particular water level in the headpond and corresponding flows down both the diversion channel and the lower Assiniboine River. Depending on circumstances, one or more of the following parameters will determine the gate settings and the corresponding flow split. These are the maximum allowable flow down the diversion, maximum allowable flow down the lower Assiniboine River and/or the maximum allowable headpond level.

In addition to maximizing flood control benefits to the city of Winnipeg, the objectives of the Portage Diversion are as follows.

- Minimize ice jams forming along the Assiniboine River downstream of Portage la Prairie. This is done by reducing flows so that the ice-related water levels at least are maintained below the crests of the dikes and preferably within the channel banks during breakup.
- Limit increases to water levels in Lake Manitoba to the maximum regulated level of 247.76 m (812.87 ft) - as of 1984. This has since been revised with the current criterion being that levels should fluctuate between 247.04 and 247.65 m (810.5 and 812.5 ft), which is somewhat more stringent than the 1984 criterion.
- The failsafe should be used infrequently and if possible, flows down the diversion channel should be limited to a maximum of 425 m^3/s (15,000 cfs).

Within those general objectives, specific operating guidelines have been adopted to preserve certain key valued components. It appears that these guidelines have not changed since 1984 and are as follows.

- The facility will be used to its maximum capability to keep water levels on the Red River at the James Avenue Pumping Station in Winnipeg below a gauge height of 5.2 m (17.0 ft), City datum. However, if flows into the headpond are less than 850 m^3/s (30,000 cfs), the critical gauge height at James Avenue could be relaxed to 5.5 m (18.0 ft) if there is a chance that the failsafe section of the diversion channel could be breached. All other flows being the same, this provides for an increase in flow down the lower Assiniboine River of about 100 m^3/s (3500 cfs).
- Flows in the diversion channel shall not be allowed to exceed 708 m^3/s (25,000 cfs).
- If flow forecasts indicate that flows into the headpond may be 566 m^3/s (20,000 cfs) or more, flows will be diverted into the diversion channel to flush out snow and ice remnants left over from the winter to improve the channel capacity.
- While an ice cover exists in the headpond, the reservoir level shall not exceed 263.65 m (865.0 ft) to provide sufficient storage to contain inflows of ice and water from upstream ice jam surges.

- The low level conduits of the diversion structure shall be closed when flow is going over its gates.
- While there is an ice cover on the Assiniboine River downstream of Portage la Prairie, flows should be limited to 142 m^3/s (5000 cfs) to prevent high ice-related water levels.
- After the ice has gone from the river, flows should be kept below 283 m^3/s (10,000 cfs) if possible to prevent excessive water level on tributaries due to backwater effects from the Assiniboine River and to minimize seepage through the dike.

In 2011, Assiniboine River inflows to the Portage Diversion were substantially greater than what it was designed to accommodate. Furthermore, the diversion channel and its various structures were taxed even more because of the reduced capacity of the lower Assiniboine River due to the issues with the dikes. This is discussed later. A significant effort was made to successfully dispatch the excess flows down the diversion channel without exceeding the maximum allowable headpond levels and without jeopardizing the integrity of both the inlet control structure and the diversion channel itself. This required a massive effort, given how much flow had to be diverted, and required that most of the operational guidelines had to be compromised. The fact that the whole system was successfully operated over the long duration of the 2011 flood speaks to the skill and determination of the operating personnel.

4.4.2 Assiniboine River Dikes and the Hoop and Holler Breach

Dike Characteristics

The first dikes were constructed along the Assiniboine River early in the 20th century to prevent flooding of adjacent farmland. When the river overtopped its banks, flows would move overland into a multitude of relic and/or existing active channels that ultimately led to either Lake Manitoba or the Red River. Prior to 1997, dikes in one form or another extended from the Portage Diversion downstream to about Baie St. Paul or the Provincial Road (PR) 248 bridge. After the 1997 flood, the dikes were extended downstream to the Headingly bridge.

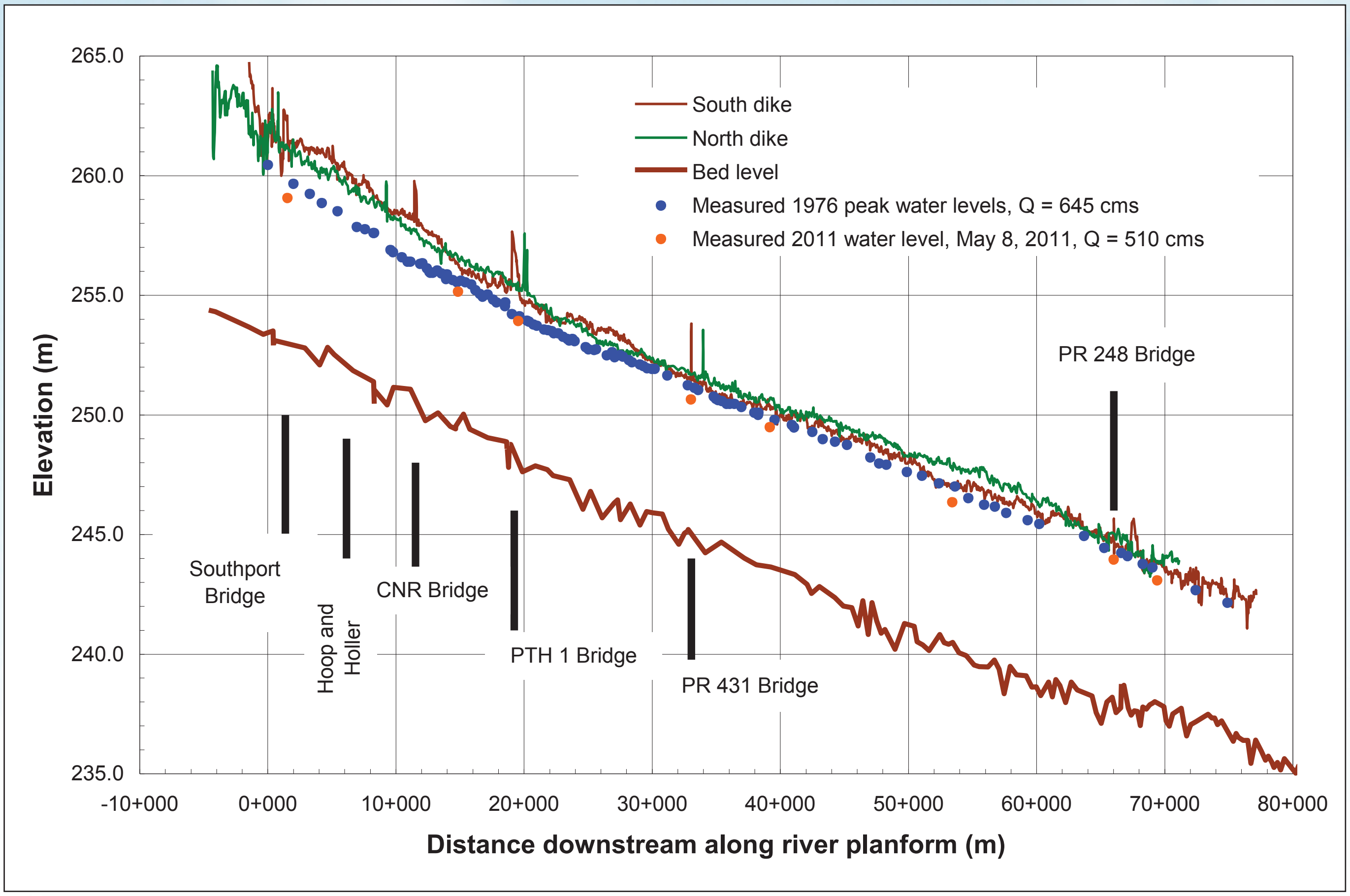
Over the years, various agencies were involved in the construction and maintenance of the dikes, so their condition varies from location to location. Even some of the most modern dikes have not necessarily been constructed out of the most suitable material and in many cases they are founded on poor quality soils. At some locations the dikes are not even owned by the Province, in spite of being an integral part of a major flood control system.

However, improvements have been made to the system over time. For example, in 2011, portions of the dikes were raised by 0.7 m (2.4 ft) to accommodate the expected flood.

While the dike cross sections vary from location to location, the current design standards, and presumably the standards to which all the dikes will eventually be upgraded, call for a top width of 3.7 m (12 ft) and side slopes of 4H:1V for dikes less than 2.75 m (9 ft) in height and 5H:1V for dikes above that height. In areas where the dikes must be placed close to the active channel, the minimum setback distance is 20 m (65 ft) to allow at least a 20-year life span on the basis of an expected average bank migration rate of one metre (three feet) per year. Furthermore, the dikes are meant to be able to convey the 400-year flood of 640 m^3/s (22,600 cfs) with at least a 0.6 m (2.0 ft) freeboard between the water level and the crest of the dike.

Figure 4.9 shows profiles of the bed of the Assiniboine River, the water levels for the 1976 and 2011 floods and the crest levels of the North Dike and the South Dike. The slope of the channel is about 0.25 m/km (1.32 ft/mile) which is typical of sand bed rivers of this size in western Canada, The top of the dike varies from about 10 m (30 ft) above the bed level at the upstream end of the dike system in the vicinity of the Southport Bridge to about 5 m (15 ft) at its downstream end near the PR 248 bridge. This is in spite of the fact that the relative water levels do not change significantly in the downstream direction. Clearly, for whatever reason, the capacity of the dikes is substantially greater near Portage la Prairie than it is at Baie St. Paul.

Figure 4.9: Bed, top of dike, and water level profiles on the Lower Assiniboine River.



Concerns have been raised about changes to the conveyance capacity of the dike system over the forty years or so that the Portage Diversion has been in operation. These concerns would arise out of the response of the river to the capture of bed sediments in the diversion headpond. This sediment deficit would promote degradation at the upstream end of the reach near the headpond and possibly promote deposition at the downstream end of the reach near Headingly. This could reduce the overall channel slope, thereby reducing the channel conveyance and increasing water levels. The overall effect would be a reduction in the capacity of the diking system. Comparison of 1976 and 2011 water levels (Figure 4.9) suggests that if there are sediment-related changes to the channel, they are local in extent and do not significantly affect water levels throughout the reach.

Furthermore, a comparison of 1976 and 2011 water levels to the 1999 rating curve at Baie St. Paul indicates no substantial shifts at the high end of the curves (Figure 4.10). If sediment deposition has occurred, it has not adversely affected the channel conveyance. A similar type of analysis at the Southport Bridge (Figure 4.11) also indicates that there does not appear to be an appreciable shift in the rating curve since at least 2002, although data prior to 2011 is quite sparse at the high end of the curve.

Figure 4.10: Rating curve for the Assiniboine River at Baie St. Paul.

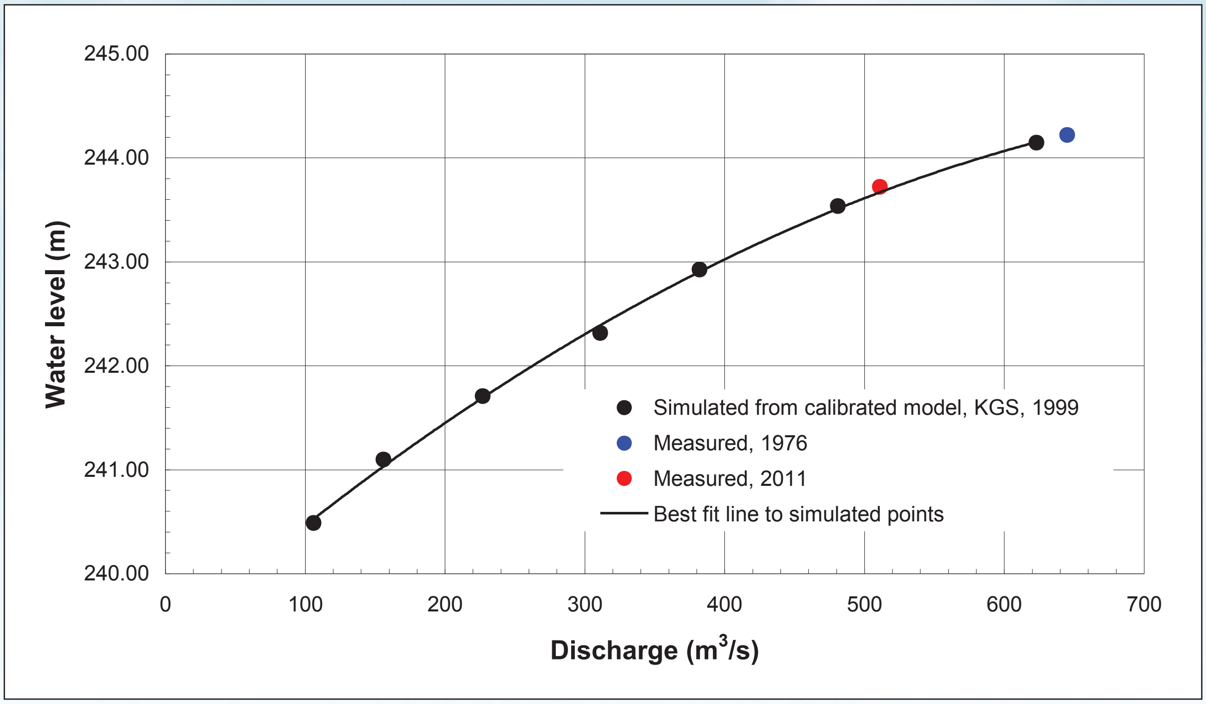
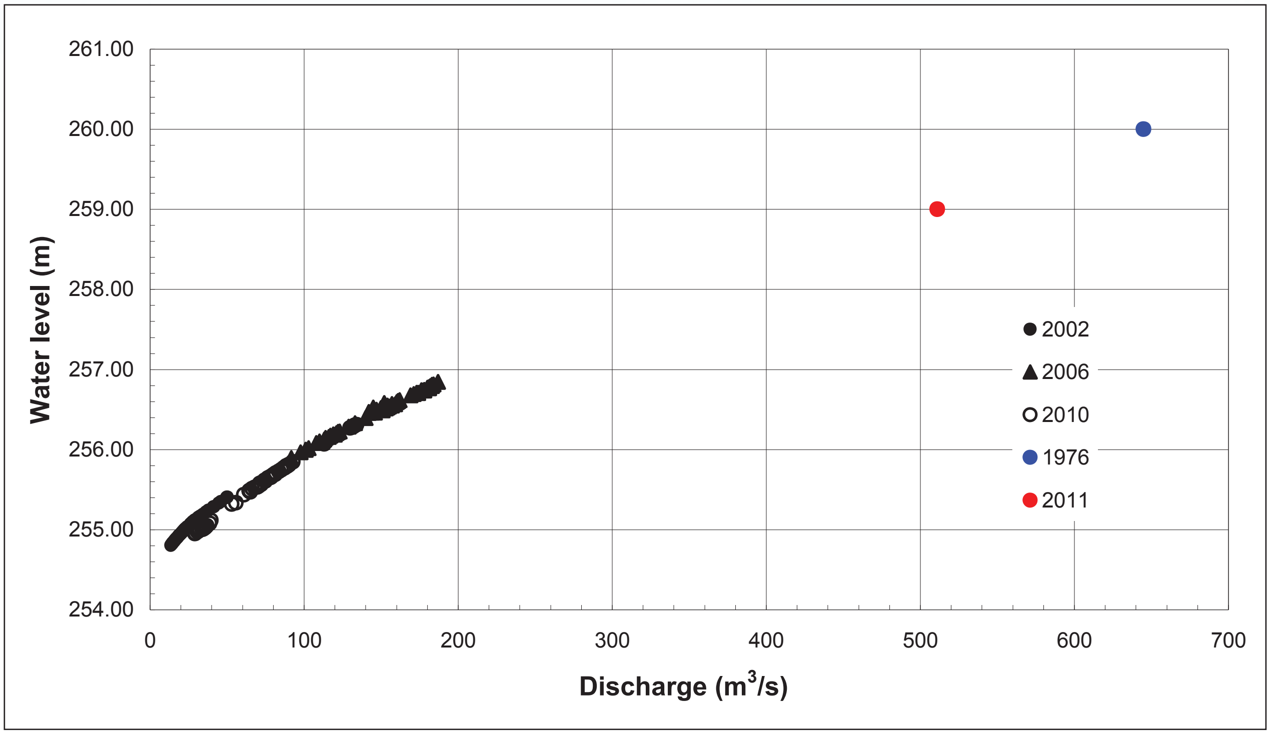


Figure 4.11: Rating curve for the Assiniboine River at Southport bridge.



The crest elevations of the dikes are more or less consistent along the entire reach with exception of the odd location where another type of structure serves as the dike. Evidently, at these locations the criteria for determining the height of the structure was more severe than that for a dike. Nevertheless, it is likely that the 1976 flood with a peak flow of 645 m^3/s (22,800 cfs) would not have overtopped the dike at any location, although it may have come very close at a few locations (just downstream of station 50+000, for example). Furthermore, there was plenty of freeboard for the 2011 flood peak of about 510 m^3/s (18,000 cfs) so that there should have been no concerns about dike overtopping.

Flows and Water Levels in 2011

The difficulties encountered with the dikes in 2011 were not related to the heights of the dikes nor their ability to convey their design discharge of 640 m^3/s (22,600 cfs). The biggest concern was the structural ability of the dikes to contain the expected high flows for extended periods. Geotechnical analyses undertaken prior to the 2011 event suggested that seepage through and/or under the dikes could undermine their integrity and eventually result in their failure. This would have been catastrophic not only for the residents and farmland area between Portage la Prairie and Winnipeg but it likely would also have destroyed large sections of the dikes.

Ultimately, the assessment of the dike capacity would raise the most controversy. While it may be easy to second guess the geotechnical evaluation, seepage calculations and observations of seepage during the course of the flood indicated that the maximum water level that the dikes generally could tolerate corresponded to a flow of about 500 m^3/s (17,700 cfs). Significant seepage issues arose when flows were allowed to exceed that magnitude even for short periods of time. At lower flows the seepage was judged to be tolerable and manageable, especially with the remedial work that was being undertaken to improve dike integrity. Ultimately, the maximum discharge that was allowed down the Assiniboine River at the Portage Diversion was about 510 m^3/s (18,000 cfs), about 130 m^3/s (4600 cfs) less than the hydraulic capacity of the dike. This corresponds to a water level reduction of about one metre (three feet) at the Southport Bridge and 0.5 m (1.5 ft) at Baie St. Paul.

Given the Assiniboine River flows that were expected upstream of Portage la Prairie (as measured at Holland), and the limiting flows that could be accommodated by the dikes, it was clear that the Portage Diversion channel would need to convey substantially more flow than its design capacity. For example, with flood peaks forecasted to be as high as 1590 m^3/s (56,000 cfs), the diversion channel would have been expected need to convey at least 1090 m^3/s (38,500 cfs) - some 380 m^3/s (13,500 cfs) greater than its design capacity. Extraordinary efforts were made to increase its capacity, largely by raising the dikes on either side of the diversion channel and reinforcing the drop structures by raising their wingwalls and adding rock to prevent bed and bank scour from undermining the structures. Through this heroic work, the capacity of the diversion channel was brought up to about 1000 m^3/s (35,300 cfs) It ultimately conveyed a peak flow of 950 m^3/s (33,500 cfs). While the integrity of the diversion channel and its drop structures was preserved, there were some losses. The bridge across the diversion channel at PR 227 was destroyed and the failsafe was overtopped so that a significant amount of farmland was flooded west of the diversion channel. On the up side, however, no residences or farm buildings were damaged. There was also considerable concern about the integrity of the railway crossings, but they appear to have remained intact. The bridge crossing just downstream of drop structure #1 was also threatened but it survived the flood.

Effects of Portage Diversion Operations on Lake Manitoba

It is clear that the runoff volume associated with the 2011 flood was well beyond what the Shellmouth-Portage Diversion-lower Assiniboine River diking system was meant to accommodate. This alone would have raised water levels on Lake Manitoba to very high levels, especially when combined with the massive inflows from Lake Winnipegosis. The failure of the Assiniboine River dikes to perform to their expected capacity, however, slightly exacerbated the water levels on Lake Manitoba. The fact that the dikes could not be operated at their intended capacity led directly to more water being shunted into Lake Manitoba than what would have occurred had the dike system been fully operational. From considerations of the outflow characteristics at Fairford, the magnitude and timing of the diversions into Lake Manitoba relative to the inflows from Lake Winnipegosis and the diversion pattern, the reduced dike capacity resulted in an estimated increase in peak Lake Manitoba levels of about 0.10 m or 0.3 ft.

Hoop and Holler

Given that the most flow the Portage Diversion channel could accommodate was about 1000 m^3/s (35,300 cfs), and the dikes on the Assiniboine River could accommodate at most about 500 m^3/s (17,700 cfs), there was a conveyance deficit that could have been as much as about 100 m^3/s (3500 cfs) based on the forecasted peak flow of 1590 m^3/s (56,000 cfs). With the diversion channel tapped out, this would have meant increasing the flows in the lower Assiniboine River, increasing water levels by between 0.5 and 0.7 m (1.5 to 2.5 ft). That prospect was not feasible and the outcome would likely have been an uncontrolled breach.

The only alternative was to construct a breach that could be used to divert water out of the Assiniboine River channel as required. This water would then be conveyed across the landscape, likely to the Red River, along existing drainage paths and local tributaries such as Elm River and the La Salle River.

After considering a number of locations for the controlled breach, the area in the vicinity of Hoop and Holler was judged to be the most feasible. At this location the breach would have limited the flow down the diversion channel to 1000 m^3/s (35,300 cfs) without adversely increasing the flows down the lower Assiniboine River. The only caveats were that it was not entirely clear when the breach would be needed, and what the exact extent of the flooding would be. During the flood, flows down the lower Assiniboine River and along the diversion channel were being monitored and reconciled with incoming flows at Holland. With flows at critical levels on both the diversion channel and the lower Assiniboine, and with Environment Canada weather forecasts indicating additional rain that would exacerbate the inflows at Holland, the breach was opened on Saturday, May 14.

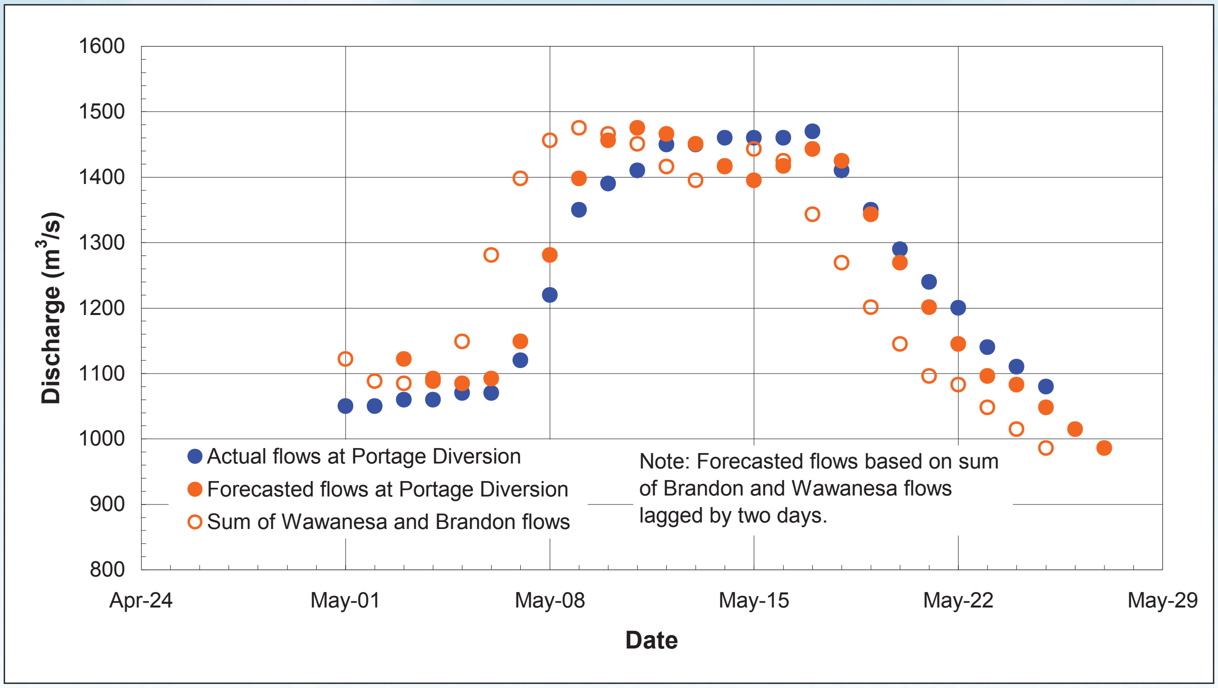
In hindsight, the rain that was forecast did not occur, the flows at Holland peaked about 1470 m^3/s (52,000 cfs) or some eight percent below the forecast peak, and only a small amount of water actually moved through the breach. The breach was closed on Friday, May 20.

It is clear that a controlled breach is much preferred to an uncontrolled breach. Therefore, the strategy employed would have been entirely reasonable. In fact, given the condition of the dikes along the Assiniboine River, it would be a worthwhile permanent addition to the flood conveyance system between Portage la Prairie and Winnipeg. What is most striking but likely understandable, given the way the flood situation was unfolding, were the attitudes that prevailed on the part of the Province during the planning for the controlled breach. *Ad hoc* decisions were being made without consulting local authorities, there was a poor understanding of how the flows through the breach would spread over the landscape, and it appears that the correct information regarding potential outcomes was not reaching the public.

Concern was also being raised about when the breach was cut and how long it was allowed to operate. Using the combined flows of the Souris River at Wawanesa and the Assiniboine River at Brandon as an indication of the expected flows at the Portage Diversion two days later (Figure 4.12), and adopting 1460 m^3/s (51,600 cfs), which would approach the maximum discharge of about 1000 m^3/s (35,000 cfs) that could be directed down the diversion channel and 500 m^3/s (17,700 cfs) allowed in the river, as the threshold discharge for opening the breach, it could have been forecasted on May 9 that the breach would need to be opened on May 11. At that time, flows at the Portage Diversion would be expected to be about 1475 m^3/s (52,100 cfs). The May 10 forecast would have called for 1470 m^3/s (51,900 cfs) at the diversion, further confirming the May 11 opening. However, on May 11, the actual flows at Holland were about 1410 m^3/s (49,800 cfs), less than the threshold flow, so it would have been reasonable to delay the opening at least until the next day, May 12. The flows at the diversion on May 12 proved to be 1450 m^3/s (51,200 cfs), somewhat of a concern but not above the threshold. Consequently, the opening would have been delayed again.

A controlled breach is much preferred to an uncontrolled breach.

Figure 4.12: Inflows to the Portage Diversion, 2011.



From May 11 on, the forecasted flows at Holland appeared to begin dropping. This would have created an expectation that flows would also begin to recede at the Portage Diversion and there would have been no need to open the breach. However, the flow reductions at Brandon and Souris were not manifested at the diversion and so concern remained high. Finally, on May 14 at which point flows at the diversion rose to 1460 m³/s (51,600 cfs), the breach was opened. It operated for about four days while flows at the diversion remained more or less constant at 1460 m³/s (51,600 cfs) and then for four more days as the flows receded.

In the period from May 14 to May 16 provisional flow data at Brandon and Wawanesa would have been indicating a more or less constant flow at the Portage Diversion in the range of 1420 to 1440 m³/s (50,100 to 50,900 cfs), suggesting no significant changes at the diversion for the period from May 16 to May 18. However, the upstream inflows fell dramatically to 1340 m³/s (47,300 cfs) on May 17 which would have signalled that the breach could have been closed on May 19. In fact, it was closed on May 20, a day later than the upstream forecast would have suggested, after confirming over a two-day period that flows at the diversion were also falling systematically.

From the benefit of hindsight, it is evident that the opening and closing of the breach were carried out as judiciously as possible, which was quite a remarkable achievement given the vagaries of tracking flows in real time, difficulties reconciling flow estimates from gauge readings, rating curves and direct discharge measurements. It is clear that the breach was opened at the correct time and closed only after a judicious assessment of the decreasing trends in the inflows at the Portage Diversion. Undoubtedly this limited the damage that could have resulted if the breach had been operating longer.

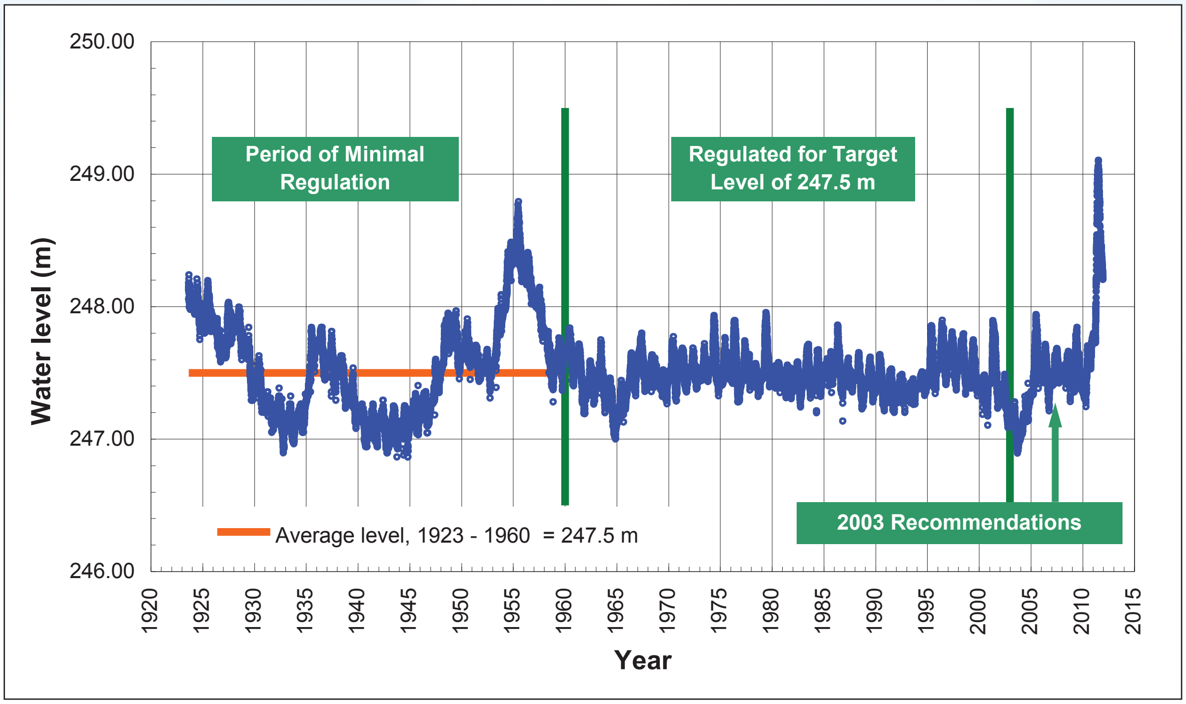
However, difficulties arose in defining the expected inundation limits as a result of the flow though the breach. Part of this was due to a somewhat conservative estimate of expected inflows at the Portage Diversion and a poor realization of the topography downstream of the breach. Hopefully in the future, operating procedures for the Portage Diversion will reflect the need for a failsafe on the lower Assiniboine River dikes and the inundation limits with their associated risks will be defined.

4.5 Fairford River Water Control Structure (FRWCS)

The FRWCS is operated to maintain suitable levels on Lake Manitoba with consideration of inflows and water levels on the Fairford River, Lake St. Martin and Dauphin River downstream of the structure. Lake Manitoba water levels and Fairford River flows have been a concern since the early 1890s when control of the natural regime was first attempted. An additional channel was dredged at the outlet of Lake Manitoba into the Fairford River in 1899 in an effort reduce high lake levels. This was followed in 1904 by minor channel improvements on the Fairford River. Neither action proved to be effective in reducing high lake levels.

The first outlet structure was built in 1934 to provide some control on outflows during low water periods, but no attempts were made to exert any control on high lake levels. After feasibility studies were conducted regarding controlling water levels on the lake from 1956 to 1958, the present structure was constructed in 1961. Since that time there has always been some controversy about the desirable range of the regulated lake levels, but in spite of those concerns, a target elevation of 247.47 m (811.9 ft) was adopted. A number of studies were undertaken by the Manitoba Water Commission between 1968 and 1973. The 1973 study recommended that the lake should continue to be regulated to a target level of 247.55 m (812.17 feet), in accordance with the operating rules of that time (Figure 4.13), and the minimum outflow from the lake through the Fairford River should not be less than 1.4 m^3/s (50 cfs).

Figure 4.13: Historical water levels on Lake Manitoba.

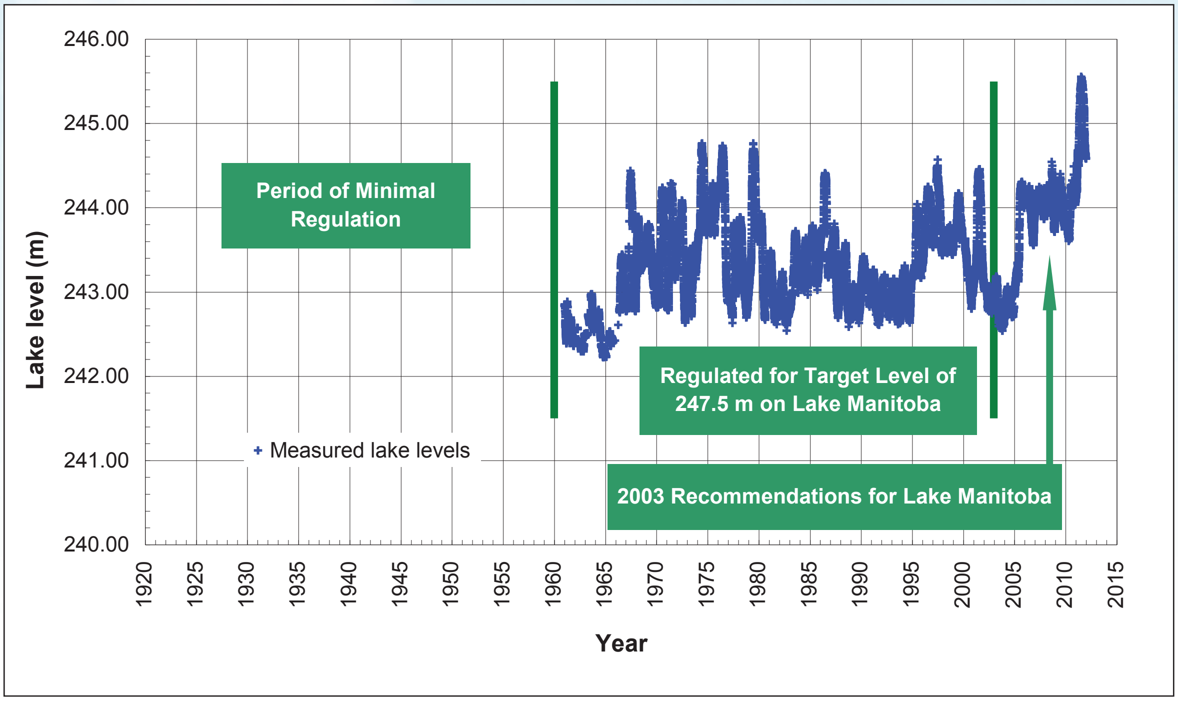


Following further study by the Lake Manitoba Regulation Review Advisory Committee in 2003, it was recommended that the lake be allowed to fluctuate more naturally to benefit aquatic habitat along the lakeshore. The main recommendation of the 2003 review was to target a water level of 247.55 m (812.17 ft) but not to intervene as long as the lake level was, or was expected to be, between 247.04 and 247.65 m (810.5 and 812.5 ft).

Flows across the FRWCS are controlled by the sequential installation or removal of stoplogs whose configuration affects the effective length and height of the structure over which water can pass. When lake levels are expected to go below 247.04 m (810.5 ft), stoplogs are inserted to reduce outflows and raise water levels. When levels are expected to go above elevation 247.65 m (812.5 ft), stoplogs are removed to increase outflows and reduce lake levels. In recent years, natural inflows from Lake Winnipegosis through the Waterhen River have been very high and so all the stoplogs have been removed for most of the time to try to keep lake levels within the prescribed water level range. The only exception to this occurs in early winter when stoplogs have been reinstalled to limit outflows when freeze-up jams, formed by the accumulation of frazil ice on the Dauphin River, create severely high water levels and cause water levels to back up into Lake St. Martin. The thickness of the ice accumulation and the ultimate water level are both a function of the flows and so by reducing flows the freeze-up level can be maintained within a reasonable range. Also, in recent years, one bay in the control structure has been allocated for fish passage and thus it does not convey flow as efficiently as the others.

The difficulty with establishing water level objectives for Lake Manitoba, is that in order to meet those objectives during periods of high inflows, releases into Lake St. Martin need to be very large. Given the relative sizes of the two lakes, the water level variations on Lake St. Martin become excessive (Figure 4.14).

Figure 4.14: Historical water levels on Lake St. Martin.



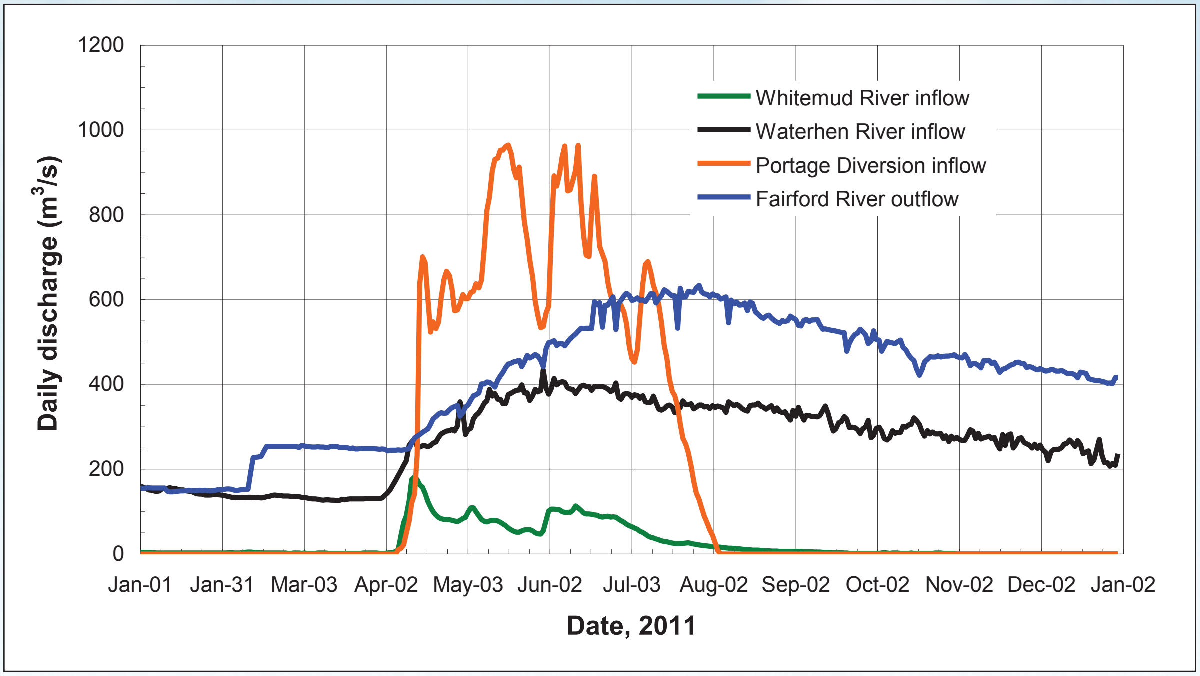
In summary, the water level and flow objectives that guided the operation of the FRWCS are listed below.

- Water levels on Lake Manitoba should be permitted to fluctuate between 247.04 and 247.65 m (810.5 and 812.5 ft) over a period of years.
- Any variance in the lake levels outside of the range shall be shared between Lake Manitoba and Lake St. Martin, insofar as this may be reasonably possible.
- The level of Lake St. Martin should be maintained within a more natural range of 242.93 to 243.84 m (797.0 to 800.0 ft).
- The minimum flow in the Fairford River should be 22.7 m^3/s (800 cfs) with a desirable flow of 28.3 m^3/s (1000 cfs).

4.5.1 Flows and Water Levels in 2011

Inflows to Lake Manitoba were the highest on record from both the Waterhen River and Portage Diversion. Outflows through the FRWCS peaked at 646 m^3/s (22,800 cfs) in late July (Figure 4.15) and continued to recede well into 2012. In 2011, levels on Lake Manitoba peaked at 249.05 m (817.11 ft) in mid-July. Over the previous winter the lake levels had gradually increased until mid-February when stoplogs were removed from the FRWCS. Then, in the second week of April, levels began to increase rapidly due to inflows from the Portage Diversion.

Figure 4.15: Lake Manitoba inflows and outflows, 2011.



4.5.2 Fairford River Water Control Structure Operation

Because of persistent high inflows the FRWCS has been kept effectively open during the period from August 2005 until the present, thereby maximizing outflows. The only exception would have been the insertion of stoplogs to effect winter flow reductions to 142 m^3/s (5000 cfs) to prevent severe freeze-up jamming on the Dauphin River. These reductions were in place from November 12, 2007 until February 4, 2008, and again from October 14, 2008 until February 6, 2009.

In the fall of 2010, even while Fairford River flows were above 200 m^3/s (7000 cfs), Lake Manitoba levels continued to remain high and indications pointed to the potential for flooding in 2011. Nevertheless, outflows were reduced again in the period November 15, 2010 to February 11, 2011 as per the winter protocols to reduce the potential for high freeze-up water levels on the Dauphin River and the subsequent possibility that high spring flows would cause extensive flooding on Lake St. Martin. Once the threat of ice-related flooding had abated, all the stoplogs were removed to once again maximize outflows and draw down water levels in Lake Manitoba as expeditiously as possible.

It is clear that the water level guidelines for Lake Manitoba were not adhered to in 2011 (Figure 4.13). Despite drawing the water levels down as much as possible by removing as many stoplogs as possible in 2010 and in 2011, the high inflows into Lake Manitoba simply overwhelmed the capacity of the FRWCS. Given the design of the structure and the water level objectives established for Lake Manitoba, everything that could be done at the structure to maximize outflows from the lake was done, even at the expense of creating severe water levels on Lake St. Martin.

During the summer of 2011 it was recognized that frazil ice could again become a problem on the Dauphin River over the winter of 2011/12. To alleviate this problem an emergency channel was constructed from the northeast end of Lake St. Martin to the lower Dauphin River and put into operation on November 1, 2011. The channel has a capacity of about 100 m^3/s (3500 cfs) when Lake St. Martin is at a level of 244.0 m (800.5 ft). With the emergency channel in place, there was no need for a severe winter flow curtailment at the FRWCS, and water levels on Lake Manitoba continued to be drawn down over the winter in anticipation of high inflows in 2012 from at least Lake Winnipegosis. This effort contributed to a 0.4 m (1.3 ft) reduction in 2012 summer water levels on Lake Manitoba and a 0.5 m (1.5 ft) reduction on Lake St. Martin.

If the FRWCS had been kept open all winter before the 2011 flood, lake level simulations suggest that the peak level on Lake Manitoba would have been 0.03 m (three centimetres or about one inch) lower. The emergency channel would have lowered the

2011 Lake St. Martin peak level by 0.5 m (1.5 ft). It is apparent that the capacity of the emergency channel is insufficient to provide significant relief in the short term during events like 2011. However, it may have some positive effects for less severe floods. Analysis to confirm these effects is still ongoing. It may be that in its present configuration the emergency channel can prove valuable over the long term if it is used in combination with a relaxed Lake Manitoba water level regime. That being said, the emergency channel did in fact meet the Province's objective of lowering both lakes close to the top end of their operating ranges by the end of summer 2012.

4.6 Red River Floodway

The Red River Floodway provides flood protection for the city of Winnipeg by diverting Red River flows around the city from a point just upstream of St. Norbert to the floodway's outlet downstream of Lockport. The key to the practicality of the floodway is that it takes advantage of the water level drop at Lockport to increase the energy head differential along the floodway.

The impetus to construct the Red River Floodway came from the 1958 recommendations of the Royal Commission on Flood Cost Benefit that was struck by the Province of Manitoba. The Commission also recommended the construction of the Shellmouth Reservoir to reduce flood peaks from the upper parts of the Assiniboine River basin and the Portage Diversion to shunt excess Assiniboine River flows into Lake Manitoba. With the synergies gained from these three projects, and making use of diking within the city, it was expected that the residents of the city would be protected up to a flood having a 160-year return period. In hindsight, with the benefit of a longer hydrologic record, the actual return period today would have been about 130 years. After the 1997 flood, it became apparent that the floodway was under-designed and that the flood risk to the city was too great from both social and economic perspectives. In the late 2000s, the floodway was widened and a number of bridges replaced to increase its capacity from about 2550 m^3/s to 4000 m^3/s (90,000 to 140,000 cfs), thereby increasing the flood protection for the city to about a 700-year event.

The floodway consists of four components - the inlet control structure located on the Red River that directs flow into the floodway, the 47 km (29 mile) long diversion channel, the outlet structure that directs flow back into the Red River and the west dike. The west dike prevents high flows and/or potential backwater created by the inlet control structure from moving northwest along the valley into the La Salle River and beyond. The unique feature about the inlet control structure is that it is located on the Red River just downstream of the inlet to the diversion channel. Flows are directed into the diversion channel by adjusting water levels on the river and allowing the shape of the diversion inlet and the flow resistance in diversion channel to determine how much water actually is diverted from the river.

4.6.1 Operating Rules

One of the most important operating objectives is to provide as much flow relief to the city as possible without adversely raising water levels on the Red River upstream of the entrance to the floodway. This is done by intensive flow monitoring on the Red and Assiniboine rivers and carefully exercising the gates. Fundamentally, the floodway was intended to operate during the spring flood period because when it was designed, summer flooding was not a significant issue. However in recent years, summer high water events appear to have become more severe, flooding infrastructure that can benefit from lower summer flood levels along the margins of the river. Thus, there has been a need to specify operating rules through legislation for both spring and summer events.

Spring Operation

The following summarize the spring operating rules as defined by legislation.

- The floodway gates should not be operated until ice on the river is flowing freely, unless flooding in Winnipeg is imminent.
- **Rule 1** - during normal floods the natural water levels on the Red River at the entrance to the floodway channel will be maintained at or below the "state of nature" until the gauge height at James Avenue reaches 24.5 ft (elevation of 229.22 m) or the river level within the city of Winnipeg reaches a gauge height of 25.83 (elevation of 229.64 m) – equivalent to 0.6 m (2 ft) below the adopted Flood Protection Level.
- **Rule 2** - during a major flood when the water level at James Avenue is about to exceed elevation 229.22 m or 230.24 m (gauge height of 24.5 ft or 27.83 ft), a constant flow will be maintained through the city while allowing water levels upstream of the floodway to rise
- **Rule 3** - during a severe flood when water levels at the entrance to the floodway approach those that may imperil the west dike of the floodway itself, all additional flows will be passed through the city.

Summer Operation

The following summarize the summer operating rules.

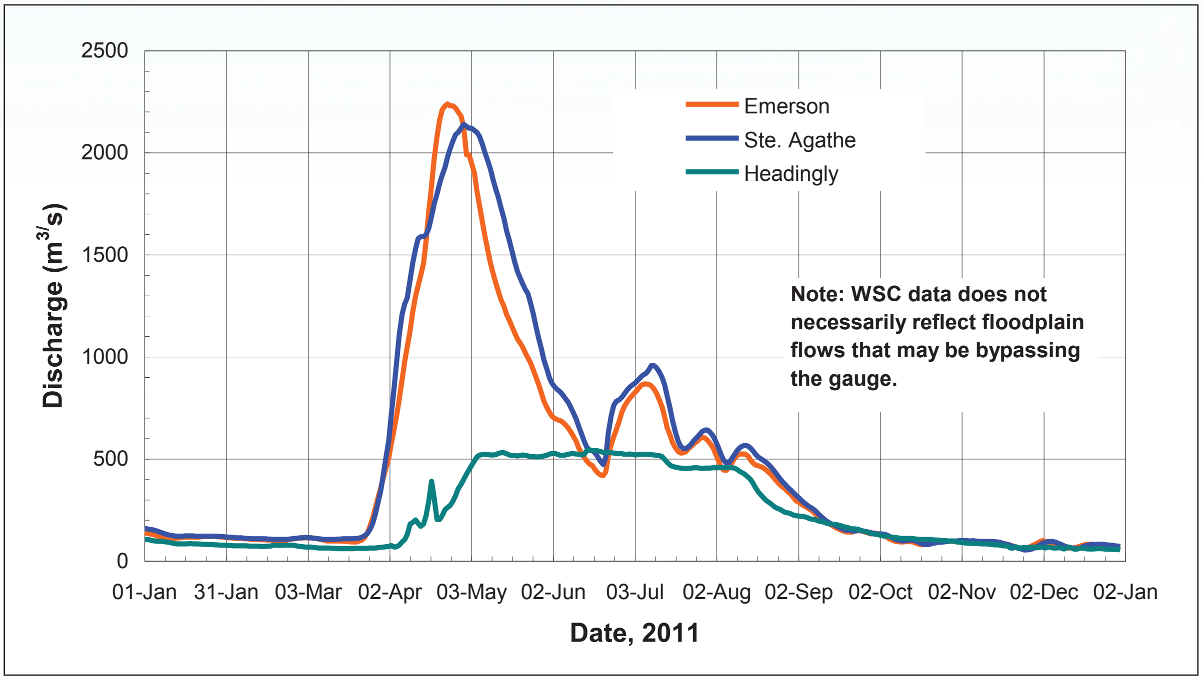
- The floodway may be operated to reduce basement flooding and sewer backup if the expected flood is severe enough to raise gauge heights at James Avenue above 14.0 feet (elevation of 226.03 m) for ten days or more if its operation can be justified on the basis of economic benefits, and only on Ministerial authority.
- Water levels on the Red River just upstream of the floodway cannot exceed 231.65 m (760.0 ft) during summer operation.

Regardless of whether the spring or summer rules are being invoked, the rules would be revoked during extreme floods if the magnitude of the flood is beyond the flood control capability of the system. In this case, the operating decisions would focus on protecting the facilities from a structural failure and would likely be made within the context of a State of Emergency.

4.6.2 Flows and Water Levels in 2011

The 2011 flood peak on the Red River occurred in late April. The flood was primarily driven by snowmelt in the upper basin in North Dakota, with the peak occurring after the runoff in many of the local contributing catchments in Manitoba was completed. The estimated peaks at Emerson and Ste. Agathe were about 2240 and 2140 m^3/s (79,100 and 75,600 cfs) respectively, with the lower peak at Ste. Agathe being due to the effects of floodplain storage (Figure 4.16). The Assiniboine River inflows peaked at or slightly after those on the Red River, but they were kept in the range of 500 to 550 m^3/s (17,700 to 19,400 cfs) by diverting water to Lake Manitoba due to concerns about the stability of the dikes on the lower Assiniboine River. The 2011 flood peak at Emerson was the fifth largest since 1913 and at Ste. Agathe it was the fourth largest since 1959.

Figure 4.16: Flows on the Red River and Assiniboine Rivers, 2011.



Floodway operation began on April 9 and continued into the first week of June (Figure 4.17). Peak flows down the floodway amounted to about 1000 m^3/s (35,300 cfs), reducing the Red River peak within Winnipeg by 50 and 30 percent respectively in the reaches upstream and downstream of the confluence with the Assiniboine River. Water levels on the Red River peaked at about 235.2 m (771.7 ft) at Ste. Agathe, at about 232.9 m (764.1 ft) just upstream of the inlet to the floodway, and at 229.5 m (753.0 ft) just downstream of the inlet to the floodway (Figure 4.18). At Selkirk, the peak water level was affected by ice conditions in the river with a peak water level of about 221.7 m (727.4 ft) occurring on April 8, just prior to the start of gate operations at the floodway.

Figure 4.17: Effects of Floodway operations on Red River flows in the vicinity of Winnipeg, 2011.

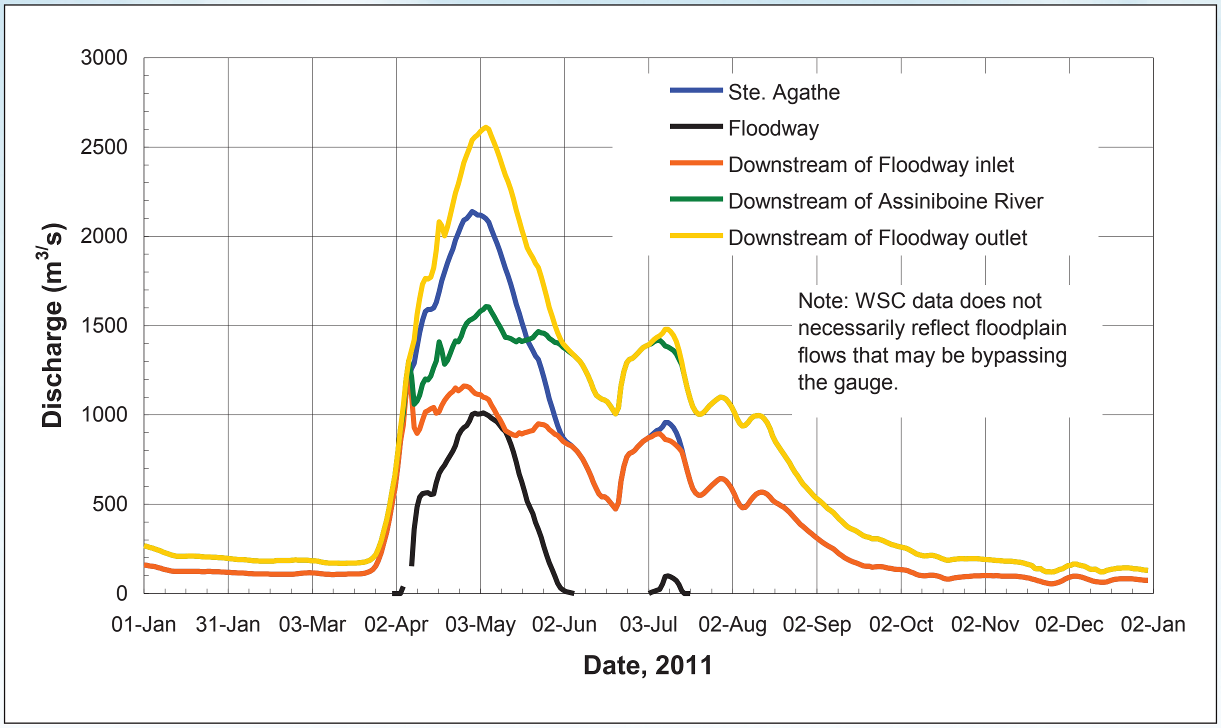
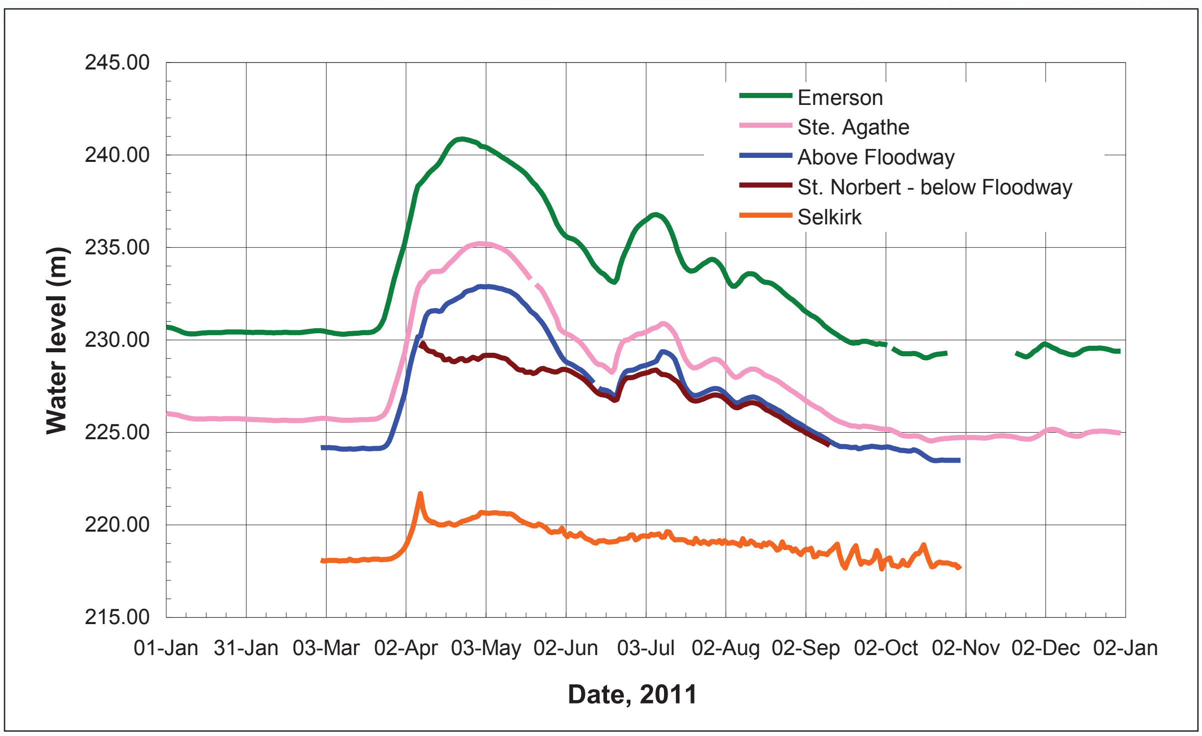
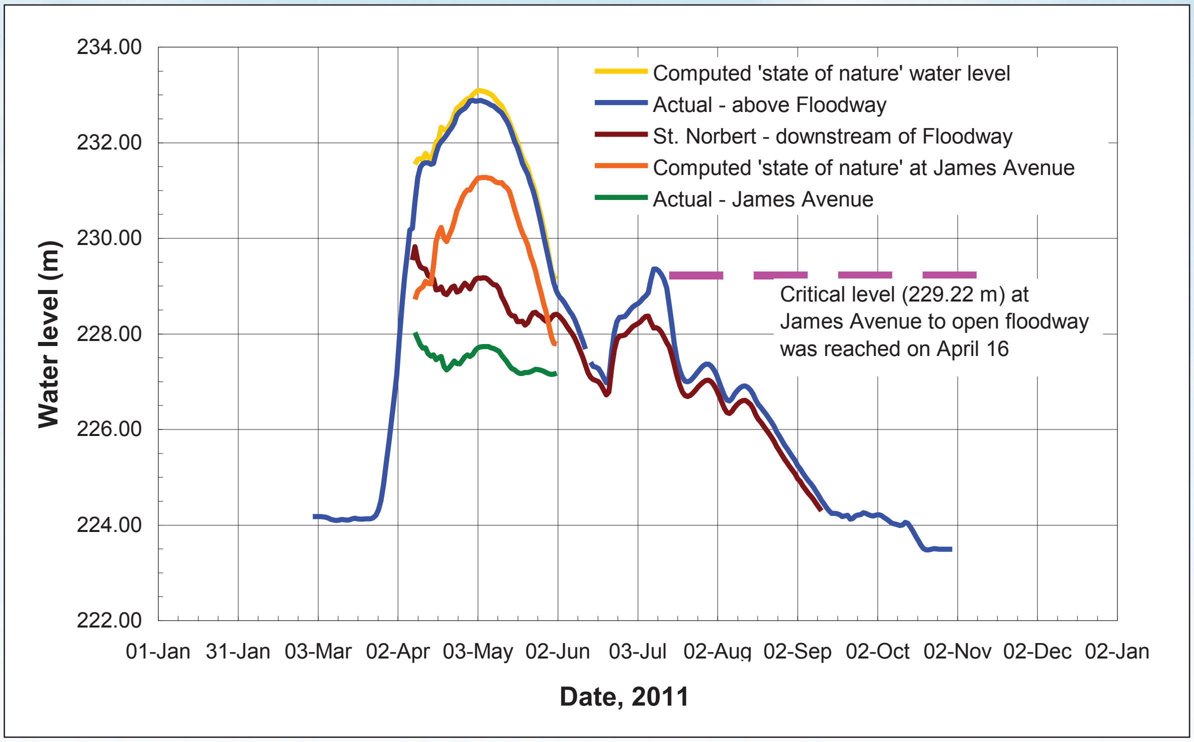


Figure 4.18: Water levels on the Red River in the vicinity of Winnipeg, 2011.



Red River levels upstream of the floodway were maintained below the "state of nature", as calculated from considerations of the effects of storage at Shellmouth Dam, diverted flows at the Portage Diversion, and breakouts on the lower Assiniboine River that would have occurred in the absence of dikes (Figure 4.19). Water levels at James Avenue were reduced by about 3.5 m (11.5 ft) at the peak of the flood.

Figure 4.19: Effects of Floodway operation on Red River water levels upstream of Winnipeg, 2011.



While the expected peak flows on Red River at Ste. Agathe never materialized in 2011, the event was still significant, but well within the range of what could be managed within the context of Rule 1 operations. Overall, there would have been nothing untoward in the way the inlet structure was operated.

4.7 Summary

The severity of the 2011 flood tended to simplify structure operations at a number of the sites examined since the primary objective became to open the structure as much as possible to maximize flow in order to either save the structure or limit the upstream flooding. Both the outlet structures on Dauphin Lake and Lake Manitoba were opened to operate at their maximums over the entire period of the flood. On the other hand, the floods on the Red River were mild enough that the Red River Floodway could be operated within the Rule 1 guidelines and it was done so throughout its operation. The operators there had a relatively easy time of it.

The biggest challenges arose on the Assiniboine River where many of the structures were under duress for the best parts of four months – April, May, June and July. Judiciously, the Lake of the Prairies reservoir was drawn down to below its conventional minimum level in late March to accommodate the expected onslaught. This strategy helped to reduce flood peaks downstream of Shellmouth Dam. For example, the flood peak at Russell was reduced by some 22 percent with reductions of 10 percent evident everywhere along the Assiniboine River between St. Lazare and Portage la Prairie.

The magnitude and duration of the flood on the Assiniboine River nearly compromised the integrity of the Portage Diversion channel, the Portage Diversion structures, and the dikes on the lower Assiniboine River. Only through a Herculean effort was the integrity of the dikes and diversion structures maintained over the course of the flood. Again, as the severity of the flood increased over the spring and early summer, the objective became not to optimize flows and water levels through judicial gate adjustments as might be the case for more benign floods, but to preserve the structures at all costs.

Aside from the destruction on Lake Manitoba, the public was exposed to two threats in the vicinity of the Portage Diversion – the massive flooding that occurred west of the diversion channel at the failsafe and the minor flooding that occurred south of the Assiniboine River in the area of the Hoop and Holler cut. The flooding at the failsafe was expected and would have been part of any normal operations if and when the diversion flows approach the design flows. The flooding at Hoop and Holler was related to the response of MIT to the anticipated high flows and the need to prevent the failure of dikes along the lower Assiniboine River. There may be an argument about when the cut was opened and closed, and perhaps the way the public was informed about the tactics at Hoop and Holler. But it is clear that under the circumstances, the situation was managed in real-time as well as could be expected given the available flow forecasts and the risks of either acting too late or not at all.

The poor quality of the dikes on the lower Assiniboine River became very apparent during the course of the flood. The role that these dikes played in reducing the capacity of the river necessitated conveying greater volumes of water through the diversion into Lake Manitoba so as not to compromise the dikes. This had an effect of increasing water levels on Lake Manitoba by about 0.10 m or 0.3 ft.

The response of the public to how the Province operated the structures is somewhat equivocal. Most Manitobans are aware of the importance of water management in the province and the need to operate water management structures in an optimal manner. Of the limited number of responders to the short online poll, most were aware of how the operations of selected structures affects the lifestyles of individuals, especially residents around Lake Manitoba and those downstream of Shellmouth Dam.

A majority of the responders indicated that they had an opportunity to provide input into how structures were operated, but at the same time it was the view of a large majority that the operations of the structures did not reflect local interests very well, particularly those structures operated by Ducks Unlimited Canada. Many of the responders had specific suggestions as to how the operation of the structures could be improved, and a majority indicated that there was a need for additional flood protection and/or a need to place a higher priority on flood control (rather than recreation, for example) in the management protocols established for individual water management structures.

The small number of responders limits the validity of the survey results because individuals who are dissatisfied with the management outcomes would tend to be more likely to respond to the poll. Furthermore, an extreme event like that experienced in 2011 would tend to produce less favourable local operational outcomes because the structures were required to operate well beyond their intended design capacity. Nevertheless, the results of the poll suggest that more attention may need to be directed towards providing contextual information about how major water control structures can be operated and reporting on the operational efficacy of these structures on a more routine basis – possibly via the local municipal authorities.

4.8 Recommendations

1. With respect to management of local surface waters and other related infrastructure, the Province develop a regional water management strategy that is both seamless and based on broad consultation among local jurisdictions. These would include municipalities and communities, First Nations communities and the Province, with the Province bringing the Government of Canada into the agreement on behalf of the First Nations.

2. Attention be directed towards providing contextual information to the public about how major water control structures can be operated and reporting on the operational efficacy of these structures on a more routine basis. Operating and other significant information related to the Fairford River Water Control Structure (FRWCS) and the associated fish ladder should be maintained and made available to the public.

3. A condition assessment study of the Fairford River Water Control Structure be conducted, and that its condition and maintenance be monitored on a regular basis.

4. A rehabilitation and preservation plan be developed and funded that allows flood control structures to be upgraded and modernized as required. More investment needs to be made to modernize monitoring and control systems at the Portage Diversion, for example.

5. A formalized process be established to disseminate information in a timely fashion respecting the operations of the flood control structures. This should include more detailed information on expected gate opening and adjustments and the implications on water levels upstream and downstream of the structures.

6. The need for a formalized dam safety review be assessed for each of the structures currently operated by MIT.

7. A study of the diking system on the lower Assiniboine River be conducted to assess the potential implications of its failure, and strong consideration be given to acting on the recommendations arising out of that assessment.

8. Special considerations for providing real-time information be developed for First Nations communities. It is important to indicate when structures are being operated and the expected changes in water levels at key locations.

9. Elected municipal officials of local jurisdictions that are affected by the day to day operation of provincial water management structures be identified and allowance made for local input during severe flood events or when significant deviations from normal operations are expected.

10. The Province embark on a program to assemble more detailed topographic information (LiDAR) generally throughout the province and specifically around Lake Manitoba, Lake St. Martin, Dauphin Lake and along the Assiniboine River.

11. A process be undertaken to re-examine the operating protocols of Ducks Unlimited Canada (DU) structures throughout the province and to hold DU accountable for the integrity and responsible operation of those structures. Dam safety studies should be undertaken for the major structures and the study results should be shared with local stakeholders.

12. A study be initiated to examine the operating protocols at the Shellmouth Reservoir with the objective of enhancing the agricultural productivity of the valley bottom lands by releasing proportionally more water in the spring and subsequently reducing summer flooding without necessarily compromising water supplies later in the year.

13. An examination of the functionality of the Shellmouth Reservoir Regulation Liaison Committee be conducted. Recommended actions include, but are not be limited to the following:
    - maintain the Shellmouth Reservoir Regulation Liaison Committee but reduce its membership to a more manageable number,
    - clarify on a more frequent basis for the members the mandate of the Committee, which is to provide local input to MIT in support of operational decisions, and to report back to the communities and interest groups they represent,
    - prepare an annual report for the public on Shellmouth Dam operations, and
    - continue to provide timely technical information and provide for face to face meetings at least twice annually at times suitable to all members.

14. Provide a more rigorous and transparent accounting of water use on the Assiniboine River downstream of the Shellmouth Reservoir, and provide annual reports on the water supplied and the actual water used within the context of the licensed allocations.

5. Flood Mitigation Measures

Suggested procedures for undertaking flood mitigation measures such as sandbagging, emergency dikes and the appropriateness of such actions.

5.1 Background

Diking has been used as an effective means of preventing flooding dating back to the protection of homes and property in the Netherlands since the 9th century and perhaps beyond that in other locations. Early dikes in the Netherlands were built with a sand core and capped with clay.

In Nova Scotia, the Acadians used aboiteau, or sluice boxes, in combination with dikes to reclaim marshlands to produce a variety of crops. Early aboiteau, which could be as old as the 1680s, were built by hollowing out a log to form a trough while slabs of wood were used to form a roof. After the appearance of saw mills in the late 1600s to early 1700s, they were built of squared timbers. Swing gates were installed at the outlet to allow fresh water to flow out of the marsh and would close against the incoming tide.

Old aboiteau have been discovered by chance as recently as 2006 and the Province of Nova Scotia undertook a $500,000 study in 2011 to assess and design a replacement for the LaPlanche River Aboiteau in Cumberland County.

The Nova Scotia Department of Agriculture protects agricultural marshlands by monitoring 240 kilometres (150 miles) of dikes and 260 aboiteaux that protect more than 17 800 hectares (44,000 acres) of agricultural marshlands.

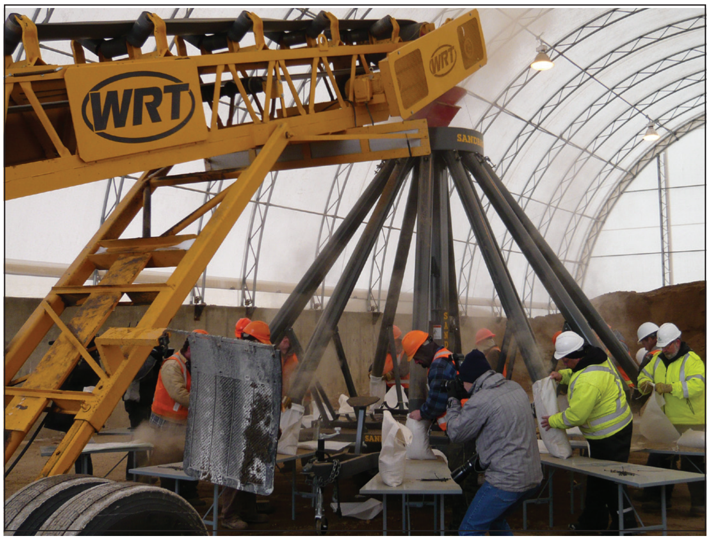
In Manitoba, dikes were built along the Assiniboine River west of Winnipeg in the early 1900s. Since the flood of 1950, there has been extensive flood-related infrastructure built in the province including the Shellmouth Dam and Reservoir, the Portage Diversion to Lake Manitoba, the Fairford outlet structure from Lake Manitoba and the Red River Floodway as well as an extensive system of dikes throughout the province. As the primary method of flood defense it is critical that dikes be well placed, well designed and well maintained. In 2011, the Province was involved in the raising and strengthening of approximately 150 km (93 miles) of existing dikes and assisting in the construction of 38 km (24 miles) of new dikes on First Nations as well as Ralls Island near The Pas.

This section of the report deals with suggested procedures for undertaking flood mitigation measures such as sandbagging, various forms of emergency dikes and the appropriateness of such actions.

5.2 Sandbagging

Globally, sandbag diking is typically the first line of defence against flooding. The proper application and construction of sandbag dikes is critical to providing proper protection. Sandbag dikes are particularly applicable in locations where access is limited, there is no wave action to contend with, such as along river banks, and the length and height of the dike is such that the use of sandbags is a viable method of creating a temporary barrier to flood waters.

Normally, sandbags are filled by hand or by using sandbag filling machines. These machines must be sized to fit the situation and the number of volunteers available. In some cases, the manpower may not be



Sandbag filling machine operating in Brandon.

available to operate the large sandbagging machines. In 2011, some municipalities and others resorted to developing makeshift sandbag filling devices rather than using the larger machines. In one case, members of a Hutterite colony developed their own sandbag filling machine to assist in flood-fighting efforts in their area.

Large sandbag machines are best suited for use in large communities with sufficient labour to operate these machines on a daily basis as well as for use by the military. The Task Force notes that many different sizes of sandbag filling machines with differing production capacities are commercially available.

Sandbag dikes should be built on flat terrain onto solid ground with underlying snow and ice removed. The sandbags should be placed in a manner as shown on Manitoba Emergency Measures Organization's website. It is important that polyethylene sheeting be interwoven into the sandbag structure to ensure that it is watertight.

While most dikes should be built to the upper decile of the flood forecast, research carried out at the University of Manitoba has determined that sandbag dikes will settle as they come into contact with flood waters. Therefore, an extra height allowance should be allowed for this circumstance. In addition, construction of sandbag dikes over five feet high should be properly supervised to ensure a stable structure.

In November of 2010, the Province took the initiative of meeting with selected contractors to discuss the concerns regarding a potential major flood and to put contractors on notice with regard to the Province's likely requirements. Tenders were subsequently issued for granular base course and rip-rap. Supply of these products began in February of 2011. The granular material was intended for use in Hesco barrier construction, and if not all was used for Hesco barriers, it could be used by Manitoba Infrastructure and Transportation for other purposes.

During the 2011 flood, some training on erecting sandbag dikes took place in the field, but it was noted by a number of individuals involved in the flood fight at the local level that more training would have been helpful.

Sandbags are relatively easy to place, and given some knowledgeable training and supervision, volunteers can construct sandbags dikes which will provide a relatively secure temporary protection from flooding. One drawback however is that sandbags are easily damaged during loading, hauling and dumping. An estimated 25 to 30 percent can be damaged during loading, transit and placement.

In 2011, much of the production of sandbags was carried out at Kapyong Barracks in Winnipeg and delivered to areas that required them. In general, municipalities that needed sandbags indicated that the supply of sandbags was steady and satisfactory. However, an issue which created ill feelings among individuals was the policy of giving preference to permanent residents over seasonal cottagers for the supply of sandbags. The Task Force agrees with this policy.

Loading sandbags in Winnipeg.

Sandbag dikes are a suitable form of diking for the conditions stated above. While some trained supervisors were available to educate volunteers in building sandbag dikes during the 2011 flood, additional supervisors would have been helpful. Construction of large sandbag dikes including those over five feet in height should be supervised by trained personnel.

5.2.1 Superbags

Super sandbags, or superbags as they are commonly known, are large sandbags which can be used to quickly build a large sandbag dike. They are commonly filled by front end loaders and are large enough that they must be placed by machines. An alternative to filling with a front end loader is to fill the superbags by hand using smaller ordinary-sized sandbags.

Superbags are used in areas where there is sufficient access .

Superbags can be used along roadways and along wave-prone beaches where there is sufficient access for the heavy equipment required to place them. They can be stacked several layers high, providing the base is stable.

Where there is not sufficient access room available for superbag placement, another form of diking should be selected. The selection may vary depending on the specific site being protected.

5.2.2 Contamination from use of sandbags

Sandbags filled with sand from one geographical area and transported to another area can cause environmental issues as a result of contaminants, such as weed seeds, in the source of the sand. Where possible, municipalities should identify sources of suitable sand for sandbagging during floods in the future. This would limit the transfer of contaminants from other areas and reduce transporation costs.

5.3 Tube-Type Dikes

Tube-type dikes such as Aqua Dams and Tiger Dams are laid out horizontally along the ground and filled with water. These tubes are approximately 0.5 to 1.0 metres (1.5 to 3.0 feet) in diameter and are particularly effective against shallow, overland flooding. For deeper water, Tiger Dams can be stacked but only if a properly engineered anchoring and strapping system is used that is engineered to site conditions. The engineering should be conducted by a professional engineer specializing in geotechnical work. Aqua Dams cannot be stacked to increase protection height. Leakage can occur from tears in the walls of tube-type dikes which can be the result of handling because of rapid deployment from one location to another under emergency conditions without time to properly inspect the tubes. Fortunately, these types of dams can be repaired.

Aqua Dams and Tiger Dams are effective against shallow, overland flooding.

These dams were often used to provide freeboard along the top of larger clay dikes, however this prevents the use of equipment to move along the top of a dike to make emergency repairs and to reinforce the dike in various locations.

Another form of shoreline protection are geotubes. These are larger tubes 2.3 to 2.4 metres (7.0 to 8.0 feet) in size and are filled with a sand slurry which forms a solid barrier as the water drains out through the fabric. These were used by the Province in 2011, primarily for wave attenuation purposes for property protection.

5.4 Hesco Barriers

Hesco barriers were developed as safety barriers for military use and used during the 2011 flood for diking in Spruce Woods Park as well as along River Road in St. Andrews. These one-metre (three-foot) square containers can be quickly filled with clay or sand by a front end loader, or by hand.

They can be linked to form a long linear dike faster than can be done with sandbagging. A Hesco dike, such as the 300-metre (1,000 foot) long dike built along River Road in 2011, can be built in a day.

Hesco barriers, built in Spruce Woods Provincial Park 2011.

A failure of the Hesco barrier occurred in Spruce Woods Provincial Park in 2011 which resulted in flooding of the Kiche Manitou Campground of the park. That portion of the campground was closed for the summer. Fortunately, no major facilities or buildings were affected. The Province attributed the failure to a sub-grade problem.

5.5 Clay Dikes

Clay dikes are commonly used where permanent large scale linear dikes are required such as along a riverbank or surrounding a community. For example, the dikes on First Nations lands were constructed of clay because of the large area that needed to be protected. A substantial supply of suitable material such as clay is required in a location nearby where damage to the surrounding area is not a substantive issue. Municipalities should identify sources of good clay material for use in the case of an emergency.

5.5.1 Dike Construction and Safety

The Task Force met with two contractors during the course of its deliberations. The hiring of large contractors with significant resources to construct dikes seemed to work well, although one smaller contractor felt that there should be a registry for all contractors to provide an equal opportunity for selection. However, the Task Force has learned that many smaller contractors were hired either directly by the Province or as sub-contractors to larger companies.

In the course of the discussion with contractors, the subject of operator safety was raised as an important point. It was noted that in the “heat of the battle to save property” equipment operators sometimes went beyond what they could reasonably be expected to do. One contractor reported having a backhoe topple over, and a bulldozer lost due to unstable soil conditions. Fortunately no lives were lost.

5.5.2 Dike Maintenance

It is essential that clay dikes be mowed on a regular basis so that they can be closely inspected for gopher holes or other small animal activity and to detect any signs of erosion. Despite close attention and regular maintenance it may be necessary to rebuild this type of dike from time to time.

Previously-used tube type diking materials should be carefully checked for damage before being put into re-use.

5.6 Dikes on First Nations Lands

Aboriginal Affairs and Northern Development Canada, the federal government department responsible for meeting the needs of northern Native communities, undertook a major effort in diking First Nations with the support of the Province. These dikes were constructed under the management of a consultant who determined that as a result of the size and length of the dikes required, clay dikes were the only practical alternative. The Task Force was told that in 2011, there was a shortage of prefabricated tube-tupe diking materials on First Nations.

Many of the First Nations required financial assistance, engineering and heavy equipment support to reinforce or construct dikes against flooding. An expanded federal financial program was used to complete much of this work. A number of First Nations communities had their existing dikes reinforced and new dikes constructed.

AANDC undertook a major effort in diking First Nations with the support of the Province.

5.7 Pump Supply

Several communities pointed out the importance of a sufficient supply of pumps for pumping storm sewers and surface water from behind dikes. Both the Province and the City of Brandon in particular stressed the importance of this and indicated that they had purchased or made rental arrangements for a large supply of pumps well in advance of the flood.

The flooding of Lake St. Martin was and remains a concern to residents and others. The Task Force was advised by the Province that the dike was secure during the flood. However, many homes were damaged by internal overland flooding. A system had been put in place to pump this water over the dike to the outside. But this action coincided with the commencement of the evacuation of the community, and the Task Force was told that the pumping effort failed..

5.8 Conclusion

The Province generally did a good job of constructing new dikes and raising and strengthening existing dikes both on their own and working with the affected rural municipalities, cities, towns and First Nations.

Further discussion on flood mitigation methods, structural and non-structural, appears in Section 8, Adequacy of Existing Flood Control Infrastructure and Section 10, Land Use Policies and Zoning.

5.9 Recommendations

15. The Province investigate the use of sandbag filling machines in a variety of sizes to best fit the size of the community and work force.

16. Dikes made of superbags stacked to a significant height be adequately engineered.

17. An inventory of all tube-type diking available in the province be undertaken and the material assessed for condition and usability in an emergency situation.

18. The Province develop a handbook providing guidelines for selecting the right type of dike and the correct way to construct all types of dikes as well as guidelines for placing tube-type dikes along the top of existing dikes for freeboard.

6.0 Review of Manitoba's Flood Forecasting system

The accuracy and timeliness of the Province's flood forecasting efforts, giving particular attention to the current state of flood forecasting practices, capabilities and technologies, and co-ordination with other jurisdictions.

6.1 Background

Evaluation of the flood forecasting efforts and subsequent results was based on discussions with both users and forecasters, experiences in other jurisdictions and a detailed comparison between forecasted and actual flows and water levels. The assessment included the following.

- A group interview of forecasting personnel that included:
    - the Executive Director of Hydrologic Forecasting and Water Management,
    - the Director of Flood Forecasting Co-ordination,
    - two current provincial forecasting staff,
    - a Manitoba Water Stewardship hydrologist that provided forecasting support during the 2011 event, and
    - a past provincial employee who was retained as a consultant during the 2011 flood.
- An interview of the previous head of the Hydrologic Forecasting Centre.
- An examination of forecasting data provided by upstream jurisdictions (Saskatchewan and North Dakota).
- An evaluation of the timeliness and accuracy of the flood forecasts by comparing forecasted levels and flows to observed levels and flows with due consideration to changing weather conditions and structure operations.
- A solicitation of the views of individual Manitobans through on-line surveys, questionnaires and public open houses.

6.2 Flood Forecasting in Manitoba

6.2.1 Objective of the Hydrologic Forecasting Centre

The Hydrologic Forecasting Centre (HFC) is part of the Hydrologic Forecasting Branch within the Water Management and Structures Division, Manitoba Infrastructure and Transportation. The primary objective of the HFC [1] is

> *"... the provision of flood condition reports, forecasts and warnings to enable effective coordination of flood response planning and flood fighting activities at all levels of government and the private sector. The Centre thus promotes public safety and flood damage reduction".* [2]

Within this context, the HFC is responsible for the operation of dams to help prevent or reduce flooding and to ensure adequate water supplies for irrigation, industrial and personal use, and for providing data and forecasts for the operation of floodways and diversions. Specific activities related to these responsibilities include;

- preparing spring flood outlook reports during the winter (Appendix C),
- issuing daily flood reports and river forecasts during spring flood events (Appendix D),
- preparing specific reservoir forecasts and operating plans,
- preparing special forecasts for floodway operations specific to the city of Winnipeg, and
- issuing flash flood watches, warnings and advisories for heavy rainfall when significant impacts are anticipated.

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1 Manitoba Infrastructure and Transportation web site - http://www.gov.mb.ca/mit/floodinfo/floodoutlook/index.html

2 It is noted that the centre has forecasting responsibility for southern and western Manitoba, with forecasting for eastern and northern Manitoba being carried out by Manitoba Hydro as part of their hydro operations in this area.

In addition, the HFC has responsibility for;

- preparing weekly river flow reports throughout the year,
- preparing periodic lake and reservoir status reports and forecasts during the open water period,
- reviewing development and subdivision proposals to ensure that they comply with provincial regulations regarding flood design criteria, surficial erosion and bank stability,
- providing data and expertise for flood proofing and for design of water control works or other infrastructure that could be sensitive to water levels, including information on soil moisture, precipitation, snow cover, evaporation, wind and rainfall intensities,
- conducting hydrologic and hydraulic analysis and modelling to determine the impacts of developments, land use changes and climate change on surface water regimes, and
- continuing to develop and/or improve flood forecasting techniques.

It is clear that the HFC is responsible for a wide range of activities within the water sector in Manitoba that go beyond the monitoring and forecasting of flood events.

6.2.2 History of Flood Forecasting in Manitoba

Following the disastrous Red River flood of 1950, the then Natural Resources Department initiated a study to determine means of reducing the flood hazard of the Red River with respect to flooding to the city of Winnipeg. While the main focus of the 1953 "Report on Investigations into Measures for Reduction of the Flood Hazard in the Greater Winnipeg Area" was an assessment of various flood control works, the report also included a number of graphical procedures that could be used to prepare runoff and streamflow outlooks for the Red River at Emerson. Subsequent to this report, procedures were developed that provided a forecast for the Red River at Winnipeg using either a peak-stage relationship between Emerson and Winnipeg or using routing procedures to simulate the conveyance of recorded or projected flows at Emerson and on local tributaries of the Red River between Emerson and Winnipeg. These procedures were in place from the mid 1950s to the mid 1970s.[3]

To forecast Assiniboine River flows, graphical runoff procedures for five major sub-basins, including the Qu'Appelle and Souris rivers, were developed in a 1952 study by the Prairie Farm Rehabilitation Administration (PFRA). The procedures utilized a variation of the unit hydrograph approach to estimate the time distribution of runoff for each sub-basin. This runoff was then routed downstream to locations of interest and a forecast was developed for those locations. In 1955, this procedure was improved by the Water Resources Branch, Department of Mines and Natural Resources by the addition of storage routing procedures for six reaches of the Assiniboine River between Kamsack and Headingly. However, due to the labourious nature of doing flow routing by hand, relationships between peak discharges at salient locations along the river were used to estimate flood peaks rather than using routing procedures. This approach was in place from the mid 1950s to the mid 1970s.[4]

In the mid 1970s, the Water Control and Conservation Branch, Department of Mines and Natural Resources established a permanent staff position and hired term staff and summer students to accelerate the recalibration and computerization of flow forecasting and routing methodologies. Because hydrologic simulation models were still in their infancy and limited funding was available to develop simulation models in house, the flow forecasting approaches developed during this period continued to employ relatively simple graphical, statistical and unit hydrograph procedures. While the modelling approaches did not change significantly, a significant improvement in forecast accuracy for the Red, Assiniboine and Souris rivers was achieved by using improved procedures of estimating soil moisture, effective precipitation (depth of runoff) and snowmelt rates, and the use of computerized procedures to analyze a much greater amount of data. The new methodologies were embodied in the MANitoba Antecedent Precipitation Index (MANAPI) model.

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[3] "Manitoba River Forecast Development – Phase I Planning and Design". Prepared by Environment Canada and Manitoba Natural Resources. Winnipeg, Manitoba. September 1985.

[4] Manitoba River Forecast Development – Phase I Planning and Design". Prepared by Environment Canada and Manitoba Natural Resources. Winnipeg, Manitoba. September 1985.

As a result, by 1978 the following improvements were developed and integrated into the forecasting procedures.

- The MANAPI procedure was calibrated on 45 tributaries within the Red, Assiniboine and Souris river basins.
- Computerized (FORTRAN DOS) Muskingum flood routing procedures were developed for both in-bank and overbank flow for the Red River from Emerson to Winnipeg, the Assiniboine River from Kamsack, Saskatchewan to Winnipeg and the Souris River from Minot, North Dakota to Wawanesa.
- Computerized (FORTRAN DOS) procedures were developed for converting observed or forecasted snowmelt and/or rainfall runoff into a flood hydrograph.

In the mid to late 1970s, Manitoba experienced a series of floods that included a major flood on the Assiniboine and Souris rivers in 1976 and a major flood on the Red River in 1979. The inaccuracy of many of the outlook forecasts and some of the operational forecasts during these events raised questions as to the reliability of the multiple regression and unit hydrograph approaches within MANAPI that were being used for runoff forecasting. The question asked at the time was could greater forecast accuracy and lead time could be achieved by the use of more physically based models. To address this concern, Environment Canada and Manitoba Natural Resources entered into the "Canada-Manitoba Flood Damage Reduction Program Agreement Respecting Flood Forecasting" which provided for a five year study "to develop and implement improved spring flood forecasting procedures for the Red, Assiniboine and Souris river basins in Manitoba."

In Phase I of the study (1981-1984), three external models and the MANAPI model were calibrated for three previous above-average spring runoff events in two relatively simple catchments. The three models tested against the MANAPI model were:

- "Hydrologic Simulation Program Fortran" (HSPF) - a physically based, continuous simulation model,
- "Streamflow Simulation and Reservoir Synthesis" (SSARR) - also a physically based, continuous simulation model, and
- "Single Linear Unit Reservoir Parametric" (SLURP) - a simpler parametric based, continuous simulation model.

The calibrated models were then applied to three other historical, high spring runoff events in those catchments to assess their performance to determine which, if any, model should be explored further. The Phase I study results indicated that the HSPF model performed the best, followed by the SSARR model, the MANAPI model and finally the SLURP model.

In Phase II (1985-1988) of the study, a performance comparison of the HSPF model relative to the MANAPI model was carried out by calibrating and applying the models to five historical events in each of three watersheds in southwestern Manitoba (Willow Creek, Gopher Creek, and Elgin Creek). As the two models had comparably poor results (average absolute error in peak flow for both HSPF and MANAPI was about 55 percent and errors in runoff volume averaged about 28 percent for HSPF and 43 percent for MANAPI) the Phase II study concluded that: [5]

"... the HSPF model does not provide significantly better streamflow simulations than the MANAPI model ... "
and recommended that:
"... an index type model of the form of the MANAPI model continue to be used for flow forecasting in Manitoba."

The primary sources of error noted at the time were related mainly to the calculation of the runoff volumes and were related primarily to:

- ... the non-representativeness of estimated area-average meteorologic inputs to the model due to ... the sparcity of the meteorologic station network",
- the inability of the models, "... to account for temporal changes to infiltration characteristics during the melt process [changes to infiltration as the soil thaws]", and
- the inability of the models, "... to simulate changes in the effective drainage area from one event to the next."

[5] "Manitoba River Forecast Development – Phase II Application and Evaluation". Prepared by Environment Canada and Manitoba Natural Resources. Winnipeg, Manitoba. June, 1988.

In addition to adequately calculating the runoff volume, the ability to simulate the movement of water along stream channels (flood routing) also is an important component of hydrologic simulation and forecasting. The Phase II study also conducted a cursory review of three routing procedures, the fundamental Muskingum-Cunge method (an improved version of the Muskingum method which continues to be used today by the Manitoba Hydrologic Forecasting Centre) and the two implicit routing procedures used in SSARR and HSPF. While the study found the SSARR model consistently produced better routing results, a visual review did not reveal significant differences between the results from any of the three approaches. As such, the study recommended that, "...the method easiest to apply should be used." Hence, the continuous use of the simple Muskingum method.

In the time between the completion of the "Manitoba River Forecast Development Study" to late in 2008, flood forecasting in Manitoba was carried out using the MANAPI simulation model and the Muskingum routing procedure by the single staff position created in the mid 1970s. During this period, forecasting refinements were primarily focused towards;

- increasing the number of small gauged sub-watersheds, which during operational forecasts would be initially used as index watersheds for the determination of both runoff and hydrograph shape but which, as flow data becomes available over the course of the flood event, transform the modelling exercise to the routing of observed flows from upstream to downstream,
- increasing the number of calibrated sub-watersheds as sufficient data became available,
- refining the Antecedent Precipitation Index (API) graphs to include newly acquired data, and
- developing an increasing number of unit hydrographs that could be used to represent "fast melt", "slow melt", "summer runoff", etc. conditions.

Due to the impending retirement of the single experienced flood forecaster, three new forecasters were hired in 2008-2009 period. However, because relatively large floods took place in 2009 and 2010, the new staff was thrown into the breach without an opportunity to receive formalized training in the use of the forecast models. In June 2010 the senior forecaster retired. A replacement forecaster was hired in December 2010. Concurrent with these developments, and with the hiring of additional staff in 2008, the HFC began converting the MANAPI model and routing procedures from the FORTRAN DOS platform to an EXCEL Macro Based platform. This provided added flexibility and convenience in terms of data transfer, data storage and the creation of graphics. The conversion of the MANAPI models from Fortran DOS continues to this day (November 2012) along with the assessment of alternative hydrologic models, including;

- HEC-HMS (in-house),
- MIKE-SHE (consultant),
- WATFLOOD (Manitoba Hydro), and
- improved MANAPI parameterization.

6.3 Flood Forecasting Procedures

The stated primary objective of Manitoba's Hydrologic Forecasting Centre (HFC) is:

> *"... the provision of flood condition reports, forecasts and warnings to enable effective coordination of flood response planning and flood fighting activities at all levels of government and the private sector."*

The Centre meets this objective through the delivery of three major flood forecasting products.

- The "Spring Flood Outlook" report is generated during the winter months (generally mid-February and mid-March and earlier if warranted). This report is intended to provide a long range assessment of the impending runoff from the perspectives of water supply and the risk of flooding.
- The "Flood Report", at times referred to as an "operational forecast" is generated daily from the start of the spring runoff period until the peak flow has passed. This report is distributed daily to emergency response agencies and to the public to support flood mitigation activities.
- The periodic "Lake Level and Reservoir Status Report" provides updates on river flows and lake and reservoir levels during the open water period.

6.3.1 General Discussion on Flood Forecasting Systems

Flood forecasting is an integral component of flood protection activities in that it provides water managers, emergency response agencies and the general public with the lead time required to evaluate options and optimize flood mitigation and/or response activities. The greatest benefits of a reliable forecasting system are realized when flooding is severe, widespread and there is sufficient lead time for water management agencies, communities and the public to respond. While increasing the lead time improves the potential to lower the level of damages and loss of life, trying to extend the lead time beyond the limit of forecasting capabilities for input parameters, such as air temperature and precipitation, can lead to inaccurate forecasts and put the credibility of the forecast system in question.

In general, flood forecasting is undertaken by the application of hydrologic models of varying complexity that quantify runoff generated from snowmelt and/or rainfall. These models require inputs of near real-time hydrologic data (streamflow, water levels, etc.) and/or climatological data (air temperature, snow water equivalents, rainfall, etc.) along with forecasts of future weather conditions to generate estimates of flows and corresponding water levels hours or days into the future on water bodies at points of interest. These estimates of future conditions are subsequently communicated to water managers, emergency management agencies and the public to allow them to conduct an informed assessment of potential mitigation actions. As such, flood forecast systems may be viewed as being comprised of four essential elements which are carried out and coordinated by trained forecasters that have a solid understanding of physiographic characteristics of the forecasting domain, water management infrastructure and its operations, flood risks to various communities throughout the forecasting domain and physical limitations of the data that is being collected and the analytical approaches that are being applied.

As such, the four essential elements of an integrated flood forecasting system are as follows.

- Field programs to collect the data required for the calibration and ultimately operation of the forecast model.
- Data management systems for the gathering, storing and retrieving of historical and near real-time data that is used as input to the model.
- Forecasting models.
- Information dissemination systems for conveying current and forecasted conditions to water managers, emergency response agencies and the public.

If all of the above components are optimized, generally reliable forecasts can be provided. However, there are many potential sources of error and uncertainty in the calibration or operational phase which will translate into comparable or larger errors and uncertainties in the forecasted flows and water levels. Some of the more notable sources of error and uncertainty include the following.

- The conversion to or approximation of "observed" basin input parameters (rainfall, air temperature, snowmelt, soil moisture, etc.) into either spatially distributed or basin average values from a limited number of point measurements.
- The accuracy of future weather forecasts (rainfall, temperature, etc.) which can lead to significant differences between what could have been entered initially into the model and what was actually "experienced".
- Measurements errors, particularly related to flow measurements during severe floods or ice conditions which can introduce errors of 20 percent or more under some circumstances.
- Incomplete or erroneous flow information due to hydrometric stations being washed out or inundated during flood events.
- Precipitation gauges being overtopped or not functioning properly (especially with respect to the sensing of snowfall) and no longer providing reliable records.
- Shifts in the stage-discharge relationships at hydrometric stations or at points of interest due to short-term changes in hydraulic characteristics as a result of sediment deposition and/or scouring of the channel bed and banks.
- Erroneous conversions of water levels to flow due ice or debris effects.
- Changes in the operation of upstream reservoirs.
- Poorly defined stage-discharge relationships due to the event being larger than the range of previous observations.

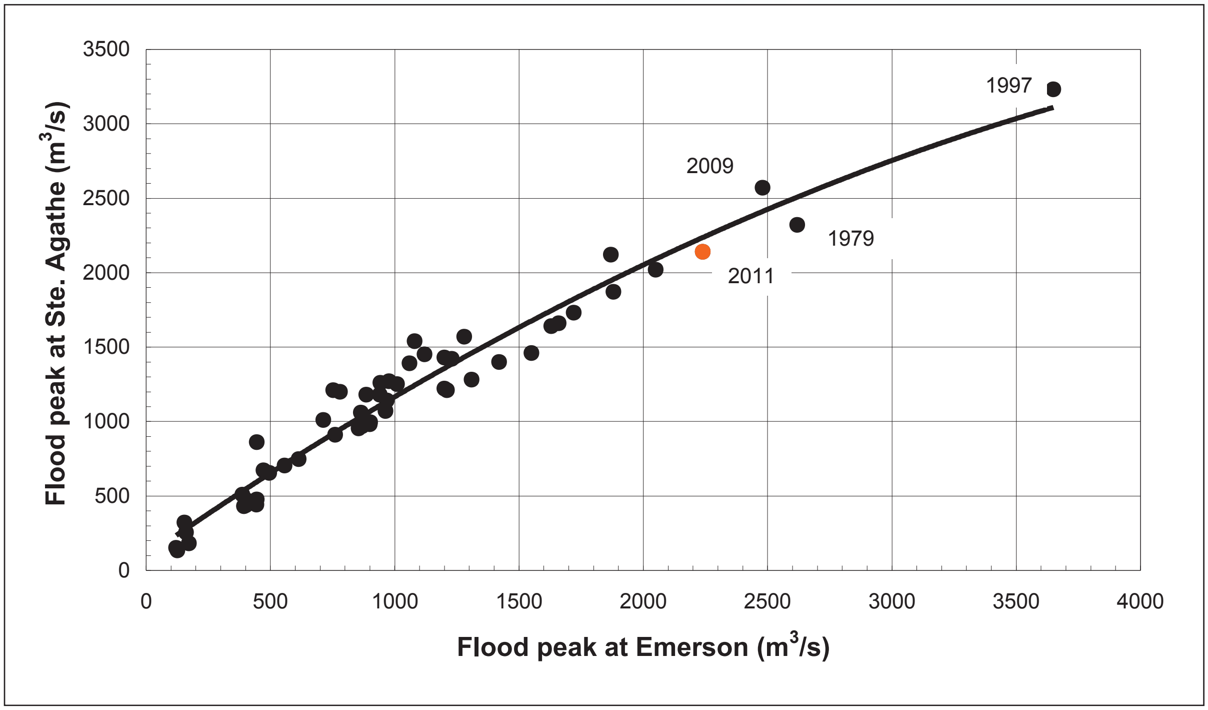
While the relative importance of the different types of uncertainties varies with the time (and lead time) of the forecasts and with the magnitude of the event, many of these uncertainties and sources of error can be reduced or eliminated by an experienced forecaster. A skilled forecaster having three to five years experience with a solid understanding of the physiographic characteristics of the watershed under consideration and of the available input data and its limitations should be able to deal with these types of errors and uncertainties if operating within a well designed forecasting environment.

The following sections assess the flood forecasting procedures in Manitoba within the context of each of the four essential elements identified above, as well as staffing and resources, to provide an understanding of the forecasting procedures and of potential improvements. A detailed evaluation of the reliability of the spring flood outlook, the operational flood report and the lake level forecasts is provided in subsequent sections.

6.3.2 Description of the Manitoba Flood Forecasting Model

The flood forecasting model for a single point of interest can be as simple as a statistical relationship that predicts the future flood peak at a downstream site on the basis of an observed peak flow at some other upstream location. An example would be the relationship between the peak flows on the Red River at Ste. Agathe and Emerson as shown in Figure 6.1. However, for areas having the areal extent and complexity of the watersheds draining through southern and western Manitoba, flood forecasting generally requires the use of relatively complex, physically based models that can simulate the rainfall-runoff and snowmelt-runoff process, and generate the resulting hydrograph for each discrete time step. Since flooding concerns are generally related to multiple points along a river system, the flood forecasting model generally also includes a routing model to simulate the conveyance of generated flows, from a single or multiple sub-watersheds along the stream course to points where there is a flood concern or to infrastructure whose operation is dependent on flow conditions.

Figure 6.1: Correlation between historical flood peaks at Emerson and Ste. Agathe. This simple correlation alone can provide about a seven day lead time for flows and water levels at Ste. Agathe on the basis of the flow at Emerson.



Physically based hydrologic models can be classified as being lumped, semi-distributed or distributed, and as either a single event model or a continuous simulation model. Lumped models treat a watershed as a single unit for inputting data and calculating runoff, with the underlying calculations generally being statistically-based representations of the physical processes. When a watershed is broken down into smaller sub-watershed units the model is referred to as a semi-distributed model. Watershed models that subdivide a watershed into grid cells are referred to as a distributed or fully distributed model. In this case, the physical processes are modelled within each cell and the interconnections between cells are used to define the drainage network. Distributed models require much more data and knowledge of watershed processes than lumped or semi-distributed models but, in general, can better represent the hydrologic complexities (depression storage, spatial distribution of precipitation, etc.) of a given watershed.

While all of the models produce a continuous flow hydrograph, the continuous simulation models differ from the single event models in terms of how they accommodate precipitation or snowmelt inputs. A single event model considers solely the total precipitation input over the duration of an event, be it a one-day, two-day or longer time period, in its computation of the total runoff volume from that event. The total runoff is then applied to a hydrograph shape to produce a continuous flow hydrograph (Figure 6.2). A continuous simulation model computes the runoff from the precipitation over each simulation time step separately. It then transforms the runoff from each time step into a response hydrograph that distributes over the runoff produced in each time step. The individual responses for each time step are then summed to produce a composite hydrograph of the basin response over time. (Figure 6.3)

Figure 6.2: Example of how a single event flood hydrograph model like MANAPI would operate. The discrete daily inputs are aggregated into one event regardless of the time period over which they occur.

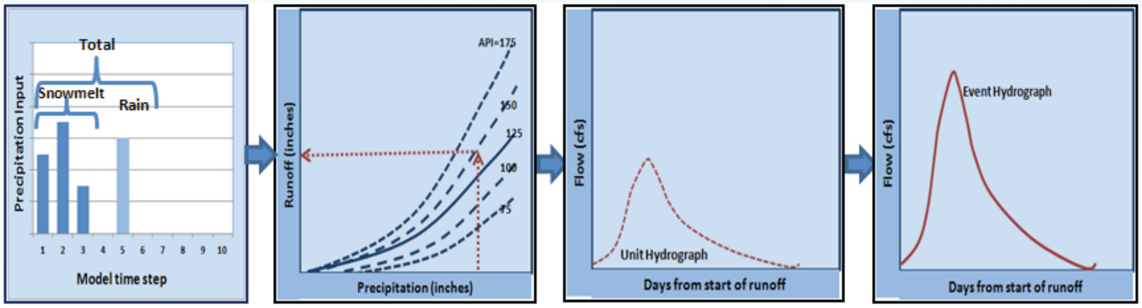
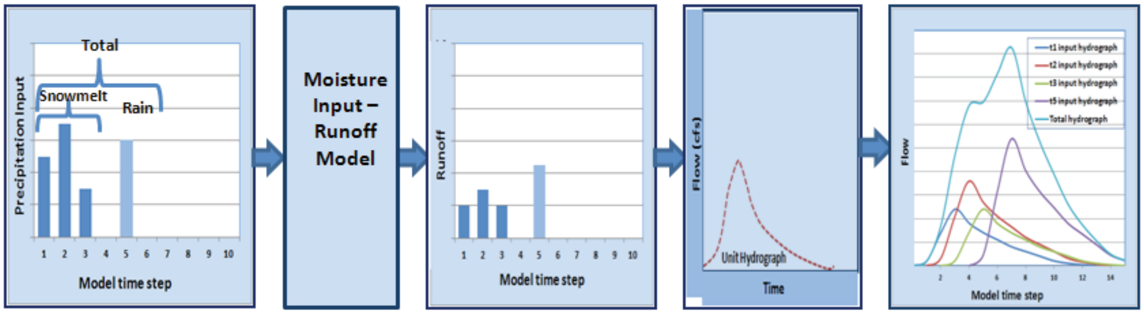


Figure 6.3: Example of a continuous simulation model. The daily inputs are considered individually and the aggregation occurs during the response phase.



The MANAPI model is a semi-distributed, event-based model that subdivides each of the Souris, Assiniboine and Red river watersheds into a number of sub-watersheds. The model computes a single runoff value for each sub-watershed resulting from a total moisture input, be it a snowmelt event, a rain on snowmelt event or a simple rainfall event, and be it over one day or several days. It then transforms the total event runoff, using a unit hydrograph, into a series of daily flows for each sub-watershed under consideration (Figure 6.2). While the model has been modified to simulate up to three independent events, all three events would be confined to using the same forecaster-defined hydrograph shape.

The MANAPI model differs from a continuous simulation model in that the latter computes the runoff and hydrograph for each computational time step rather than for the entire event. The hydrographs generated for each computational time step are then summed to produce a composite hydrograph of the basin response (Figure 6.3) that reflects the entire event. Being an event model, the MANAPI model has much less flexibility in terms of simulating the flood hydrograph from events that involve freeze-melt cycles or significant variation in daily inputs, such as might arise from a rain on snow event.

In 2011, the forecasting process used by the HFC was comprised of three EXCEL Workbooks - a workbook which generated forecast hydrographs for the Red River from Emerson to the Red River Floodway, a workbook which generated forecast hydrographs for the Souris River from the International Boundary (Westhope), with the option of starting at Minot, ND, to its confluence with the Assiniboine and a workbook which generated forecast hydrographs for the Assiniboine River from the Shellmouth Dam to the Portage Diversion. Each workbook utilized the following three MANAPI components in the generation of flood forecasts.

i. Sub-watershed specific graphical relationships that related the depth of runoff to total winter precipitation were used to compute the depth of snowmelt runoff volumes from sub-watersheds within the larger Assiniboine, lower Souris River and lower Red River watersheds.
ii. A procedure that applied the previously-computed runoff volume to a sub-watershed specific unit hydrograph, based on the assumption of proportionality, to generate an output flood hydrograph from each sub-watershed for the event under consideration.
iii. A subroutine that conveyed the sub-watershed flood hydrograph outputs, along with the flood hydrograph for the Souris River at Minot and for the Red River at Pembina (either observed or forecast by the U.S. National Weather Service), downstream along the main stem of the Souris, Assiniboine, and Red rivers using Muskingum routing procedures to generate flood forecasts for a number of points of interest.

The derivation and limitations of elements within each of these components are discussed below in more detail.

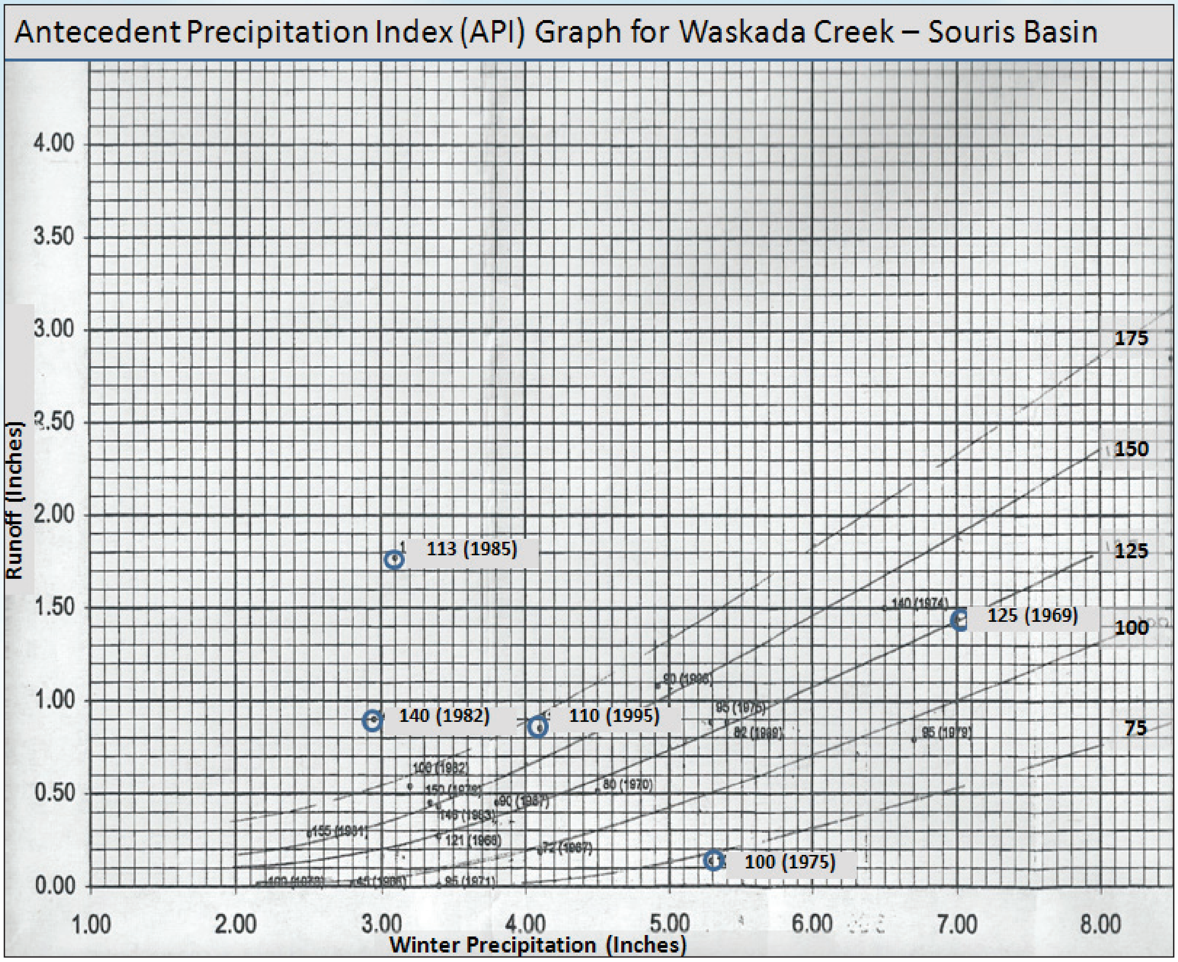
The MANAPI Unit Hydrograph

There are a number of well established procedures for developing unit hydrographs based on the concept of deriving a response function that is related to the physiographic characteristics of a watershed for a unit input for a selected time period. The procedure used in the MANAPI model is one in which a number of historical snowmelt hydrographs, representing either average, rapid or gradual melt conditions over varying time periods, are plotted, and best-fit, average, rapid or slow melt hydrographs are visually developed from the plots. The volume under each of the hydrographs is subsequently adjusted to a unit input - approximate the equivalent of one inch of runoff in this case. It is noted that the derivation of the MANAPI unit hydrograph is not based on consistent time periods and therefore violates the fundamental basis of unit hydrograph application. Instead, the shape of the MANAPI hydrograph is related as much to the input characteristics (rate at which snow melts or to the temporal distribution of rainfall) as it is to the response characteristics of the watershed. The time to peak for the unit hydrographs developed by the HFC is one whose time to peak is based more on snowmelt rates rather than the basin response time. As such, it cannot simulate unique runoff well for events that have not been experienced before or that depart significantly from the average of the historical events.

Runoff-Precipitation-API Relationship Graph

The procedure used to estimate the runoff to be applied to the unit hydrograph for each sub-watershed is a graphical procedure that relates runoff to the “total winter precipitation” and the “antecedent precipitation index” or API. The graphical relationship between these parameters is unique to each sub-watershed. The relationship is based on a correlation of the spring runoff volume to the API and the total winter precipitation for each year of record. The computed values are then plotted on a graph with the winter precipitation along the abscissa and the runoff depth (volume divided by basin area) on the ordinate, with the corresponding API value indicated for each point. A series of curves are then fitted to the data, either visually or statistically, to allow for the determination of the runoff depth for any given winter precipitation for the prevailing API in that year (Figure 6.4).

Figure 6.4: Runoff - winter precipitation-API curves for the Waskada Creek watershed in the greater Souris River watershed - ostensibly typical of those for other watersheds. The actual API values and the curve-based API values are not well reconciled.



Due to the scarcity of direct soil moisture information in the early years of development, the APIs were computed based on the sum of the weighted monthly percent of normal precipitation (antecedent precipitation) from May to October of the previous year using the following weightings:

May	June	July	August	September	October
0.07	0.08	0.12	0.18	0.25	0.30

In more recent years the API computation process has also incorporated the use of soil moisture surveys and satellite imagery provided by Manitoba Agriculture, Food and Rural Initiatives, Environment Canada and other agencies.

In the early days of model development, because of the scarcity of information of snow on the ground, the total winter precipitation for each gauged sub-watershed was initially computed as the total precipitation from November 1 of the previous year to the date of the snowmelt peak. In more recent years, however, the winter precipitation has been computed using maps that incorporate the cumulative precipitation from freeze-up to the date of the snowmelt peak, snow survey measurements, satellite images of snow water equivalent maps produced by Environment Canada and airborne gamma data gathered by U.S. National Weather Service (NWS). It is evident that the methods by which both the amount of snow available for runoff and the API are determined have changed significantly over the years. These changes undoubtedly bias the API curves to a certain degree. Given the coarseness of the forecasting procedures and all the inherent errors that can occur it probably is not that big of an issue. Nevertheless, it would be appropriate in the future to maintain as much consistency as possible in how the two parameters are determined.

Figure 6.4 shows the runoff-precipitation-API graphical relationship developed for Waskada Creek, a sub-watershed of the Souris River watershed. Individual historical point "observations" are used to develop the runoff-precipitation relationship for the varying levels of API. It is clear in the figure that often there are significant differences between the plotted values and the runoff prediction that would be made on the basis of the graph. This raises concern about both the reliability of runoff estimates from the API curves and therefore the generated flood hydrographs, notwithstanding the issues with the derivations of the so-called unit hydrographs. Furthermore, it is noteworthy that the graphs were developed on the basis of snowmelt runoff, or runoff from frozen soil conditions, when there would be minimal infiltration. As such the graphical relations cannot provide reliable estimate of runoff from precipitation events that occur once soils begin thawing, typically shortly after the snowmelt peak occurs.

As the HFC has not developed unit hydrographs based on the basin response time, and has not developed a rainfall runoff relationship for spring and summer conditions, the MANAPI procedures cannot provide reliable estimates of runoff volumes after the spring runoff event. Due to these limitations, the HFC had to, and in fact did in 2011, generate forecasts using improvised procedures and/or by simply routing measured flows from upstream. Such improvisations likely produced mixed results whereby in some cases they improved performance, but their ad hoc development would have reduced confidence in the forecast results.

Routing Procedures

The routing of flows on rivers is a critical component of the flood forecasting system. Fortunately, the routing process is a relatively straightforward hydraulic problem and it is amenable to a simple analysis. There are a number of approaches that can be taken. The most straightforward is a simple translation of flows from one location to another on the basis of the time of travel along the river. The travel times may be assessed strictly on the basis of past events, and extrapolations to events beyond those experienced are not complicated. As long as there is good accounting of tributary inflows, the results of this approach are certainly within the accuracy of the hydrologic component of the flood forecast. A more complex, and theoretically the more accurate, approach to flood routing is to use a fully dynamic simulation model that takes into account all the hydraulic components of the unsteady flow phenomenon. This approach requires well defined channel geometries (based on a large number of measured channel cross sections) and a very sophisticated and well calibrated model to realize the maximum benefit of this powerful approach.

The Muskingum routing method used by the HFC is a compromise of the fully dynamic model, but is a marked improvement over the travel time approach. This method is a variation of the reservoir routing technique and takes into account increasing channel storage during the rising limb of the hydrograph and decreasing channel storage on the falling limb. This allows for the implicit consideration of varying flow velocities and corresponding travel times over the range of flows within the rising and falling limbs of the flood. The approach is easily calibrated by comparing simulated hydrographs to measured ones by optimizing two relatively simple parameters and is easy to apply since it does not require any channel geometry data.

Given the experience that the HFC has using the Muskingum routing method, it is not likely that investing significant amounts of resources into another stand-alone routing model would be worthwhile. However, if a different runoff model will be used, it is suggested that the routing procedure that accompanies that model is adopted. The efficacy of the routing components are not critical to the outcome of forecast and any reasonable routing approach should suffice as long as it does not require extensive channel surveys.

Dependencies on U.S. National Weather Service (NWS) Forecasts

As indicated earlier, the HFC utilizes the MANAPI model to generate sub-watershed hydrographs solely for areas between Emerson and the Red River Floodway, or for approximately 17 000 km^2 or 6600 $mile^2$ (14 percent) of the 119 000 km^2 (46,000 $mile^2$) drainage area of the Red River at the floodway. The Manitoba HFC traditionally relies on the NWS forecast for the Red River at Pembina (Emerson) to synthesize the hydrograph for the 102 000 km^2 (39,400 $mile^2$) drainage area upstream of Emerson. On the Souris River, the HFC, while having the ability to start the modelling from Minot, ND, generally relies on the NWS forecast for the Souris River at Westhope to synthesize the flood hydrograph for the 43 700 km^2 (16,900 $mile^2$) area upstream of Westhope – about 71 percent of the 61 100 km^2 (23,600 $mile^2$) drainage area of the Souris River at Wawanesa.

Thus, the NWS forecasts at these locations are without doubt the single most important factors in delivery of reliable forecasts for the Red and Souris rivers in Manitoba. In fact, the NWS forecasts appeared to have played a critical role in the reliability of the 2011 forecasts. While there may be close collaboration with NWS, there nevertheless appears to be no formal arrangement to ensure the continued delivery of this product. It would be important either to have some agreements in place guaranteeing these products in the future, or work should be directed towards putting formalized forecasting procedures in place for the areas of these watersheds that are outside of Manitoba.

6.3.3 Data Collection

In cold climate areas, such as Manitoba, the hydro-meteorological data collection network required for flood forecasting generally includes the collection of streamflow, precipitation, snow water equivalents, soil moisture and temperature data. The number of streamflow stations required for operational forecasts depends on the model that is being used, confidence in how gauged watersheds represent ungauged ones and how the large watersheds are subdivided into sub-watershed units. With respect to precipitation, soil moisture and air temperatures, these data should be collected at a sufficient number of sites to permit reasonably accurate estimates of the spatial distribution and/or the average values of any of these parameters within the context of any particular sub-watershed that is being modelled. Generally, there is a sufficient number of these sites if they remain operational. The more critical requirement is management of these large volumes of data and the ability to assemble the data in a timely manner so it can be interpreted and inserted into the forecasting procedures. Modern data handling systems are well suited for this kind of work.

Streamflow cannot be measured directly on a continuous basis but rather is derived from the measurement of water levels which are subsequently converted to a flow using a stage discharge relationship. Since hydrologic models simulate streamflow, the streamflow data collection program should also include a field monitoring program during the operational forecasting period. This is important to identify any potential changes in the stage-discharge relationship and to ensure the conversion of water levels to a flow (and subsequently the conversion of the forecasted peak flow to a peak stage) reflects the most up to date channel conveyance characteristics, and to resolve any other data collection issues that may develop during flood events. Modern flow measurement technology such as acoustic doppler flow meters are essential components of a streamflow measurement program.

Streamflow Data

A review of the hydrometric network for the Souris, Assiniboine and Red river basins indicates that in 2011 the main stem of all three stream courses were extensively gauged both within Manitoba and in upstream jurisdictions, and that all data was transmitted and accessible on a near real-time basis. Similarly, most of the tributary streams in Manitoba were gauged and all data was transmitted and accessible on a near real-time basis. As such, the hydrometric network for all three mainstream courses is deemed to be adequate to meet all flood forecasting requirements.

While the number and locations of the hydrometric stations appear to be adequate to meet flood forecasting requirements it is noted that two hydrometric gauging sites (Assiniboine River near Virden, and Assiniboine River near Griswold) were inaccessible due to flooding and were unable to provide data during the week prior to the 2011 flood peak at Brandon. As these are key stations in forecasting flows at Brandon and the Portage Diversion, consideration should be given to flood proofing these sites to avoid similar future occurrences. In fact, backup processes (local on-site personnel and rugged water level measurement devices) should be in place at key hydrometric stations on the main stems of the Red, Souris, and Assiniboine rivers - and on other major rivers - during large floods.

Field support during the 2011 flood was described by HFC staff as outstanding. Eighteen water metering crews were deployed and conducted approximately 5500 observations to support real-time decisions and verify stage discharge relationships. Due to the extent and longevity of the flooding, extensive use was made of private sector crews that utilized the most modern streamflow measurement technologies.

Precipitation Data

Precipitation is one of the key inputs to flood forecasting models. To provide a reliable long-lead forecast, the precipitation monitoring network should be able to provide an adequate definition of the intensity and spatial distribution of precipitation on a near real-time basis.

HFC staff indicated that precipitation data was gathered in 2011 from a number of sources including Environment Canada, the U.S. National Weather Service, the Community Collaborative Rain, Hail and Snow Network and WeatherFarm. All provided data via the web. While spatial distribution of climate stations appeared to be sufficient (perhaps with the exception of rural areas in Saskatchewan), access to the data was complicated by the lack of a data management system that automatically captures and downloads this third party data. HFC staff gathered climate data by visiting the above noted websites, accessing the data from the numerous climate stations one station at a time and finally copying and pasting data from the website to EXCEL spreadsheets where it was subsequently processed into a usable format. Due to this manual process of accessing climate and other data, staff frequently had to start work at approximately 2:00 am to ensure that all data had been gathered and manipulated into a usable format so as to complete the daily flood forecasting deadlines. Clearly, this is not good use of resources.

Snow Water Equivalent Data

Sources of snow water equivalent data collected by HFC include snow surveys conducted within Manitoba and eastern Saskatchewan prior to the preparation of each Spring Outlook Report and satellite images of snow water equivalents across the Prairie Provinces, in the Dakotas and Minnesota prepared by the Climate and Research Division, Environment Canada. HFC also gathered data from maps of snow water equivalents across southern Manitoba and Saskatchewan interpreted from airborne gamma data prepared by the U.S. National Operational Hydrologic Remote Sensing Center, NOAA. In general the amount of data and its general regional distribution appears to meet the requirements of the MANAPI model in spite of the ad hoc way in which some of the data is provided. However, there is concern about the quality of the snow water equivalent data that is being collected by the automated stations operated by Environment Canada. Furthermore, many of these automated stations no longer collect “snow on ground” data, thereby making it difficult to determine the time when snowmelt would cease.

Some of these data can be replaced by volunteer networks. However, long term reliance on year to year consistency in the data that is crucial to maintaining a rigorous forecasting methodology cannot be maintained by volunteer programs. As mentioned earlier, it is important to maintain some level of consistency between the data that is collected today and the data upon which the API curves are based. A well-funded strategic program to ensure an adequate characterization of the winter precipitation and the compilation of the corresponding snow water equivalent data would be a necessary component of the forecasting system.

Soil Moisture Data

Soil moisture data is required to determine the API conditions to be used in the determination of runoff from the runoff-winter precipitation-API relationship graphs. Data and information used for the estimation of API include an airborne (gamma radiation) based soil moisture map for southern Manitoba, southeastern Saskatchewan, North Dakota and Minnesota prepared by the U.S. National Operational Hydrologic Remote Sensing Center, NOAA, soil moisture measurements made at freeze-up in the previous year and precipitation maps of cumulative precipitation during the previous May to October period. While the airborne based soil moisture maps provide adequate areal coverage, there is a need for additional soil moisture measurements in North Dakota and Saskatchewan to better ground truth these areal maps.

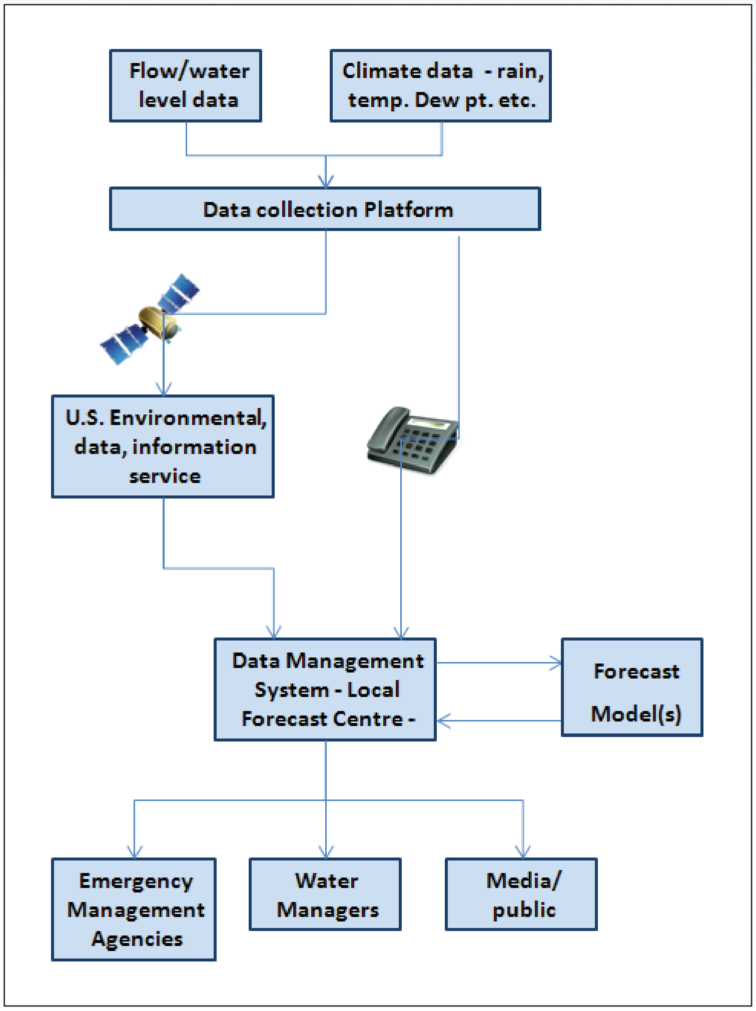
Weather Forecasts

While flood forecasting can be carried out on the basis of observed precipitation, the inclusion of future weather (precipitation, temperature, etc.) can provide valuable additional lead time for implementing response activities. Currently the HFC obtains weather forecasts by accessing various websites (Environment Canada, The Weather Network, Manitoba Fire Program and the U.S. National Weather Service) and downloads weather maps and/or forecasts. This process of gathering weather forecasts appears to meet Manitoba’s flood forecasters current requirements. However, as these weather forecasts are generally focused on major urban centres, rather than key watershed areas used in the flood forecasting, these data providers could potentially improve the flood forecasts by providing more complete information on the areal distribution of the precipitation forecasts. It would be worthwhile for HFC to work with Environment Canada to develop tools that provide this type of information in a more systematic and user friendly format that is consistent with the spatial extents of the forecasting domain.

6.3.4 Data Management Systems

Once data have been collected at sites throughout the river basin, the data must be transmitted to a location where it can be stored, quality controlled, processed, accessed and applied. As the more complex models often simulate a number of sub-watersheds and track a number of hydrologic processes (snow accumulation, snow melt, soil moisture, evapo-transpiration, etc.) for each time step in each sub-watershed, they generally require the input of a number of critical hydrologic and climatic parameters (water levels, streamflow measurements, point temperature, point rainfall, etc.) from dozens or even hundreds of hydrometric and climatological stations. The data gathering, validation and manipulation process becomes even more complex for watersheds that may straddle two jurisdictions (such as the Souris and Red rivers) with different units of measurement being employed. In these situations, the data gathering, validation and preparations of input files can become an overwhelming task that consumes most of the forecaster's time and leads to a loss of reliability in the forecast. In recent years, there have been a number of data management systems developed that can automatically gather most data and information from various sources, provide quality control and assurance of the data, convert data to a common unit (the SI system is recommended), prepare input files for the forecast model and help in the dissemination of information by automatically updating websites that report on observed or forecasted flows (Figure 6.5). This frees the forecaster to concentrate on the forecast rather than data gathering and manipulation.

Figure 6.5: An example of an integrated data management and forecasting system.



The HFC currently does not have a fully operational integrated data management system. While a version of the "AQUARIUS" data management software was acquired in 2009, it has not been fully implemented. Only the downloading of WSC real-time streamflow data has been activated. Because of the lack of a data management system, all data gathering, quality control and data manipulations are carried out manually and are stored either in text files or EXCEL workbooks. Examples of some of the time consuming data gathering and processing currently being carried out manually include the following.

- The websites of various sources of climatic information are visited to gather precipitation for dozens of climate stations, repeatedly accessing data from one station at a time (because these sites generally display only one station at a time), copying and pasting the station's data into spreadsheets and repeating this step until all data for dozens of climate stations have been copied and pasted before processing and calculating regional precipitation patterns.
- Field measurements of flows and water levels are entered manually into spreadsheets and analysis is carried out to determine what, if any, shift may have occurred in the stage-discharge relationship at the various hydrometric sites. These shifts are subsequently used to modify stage-discharge relationships which are used to convert near real-time water levels to a discharge and forecasted peak flows to a peak water level.
- Considerable effort also goes into converting Canadian hydroclimatic data, which is reported in SI units, into the US Customary system of units that is employed by the HFC.

Implementation of an integrated data management system that automates the type of activities described above would greatly enhance the forecaster's ability to produce as reliable of a forecast as possible rather than dealing with the more mundane data processing. It is recommended that AQUARIUS or a similar type of system be implemented to carry out these functions.

6.3.5 Information Dissemination Systems

The ultimate goal of a flood forecasting system is to ensure the safety and security of the public and to protect property. To achieve this result, however, means that water managers, communities and the public must receive and understand the forecasts. Currently the flood forecasts are communicated by means of:

- Spring Flood Outlook reports that are prepared about mid-February and mid-March of each year, and more frequently if warranted,
- daily operations reports that are prepared during the active snowmelt period and over the summer when flooding is a concern, and
- lake level condition and forecast reports.

All of these reports are placed on a website for public viewing. In addition to these reports, water conditions and forecasts are also currently communicated to water managers, operations staff, senior managers and elected officials through daily telephone conferences or briefing sessions. Again, due to the lack of a data management system, the preparation of flood reports and the updating of lake level condition reports relies on time consuming manual copying and pasting of model results and hydrologic data and information all of which can have a significant impact on the lead time of the forecasts.

It appears that the public does not appreciate the effort that has gone into the dissemination of flood information. Twenty-six persons responded to a survey on "the accuracy, timeliness and reliability of the Province's flood forecasting efforts" that was placed on the Task Force website during August 13 to October 17, 2012 period. The survey results indicate the following.

- Nineteen of 25 persons following the forecasts stated they received their forecast from the media, while five received it directly from flood reports.
- Ten of 22 respondents indicated they were not fully able to understand the forecast.
- A number of respondents indicated that forecasting information was received too late, while 21 of 23 respondents stated that they acted on the forecast, while at the same time nearly half of respondents felt the forecasts were inaccurate.
- Seventeen of 23 persons replied that they felt that forecasting or communication of the forecast could be improved.

Overall, Manitobans tended to follow the flood forecasts with great interest and acted upon them. A majority of the responders to the poll understood the information that was being presented, but a larger majority indicated that the information should be simplified. One of the issues was not understanding the level of risk associated with the upper and lower bounds of the forecast range. Few of the responders could decide whether to plan for the low end or the high end, with the high end becoming the adopted forecast.

Some of the media indicated that the forecasts were being produce in a timely manner and appeared to address the main areas of concern. However, there appears to be a need for simpler charts and perhaps better diagrams and schematics to illustrate the magnitudes both of past events and of forecast events within the context of the local conditions. About half the responders to the poll felt that forecast was not useful, but nevertheless took action on the basis of the forecast. Forty percent found the forecasts to be "very" inaccurate and a majority of the responders want to see the forecasts improved. A majority of the public felt that the forecasts were either "very inaccessible" or "poorly accessible".

The very small number of responders limits the validity of the survey results because individuals who are dissatisfied with the forecasting outcomes would tend to be more likely to respond to the poll than those who were satisfied. Furthermore, an extreme event like that experienced in 2011 would tend to produce less favourable forecasting outcomes because the forecasters are working in a domain seldom experienced. Nevertheless, the results of the poll suggest that more attention may be needed to develop a more rugged forecasting system that can operate well even in extreme floods like 2011.

Communicating through the media requires specialized training. Given that most respondents were receiving the forecasts through the media, the HFC may wish to consider having a trained spokesperson to deliver forecasts to the media. While most respondents indicated they take action on the basis of the forecast, many indicated they don't fully understand the forecast in its current format or that they believe it to be unreliable. A periodic user analysis would help to develop closer ties and interaction between the forecasters and user groups and provide a greater understanding how best to meet their needs.

6.3.6 Staffing and Resources

The HFC is currently comprised of a director, two forecasters with a hydrologic background, one hydraulic engineer and one forecast systems specialist. In 2011 each was given the responsibility for generating flood forecasts for an assigned basin. Due to the lack of a dedicated operations centre, the forecasts were carried out from each individual forecaster's office. The process seemed to work reasonably well up to mid-April when a series of rainfall events in the headwaters of the Souris River, the Assiniboine River and in the Dauphin Lake area gave rise to flooding concerns over an expanded area. This was accompanied by a significant increase in the requirement for near real-time data and field measurements to assess the situation. At this stage, the HFC transformed a board room into a temporary operations centre where forecasters could work collaboratively without interruptions, lay out maps and exchange and coordinate information more effectively.

Due to the lack of an automated data management system for handling the increased data requirements, one or two of the forecasters also began to work late into the night and/or start work at 2:00 am in order to gather as much of the necessary climate and forecast data as possible. Once the rest of the forecast team started the day's work, the data, which by now was likely dated, were reviewed by all team members and entered into the GIS system, (provided the single licence was not being used by other staff within the Government of Manitoba) as a precursor to the preparation of the daily forecasts. The need to begin providing forecasts for areas not previously modelled, and of wind set-up and wave action on lakes, put further stresses on the resources. While an attempt was made to address these pressures by retaining consultants and recruiting additional support from other areas within government, these efforts were of limited benefit. While the additional resources may have been experienced hydrologists, they would not have been intimately familiar with operational forecasting procedures.

The problems encountered during the 2011 flood operations are a clear indication that current level of resources in the HFC are inadequate for floods of the magnitude and areal extent of the 2011 event. Similarly, it is obvious from the 2011 event that the following resources are critical to future operations.

- An full time operations centre which has dedicated computers located outside the current managed system, telephones, software and other communication equipment as well as adequate room for laying out visual materials.

- A fully functional data acquisition and management system with adequate professional and technical support to develop and maintain the system and to provide data collection and management support to forecasters. This would include:
  - a data management systems specialist to develop and maintain the system and potentially provide forecast assistance, and
  - data management technologists to gather and quality control all hydroclimatic data to enter field observations and to review any changes in stage discharge relationships.
- Provided the above two conditions are met, the current complement of four dedicated forecasters should be sufficient to develop, maintain and apply hydrologic forecasting models in the delivery of operational forecasts for the Province, to provide water level forecasts for lakes including wind set-up and wave action forecasts and to develop and maintain automated processes for updating of current conditions reports.

6.4 Evaluation of Flood Forecasting Accuracy

The evaluation of the accuracy of the flood forecasts is a very difficult process because of all the unavoidable confounding effects that can lead to errors in the forecast. Nevertheless, the following sections provide an evaluation of the performance of the HFC with respect to the outlook forecasts, on the basis of the content of the spring flood outlook reports, and the operational forecasts and on the basis of the contents of the flood sheets. The evaluation is based on a comparison of the forecasted conditions to the actual events as represented by the preliminary WSC discharge data, most of which likely would have been available to the forecasters on a real-time basis during the flood. This evaluation somewhat has the benefit of hindsight, which in this case is not used to be critical, but rather to understand what actually happened and to formulate recommendations and process improvements.

As mentioned earlier, flood forecasting models are essentially mathematical representations that have been calibrated for a particular physical system that simulate the hydrologic response of a watershed based on previous known point observations of precipitation inputs (rainfall, snowmelt) and current flow conditions. In operational forecasting, precipitation inputs entered into the model are initially based on assumed meteorological conditions one or two months in the future. These are characterized statistically as below normal, normal or above normal conditions as defined by the historical climate record. At this stage, the accuracy of a flood forecast is primarily a function of how well the weather forecast is able to represent the quantity and spatial distribution of the moisture input and as such, the accuracy can be very poor. Due to the large error generally associated with these long-lead forecasts, including the non-occurrence of a forecasted precipitation event, it is not uncommon for forecasters to issue qualitative and conditional forecasts at this stage, rather than quantitative flood forecasts.

Operational forecasts, on the other hand are typically based on three to five day precipitation forecasts. Greater accuracy would be expected because these forecasts are derived from process-based weather models rather than statistical projections. After the forecasted quantity and spatial distribution of the precipitation has been verified, the accuracy of the flood forecast is largely dependent on the quality of the runoff model and how accurately the point observations are able to represent the quantity and spatial distribution of the precipitation input. It is believed that at this stage a reasonably well calibrated model with an adequate climate observation network should be able to provide flood peak flow forecasts that are within plus or minus 25 percent of what would actually occur. However, as time after rainfall elapses, and as the flood hydrograph for headwater streams and tributaries is observed, the forecast for at least the larger watersheds such as those of the Souris, Assiniboine and Red rivers would be primarily dependent on the estimated contribution from ungauged areas and on the routing of observed upstream and tributary flows to points of interest. Given that high degree of hydrometric monitoring within the Souris, Assiniboine and Red rivers, at this stage a well calibrated routing model should be able to provide flood peak flow forecasts that are within plus or minus 10 percent of actual. A review of previous flood events for the Red River would seem to suggest that this level of accuracy can be provided with a four to eight day lead time. While a detailed assessment was not carried out for the Souris and Assiniboine, the data would seem to suggest that this level of accuracy likely can be attained with a two to three day lead-time.

6.4.1 Spring Outlook Forecast

In 2011, the HFC put out "Spring Flood Outlook" reports on January 24, February 24 and March 25 based on the ambient hydro-meteorological conditions and the complex modelling procedures described earlier and illustrated in Figure 6.6. The reports (Appendix C) generally contained maps and information about soil moisture conditions in the previous fall prior to freeze-up, snow water equivalent on ground, runoff potential and flood mitigation activities for southern and western Manitoba. The reports also contained graphs and tables that provided the expected 2011 spring peak level, the critical flood level and maximum observed water levels in previous high flood years for various points along the main stem of the Souris, Assiniboine and Red rivers. The outlook reports also provided a forecast of the 2011 peak discharge and historical peak discharges for a number of tributary streams. The predicted spring flood stages and discharges were provided for three scenarios.

- A "favourable weather condition" in which total precipitation at the start of runoff is equal to the current snow on ground plus a relatively low level (90 percentile level where the expected additional precipitation would be exceeded in nine out of ten years on average) of additional precipitation in the time interval between the date of the report and the projected April 15 peak flow date.
- An "average weather condition" in which the total precipitation at the start of runoff is equal to the current snow on ground plus the expected normal (50 percentile level) additional precipitation in the time interval between the date of the report and April 15.
- An "unfavourable weather condition" in which the total precipitation at the start of runoff is equal to the current snow on ground plus a relatively high level (10 percentile level where the expected additional precipitation would be exceeded in only one out of ten years on average) of additional precipitation in the time interval between the date of the report and April 15.

Figure 6.6: Flow chart that illustrates the large number of steps and data types required to produce a spring snowmelt runoff outlook report.

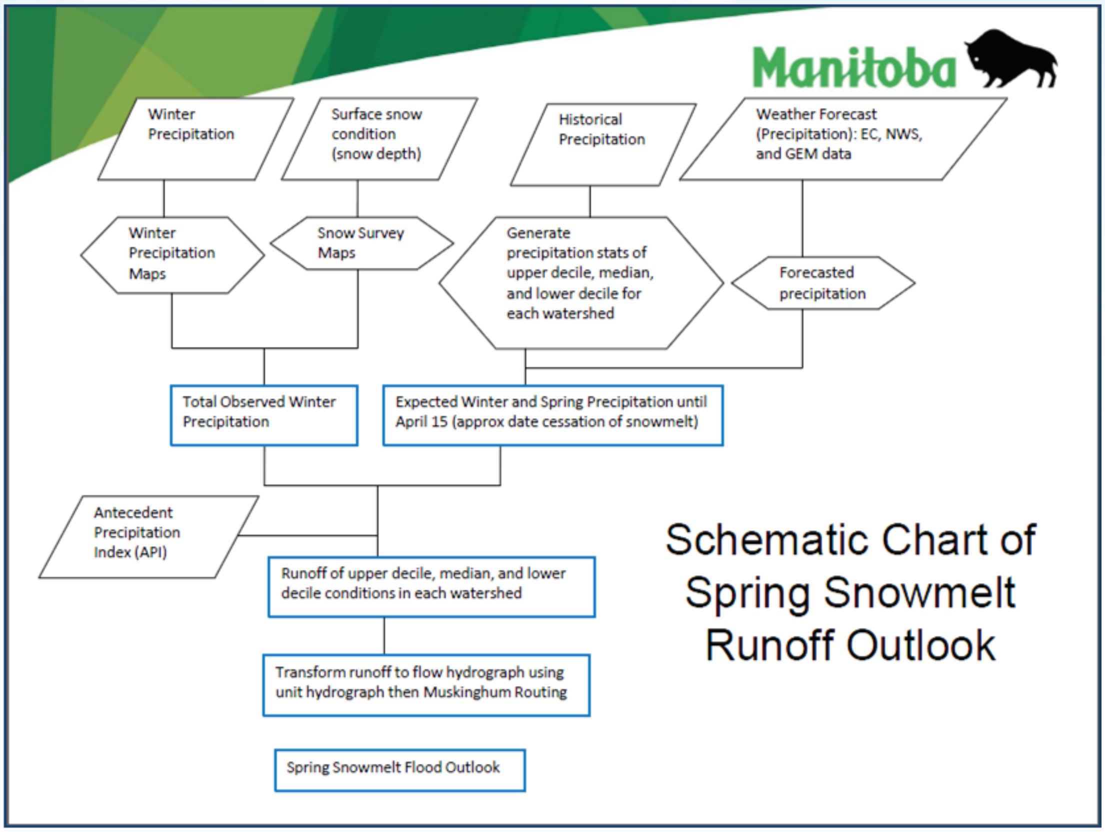


Table 6.1 provides a comparison of the peak water levels forecasted in the February 24, 2011 outlook report to the peak water levels forecasted in the March 25, 2011 report. The March 25 forecast had a significantly smaller, albeit still relatively large, range between the upper decile (UD) and lower decile (LD) forecasts than the February report. The reduction in the range between the February and the March report is a reflection of the fact that the additional precipitation between February 24 and March 25 had now been observed and was a known quantity, thus leaving a shorter period of time - 21 days versus 50 days - over which the future precipitation was an unknown. However, the relatively large range between the upper decile and lower decile forecasts still apparent in the March 25 report reflected the continued uncertainty in terms of the precipitation that could have occurred in the remaining weeks, and the continued uncertainty as to whether it would be a prolonged, average or rapid snowmelt event. It is not clear, however, if the uncertainty also includes potential errors in the runoff modelling methodology, i.e. the effects of errors in the API values and inaccuracies introduced by using unit hydrographs that may not reflect watershed responses.

Table 6.1: Comparison of February 24 and March 25 spring flood forecasts

Location	February 24 Peak Level Forecast (m)*				March 25 Peak Level Forecast (m)*			
	Lower Decile	Median	Upper Decile	Range	Lower Decile	Median	Upper Decile	Range
Red River								
Emerson	240.9	241.4	241.5	0.6	241.1	241.4	241.5	0.4
Letellier	239.1	239.6	239.9	0.8	239.4	239.6	239.7	0.3
St. Jean	238.4	238.7	239.0	0.6	238.5	238.7	239.0	0.5
Morris	237.7	238.4	238.8	1.0	238.2	238.4	238.7	0.5
Ste. Agathe	235.3	236.3	236.8	1.5	235.6	236.3	236.6	0.9
St. Adolphe	233.8	235.0	235.5	1.7	234.2	235.0	235.4	1.2
Above Floodway Inlet	232.7	234.5	235.1	2.4	233.7	234.4	234.7	1.1
Below Floodway Inlet	229.5	230.3	231.4	1.9	229.8	230.2	231.3	1.5
Assiniboine River								
St. Lazare	391.9	392.5	392.9	1.0	392.3	392.7	393.1	0.9
Miniota	378.9	379.5	380.1	1.2	378.9	379.5	380.0	1.1
Virden	370.9	371.2	371.7	0.7	371.0	371.2	371.6	0.6
Griswold	365.3	365.6	366.8	1.5	365.6	365.9	366.4	0.8
Brandon	358.0	359.0	360.1	2.2	358.2	358.9	359.7	1.5
Baie St. Paul	240.7	241.0	244.1	3.4	240.5	241.6	242.9	2.4
Souris River								
Coulter	431.8	432.7	433.5	1.8	432.6	432.8	433.2	0.7
Melita	429.5	429.8	430.2	0.7	429.8	429.9	430.0	0.2
Napinka	427.1	427.7	428.1	0.9	427.6	427.8	428.0	0.3
Hartney	422.6	423.3	424.0	1.4	423.4	423.7	424.1	0.6
Souris	412.6	413.3	414.2	1.6	413.2	413.6	414.2	0.9
Wawanesa	351.2	352.3	352.9	1.7	352.1	352.4	352.9	0.8

** Data provided by Manitoba Infrastructure and Transportation*

Tables 6.2 and 6.3 provide a comparison of the forecasted peak flows and water levels provided in the March 25 outlook forecast to actual snowmelt peak water levels in 2011. Table 6.2 indicates that for the Souris River, which experienced a snowmelt peak in the April 21-25 period, the lower and upper decile peak flow forecasts varied between about -10 to +22 percent from the median, and that the actual peak throughout the basin was between 11 percent and 27 percent larger than the forecasted upper range. On the Assiniboine River the lower and upper decile peak flow forecasts varied from about -30 to +38 percent from the median, a much larger range than for the Souris. While the date and magnitude of the actual snowmelt peak is difficult to determine with precision for the Assiniboine River, it would appear that it occurred near the end of April and that, while it is disguised by the increase in flow associated with the April 29-30 rainfall, it was within the forecasted range. On the Red River, which peaked in mid to late April, the lower and upper decile forecasts varied from about -15 to +23 percent from the median. The actual snowmelt peak flows were generally about 10 to 12 percent below the forecasted lower range.

The actual peak water levels came in within the range of the outlook forecast on the Assiniboine River only because the forecasted range was so large. On the Souris River the actual water levels proved to be somewhat lower than what was forecast while on the Red River the levels came in substantially lower than what was called for in the outlook forecast (Table 6.3).

Table 6.2: Comparison of the March 24 spring flood forecast to actual snowmelt flood peaks

Location	Range of Peak Discharge Forecast *				2011 Snowmelt Peak Discharge			
	Lower Decile (m^3/s)	Median (m^3/s)	Upper Decile (m^3/s)	Range as Percent of Median	Actual Peak (m^3/s)	Date	Peak Above or Below Range (m^3/s)	Percent Above or Below Range
Red River								
Emerson	2490	2920	3600	-15/+23	2240	Apr 24	-252	-10
Letellier	2550	2990	3680	-15/+23	-	Apr 26	-	-
Morris	2480	2900	3570	-14/+23	-	Apr 29	-	-
Ste. Agathe	2420	2820	3480	-14/+23	2140	Apr 30	-279	-12
Above Floodway	2430	2820	3470	-14/+23	2150	May 04	-271	-11
Assiniboine River								
St. Lazare	254	373	519	-32/+39	375 (1)	Apr 26	In Range	In Range
Miniota	303	434	598	-30/+38	495 (1)	Apr 27	In Range	In Range
Virden	319	450	617	-29/+35	547 (1)	Apr 30	In Range	In Range
Brandon	353	480	650	-26/+35	622 (1)	Apr 30	In Range	In Range
Souris River								
Coulter	264	295	360	-10/+22	430 (2)	Apr 21	70	19
Melita	294	325	389	-10/+19	494	Apr 22	105	27
Napinka	291	323	386	-10/+19	-	-	-	-
Souris	342	381	452	-10/+19	510	Apr 23	58	13
Wawanesa	340	379	450	-10/+19	501	Apr 25	51	11
Tributaries								
Qu'Appelle River	161	173	191	-7/+10	345	May 05	154	81
Shell River	11.0	13.0	16.0	-13/+22	72.0	May 11	56.0	350
Antler River	76.0	85.0	93.0	-10/+10	79.0	Apr 18	In Range	In Range
Pipestone Creek	48.0	54.0	62.0	-12/+14	124	Apr 16	62.0	100
Medora Creek	25.0	27.0	31.0	-10/+14	23.5	Apr 09	-1.5	-6

** Data provided by Manitoba Infrastructure and Transportation*

Notes: (1) Estimated based on apparent date of snowmelt peak. (2) Flow at Coulter assumed to be the same as at Westhope.

Table 6.3: Comparison of March 24 snowmelt peak level forecast to actual peak level

Location	Range of Peak Level Forecast*				2011 Spring Peak Level	
	Lower Decile (m)	Median (m)	Upper Decile (m)	Range as Percent of Median	Actual Level (m)	Height Over/Under Upper Decile (m)
Red River						
Emerson	241.1	241.4	241.5	0.4	240.9	-0.6
Letellier	239.4	239.6	239.7	0.3	239.2	-0.6
Morris	238.2	238.4	238.7	0.5	237.5	-1.2
Ste. Agathe	235.6	236.3	236.6	0.9	235.2	-1.4
Above Floodway	233.7	234.4	234.7	1.1	232.8	-1.9
Assiniboine River						
St. Lazare	392.3	392.7	393.1	0.9	392.7	In Range
Miniota	378.9	379.5	380.0	1.1	379.6	In Range
Virden	371.0	371.2	371.6	0.6	371.7	0.1
Brandon	358.2	358.9	359.7	1.5	359.3	In Range
Souris River						
Coulter	432.6	432.8	433.2	0.7	-	-
Melita	429.8	429.9	430.0	0.2	430.3	0.3
Napinka	427.6	427.8	428.0	0.3	-	-
Souris	413.2	413.6	414.2	0.9	414.4	0.2
Wawanesa	352.1	352.4	352.9	0.8	352.9	In Range

** Data provided by Manitoba Infrastructure and Transportation*

The underestimation of the flood peaks on the Souris River and the overestimation of peak flows on the Red River, in spite of a relatively large range between the upper and lower decile forecasts, is not a reflection of the forecaster's skills. Rather, it is a reflection of the inability of such long lead time forecasts to take into account the full range of all meteorological uncertainties (rain, temperature, warming pattern, etc.) without resorting to such a wide range in forecasted flows that it essentially renders the forecast useless.

The 2011 Spring Flood Outlook Reports were, without question, instrumental in the early mobilization of flood mitigating activities and resources and provided a somewhat reasonable projection of the snowmelt peak given the significant amount of lead time. However, the inability of these forecasts to take into account rain that fell after April 15, and the fact that many of the larger historical floods have been generally associated with rain on snow during or shortly after the snowmelt period, the forecasts provided in these reports were ultimately of limited use, while at the same time creating false expectations. Furthermore, since the reliability of a forecast would be judged on how it compares to the absolute peak, not on the basis of how accurate it would have been had it not been for the additional rainfall, there would be a high risk of producing a bad forecast. Furthermore, the detailed information in these long range outlook forecasts could be counterproductive in that they can, and do, create situations where the forecasters' credibility comes into question, not because of poor forecasting capabilities, but because of unrealistic expectations.

6.4.2 Summer Flood Forecasts - Flood Sheets

In 2011, Regulatory and Operational Services of Manitoba Water Stewardship put out a daily, or near daily, operational forecast (flood sheet) for five main regions/river basins within the province:

- The Pas-Swan River Region that comprised at least eight locations, including the North Saskatchewan River at the Pas,
- Manitoba Lakes that comprised 13 locations, including Dauphin Lake and Lake Manitoba,
- Assiniboine River and its major tributaries that comprised 20 locations, including Brandon and Portage la Prairie,
- Souris River that comprised 15 locations, including the town of Souris, and
- Red River that comprised 20 locations, including those at Emerson and Ste. Agathe.

Appendix D contains examples of these flood sheets that demonstrate the locations of concern and the type of data that was being reported. For a widespread flood like 2011, there would have been a need to assess, forecast and report flows and/or water levels at 76 locations, at least, on a daily basis. This was a somewhat daunting task. The flood sheets provided a range of information about flows and/or water levels that would include, but not be limited to the following.

- A report of the conditions on the day, or just prior to the day, that the flood sheet was prepared. This would have included an estimate of the flow and the water level or stage. The daily report would also document the change in flow or water level since the last report and the total increase over the duration of the flood, relative to some baseline condition.
- The forecasted peak stage or discharge and the expected date or range of dates of its occurrence. These were the most critical pieces of information contained in the flood sheets since they provided an outlook for what would be expected and help guide the level and scope of mitigation measures at each of the salient locations.
- The existing channel capacity or critical water level and the elevations of any salient structures. These levels were important reference levels to assess the severity of the forecasted flood event.
- Finally, previous peak stages and/or flows were provided for one or two severe events in the historical period. These assisted in providing a framework for local authorities or residents to assess the severity of the event that was unfolding.

The flood sheets were provided as soon as possible during the day, and were usually prepared in the very early morning. Most of the information in the flood sheets was known *a priori* - the historical flood levels and the incipient flood levels or elevations of structures, for example. The current conditions were based on the most up to date data that were provided from field staff, from real-time gauges operated by the Province or supplied in real time by WSC. These data can be assembled in a routine manner except when gauges are inoperative or errors are made when carrying out field measurements. The conversion of water levels to flows, and vica versa, however, requires an understanding of the local hydraulic conditions. These may be complicated by changing channel characteristics during the course of a flood and a systematic methodology is required to allow for the updating of rating curves (relationship between water level and discharge) on a real-time basis.

As per the locations identified in the Terms of Reference for this review, the reliabilities of the operational forecasts were assessed over the time period between mid-April and when the flood peak occurred for the following locations:

- North Saskatchewan River at The Pas,
- Dauphin Lake,
- Souris River at Town of Souris,
- Assiniboine River at Brandon,
- Assiniboine River at Portage la Prairie (Holland),
- Red River at Emerson and Ste. Agathe, and
- Lake Manitoba.

North Saskatchewan River at The Pas

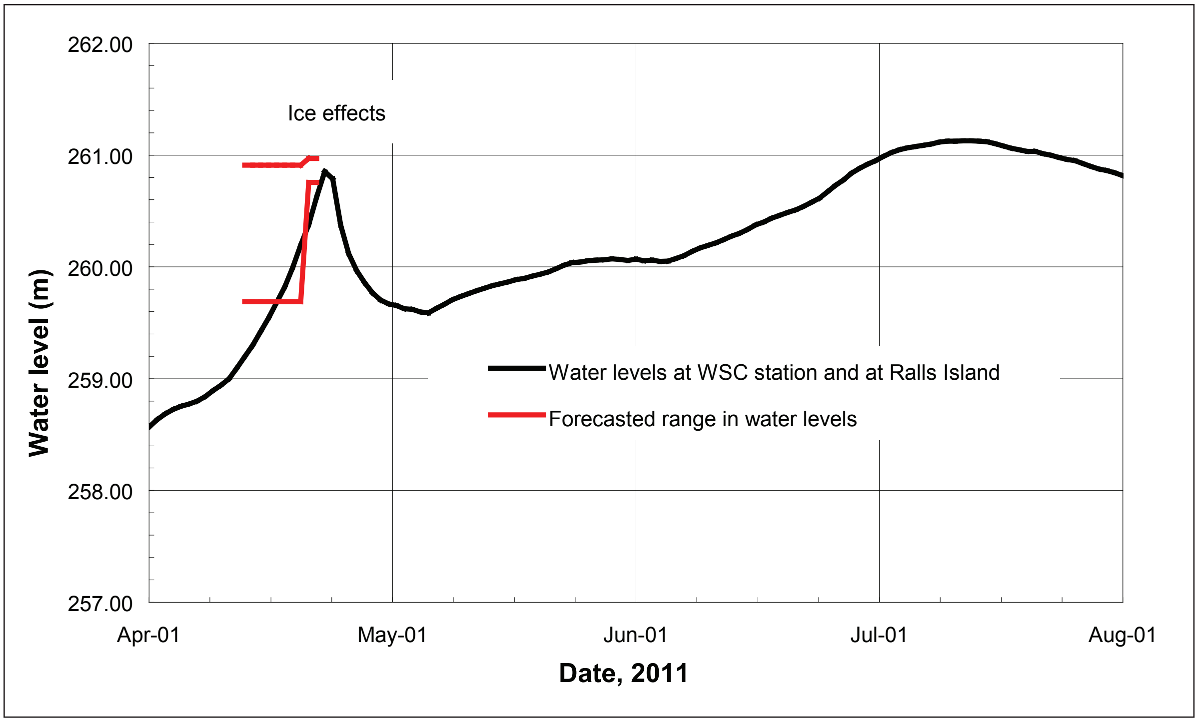
Flow and water level forecasts for the Saskatchewan River at The Pas were undertaken for a variety of locations extending from the Hwy 10 bridge downstream to the WSC hydrometric gauge and subsequently to Ralls Island, a distance of about 10 km. The WSC gauge would have the best water level record over the pre-flood period but water levels also were of interest at the bridge and Ralls Island because of the temporary dikes (some of which were meant to become permanent) that were being constructed at those locations. This review is focused on the Ralls Island and WSC gauge locations since water levels at those two sites are almost identical and both could be served by the same water levels forecast.

Typically, two types of events are forecasted at The Pas, open water flood levels and ice jam flood levels. The open water floods are forecasted by routing outflows from Tobin Lake (a hydropower installation operated by SaskPower) downstream though Cumberland Lake and ultimately to The Pas. Knowing the outflows at Tobin Lake and accounting for storage effects in Cumberland Lake allows for a systematic evaluation of flows and subsequent water levels at The Pas. The more severe floods at The Pas appear to be a result of high outflows from Tobin Lake with a relatively small contribution from local inflows such as the Carrot River. The lag time between peak releases from Tobin Lake and the peak at The Pas is about 10 days as evident in 2011. Clearly, knowing in advance the expected timing and magnitude of the peak outflow at Tobin Lake would allow for more lead time, but just relying on real-time information at Tobin Lake still provides at least 10 days of advance warning for the peak at The Pas.

Forecasting ice jam floods is much more complicated and involves not only a forecast of the flow, but also a forecast of how the ice cover will respond to the increasing flows during the early part of the snowmelt runoff period. The forecasting methodology involves an assessment of the water level at which the ice cover will mobilize, its tendency to accumulate into a jam, and finally, the expected thickness of the ice accumulation and the associated water level - both of which are a function of the flow. Although there is a theoretical framework for these processes, extensive model calibration on the basis of empirical measurements are required to produce reasonably accurate forecasts.

In 2011, the forecast at The Pas focused on the ice-related water levels with no apparent attempt to predict the timing of the peak level. The first forecast of expected water levels was made on April 13, by which time water levels had increased about 1.6 m (5.2 ft) from the late-winter levels (Figure 6.7). The flow at that time would have been about 850 m^3/s (30,000 cfs). The expected range in the ice-related peak water level was estimated on the basis of routed outflows from Tobin Lake and an assumed local inflow contribution that would be equal to an appropriate analogous year. The range in water levels was expected to be between 259.7 m (852.0 ft) and 260.9 m (856.0 ft), a difference of 1.2 m (4.0 ft). This forecast was subsequently amended to a range of 260.8 m (855.6 ft) to 261.0 m (856.3 ft) on April 22 at a point about two days prior to when the peak actually occurred. The peak ice-related level turned out to be 260.9 m (856.0 ft), about 0.10 m (0.3 ft) below the top end of the predicted range. Forecasting of water levels was discontinued after the ice-related peak occurred even though flows continued to increase until about July 6 when the river peaked at a flow of about 2300 m^3/s (81,000 cfs) and a corresponding water level of 261.1 m (856.6 ft).

Figure 6.7: Comparison of actual and forecasted ice-related water levels, Saskatchewan River at The Pas.



Overall, the forecast ended up being useful because the ice-related water levels never exceeded the upper end of the forecasted range and the open water flood only exceeded that upper end of the forecast range by about 0.1 m (0.3 ft). However, from a methodological perspective in which the range of the ice-related water level forecast is based on an adopted range of ice-related hydraulic parameters, a good forecast would have had the ice-related peak fall somewhere close to the mid-range of the forecast. Therefore, the forecast was not as good as it could have been, either because of an inadequate understanding of the ice parameters or a poor forecast of the flows. From discussions with personnel in the forecasting group it was not clear what contributed to the forecasting outcome.

Dauphin Lake

Dauphin Lake water levels fluctuate in response to differences between inputs which include inflows from contributing watersheds such as the Valley River and precipitation directly over the lake, and outputs which include outflows via the Mossy River and evaporation from the lake surface. On average, Dauphin Lake tends to rise during the April to mid-June period when inputs exceed outputs, and tends to fall after mid-June when outflows and evaporation exceed the inputs.

Fundamentally, because the relationship between the lake level and the outflow is well known and because the gross evaporation does not vary appreciably from year to year, the lake level could be forecasted fairly accurately to within a fairly narrow range if the total inflow volumes could be reasonably forecasted. However, while the spring snowmelt runoff volume, which is dependent on the accumulated snowpack, can be forecasted with a reasonable level of accuracy, there is total uncertainty, particularly in wet years, as to level of the additional precipitation and runoff that could be expected in the ensuing months. As such, the procedure that has been adopted for the simulation and subsequent forecast of lake levels is one in which the inflows from selected analogous years are applied to a lake water balance model to generate a simulated set of lake levels from which the peak level can be extracted. The projected future levels are updated, presumably by selecting a more representative year, only if the simulated lake levels appear to be deviating significantly from the actual lake levels.

In 2011, the lake level began to rise in early April in response to snowmelt inflows (Figure 6.8) reflected in the Valley River discharge hydrograph. The lake levels then responded again to additional significant inflows in early May that were derived from a rain event in late April as represented by 40 mm (1.6 inches) of rain in the last two days of April at Gilbert Plains (Figure 6.9). Subsequent rainfall events that occurred throughout May and into mid-June continued to generate additional inflows, albeit at a progressively lower rate due to the reductions in the runoff coefficients (drying out of the landscape), thereby increasing lake levels until late June when the water level peaked at about 262.3 m (860.6 ft). After that date, in spite of a number of major rain events, the runoff produced by the basin was less than the evaporation and outflow from the lake, and lake levels dropped over the rest of the year.

Figure 6.8: Valley River Inflows and Dauphin Lake water levels, 2011.

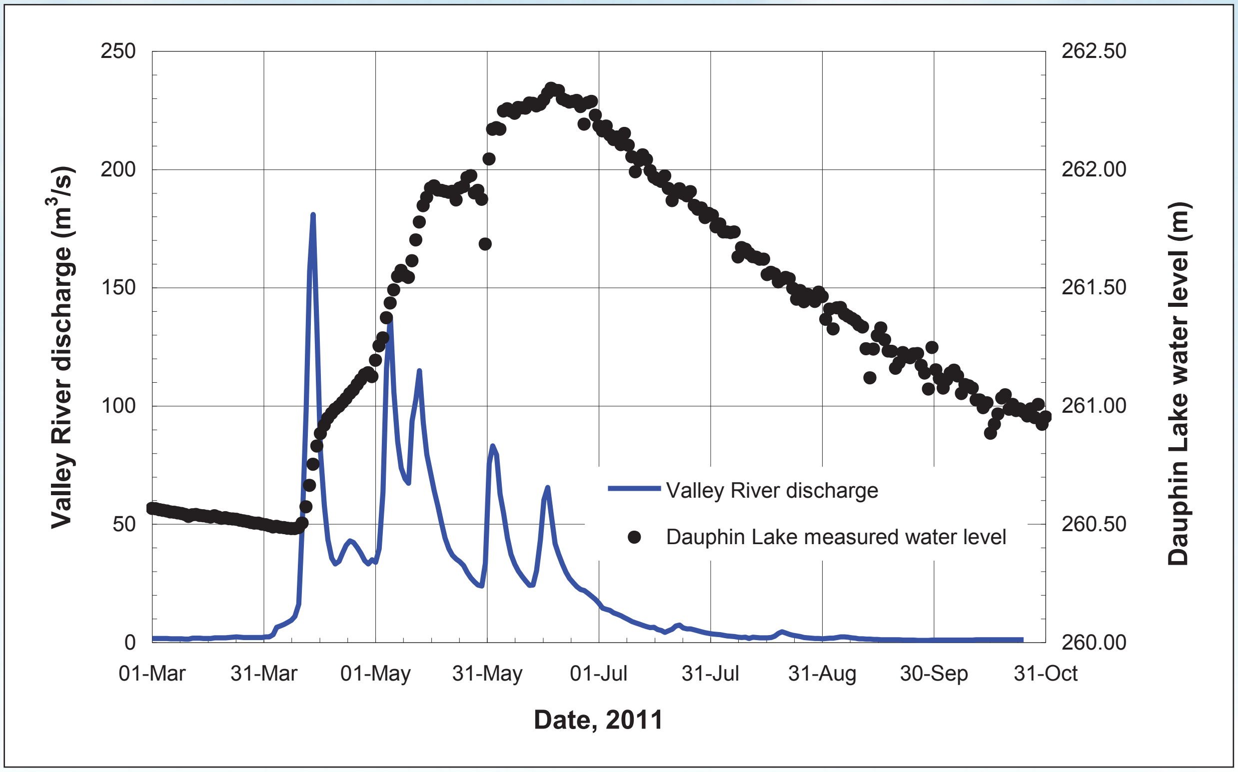
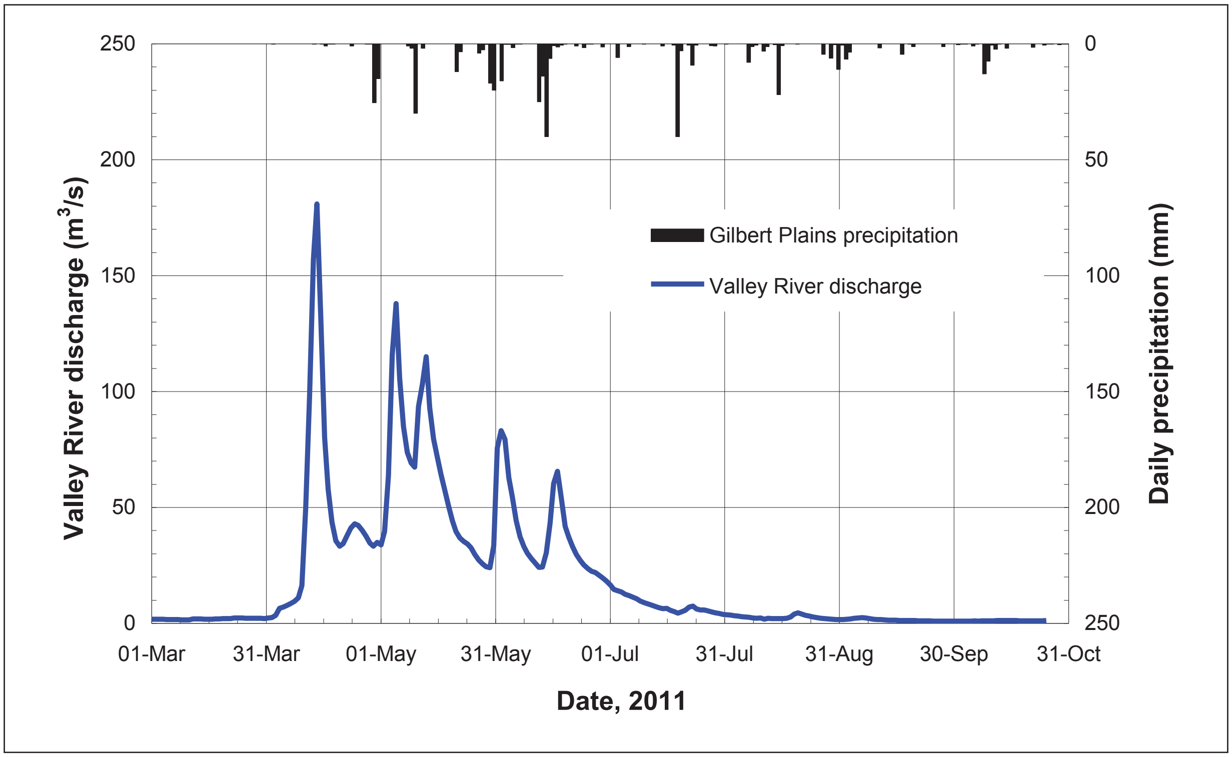
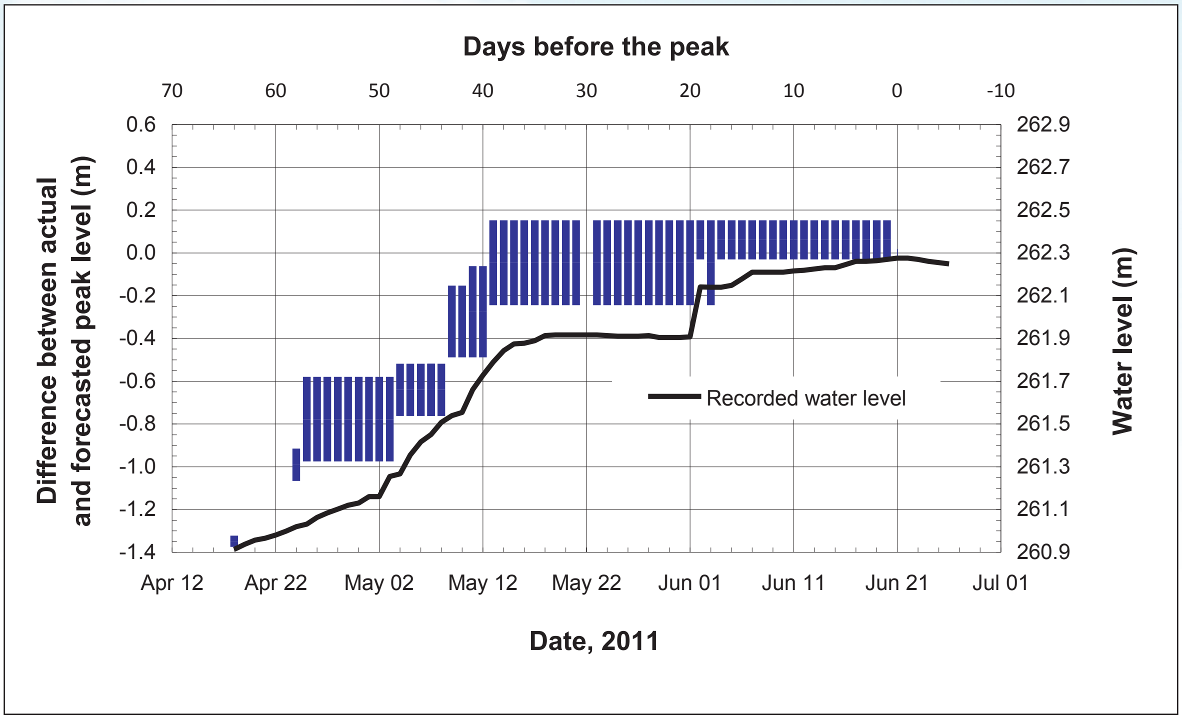


Figure 6.9: Precipitation and flows in the Valley River watershed, 2011.



The first forecast of the peak lake level was made on April 18 (Figure 6.10) on the basis of the accumulated snowpack and the expected runoff. This forecast suggested a peak lake level of about 260.9 m (856.0 ft), or about 1.4 m (4.6 ft) lower than what was eventually experienced. As the April 18 water level for Dauphin Lake was already at an elevation of 260.9 m (856.0 ft), this initial forecast was obviously in error. The forecast was upgraded on April 25 once the spring runoff was nearly complete and its severity known. While the lake initially appeared to plateau within the range of this forecast, ultimately this forecast was still 0.6 to 1.0 m (2.0 to 3.3 ft) too low due to subsequent rainfall in the basin and the resulting high runoff from the contributing watersheds. The forecasted peak was increased again to between about 262.1 and 262.5 m (860.0 to 861.2 ft) on May 13, close to the end of a period of runoff that occurred as a result of two precipitation events that occurred in the first two weeks of May. This forecast proved to be within plus or minus 0.2 m (0.7 ft) of the actual peak that occurred some 40 days after the forecast.

Figure 6.10: Difference between actual and forecasted peak level - Dauphin Lake.

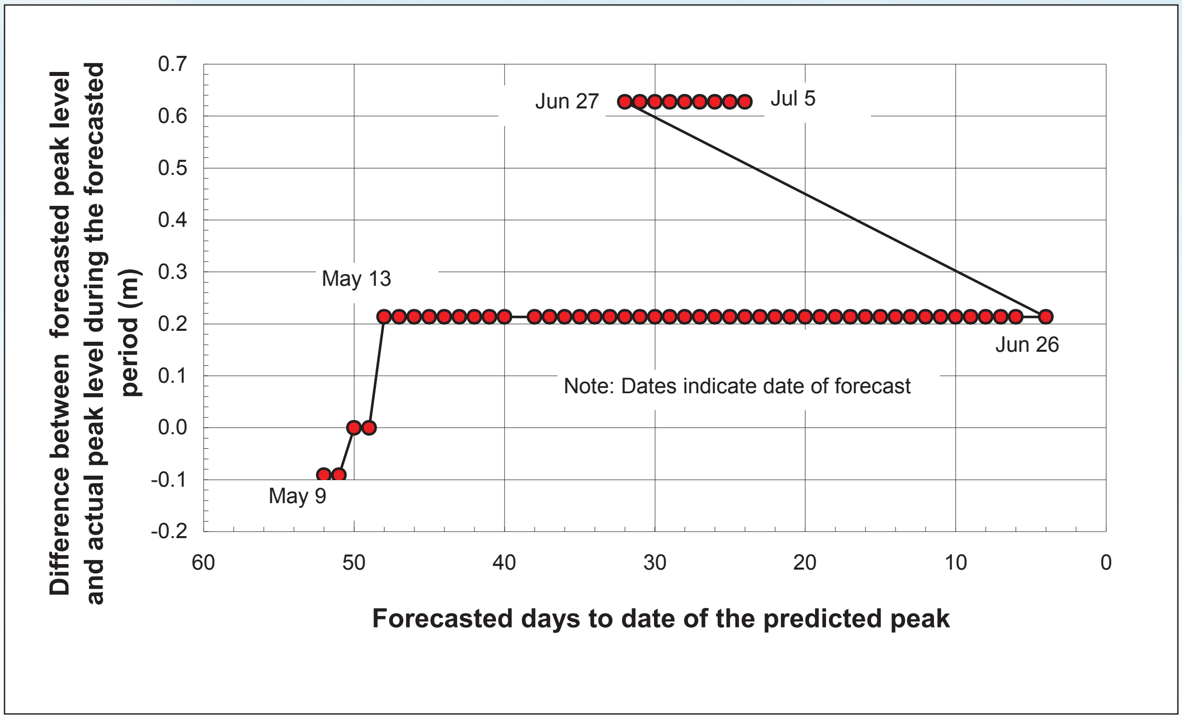


On June 2, after the completion of runoff from several additional storms, the forecast range was refined such that the bottom of the range ended up being equal to the actual peak and the top end of the range was about 0.2 m (0.7 ft) higher than the peak.

It is clear that the forecast was upgraded numerous times during the forecasting period in response to the multiple rain and ensuing runoff events. Generally, however, the forecasted peak level tended to be between 0.2 and 0.6 m (0.7 to 2.0 ft) higher than the prevailing lake level. Notwithstanding the effects of the severe wind event that occurred in late May, the forecast in early June that led up to the peak on June 21 was about 0.2 m (0.7 ft) higher than the actual peak. From the consideration of the area of the contributing basin, the area of the lake and the outflow that could be expected, an increase in lake level of 0.2 m (0.7 ft) would correspond to an equivalent runoff depth of about 17 mm (0.7 inches) which for a summer runoff event would require a rain event of more than 100 mm (4 inches) over all the contributing watersheds. This seems like an unlikely possibility given the large contributing area and the minimal response of the Valley River to late summer rain events (Figure 6.9).

While Figure 6.10 is concerned with the forecast accuracy up to the time of the peak water levels, Figure 6.11 shows how the accuracy of the upper bound of the forecasted water level changed relative to the forecast period in the time leading up to the peak lake level. On May 9, the peak was forecast to occur about 52 days into the future (June 30) but it was underestimated by about 0.1 m (0.3 ft). On May 13 the peak was estimated to occur 48 days into the future (still June 30) but it was overestimated by 0.2 m (0.7 ft). The forecasted date of peak did not change (always forecasted to be June 30) until June 27 when it was changed to July 29, even though the peak had already occurred on June 21. At that point, the peak water level was overestimated by about 0.6 m (2.0 ft).This was likely because of an allowance was made for either wind-affected lake setup and wave uprush or additional rain and runoff that was expected in the forecast period which never occurred, or if it did occur it did not produce significant runoff.

Figure 6.11: Evolution of accuracy of forecast water levels on Dauphin Lake, 2011.



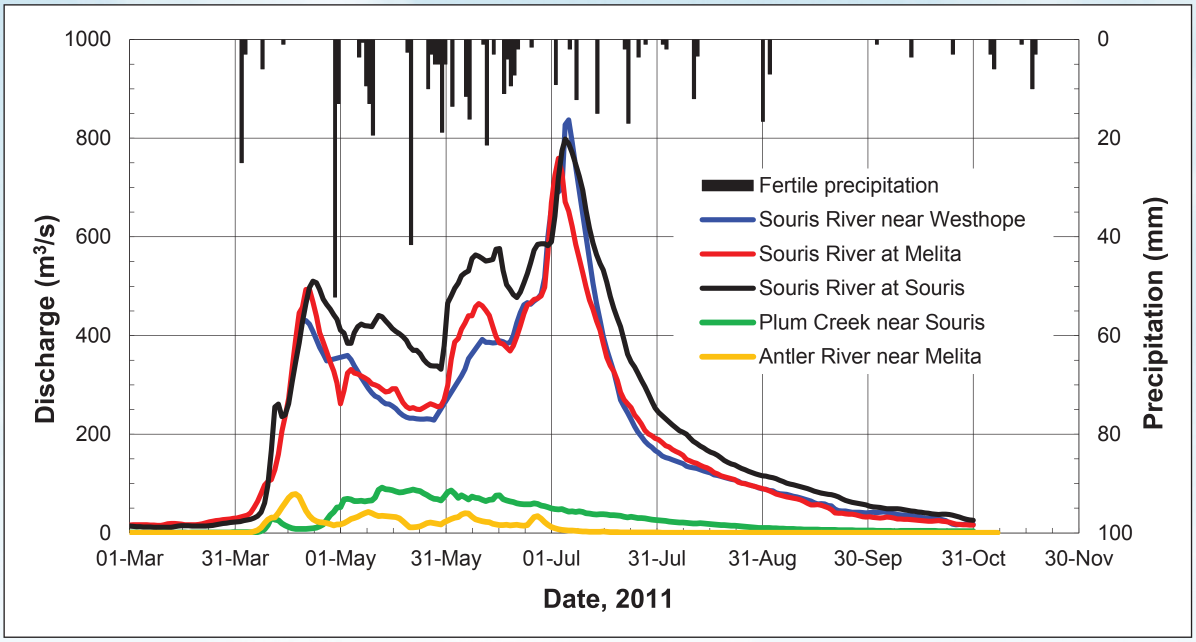
Overall, the peak level of Dauphin Lake was predicted to be about 0.2 m (0.7 ft) higher than it actually was, as long as 40 days in advance of the date of the actual peak. This should be considered to be a good forecast. Difficulties appeared to arise after the peak when the expected rain-related runoff did not occur and the lake level forecast ended up being 0.6 m (2.0 ft) too high.

Souris River at the Town of Souris

Forecasts for the Souris River are based on the routing of the flood hydrograph downstream from Westhope while including flows from the local, mostly gauged, sub-watersheds within Manitoba. The flood hydrograph at Westhope is generally synthesized on the basis of five to seven day forecasts of flows provided by NWS. The HFC has the option of starting the model from Minot, ND if there is uncertainty as to the reliability the NWS forecast for Westhope. On average, the peak at Westhope constitutes about 70 percent (more in the case of large floods) of the peak in the lower Souris River at Wawanesa. As such, flood forecasts for the Souris River in Manitoba are highly dependent on the accuracy of the forecasted or observed flows for the Souris River at Westhope and Minot, ND.

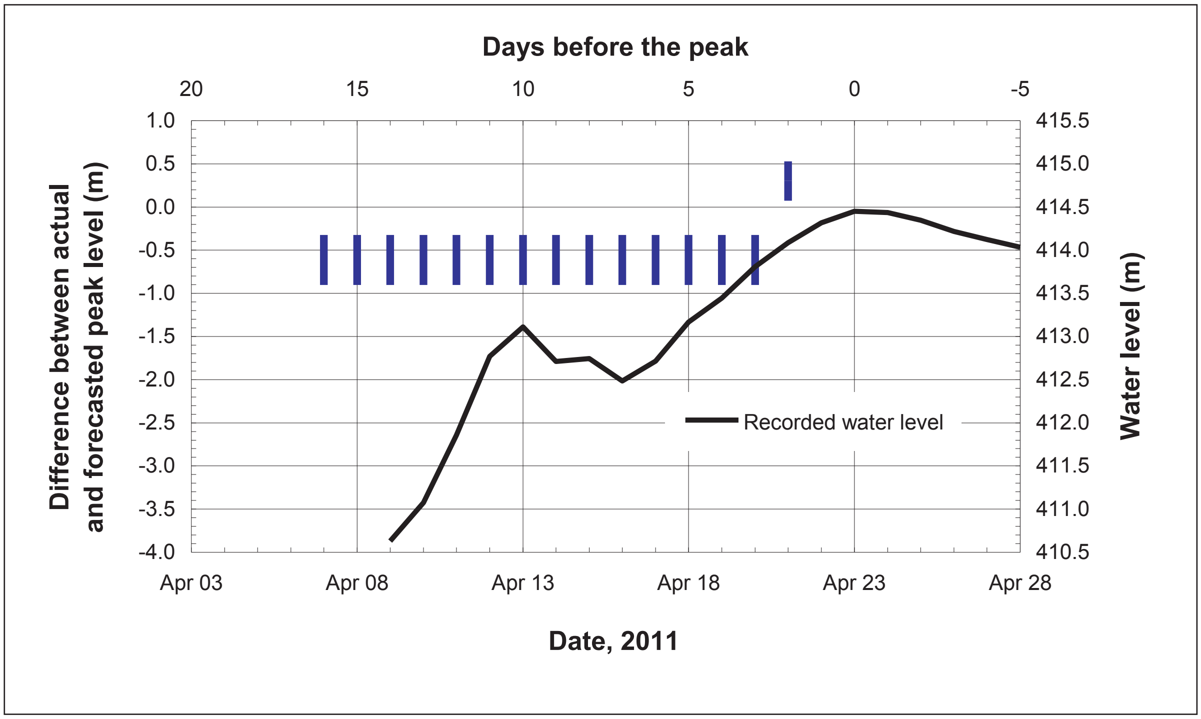
In 2011, the forecast period on the Souris River extended over three months and was complicated by almost continuous rain in May, June and July (Figure 6.12). There were, however, two distinct and separate peaks. The spring peak related to snowmelt runoff occurred in late April and the summer peak in early July occurred as a result of significant rain events in May and June. Only the forecasts for those two individual peaks at the town of Souris are evaluated herein to eliminate the confounding effects of rain on the assessment of the accuracy of the intermediate forecasts.

Figure 6.12: Precipitation and flows at selected locations in the Lower Souris River watershed, 2011.



The first operational forecast for the spring peak was made on April 7, some 16 days before the spring peak arrived on April 23 (Figure 6.13). The forecasted peak water level range for this event was consistently about 0.5 to 1.0 m (1.6 to 3.3 ft) too low for the entire period between April 7 and April 20. On April 21, two days before the peak occurred, the forecast was revised upward. At that point the upper limit of the range of the forecast called for water levels that exceeded the actual peak by about 0.5 m (1.6 ft). The lower limit of the forecast was close to the actual peak.

Figure 6.13: Comparison of actual and forecasted spring peak levels on the Souris River at Souris.

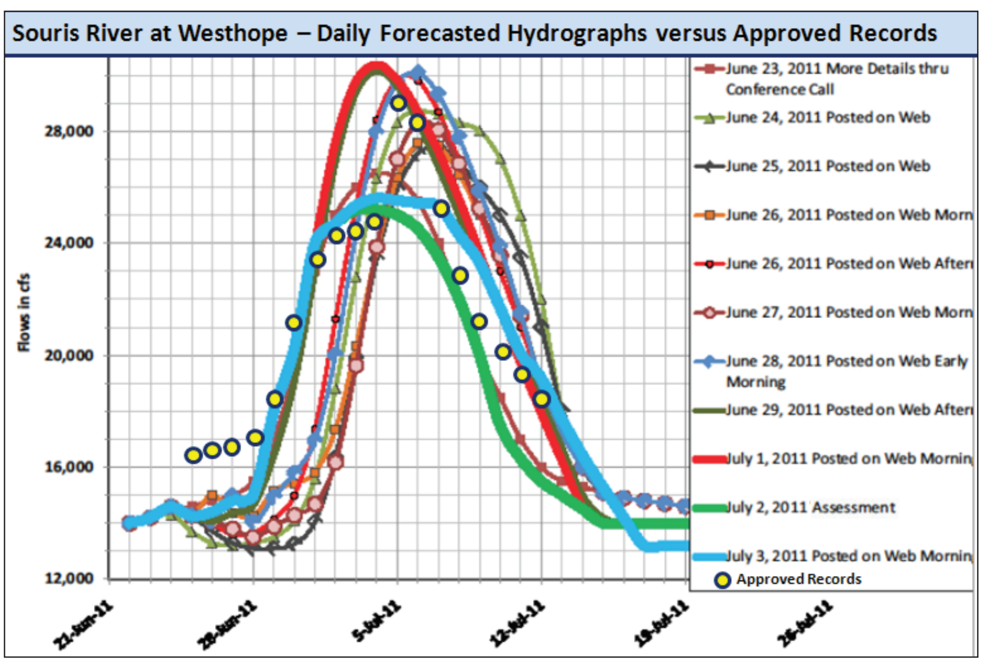


Given that by mid-April all tributaries in southern Manitoba had peaked and were well into recession, and that nearly 75 percent of the drainage area between Westhope and Souris is gauged, the forecast at this stage should have been primarily based on the routing of the synthesized hydrograph for Westhope and observed local inflows between Westhope and Souris. This would have provided a more accurate forecast than that issued on April 7. The fact that this increased level of accuracy was not attained until April 21, two days after the peak flow had already been declared for Melita, would seem to suggest that there was uncertainty about the forecast at Westhope, which cannot be assessed as these forecasts were not archived, the routing model between Westhope and Souris is unreliable, or a procedure other than flood routing was being used to generate the Souris forecast.

It is curious that on April 18 a revised forecast was made for the Souris River at Melita but there was no corresponding revision to downstream locations, as would be expected. This would seem to suggest that the revised forecast on April 21 was made on the basis of the observed flows at Westhope and Melita with allowances for local inflows between those stations and Souris, as suggested by the measured flows on Plum Creek and Antler River (Figure 6.12). Adding local inflows of 100 m^3/s (3500 cfs) on the basis of the Antler Creek and Plum Creek gauges (if their flow was prorated on an area basis) to the Westhope peak of about 420 m^3/s (14,800 cfs) would have resulted in a peak flow at Souris of about 520 m^3/s (18,400 cfs). This would have produced a peak water level of 414.5 m (1359.9 m) that would have matched the actual peak exactly. The 0.5 m (1.6 ft) buffer added by the forecast provided for the potential for the peak flow to be greater by some 100 m^3/s (3500 cfs), or 15 percent, than what was actually forecast. This would have been equivalent to a 100 percent overestimate of the local inflows between Westhope and Souris.

The last operational forecast is focused on the period between June 22 and July 5 (Figure 6.12). During this period, flows at Souris increased from about 500 m^3/s (17,700 cfs) to about 800 m^3/s (28,300 cfs) in response to significant amounts of rain in mid-May. While the hydrographs for sub-basins between Westhope and Souris were known, as they had peaked and were in recession by June 21, considerable uncertainty in the synthesized flows for Westhope (Figure 6.14) continued throughout the event. The forecasts for Westhope, and likely for other locations throughout the system, were further complicated by the collapse of the Coulter Bridge, downstream of Westhope on July 1 and two conflicting discharge measurements, one on July 1 indicating a flow of about 700 m^3/s (24,700 cfs) the other on July 3 indicating a flow of about 870 m^3/s (30,700 cfs) for the same water level.

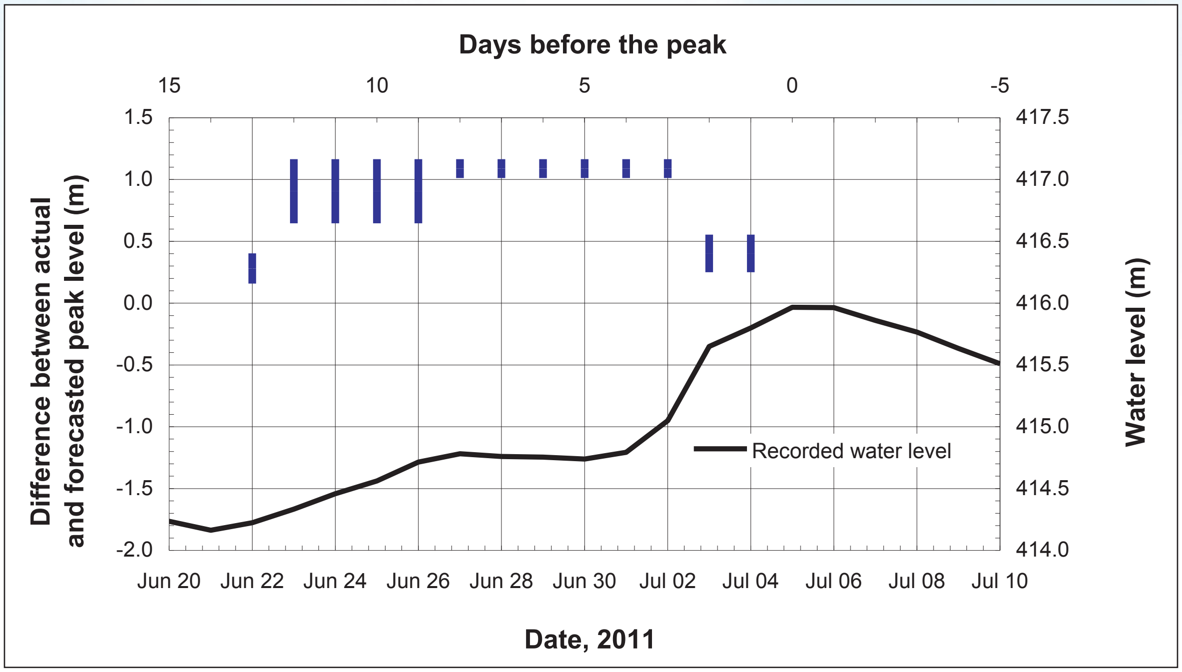
Figure 6.14: Forecast hydrograph for the summer flood event at Westhope.



The first forecast for this summer event was made on June 22, based on a NWS forecasted peak flow of 680 m^3/s (24,000 cfs) which was to occur on July 15. It suggested an expected peak water level range at Souris of 416.2 to 416.4 m (1365.5 to 1366.1 ft), about 0.2 to 0.4 m (0.7 to 1.3 ft) higher than what actually occurred (Figure 6.15). The HFC contacted NWS late on June 22 to express concern over the NWS forecast. On June 23 NWS raised its forecast for Westhope to 750 m^3/s (26,500 cfs) which resulted in the forecasted peak at Souris being raised to a range of 416.3 to 417.3 m (1365.8 to 1369.1 ft) now more than about 0.3 to 1.3 m (1.0 to 4.3 ft) higher than what was actually experienced. The top end of this range was maintained in the forecasts until July 2, three days before the peak, when the forecast was downgraded to a range of 416.2 to 416.6 m (1365.5 to 1366.8 ft). This still proved to be 0.2 to 0.6 m (0.7 to 2.0 ft) higher than the actual peak level.

Notwithstanding the poor discharge records, which still are only in a provisional state, the wide range in the forecasted water levels at Souris would seem to reflect the uncertainty in the NWS forecasted flows for Westhope. This uncertainly could have been due to a number of factors, including errors in discharge measurements, unknown backwater effects on water levels and complex floodplain flows. However, the residual error of 0.2 to 0.6 m (0.7 to 2.0 ft) in final forecast would seem to suggest that the routing model may not be as reliable as it could be.

Figure 6.15: Comparison of actual and forecasted summer peak level - Souris River at Souris



The evolution in the accuracy of forecasting and the date of the summer peak is shown in Figure 6.16. On June 22, the peak was forecasted to occur between July 16 to July 22, between 11 and 16 days after it actually occurred. Following a call from the HFC to the NWS expressing concern over the July 22 forecast for Westhope, NWS refined their Westhope forecast. From June 13 to July 4, the forecasted date of the peak varied from the actual date of the peak (July 5) to five days later (July 10) than when the peak actually occurred.

Figure 6.17 shows the evolution of the accuracy of forecasted water levels in relation to the forecast period in the time leading up to the summer peak. From June 23 (14 days out from the peak) until July 2 (five days in advance of the peak) the forecasted worst-case peak water level was overestimated by 1.2 m (3.9 ft). Only on July 5, virtually at the peak of the event, was the worst-case peak water level adjusted downward to a level 0.3 m (1.0 ft) greater than the actual peak level.

Forecasting the last and largest summer peak would have required an understanding of the flow at Westhope, the attenuation in the flood peak between Westhope and Souris and the local inflow between those two locations. To be conservative in the forecast, one could assume that there was no attenuation between Westhope and Souris and that the peak flow at Souris would be comprised of the Westhope flow plus the local runoff. Alternatively, a less conservative, but still conservative, forecast could be based on the assumption that the attenuation is offset by local inflow and the peak flow at Souris is more or less identical to that at Westhope. The least conservative forecast would factor in the attenuation and neglect the local inflow.

Notwithstanding the potential complications associated with the collapse of the Coulter bridge, the late June and early July NWS forecast called for peaks at Westhope between 800 and 850 m^3/s (Figure 6.14) or between 28,300 and 24,100 cfs. As early as June 23, one would have expected a local inflow of at most 200 m^3/s (7000 cfs) between Westhope and Souris on the basis of flows on Antler Creek and Plum Creek if their flow was prorated on an area basis. For this hydrologic scenario, the most conservative forecasting assumption would have produced a forecasted peak flow estimate of between about 1000 and 1050 m^3/s (35,300 and 37,100 cfs) at Souris which would produce a peak water level of about 416.8 to 417.0 m (1367.5 to 1368.1 ft). The actual forecast predicted a maximum water level of about 417.2 m (1368.8 ft) which would be equivalent to a discharge of about 1150 m^3/s (40,600 cfs). This would have been some 100 to 150 m^3/s (3500 to 5300 cfs) greater than could be expected from consideration of the Westhope forecast and the local inflows.

The actual peak at Souris was about 800 m^3/s (28,300 cfs) which, from the consideration of local inflows, suggests that the attenuated peak from Westhope was about 600 m^3/s (21,200 cfs), a reduction of some 200 m^3/s (7100 cfs) due to floodplain storage. This suggests that both the local inflows and the peak attenuation between Westhope and Souris were poorly estimated. This may be because meteorological forecasts that were indicating significant rain events that did not materialize and/or the routing model did not adequately reflect floodplain storage effects at such high flows.

Figure 6.16: Comparison of actual and forecasted date of summer flood peak - Souris River at Souris.

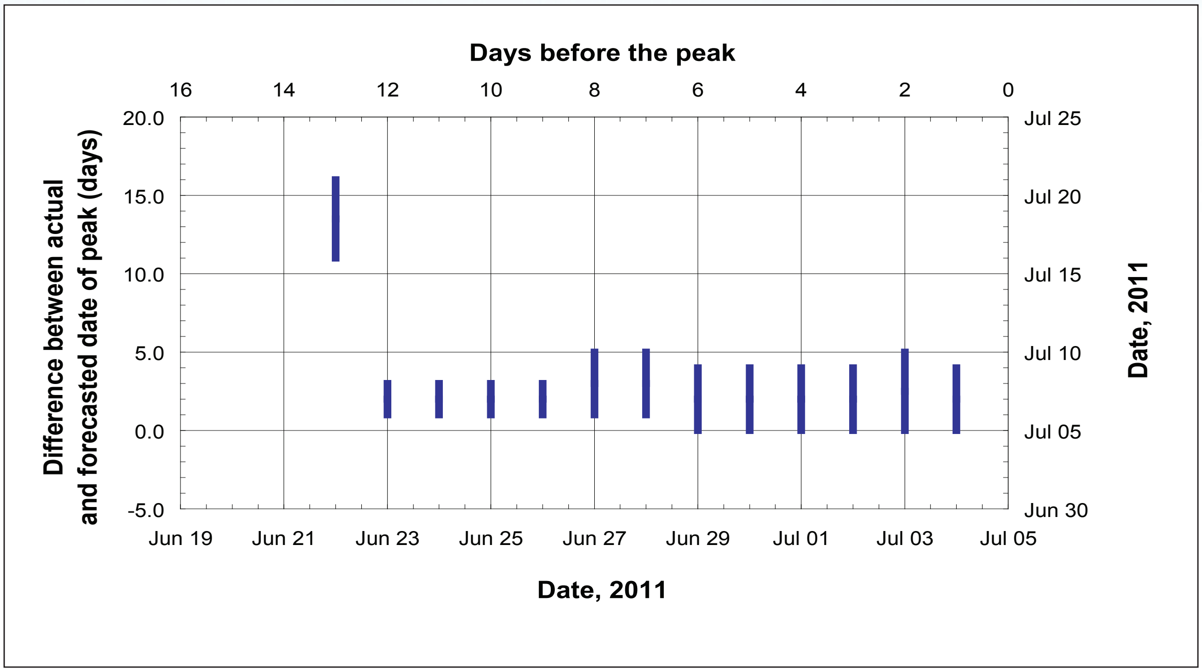
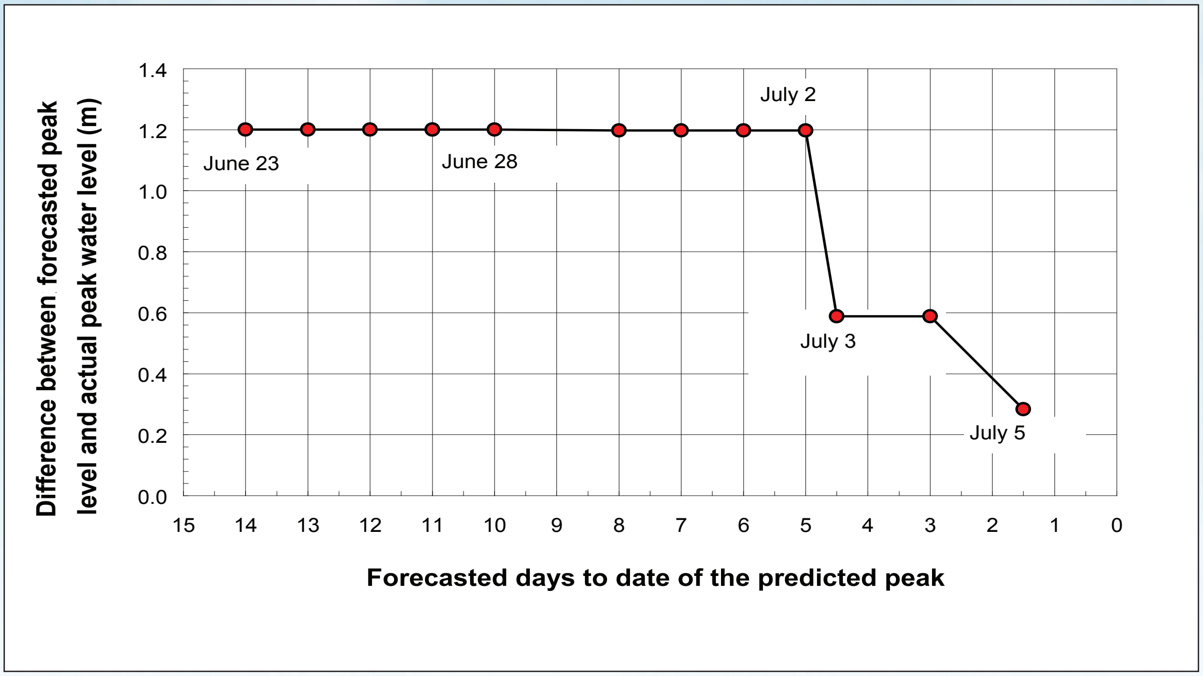


Figure 6.17: Evolution of accuracy of forecast water levels over time for the summer flood peak, 2011 - Souris River at Souris.



As in the case of the Dauphin Lake forecast, there also appears to be considerable difficulty in dealing with the runoff produced by summer rain events in the Souris River basin. One thing is clear from Figure 6.12, however, that significant summer rain events do not necessarily produce any significant runoff in the local basins, particularly in July and August.

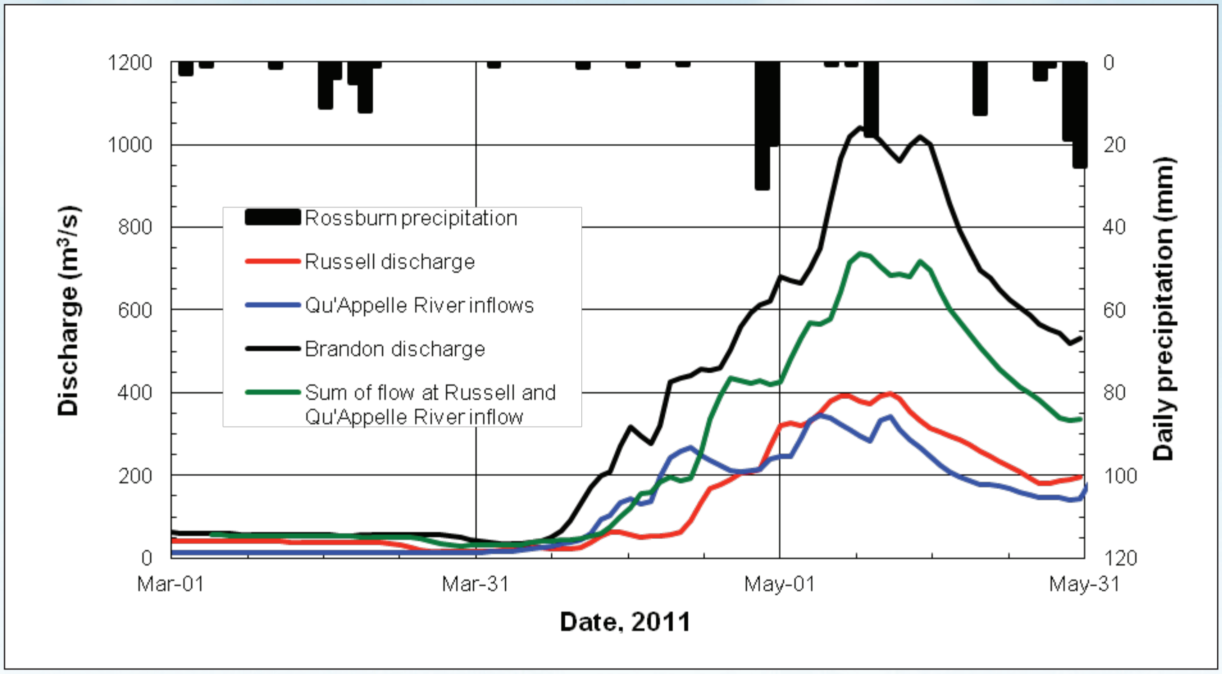
Assiniboine River at Brandon (Grand Valley)

Forecasts for the Assiniboine River are based on generated/observed flows from 10 gauged sub-watersheds, including the Qu'Appelle River, and 13 ungauged sub-watersheds. These are entered into a model that routes the flows through six reservoirs that includes Shellmouth and through a number of distinct channel reaches along the main stem of the Assiniboine River. The seven gauged sub-watersheds comprise about 30 percent of the total drainage area between Russell, Welby and Brandon.

For operational forecasting, the flow at Brandon can be represented by the sum of Assiniboine River flow at Russell (lagged three days), the Qu'Appelle River flow at Welby (lagged four days) and the inflows from the seven gauged tributaries (one of which is the Little Saskatchewan River) upstream of Brandon prorated to account for the ungauged area. With a real-time accounting of flows in the basin upstream, it should be possible to provide a reasonably accurate forecast of both the flow and the water level at least three to five days into the future (Figure 6.18) based simply on observed flows upstream. However, forecasting the magnitude and time of the peak further in advance than three to five days (as might be required for flood mitigation) is problematic because rain during the forecast period can significantly alter the outcome and make the forecast on any given day obsolete.

In 2011, the peak water level at Brandon occurred on May 9 due to rainfall-related runoff superimposed on the initial snowmelt event. The snowmelt runoff started in early April then tapered off on April 16, due to a return to below zero air temperatures, and then resumed at somewhat accelerated rate on April 18. The increase became more pronounced following a storm event on April 29/30 that deposited 10 to 30 mm (0.4 to 1.2 inches) of rain and snow in the headwaters of the Qu'Appelle and Assiniboine basins. This was a considerably lower amount than the 20 to 80 mm (0.8 to 3.0 inches) which had been forecasted. The Assiniboine at Brandon peaked at 1040 m^3/s (36,800 cfs) on May 9.

Figure 6.18: Precipitation and flows at selected locations in the Assiniboine River watershed upstream of Brandon.

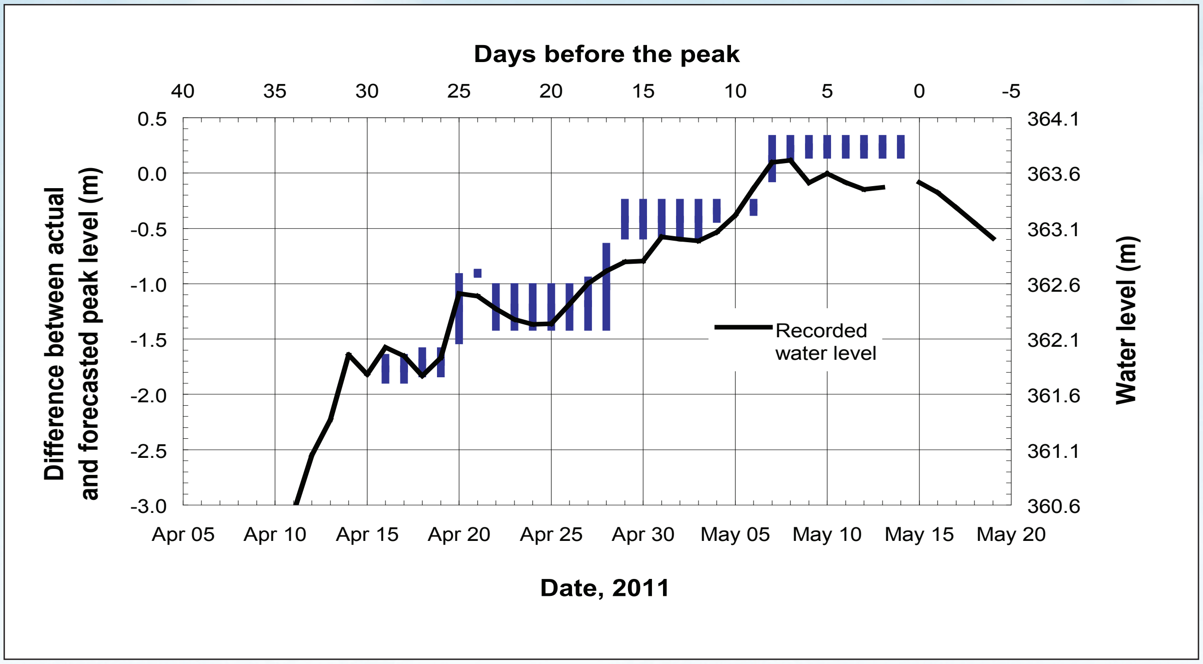


While forecasts for the Assiniboine were first issued on about April 7, the first forecast for Brandon (Grand Valley) were not issued until April 16. The initial forecast in the April 16 to 19 period (Figure 6.19) underestimated the ultimate peak by about 1.6 to 1.8 m (5.2 to 5.9 ft). But at the time of this forecast, the forecasters could not have anticipated the rainfall event that was to take place on April 29. On April 20 the forecasted lower bound on the peak level was increased by 0.3 m (1.0 ft) while the upper bound was increased 0.67 m (2.2 ft), likely in response to the actual observed water level having exceeded the previous forecast. The upper bound of the new forecast, however, was only 0.15 m (0.5 ft) above the observed level.

On April 21, Brandon (Grand Valley) and all upstream sites were reported as having crested, even though the Qu'Appelle at Welby and the Assiniboine at Russell, with the return of warmer weather, had risen significantly above their April 15 peaks. This would suggest that at the time, the forecasters were not aware of the precipitation and/or snow still on the ground in the headwaters of the tributaries. On April 22, the day after Brandon had been reported as having crested, the forecast was resumed with the new forecasted range varying from 362.2 to 362.6 m (1188.3 to 1189.6 ft), or from 0.17 m (0.56 ft) less than to 0.2 m (0.66 ft) greater than prevailing water levels. This forecast range continued virtually unchanged until April 28.

While it is difficult to say conclusively, the flood hydrographs for Russell, Welby and Brandon would seem to suggest that the snowmelt peak would likely have occurred on or about April 28 to 30. It would have achieved a maximum level of about 362.7 m (1190.0 ft) or between 0.7 and 0.9 m (2.3 and 3.0 ft) above the April 16-19 forecast range and between 0.1 and 0.5 m (0.4 and 1.7 ft) above the April 22-28 forecast.

Figure 6.19: Difference between actual and forecasted peak level - Assiniboine River at Brandon (Grand Valley).



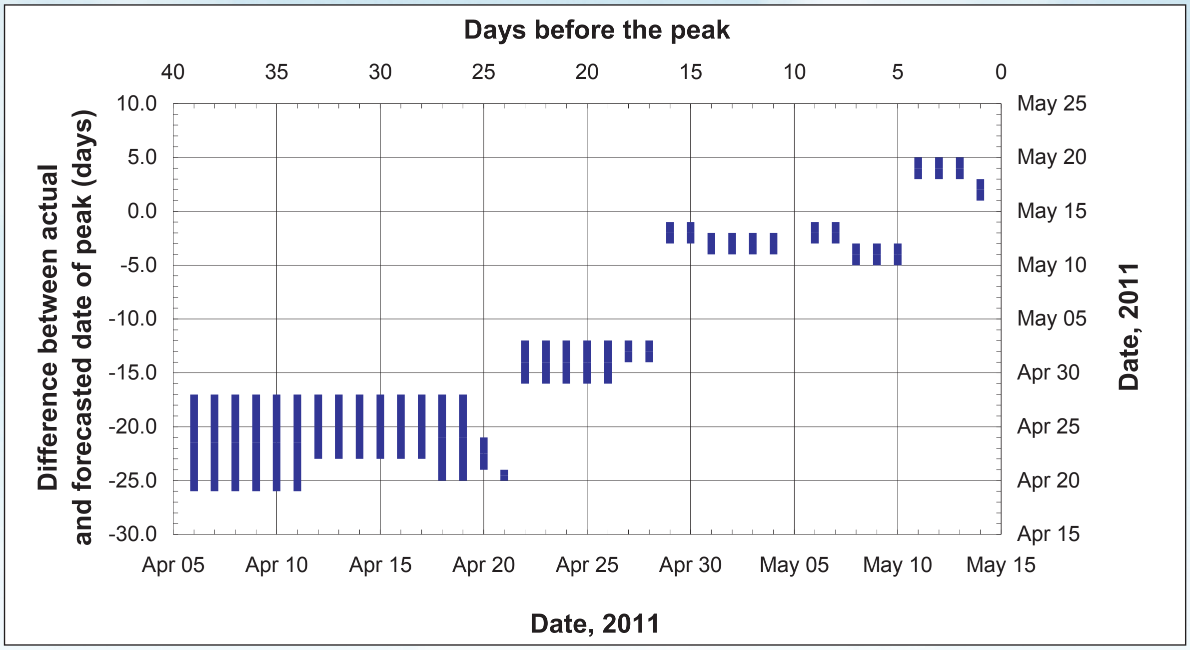
On or about April 28, a weather forecast was issued calling for 20 to 80 mm (0.8 to 3.1 inches) of precipitation in the headwaters of the Qu'Appelle and Assiniboine over the following few days. This would have created the expectation for flows to increase at Brandon. However, because the MANAPI model is principally a snowmelt model, it could not be used to generate a reliable rainfall runoff forecast in this situation. Instead, an alternative procedure based on the U.S. Soil Conservation Services' runoff Curve Number (SCS-CN) was used to calculate the runoff volumes and a synthesized summer hydrograph was developed "on the fly" to calculate the flows. The April 29 forecast had a range of 363.0 to 363.3 m (1190.9 to 1191.9 ft) or 0.4 m (1.3 ft) to 0.7 m (2.3 ft) below the actual peak level on May 9.

The April 29 forecast was maintained until May 3 even though only 10 to 30 mm (0.4-to 1.2 inches) of the forecasted 20 to 80 mm (0.8 to 3.1 inches) of precipitation was realized. It is difficult to assess the performance after May 3 as each day's forecast appears to be a slight adjustment being made in response to observed water levels exceeding the lower limit of the previous days forecast, while maintaining the lower limit of 0.1 to 0.3 m (0.3 to 1.0 ft) higher than the water level that had been experienced the previous day. This is likely a result of water level data at Virden and Griswold no longer being available due to the inundation of these gauges.

With respect to forecasting the time of the peak (Figure 6.20), the initial April 6 to 12 forecasts called for the snowmelt peak to occur between April 19 and April 28. While it is difficult to say precisely when the snowmelt peak would have occurred, the flood hydrographs for Welby, Russell and Brandon would seem to suggest it likely would have occurred around April 28 to 30. The cooling trend during the April 12 to 18 period, and likely the lack of knowledge of snow conditions in the upper parts of the basin during this period, resulted in an erroneous report that the Assiniboine River at, and upstream of Brandon, had crested by April 21.

However, the revised forecasts from April 22 to April 28 correctly called for the snowmelt peak to occur between April 29 and May 3. The April 29 to May 6 forecasts, which followed the April 29 to 30 precipitation, called for the peak to occur between May 11 and 14, when it actually occurred on May 9. This error in the forecasted timing of the peak by some two to five days is understandable for two reasons. The forecast was based on new procedures developed "on the fly" and the peak flows in the Assiniboine were nearly two times larger than previous record flows and as such would likely have shorter times of travel than had been previously calibrated for the Muskingum routing model.

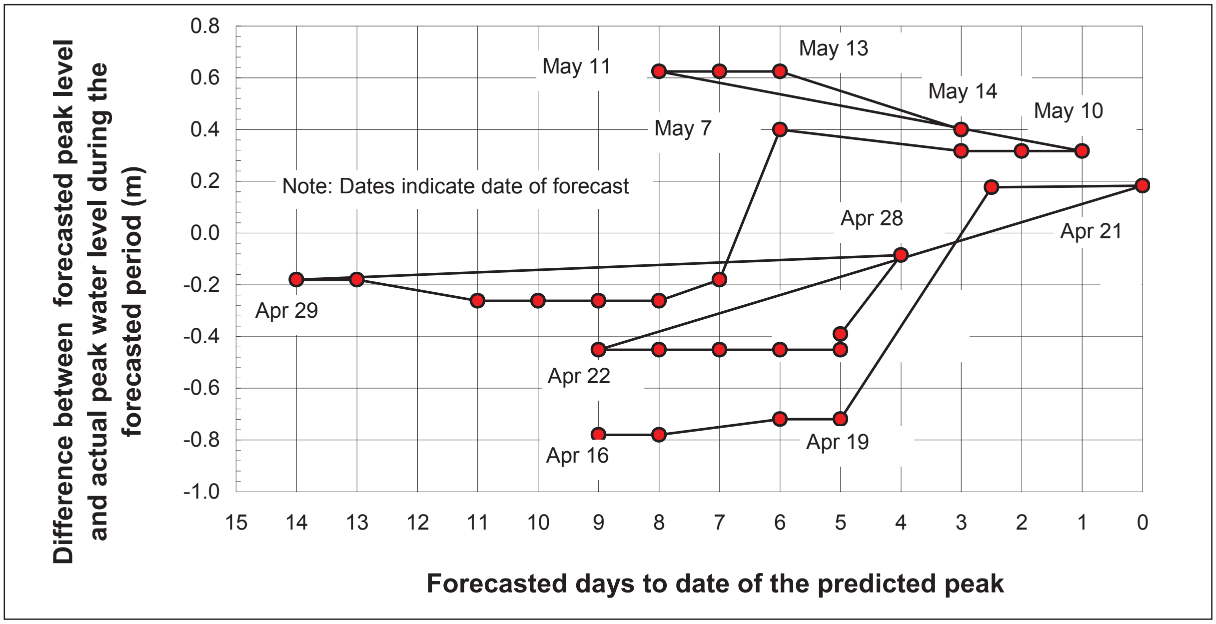
Figure 6.20: Difference between actual and forecasted date of peak - Assiniboine at Brandon (Grand Valley).



It is apparent that there were difficulties reconciling the need to forecast a certain time into the future with the ability to make that forecast from considerations of both the future rain and the corresponding response of the basin upstream of Brandon. So while it would be possible to provide five day forecasts on the basis of measured flows upstream, it would not be possible to forecast flows further into the future because of all the unavoidable uncertainties related to changing meteorological conditions.

Figure 6.21 illustrates the accuracy of water level forecasts at Brandon as a function how far into the future the upper bound of the water level was being forecast at different times during the flood event. One would expect the accuracy of the level forecast to improve as the forecast period decreased because there would be less chance for confounding effects to be introduced. In fact, that appears to be case but with some exceptions. Generally, when the forecast period was five to nine days (April 16, April 19, May 11, May 13, forecasts for example) the error in the water level forecast was as much as plus or minus 0.6 to 0.8 m (2.0 to 2.6 ft). This would have been equivalent to a range in the forecasted peak flow of some 700 m^3/s (25,000 cfs) or plus or minus 40 percent.

Figure 6.21: Evolution of accuracy of forecast water levels over time for the summer flood peak, 2011 - Assiniboine River at Brandon.



When the time period was less than three days (April 21, May 10, May 14, for example) the forecast error reduced to less than 0.4 m (1.3 ft), equivalent to a discharge range of about 200 m^3/s (7000 cfs) or about plus or minus 10 percent.

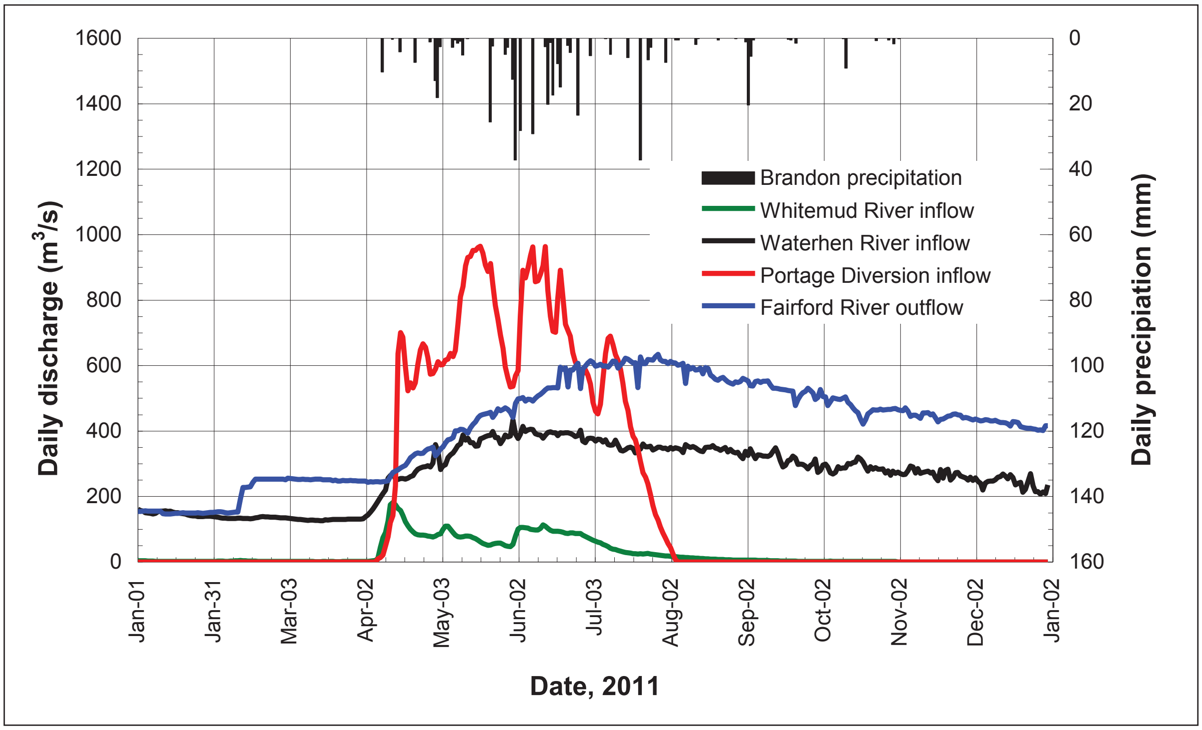
Assiniboine River at Portage la Prairie

While water level forecasts were provided for most locations in Manitoba in 2011, Portage la Prairie was the exception. At this location only, the discharge was required because a discharge criterion was being used to limit the flow down the Assiniboine River below the Portage Diversion. Therefore, the efficacy of the ultimate forecast at Portage la Prairie was not limited by the reliability of the rating curve at the high end of the discharge spectrum.

Flows at Portage la Prairie can be represented very well by the flows at Holland, lagged by about one day or less. Furthermore, the flows at Holland are a composite of flows at Brandon and inflows from the Souris River as measured at Wawanesa, lagged by two days (Figure 6.22). Thus, as long as these gauges remain operational, it is easy to produce a relatively accurate three to five day forecast for Portage la Prairie. Longer forecasts are more difficult and require more complicated routing from stations upstream and therefore are susceptible to confounding effects from local precipitation whose effects on runoff need to be determined and added to the routed flows.

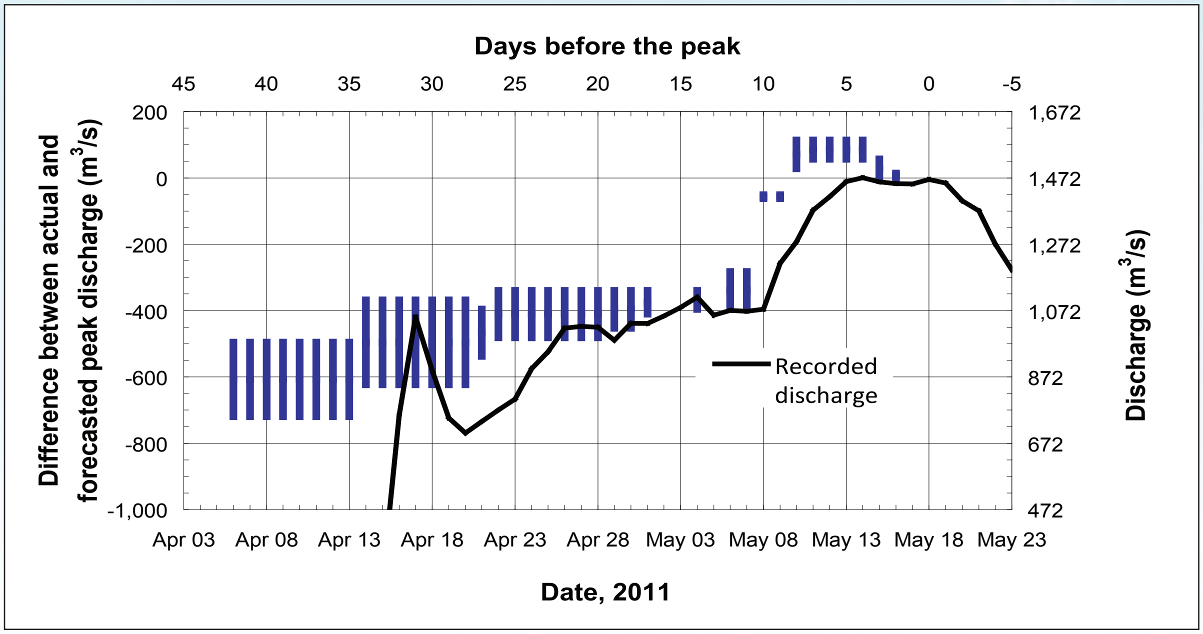
The flows at Portage la Prairie were forecasted with a relatively high accuracy. For example, in early April (almost a month in advance of the spring peak) the forecasted peak flow was estimated to be between 800 and 1000 m^3/s or 28,300 and 35,300 cfs (Figure 6.23). This was about 10 to 25 percent lower than the actual snowmelt peak of about 1100 m^3/s (38,800 cfs) that occurred in late April before the effects of the late April rains became evident. In late April as the snowmelt peak approached, the forecasted discharge was updated twice, first to a range of 900 to 1100 m^3/s (31,800 to 38,800 cfs) and then to a range of 1000 to 1150 m^3/s (35,300 to 40,600 cfs). This was a significant improvement as both of these forecasts essentially bracketed the ultimate spring peak.

Figure 6.22: Precipitation and flows at selected locations on the Assiniboine River upstream of Holland.



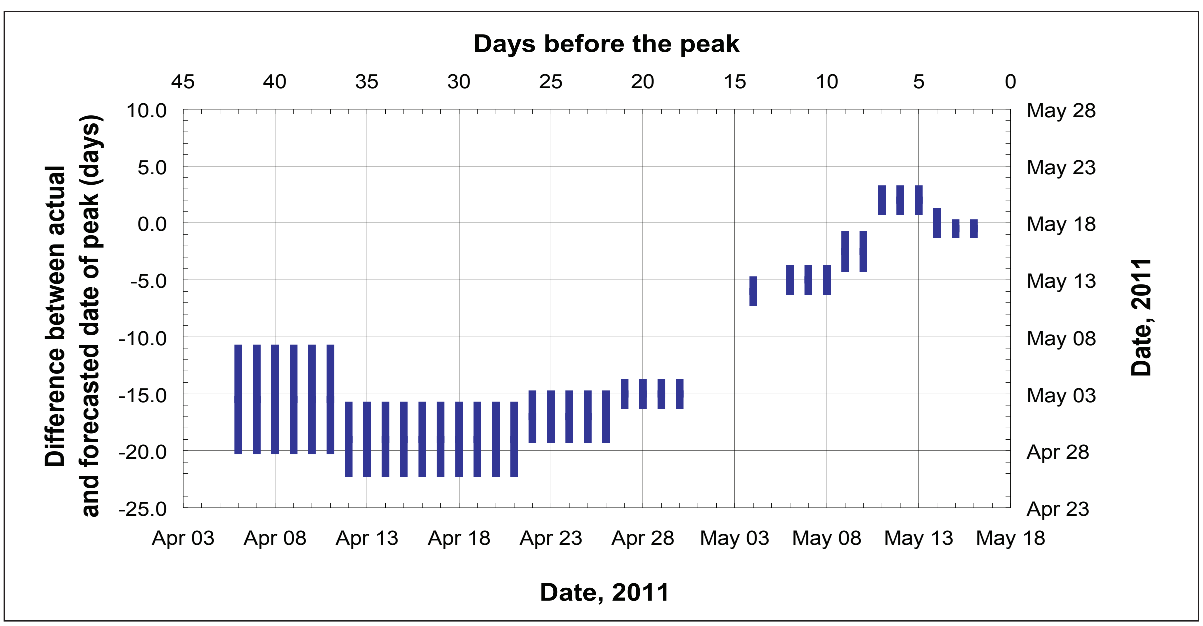
In early May, as the effects of the late April precipitation became evident, the range of the forecast was updated to between 1100 and 1200 m^3/s (38,800 and 42,400 cfs) which fell short by between 300 and 400 m^3/s (10,600 and 14,100 cfs), equivalent to about a 20 to 25 percent under-prediction. By May 10 (some five to 10 days before the peak), when it was evident that the local runoff would not be a significant factor and routing from upstream would represent a greater proportion of the flow, the forecasted range in flows was 1550 to 1600 m^3/s (54,700 to 56,500 cfs) or about two to seven percent above what was actually realized. The larger error range appears to be typical of those encountered when trying to estimate rain-related runoff to determine the peak flows. The error appears to decrease dramatically once the model progresses to where the forecast is based primarily on the routing of observed upstream flows. So, if reliance cannot be placed on routing, because of significant local inflows, due to forecasted or measured rain events, the forecast errors can be quite large. Alternatively, if local inflows are negligible, and the routed flows represent a majority of the flow, the forecast accuracy can be quite good.

Figure 6.23: Difference between actual and forecasted peak discharge - Assiniboine River at Portage.



In an absolute sense, disregarding all the confounding effects of melt rates, rain events and routing difficulties, Figure 6.24 shows the errors associated with trying to predict the date of the actual peak. The peak discharge occurred on about May 18. On April 8, some 40 days in advance of the peak, the predicted date of the peak was between 11 and 20 days in advance of when it actually occurred. On April 28, about 20 days in advance of the peak, the prediction was still about 15 days too early. By May 13, only five days in advance of the peak, the date of the peak was forecasted to be one to three days later than when it actually occurred. On the day of the peak, obviously, the predicted date of the peak was exact.

Figure 6.24: Difference between actual and forecasted date of peak - Assiniboine River at Portage.

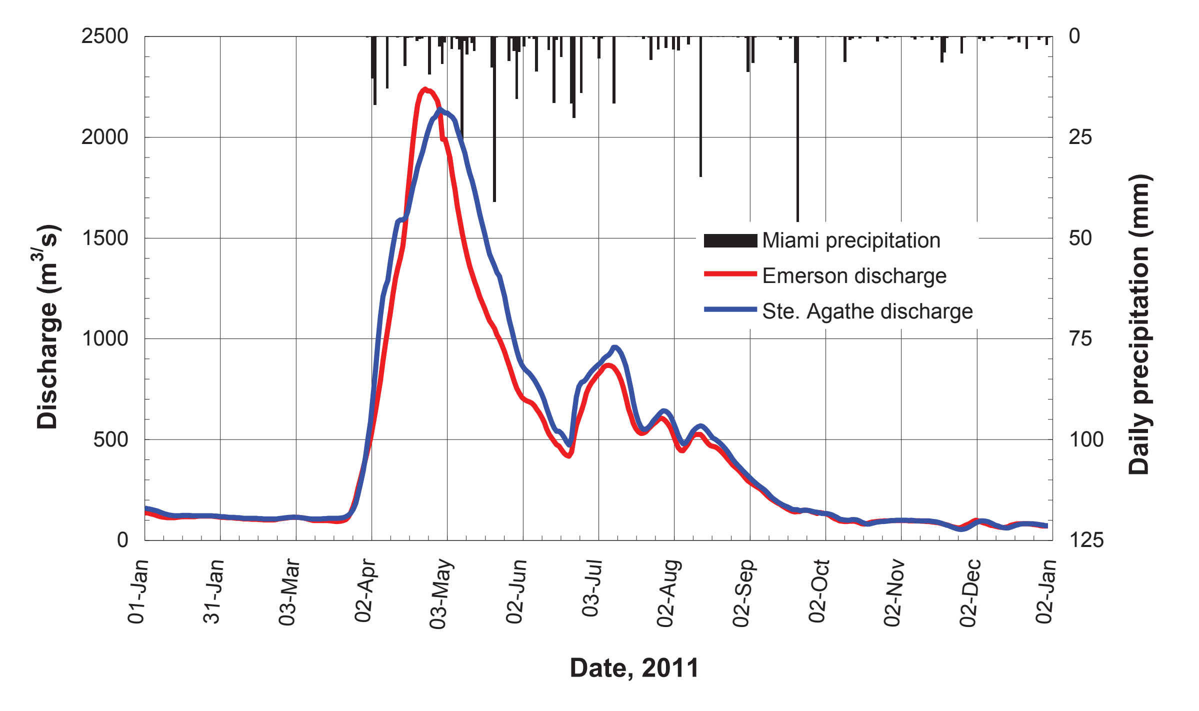


Red River at Emerson and Ste. Agathe

The Red River is one of the most densely monitored rivers in Manitoba because of the severe flooding that can occur in the valley when the river spills its banks and because there is a need to manage the flows in the Red River Floodway to reduce flood damages within the city of Winnipeg. The operation of the floodway is controlled to a very rigid set of specifications to optimize the benefits to Winnipeg without adversely affecting residents upstream. Emerson and Ste. Agathe are key locations on the Red River. The WSC gauge at Emerson defines the flows into Manitoba and the gauge at Ste. Agathe is a long-standing first order WSC station that represents a significant portion of the flow at the entrance to the floodway.

The 2011 flood peak on the Red River was the fifth largest on record at Emerson, so it certainly was severe. In hindsight, however, from an operational forecasting perspective it was a relatively straightforward event (Figure 6.25). Runoff from North Dakota, augmented by inflows from the Pembina River, produced a peak on the Red River at Emerson on April 27. This peak travelled downstream to Ste. Agathe over a period of six days, peaking there on May 3. Inflows between Emerson and Ste. Agathe appeared not to be confounded too much by precipitation in the lower part of the basin, although there was a considerable amount of rain (Figure 6.25). Irrespective of the rain, however, the peak flow at Ste. Agathe was lower than at Emerson because of attenuation of the peak due to floodplain storage. The challenge of the 2011 forecast was to quantify the expected magnitude of the peak at Emerson, assess the significance of the local inflows between Emerson and Ste. Agathe and properly route the peak from Emerson to Ste. Agathe.

Figure 6.25: Flows on the Red River at Emerson and Ste. Agathe.

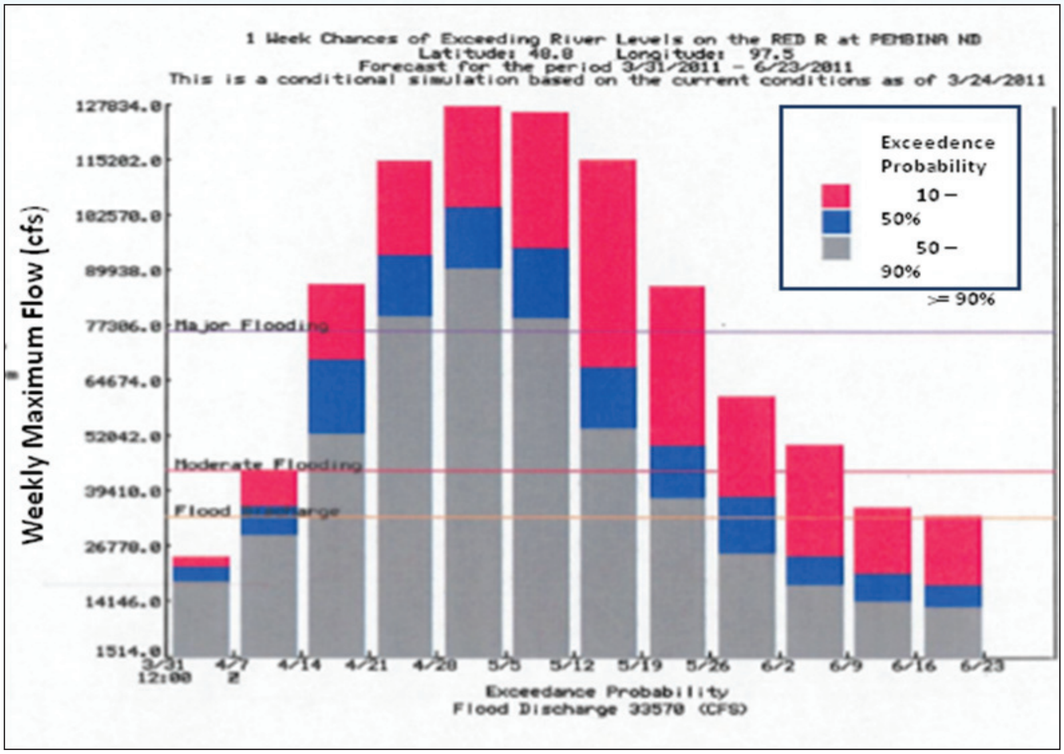


Forecasts for the Red River at Ste. Agathe are based on a generated or observed flood hydrograph for the Red River at Emerson and generated or observed inflows from local sub-watersheds, most of which are gauged, between Emerson and Ste. Agathe. These inflows are then routed down the main stem of the Red using Muskingum routing which simulates the conveyance and attenuation of flows due to channel and floodplain storage. The flood hydrograph at Emerson is initially generated from the NWS flow estimates and the flood hydrographs for the local sub-watersheds between Emerson and Ste Agathe are generated using the MANAPI model. As the 102 000 km^2 (39,400 $mile^2$) drainage area at Emerson represents nearly 90 percent of the 115 000 km^2 (44,400 $mile^2$) drainage area at Ste. Agathe, the NWS forecast is generally the single most important component in the reliability of the forecast for both Ste. Agathe and for the Red River upstream of its confluence with the Assiniboine River.

On March 24, the NWS forecasted the expected range in flow at Pembina (Emerson) to be between 2500 and 3600 m^3/s (88,300 and 127,100 cfs) corresponding to a water level range of 241.5 to 243.0 m (792.3 to 797.2 ft) with the peak occurring sometime in the last week of April (Figure 6.26). On April 11, the NWS forecast was downgraded to between 2300 and 3000 m^3/s (81,200 and 105,900 cfs). In fact, the peak flow at Emerson proved to be only about 2200 m^3/s (77,700 cfs) - well below the initial NWS forecast and at the bottom of the range of the updated NWS forecast. The March outlook provided by the HFC indicated an expected water level range of between 240.9 and 241.4 m (790.4 and 792.0 ft) at Emerson. In hindsight, this was totally inconsistent with the NWS March forecast but proved to be remarkably accurate with the actual peak coming in at 240.9 m (790.4 ft).

The March outlook forecast for Ste. Agathe provided by Manitoba indicated that the expected water level range would be 235.6 to 236.5 m (773.0 to 775.9 ft), which would be equivalent to a peak flow range of 2300 to 3500 m^3/s (81,200 to 123,600 cfs), and which, even ignoring any routing attenuation, would suggest a local area input of between 100 and 500 m^3/s (3500 and 17,600 cfs), or within the maximum range of historical local area contributions. In fact, the peak water level at Ste. Agathe came in at about 235.0 m (771.0 ft), equivalent to a flow of about 2100 m^3/s (74,200 cfs) and lower than what was forecast. Although not stated explicitly in the forecasts, it is likely that the upper limit was based on the assumption that precipitation would be in the upper 10 percentile of historically observed precipitation, which if it had materialized, could have generated a significant amount of runoff in the lower basin simultaneously with the arrival of the peak from Emerson.

Figure 6.26: March 24 NWS forecast of expected peak flows for the Red River at Pembina. Note that the chart contains US Customary units.



The 30-day time period between the date when the March outlook forecast was provided and when the peak water levels were experienced provided opportunities to update the forecast given the systematic way in which the flood was evolving. For Emerson, the first operational forecast was made on April 6 (Figure 6.27) with the projected range in peak water level estimated to be between 241.2 and 241.5 m (791.3 and 791.7 ft) which would have been 0.3 to 0.6 m (1.0 to 2.0 ft) greater than the actual peak. This was downgraded to a range of 240.9 to 241.3 m (790.4 to 791.7 ft) on April 10, and further refined on April 13 (some 12 days before the peak) to a range of 241.1 to 241.3 m (791.0 ft to 791.7 ft) which would have been about 0.2 to 0.4 m (0.7 to 1.3 ft) greater than the actual peak. This forecast was maintained virtually until the date of the peak. In this respect, the NWS forecast which formed the basis of Manitoba's forecast for Emerson was quite a remarkable forecast. The forecast of the timing of the peak was also very good (Figure 6.28). The early April forecast was good to about plus or minus seven days and by mid-April the timing was being forecasted to about plus or minus two days. Again, this demonstrates the remarkable accuracy of the NWS forecast.

Figure 6.27: Difference between actual and forecasted flood peak level - Red River at Emerson.

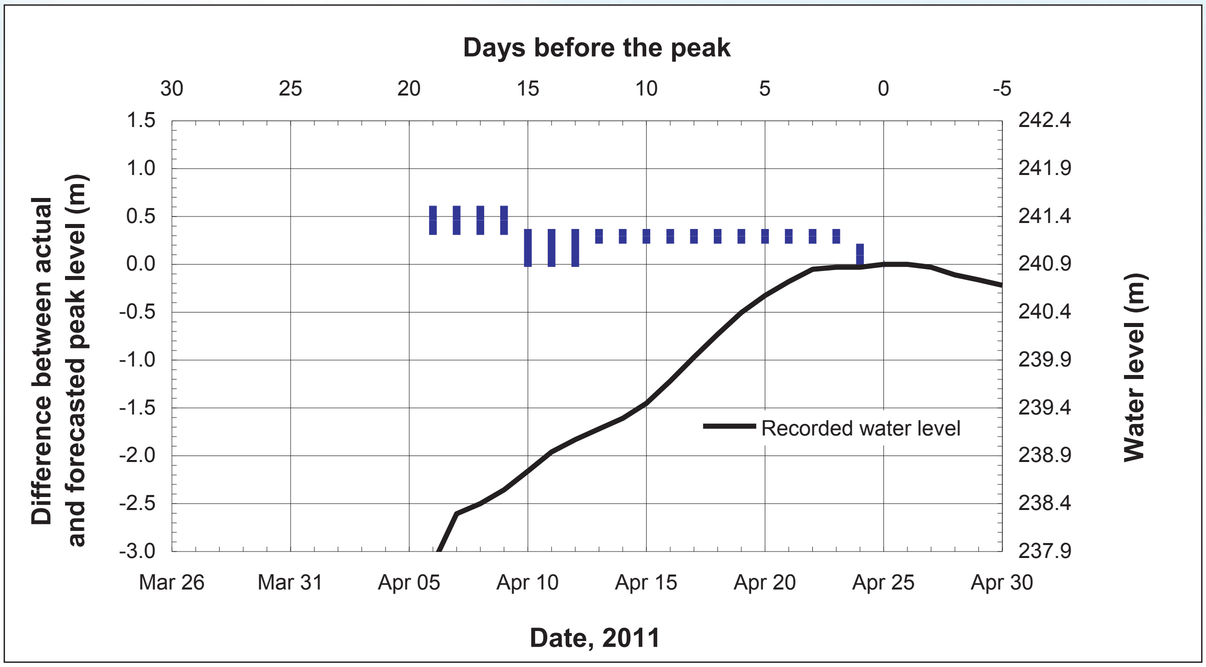
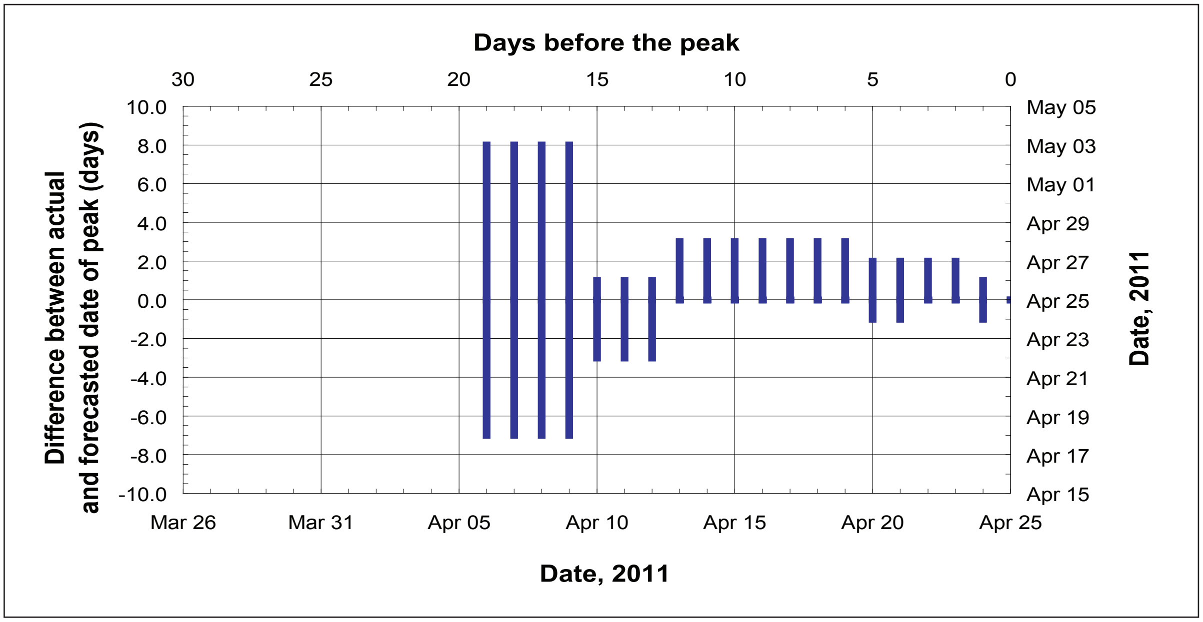
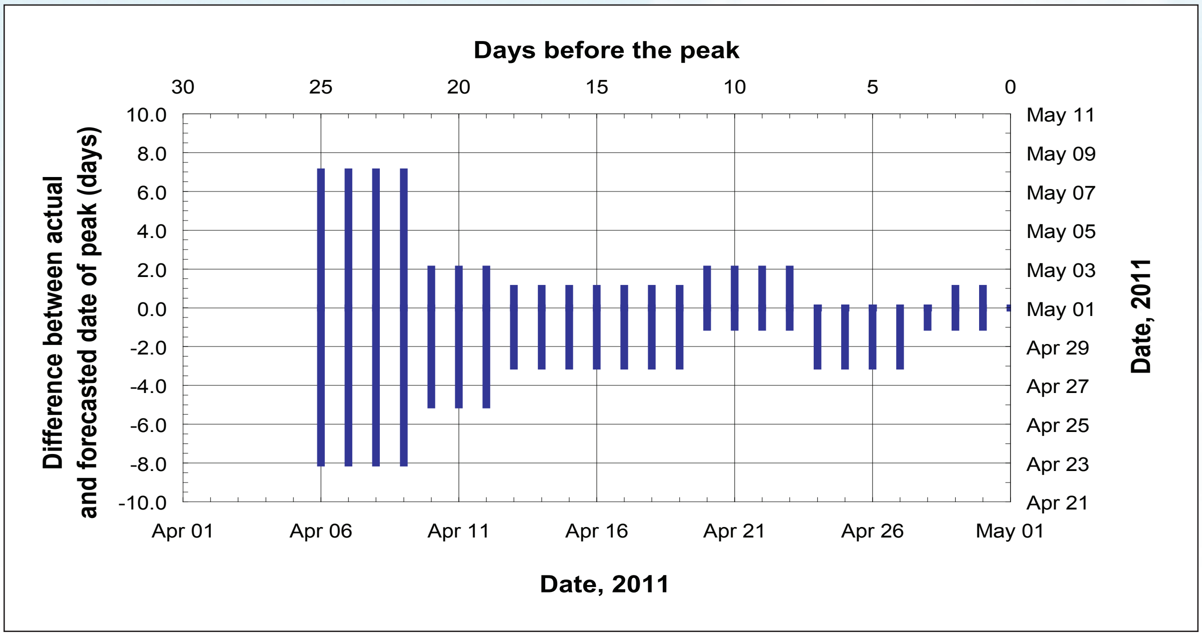


Figure 6.28: Difference between actual and forecasted flood date of peak - Red River at Emerson.



The updated or operational forecasts at Ste. Agathe tell a different story. The date of the peak (Figure 6.29) was forecasted quite well (ranging from plus or minus about seven days in early April to plus or minus two days in late April) as would be expected given accuracy of the NWS forecast for Emerson. However, the water level forecast was very poor, especially considering that the U.S forecast at Emerson constituted about 90 percent of the flow and that most of the intervening drainage area between Emerson and Ste. Agathe is gauged. Initial operational forecasts in early April proved to be between 1.1 and 1.4 m (3.6 and 4.6 ft) too high. The forecasted peak was downgraded (Figure 6.30) as the flood evolved. On April 11, the median peak flow was estimated to be 2800 m^3/s (98,900 cfs). On April 19 the median and upper decile peaks flows were estimated to be 2600 and 2800 m^3/s (91,800 and 98,900 cfs) respectively, and on April 27, the median peak flow was estimated at 2300 m^3/s (81,200 cfs) Most of these were substantially greater than the realized peak flow of 2140 m^3/s (75,600 cfs).

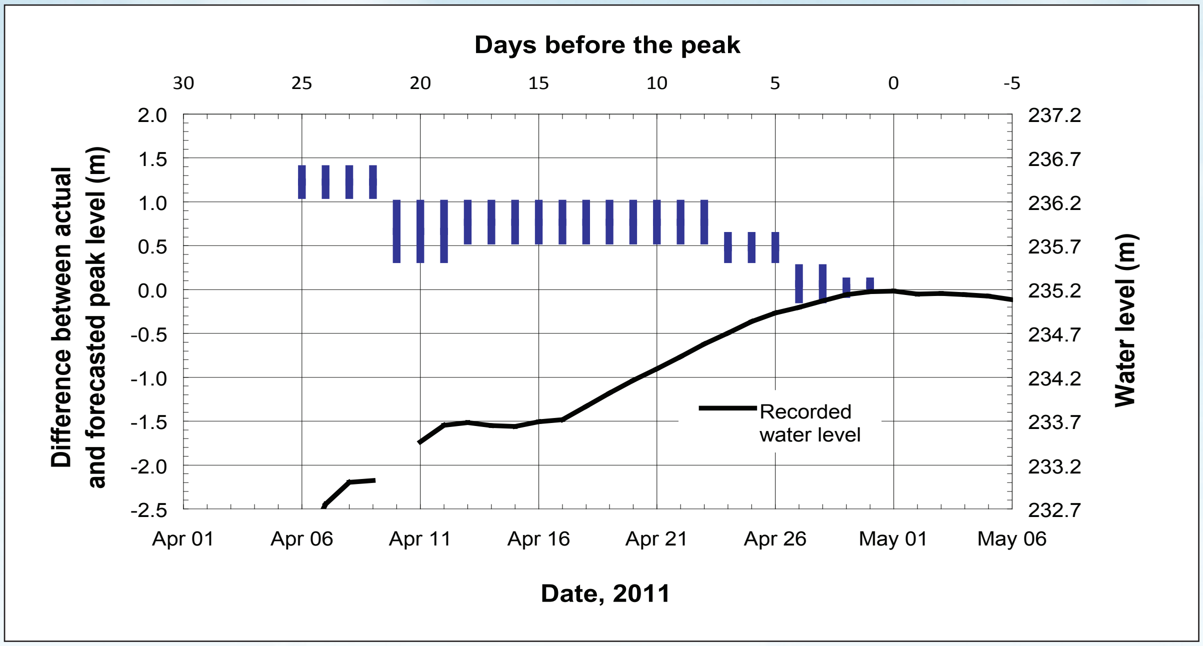
Figure 6.29: Difference between actual and forecasted date of peak - Red River at Ste Agathe.



So, in the seven to 21 day period before the peak, the peak water level was still being overestimated by 0.5 to 1.0 m (1.6 to 3.3 ft), an error in the discharge estimate of 20 to 40 percent. Finally, on April 23 (seven days before the peak) the forecast improved, likely when it was determined that the projected local runoff was not being realized. The peak water level range was downgraded to a range of 235.5 to 235.8 m (772.6 to 773.6 ft), still some 0.3 to 0.6 m (1.0 to 2.0 ft) greater than the realized peak. It was not until virtually the day of the peak that the range of the water level forecast at Ste. Agathe reflected the actual peak water level.

It is clear that there were good and bad sides to the Red River forecasts. The forecasts of the timing of the flood peak and its magnitude at Emerson were very good. Given the quality of the Emerson forecast, one would expect that the Ste. Agathe forecast would also have been reasonable. It is evident that major miscalculations were made with respect to the volume of runoff produced in the lower basin of the Red River. This is consistent with what appears to have been the problem with the operational forecasts in the rest of the province, that is, the inability of the API graphs within the MANAPI model to provide reliable estimates of local runoff on the basis of either measured or forecasted precipitation.

Figure 6.30: Difference between actual and forecasted peak level - Red River at Ste Agathe.



Lake Manitoba

Forecasting water levels on Lake Manitoba is a two step process. These are determined in advance by what the ambient water levels will be within a two to three week window and determining the effect that winds have on the ultimate water level within a two to three day window. Forecasting ambient water levels for a two to three week period should be a relatively straightforward process with the exception of accounting for inflows from the Portage Diversion, which is what is being addressed herein. Prediction of wind-related water levels relies mostly on a forecast of the severity and duration of winds along the lake and it would not be within the purview of the forecasting group.

In general, water level forecasts for lakes are carried out using a water balance approach - the change in the lake level over a specified time period being equal to the difference between the inflows and the outflows averaged over the lake surface area. In the case of Lake Manitoba, the inflows are derived from Lake Winnipegosis (through the Waterhen River), the Portage Diversion, local watersheds around the lake (including the Whitemud River) and precipitation directly over the lake. The outflows are comprised of evaporation from the lake surface area and flows through the Fairford River Water Control Structure (FRWCS) at Fairford.

Most of the natural inflow into Lake Manitoba occurs through the Waterhen River after passing through Lake Winnipegosis. The storage in Lake Winnipegosis significantly smoothes and lags the week to week variability in runoff such that these inflows are relatively constant and can be projected with relatively high accuracy for long periods of time. This provides an opportunity to produce water level forecasts with a relatively long lead time. Furthermore, given the magnitude of inflows through the Waterhen, and the rather large size of Lake Manitoba, natural inflows from the local drainage area are relatively small and as such do not contribute significantly to the changes to the lake level over periods of at least as long as two weeks. Precipitation, while a significant component over the long term, can be estimated based on observed and average future conditions, thus leaving inflows from the Portage Diversion as the only unknown input. In terms of outflows from the lake, evaporation is relatively constant from year to year and also can be reasonably estimated from historical data.

Furthermore, outflows from the lake at Fairford vary systematically with the lake levels and as such it should be quite a straightforward process to produce a 10 to 14 day, or even longer, water level forecast for the lake if the inflows from the Portage Diversion can be forecast. Of course, the Portage Diversion inflows depend on the operating protocols at the Portage Diversion, the capacity of the lower Assiniboine River dikes, and the expected flows on the Red and Assiniboine rivers. In most years, inflows through the Portage Diversion are quite small and any errors in their forecast are masked by significantly larger inflows from the Waterhen River. In 2011, however, this was not the case and inflows from the Portage Diversion (Figure 6.31) contributed significantly to the increase in the lake level, approximately 0.6 m or about 50 percent of the total water level increase that was experienced over the summer months, according to some estimates. Therefore, the accuracy of the 2011 Lake Manitoba ambient water level forecast depended very much on the ability to forecast the flows on the Assiniboine River at Holland.

From the data in the flood sheets, as represented in (Figure 6.32), it is clear that the lake level forecast was concerned mostly with providing 3 to 12 day forecasts on the basis of the current water levels and identifying the expected range in water levels that could develop during that forecast period. The water level forecast was updated (ratcheted upward over the course of the flood) whenever the lake level increased, and a new water level range was prescribed on the basis of the expected range of inflows.

The forecasted water level range for the forecast periods varied from 0.10 to 0.25 m (0.3 to 0.8 ft), ostensibly in response to the varying confidence in estimating inflows during each period, with the larger the range the less confidence in the inflow forecast. For example, after accounting for natural inflows and the outflow at Fairford (typically almost equal in magnitude), the forecasted water level range for the period May 7 to May 17 suggested an adopted range in the net daily inflows of -550 to +820 m^3/s (-19,400 to +29,000 cfs) This was a huge range given what was being experienced at the Portage Diversion. In the June 15 to June 25 period the adopted range in the net daily inflows was -275 to +275 m^3/s (-9700 to +9700 cfs), likely due to the expected reduction of inflows from the Portage Diversion, but in spite of continuing high flows on the Assiniboine River that should have maintained expectations of significant inflows from the Portage Diversion.

Figure 6.31: Precipitation and Lake Manitoba inflows and outflows, 2011.

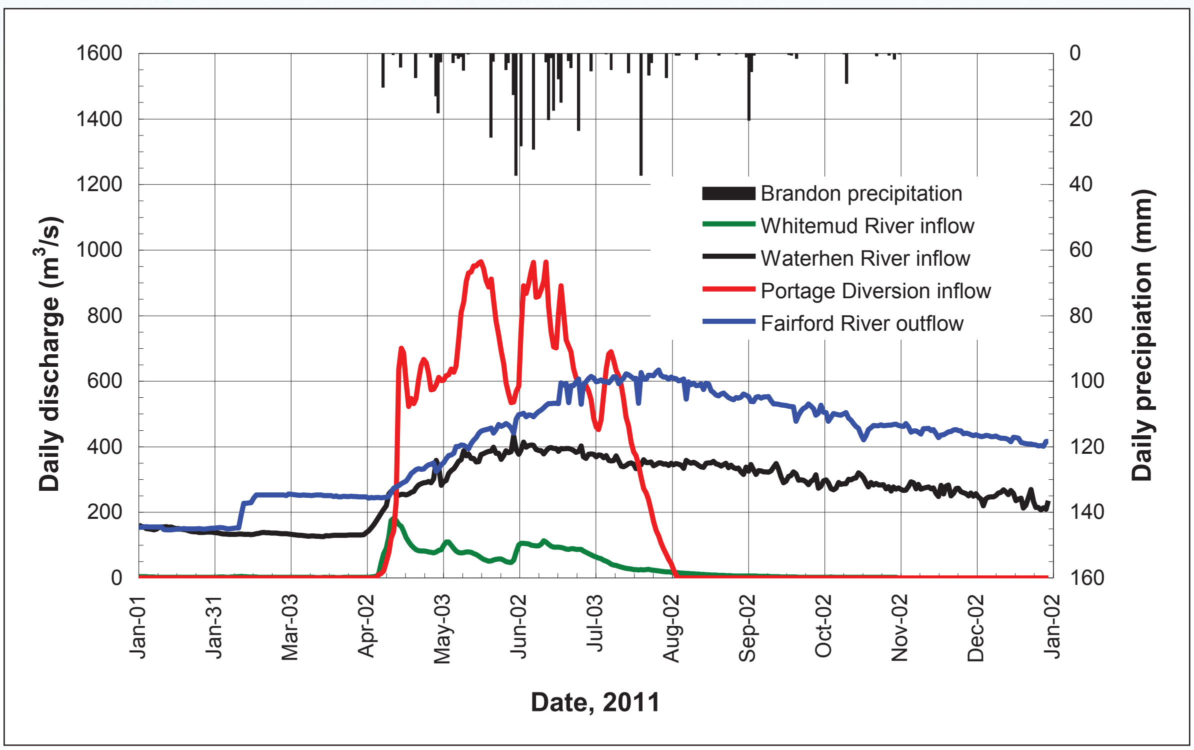


Figure 6.32: Difference between actual and forecasted peak level - Lake Manitoba.

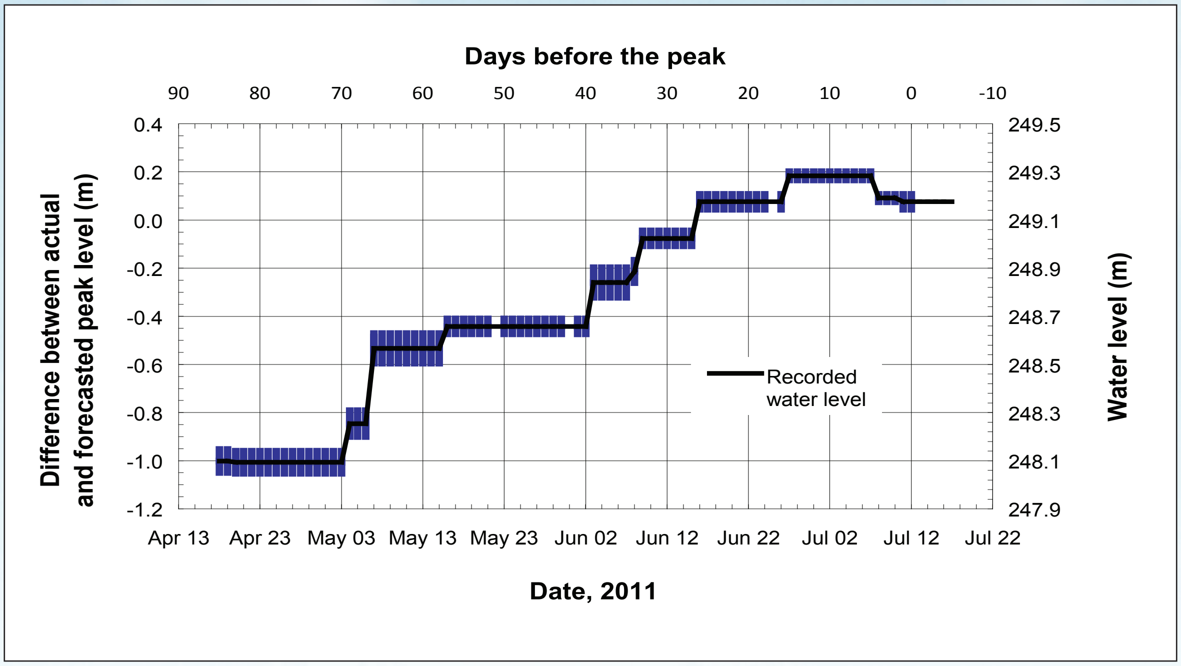
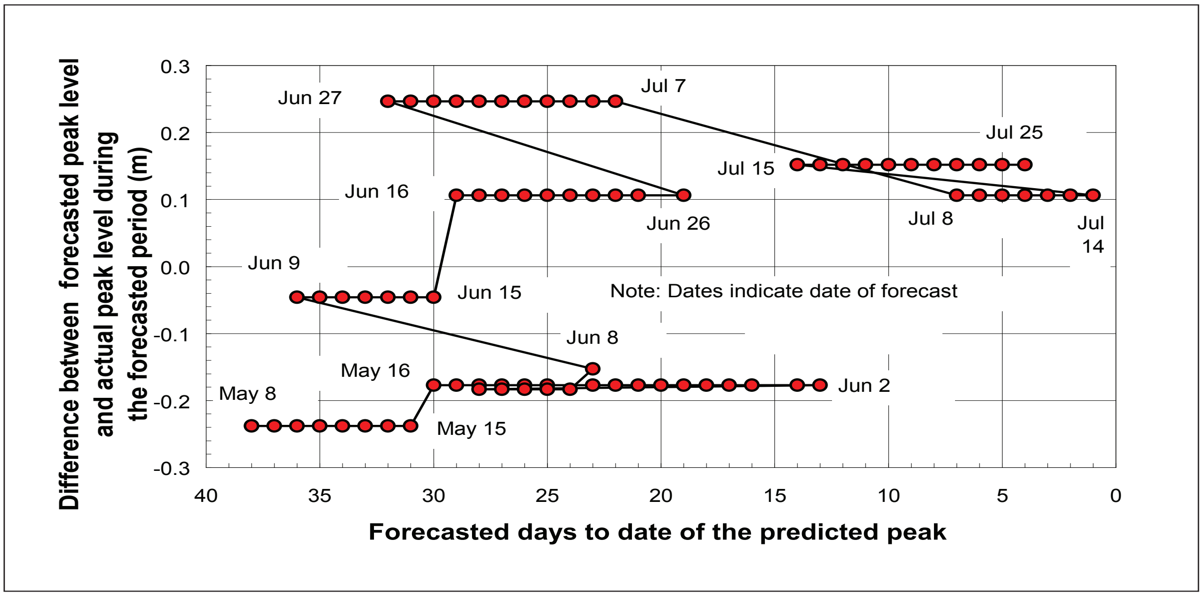


Figure 6.33 illustrates the accuracy of the lake level prediction as a function of the forecasted time period as the forecasts evolved during the period May 8 to July 25. Between May 8 and May 15 the water level forecasts were being made for June 15 (between 38 days and 31 days out) and the upper range of the water level for that day was under-predicted by about 0.25 m (0.8 ft). Between May 16 and June 8 the water level forecasts were being made for June 15 (between 30 days and 13 days out) and the upper range of the water level for that day was under-predicted by about 0.18 m (0.6 ft). Even in the period between July 8 and July 14 when the water level forecasts were being made for July 15 (between one and seven days out), the upper range of the water level for that day was over-predicted by about 0.11 m (0.4 ft). The most accurate forecasts came in the period June 9 to June 15 when the water levels were being forecast between 30 and 36 days into the future within about 0.05 m (0.2 ft). On the whole, it appears that there is no consistency between the forecasted time period and the accuracy of the water level forecast for the Lake Manitoba forecasts.

Figure 6.33: Evolution of accuracy of forecast water levels on Lake Manitoba, 2011.



Overall, it is difficult to rationalize the water level forecasts for Lake Manitoba. It appears that there was no strategy to link the potential Portage Diversion flows to the forecasted flows in the Assiniboine River and thereby provide a long lead upper limit to the water level on the basis of the expected Portage Diversion inflow volumes. This projection of future diversions appears not to have been accounted for even as late as June 1. At that point, it was clear that the inflow volumes that resulted from the summer rain events were much larger than what had ever been experienced in the past and high flows were still being experienced on the Souris and Qu'Appelle rivers and on the Assiniboine River at Brandon.

6.5 Conclusions

The flood of 2011 was unprecedented in terms of magnitude, areal extent, and duration. Given the scope of the flood and the tools available to the HFC to deal with the sheer volume of real-time data, providing a timely and reliable forecast would have posed a challenge to the most experienced of forecasters, let alone a forecast team whose experience in operational forecasting ranged from six months to three years. In spite of their limited experience, the HFC was able to identify and effectively communicate the potential risk of flooding as early as December 2010, thus providing water managers the opportunity to adjust reservoir levels so as to maximize flood reduction capabilities and providing many communities with the required lead time to prepare for the event.

The Task Force heard from a number of sources that the inadequacy, or lack, of succession planning within the provincial government was a concern. This was particularly evident in the HFC where relatively inexperienced forecasters were required to deal with a flood event far beyond anything they had ever faced. The Province should take steps to address this issue for the future.

From the perspective of the spring outlook reports, the HFC recognized the risk of flooding and took the decisive action of issuing a special Runoff Outlook Report in January 2011 to communicate the growing risk of flooding in spite of the uncertainty of future weather conditions which would obviously have an impact on the magnitude of the flood. In the February 24, and March 25, 2011 reports, HFC forecasters accurately communicated that

> *" ... the 2011 spring flood potential remains high for much of Manitoba including the Red, Souris, Pembina, Assiniboine, Winnipeg, Saskatchewan and Fisher rivers as well as the Interlake region."*

And while the projections that

> *"...average weather conditions along the Red River could result in a flood higher than 2009 while unfavourable weather conditions could result in Red River water levels reaching those experienced in 1997."*

were somewhat inaccurate, in that the 2011 flood peaks were about 10 to 15 percent lower than the 2009 peak, the difference is understandable. The long lead time contributed to the overestimate in the March forecast. A review of the snowmelt peak that was observed or would have been observed in the absence of rain following the snowmelt event, indicates that the actual peaks would have been within the forecasted range for the Assiniboine River and about 10 to 20 percent above these early projections for the Souris River. This was pretty good for a forecast made so early in the season.

In general, the melt conditions seemed to follow a fairly regular snowmelt pattern with most smaller streams and the headwaters of the larger rivers experiencing their snowmelt peaks by mid to late April. However, a series of rainfall events in mid to late April in the headwaters of the Souris River, Assiniboine River and in the Dauphin Lake area, on saturated and frozen soil conditions, began to give rise to increased flooding concerns over an expanded area. The forecasting situation was further complicated by the following.

- The inability of the MANAPI model to provide reliable runoff forecasts for rainfall events.
- The lack of a data management system for handling large volumes of hydroclimatic data.
- The lack of a flood operations room where forecasters could work collaboratively and without interruptions.
- The lack of dedicated GIS software, which at times slowed the forecast due the software being used by other departments.
- The need to begin providing forecasts for wind set-up and wave action on lakes.
- The need to provide daily Ministerial briefings as well as briefings to water managers, operations staff, elected officials and the media.
- A large number of enquiries from concerned elected officials, the media, and the public.

The HFC forecasters attempted to overcome these obstacles by the following.

- Developing rainfall-runoff models "on the fly" for sub-watersheds in the Souris, Assiniboine, and Red rivers as well as for a number of streams that previously had not been modelled.
- Mobilize significant field staff and other resources to provide near real-time data and field measurements to assess the situation as events unfolded.
- Transforming a board room into a temporary operations centre where forecasters could work without interruptions, lay out maps, and exchange and coordinate information more effectively.
- Beginning work at 2:00 am to assemble the data required for input to forecasting models in order to meet reporting deadlines.
- Working 12-18 hour days continuously for a period of about 100 days.
- Retaining consultants to carry out some of the lake level forecasts.
- Recruiting additional support staff from other areas to help with the forecasts.

Eventually, all of these factors in combination with the relative inexperience of the forecasters began taking their toll on the accuracy and reliability of the forecasts as evidenced by the following.

- Erroneous discharge measurements were left unaddressed for extended time periods without trying to reconcile differences in reported flows.
- There was a lack of follow-up with other agencies such as the NWS to resolve concerns with forecasts for the Red and Souris rivers even though they are critical components in the production of forecasts in Manitoba.
- There was a failure to implement alternative field measurement procedures to obtain water level information critical to the Brandon forecast at the flooded hydrometric stations on the Assiniboine River at Virden and Griswold.
- There were inaccuracies in the projection of peak lake levels for Lake Manitoba because of a failure to link Portage Diversion flows to what was forecasted, and ultimately experienced, on the Assiniboine River at Brandon and on the Souris River.

From an operational perspective, and with respect to the issuance of the daily flood sheets over the spring and summer period, the above shortcomings appeared to have played a role in the quality of the forecasts at a number of locations throughout the province. It would be unfair to place a negative connotation of the results of the forecast evaluations because conditions change and often, assumptions that go into the forecasts no longer apply, due to changing meteorological conditions and other unavoidable circumstances, through no fault of the forecasters. However, from the perspective of the public, it only judges the reliability of the forecast in hindsight on the basis of how it must respond to the forecast without much concern for why the forecast could have been in error. From this perspective, the evidence suggests that the forecasts were relatively good for the Saskatchewan River at The Pas, the Assiniboine River at Portage la Prairie and the Red River at Emerson. However, the forecasts were tentative for Dauphin Lake and the Assiniboine River at Brandon, and quite poor for Lake Manitoba, the Souris River at Souris and the Red River at Ste. Agathe.

It appears that a more rigorous approach to quantifying runoff resulting from summer rain events and a closer attention to the nuances of the routing of flows down the major river systems would have improved the forecast outcome at many locations where it appears to have fallen short in 2011. Regardless, if the expected lead time of the forecast is long, say more than a week, adverse and rapidly changing weather conditions could confound the flood forecast regardless of how rigorous a system is in place. In many situations it may be counter-productive to try to provide absolute forecasts that extend many days into the future because inherently they will be in error and will put into question the credibility of future forecasts. It would be preferable to establish an operational forecast period that is consistent with the ability of the forecast methodology to provide reasonably accurate weather forecasts.

Given the lengthy duration of this event and the personal sacrifice required to provide continuous delivery of an operational forecast, it is believe that overall, the HFC displayed a high level of commitment and professionalism. While there are a number of areas where improvements could have been realized, and these likely will be put in place as a result of the experience gained during the 2011 flood, it is believe that the HFC provided reasonable forecasts under very trying circumstances. Furthermore, it is believed that the HFC has a solid technical understanding of hydrology and hydrologic models, as shown by its ability to develop rainfall-runoff models on the fly to overcome limitations of the MANAPI model. However, it is noted that, aside from their technical skills, forecasters are frequently required to communicate with field staff, data providers, neighbouring jurisdictions, water managers, and the public in order to obtain information and to deliver their forecast. This tends diffuse their forecasting energies into less productive activities.

6.6 Recommendations

A number of recommendations have arisen out of the above review. They are presented as follows in no particular order of priority, but listed under three general categories. These are political and institutional actions that may require policy decisions and or other departmental inputs, operational actions that should be taken at a departmental level and technical actions that would address science-based issues and forecasting protocols. The recommendations follow.

Political and Institutional

19. The Hydrologic Forecasting Centre (HFC) forecasts for the Red River and the Souris River are comprised of the U.S National Weather Service (NWS) forecast for the Red River at Pembina (Emerson), the NWS forecast for the Souris River at Westhope, and HFC forecast for local drainage areas in the Province. The NWS forecasts are the most important factors in delivery of reliable forecasts for the Red River and Souris River. There is no formal arrangement to ensure this product is of a high quality nor to ensure the continued delivery of this product. Manitoba establish an agreement with NWS to ensure the continued delivery of those forecasts, and that Manitoba arrange for a biennial forecasting workshop/conference with NWS, Saskatchewan and North Dakota forecasters to promote this relationship, develop an understanding of their inter-dependence and evaluate the potential to adopt the same flood forecasting platform.

20. Explore the feasibility of developing a closer relation with meteorologists at Environment Canada (EC) and NWS towards obtaining "best effort" precipitation forecast during flood risk periods.

21. The Province consider having a dedicated, trained spokesperson(s) to deliver forecasts to the media. This (these) person(s) should be intimately familiar with technical terms and understand both the limitations and the potential benefits of a flood forecasting system.

22. The HFC conduct a user analysis to obtain a better understanding of how best to deliver its forecast, develop closer ties and interaction between the forecasters and user groups and develop user-friendly (perhaps graphical) ways of communicating the flood forecasts.

23. Consideration be given to providing prior cross-training to Provincial staff who may be seconded during an emergency to assist in the HFC. Consideration also be given to increasing forecaster salaries and improving the work environment in order to make forecasting a growth position for experienced staff in other areas and to attract qualified forecasters.

24. Document and publish (for public use) all relevant hydrologic and hydraulic data gathered during the flood and incorporate that data in the upgraded flood forecasting protocols. Consider funding an appropriate number of graduate students at the appropriate academic institutions to carry out this work.

25. Since the projections within the Spring Outlook Reports in February amd March are of limited reliability in terms of providing reliable peak water level forecasts, while at the same time potentially creating false expectations, and possibly putting the forecasters credibility into question, the Province consider simply providing a qualitative (high, medium, low) assessment of flood <u>risk</u> rather than flood <u>elevations</u> in these reports.

26. The HFC convert to using the SI system in providing forecasts over an appropriate transition period that is reconcilable with the development of updated forecasting procedures.

Operational

27. Modern flood forecasting operations rely on the collection, transmission, capturing, processing, storage, and quality control of significant amounts of near real-time hydroclimatic data from dozens of sources. Modern flood forecasting also requires frequent and ongoing interaction between members of the forecast team and between forecasters and field staff, data providers, neighbouring jurisdictions, water managers and the public in order to remain on top of rapidly changing conditions, to clarify information and to deliver their forecast effectively and without interruptions. It is recommended that the Province provide the forecasters with dedicated data management systems, computer hardware and software that are external to the managed computing environment and communication devices that are housed in a dedicated space such as an "Operations Forecasting Centre".

28. The HFC add technical support positions to manage the flow of data. Once an Operations Forecasting Centre and integrated data management system with this support staff have been implemented, forecasters should be allowed to focus fully on the development of forecasting tools, optimizing the computer hardware, automating data management and the delivering flood forecasts and current condition reports.

29. The HFC consider forecasting in shifts with a senior forecaster and an assistant always present with adequate technical support so that the previous day's data can be analysed overnight and a forecast prepared by mid-morning to provide the resources on the ground enough time to mitigate upcoming events.

30. The Province acquire at least two additional Acoustic Doppler flow meters to allow field personnel to conduct more timely and accurate discharge measurements during the flood. Ensure that personnel are trained in the use of the equipment. Rent additional equipment as required and/or contract private sector resources as in 2011 to expand capabilities if required.

31. Senior forecasters visit functioning forecasting operations in other jurisdictions to obtain a broader understanding of how best to organize forecast protocols and to meet Manitoba's forecasting requirements.

32. Spring Flood Outlook reports and Flood Reports briefly outline the weather assumptions used rather than stating the generic "favourable" and "unfavourable" conditions.

Technical

33. The MANAPI model, in its current state, is a snowmelt model. Contrary to traditional understanding, most of the largest floods in Manitoba are the result of rainfall on top of, or shortly after, the snowmelt event. The model was last reviewed in 1985. Many developments in modelling procedures have occurred since then. It is recommended that the Province examine other flood forecasting models to determine which model may best meet its forecasting requirements.

34. The Province explore alternative routing procedures that are compatible with more modern flood forecasting software and collect sufficient field data to ensure routing efficacy.

35. The collection of data that is to be used to characterize the spatial distribution of precipitation should be systemized and that systematic approach be maintained to ensure consistency from year to year. The integrity of this system should maintained at all costs.

36. If there is reluctance to adopt an alternative forecasting system, the API approach and the unit hydrograph concept should be refined more rigorously. At least the shape of the unit hydrograph should be decoupled from the historical melt rate.

37. The needs for additional soil moisture measurement sites be identified to fill gaps in the major river basins including North Dakota and Saskatchewan and provide proposals on how this information, especially in other jurisdictions, could be collected.

38. A modernized systematic methodology be established to provide spatial estimates of real time meteorological parameters in salient watersheds to improve the characterization of the precipitation (rain, snow, and snowmelt) in these watersheds. Particular attention should be placed upon the measurement of the winter snowpack. The need to establish an extensive snow surveys program to augment the Environment Canada precipitation data and the airborne imagery should be investigated and implemented if required.

39. The forecasting unit carry out an evaluation of the precipitation network for areas for which they have forecasting responsibilities to determine potential gaps in the monitoring of rainfall. Identify and install meteorological stations to support the assessment of rainfall accumulations in salient watersheds within this context.

40. Procedures for the operational forecast be rationalized to reconcile the rainfall runoff modelling component with the flow routing component.

41. Reliance on distributed local ad hoc precipitation monitoring for the systematic operational forecast be minimized. Use only as supplementary data to assist in interpreting the implications of the daily forecasts.

42. Ice-related forecasting methodologies and protocols should be defined explicitly, empirical data that is used to define ice-related water levels should be examined within the context of existing ice hydraulic principles and an explicit criteria for when forecasting should cease in the period after the ice clears should be developed. Historical analogues should be employed to test these forecasting methodologies.

43. The practice of providing one or two decimal points in the water level forecasts places undue expectations on the reliability of the forecast. It is recommended that the inferred precision in the published forecasts reflects the accuracy of these forecasts.

44. Since it appears that the forecast flood level ranges are based on the expectations of realizing a certain amount of future precipitation, and there does not appear to be any effort to report on how potential errors in the modelling assumptions could contribute to the forecast range, it is recommended that the HFC develop an understanding of the contribution of the potential variability in the adopted model parameters to the magnitude of the forecasted water level range.

7. Flood Preparedness, Flood Fighting Capacity and Response

The level of flood preparedness, flood-fighting capacity and response by the Province, the cities of Winnipeg and Brandon, other municipal governments and individual citizens in dealing with the flood.

7.1 Background

Preparedness is typically understood as consisting of measures that enable different units, individuals, organizations, communities and societies to respond effectively and recover more quickly when disasters strike. Preparedness efforts also aim at ensuring that the resources necessary for responding effectively in the event of a disaster are in place, and that those faced with having to respond know how to use those resources. The activities that are commonly associated with disaster preparedness include developing planning processes to ensure readiness, formulating disaster plans and stockpiling resources necessary for effective response. Developing skills and competencies through training and exercising to ensure effective performance of disaster related tasks is also an important part of preparedness.

Manitoba's Emergency Measures Organization (EMO) is established under Manitoba's *Emergency Measures Act*. The broad purpose of EMO is to safeguard life, property and the environment before, during and after an emergency or disaster. In doing so, EMO coordinates provincial emergency preparedness planning and training, response and recovery operations, and administers and delivers Disaster Financial Assistance. In Manitoba, EMO reports directly to the Minister of Manitoba Infrastructure and Transportation.

As part of emergency preparedness, EMO is responsible for developing, implementing and maintaining a provincial Emergency Preparedness Program. It also ensures that municipalities prepare, update and exercise their emergency management plans.

EMO operates within five regions covering the entire province. Each region has one Regional Emergency Manager responsible for liaison with the municipalities in that region. EMO headquarters is in Winnipeg, and provides support to the regions.

Emergency management organizations across Canada, within the provinces, all operate under similar guidelines and procedures in managing the emergency management programs and during real-time emergencies, co-ordinate a response by all agencies. Training and exercise programs are also very similar across the country with emphasis placed on provincial/municipal priorities.

EMO safeguards life, property and environment before, during and after a disaster.

The Province recognized early in the fall of 2010 that there would be major flooding throughout Manitoba in the spring of 2011. The Province issued its first spring flood outlook for 2011 on

January 24th. It indicated the potential for flooding was high for much of Manitoba including the Red, Assiniboine, Souris, Pembina, Winnipeg, Saskatchewan and Fisher rivers, as well as in the Interlake. It also warned that localized overland flooding was expected in most of central and southern Manitoba. The second outlook, released on February 24th, was similar, but added that additional snowpack in the southern Red River basin could result in higher flood levels on the Red than earlier predicted. The bulletin also indicated that flooding in Manitoba could be impacted by conditions in other jurisdictions.

EMO began early stage planning well ahead of the eventual flood. They opened the Manitoba Emergency Coordination Centre, and searched out sources for equipment and informed municipalities of the impending flood. In March, the Province announced the purchase of two sandbag machines, bringing the total in the province to five. One of these machines was allocated to Brandon. At the same time, the Province announced that provincial funding was being made available to help raise the dikes along the Assiniboine River in Brandon. A week later, Manitoba Infrastructure and Transportation (MIT) indicated it would begin work to reinforce and raise the dikes along the Assiniboine River between Portage la Prairie and Headingly.

The Manitoba Emergency Coordination Centre (MECC) is the nerve centre of all operations during an emergency in Manitoba. EMO is responsible for maintaining and equipping the Centre, and for supervising the Centre when it is in operation. All provincial government departments and agencies, and non-government organizations involved with the emergency are allotted work stations in the MECC. The MECC provides information and communications links to all its partners at the federal, provincial and local levels. All municipalities in Manitoba have their emergency plans stored within the MECC.

In 2011, the Manitoba Emergency Coordination Centre became operational in the spring of 2011. It remained open for a total of 103 days. This compares with only 33 days during the 1997 Flood of the Century.

The EMO head office is located on the 15th floor of 405 Broadway Avenue in downtown Winnipeg. This location causes many concerns and logistical problems, both operationally and administratively, during an event. Access is difficult and there is a shortage of long-term parking. Easy access to the MECC by responding departments and emergency management agencies during an emergency event is critical. The potential for the loss of power to the downtown is another serious issue. This unit should be relocated to a more appropriate, accessible and secure location.

7.2 Military Assistance

The Canadian military played a crucial role in fighting the 2011 flood. Early in the flood, the military began monitoring the situation in conjunction with Public Safety Canada and Manitoba's EMO. On May 8th, Mother's Day, a Request for Assistance from the Province was forwarded to Public Safety Canada to help address the potential of failure of the Assiniboine River dikes between Portage la Prairie and Winnipeg.

The Canadian military played a crucial role in fighting the 2011 flood.

The Province's request for aid from the Canadian military is a process that follows strict guidelines as outlined and managed by the federal government. When the provincial government no longer has the resources or the ability, or lacks expertise to deal with an emergency event, the Canadian Forces respond under their Domestic Operations program. The request for Canadian Forces operations can only be made from the provincial minister responsible for managing the emergency through the provincial government to the federal minister responsible for the Canadian Forces in Canada in conjunction with Public Safety Canada.

The military received notification at 6:00 pm May 8th, and by 10:00 am the following morning, military personnel were sandbagging the areas of concern along the dikes. Between May 9 and 27, the military also provided assistance in Brandon, along the Portage Diversion, Portage la Prairie, St. Laurent and other locations. They also protected many private homes using aqua dams and tiger tubes, and provided assistance producing sandbags at Kapyong Barracks in Winnipeg. At the peak of the operation about 1800 military personnel were involved.

Late on Saturday, July 1st, the Province forwarded a second Request For Assistance for help in protecting the town of Souris, which was being threatened by the third peak on the Souris River. By noon the next day, military personnel were armouring the newly constructed earth dikes in the town with sandbags. Approximately 400 personnel were involved.

The Canadian military has an excellent working relationship with all provincial emergency management organizations, including Manitoba's Emergency Measures Organization. Their efforts during the 2011 flood were greatly appreciated.

7.3 Emergency Measures

Overall, the Province, through the Emergency Measures Organization (EMO) and Manitoba Infrastructure and Transportation (MIT), did due diligence in responding to the 2011 flood. This was a province-wide event, and it changed by the moment. Some situations in hindsight could have been handled better and hopefully, through this review, future events such as this will be addressed more effectively.

The Task Force consulted with emergency management coordinators for both the cities of Winnipeg and Brandon, along with several municipalities and stakeholder groups. The 2011 flood was basically a non-event for Winnipeg. Brandon, however, was much more involved, at times, pushing the limits of its response capabilities.

Both Brandon and Winnipeg have very good working relationships with EMO and other provincial government service providers. Brandon has a very robust Emergency Management (EM) plan and a full time EM coordinator. Winnipeg also has a full time coordinator. Since they are large municipalities, most EM events are dealt with in-house.

During consultation, many persons indicated that EMO just didn't have enough staff, in the field, municipal offices and in the EMO head office, to keep up with the demands for service. Most people did advise however, that those EMO employees that worked with them did so in a commendable manner, but they were stretched to their limits.

Several responders working through EMO advised they work under the Incident Command System (ICS) and felt that many who attended did not have ICS training and did not understand how the system worked. The Incident Command System is a standardized on-scene emergency management concept specifically designed to allow its user(s) to adopt an integrated organizational structure equal to the complexity and demands of single or multiple incidents, without being hindered by jurisdictional boundaries.

The Task Force heard many complaints of lack of training in emergency management provided by the Province (EMO). This issue is a direct result of lack of training staff (1 on strength) and the closing of the federal government's EM training centre in Ottawa. Training was also affected because 2010 was a municipal election year in Manitoba. Though training is offered to both provincial and municipal elected officials, participants were few. EMO would like to see a mandatory training requirement for all elected officials. Given the multitude of EM events that EMO has had to deal with province-wide in the past several years, unfortunately response has taken priority over training.

As flood preparation began over the winter and into the spring, many municipalities were faced with leadership changes within their communities because of the municipal elections in the fall of 2010. Though EMO was spread thin to assist most communities, the communities were thankful for EMO's assistance, especially when it came to declaring states of emergency and requesting assistance from the Province. Smaller municipalities are more likely to turn to the Province for assistance on a more regular basis as they do not, for the most part, have the resources to deal with major EM events, especially like that of the 2011 flood. Municipalities advised the Task Force that without advanced (prior to emergencies) EM training, most elected officials felt that the learning curve was too steep, especially during an event such as the 2011 flood.

Issues related to flood forecasting was a problem faced by EMO and its responders. Operational and administrative decisions became difficult. Consequently, decisions always erred on the side of caution, which often unintentionally placed added stresses on an already very stressful situation.

An after-action report outlines the steps taken by EMO during an event and reviews its practices. The Task Force was unable to obtain EMO's after-action report. As a result, the Task Force is unable to comment on whether EMO has a framework to analyze the Province's response to this event.

Many of those consulted firmly believe that the Province, and MIT in particular, did not, listen to `local knowledge` thereby making decisions that caused more concern among residents than good.

The construction industry in Manitoba was a critical partner with EMO/Province during the 2011 flood. Representatives of the industry have indicated that during the flood, working relationships with MIT staff were good. However, when it comes to emergency management, the construction industry is not clear on what they can and cannot do before, during and after an emergency event. A number of construction operators at different sites reported no or poor coordination, and communication with the Province at times was confusing and frustrating.

The construction industry should be involved with EMO in preplanning for an event such as this. The industry also pointed out that it was not included as part of the Manitoba Emergency Coordination Centre (MECC), and perhaps should be. Members of the construction industry should receive emergency management training.

The Task Force heard of issues with volunteers, mostly too many to deal with, which is a good thing, but difficult to manage. There was also concern brought forward related to injuries to volunteers. Each municipality is responsible to ensure that volunteers are registered, and once registered, they are covered under the *Workers Compensation Act*. Any costs associated with an injury are borne by the municipalities.

Non-First Nations, Northern Communities - the Northern Association of Community Councils (NACC) - struggled before, during and after this 2011 flood event. Representatives of that organization made a presentation to members of the Task Force. They cited lack of resources, training and communication, and isolation as the reasons for the many hardships that were experienced by their communities.

The Task Force heard many complaints from municipalities and First Nations communities concerned that during flood events, they could be cut off from the rest of the province as most only have one or two roads into their communities.

The building of commercial areas and homes on land subject to flooding is a concern to EMO. EMO has a business continuity program, most businesses do not.

7.4 Roles and Responsibilities of Emergency Management

It is important to ensure that the roles and responsibilities of all stakeholders in emergency management are clearly defined and understood.

Traditionally, the responsibility to deal with an emergency is placed first on the individual. As the capacity of the individual to cope with the emergency diminishes, the responsibility then shifts to successive levels of government, as the resources and expertise of each are needed. This recognizes that when an emergency occurs, people will see to their own safety to the greatest extent possible. Individuals then seek outside assistance from local, provincial or territorial authorities. Provincial and territorial governments will in turn request federal support if an emergency expands beyond their capacity.

Four basic pillars of effective emergency management in Canada have been adopted and must be taken into consideration in all aspects of emergency management planning and operations. They are described below.

Mitigation – Actions taken to prevent or reduce the consequences of an issue or emergency. Mitigation activities aim at identifying possible issues and emergencies. It consists of identifying the vulnerabilities and in taking proactive measures to mitigate the situation.

Preparedness – Actions taken to prepare for effective issue or emergency response. Preparedness activities consist of all hazard planning for response and recovery during emergencies as well as training and exercising of the plans.

Emergency Management provided mitigation, preparednesss, response and recovery.

Response – Actions taken to deal with the consequences of an issue or emergency. The response activities are put forward to take control and contain negative impacts. The response will require a complex level of coordination of operations and communications depending on the nature of the emergency. Response includes agency response, resource coordination, organizational structure, protection and warning systems and communications.

Recovery – Steps and measures taken after the emergency to repair and restore conditions to an acceptable level that existed prior to the emergency. Recovery measures actually begin during response. Recovery also reduces the future vulnerabilities of the community and improves planning for future events.

Emergency Measures Organization

Powers and Duties – The Emergency Measures Organization shall:

- subject to the approval of the Lieutenant Governor in Council, prepare and maintain disaster assistance policies and guidelines for emergencies and disasters in Manitoba,
- consult with local authorities, government departments, the Government of Canada and the private sector in order to prepare specific proposals for the establishment and implementation of disaster assistance programs,
- develop and maintain policy and procedures for the submission and processing of claims for disaster assistance,
- receive and assess all disaster assistance claims from local authorities, government departments, the Government of Canada or the private sector,
- dispose of all claims for disaster assistance by providing disaster assistance or dismissing the claims, and
- perform other duties vested in it by this Act and the regulations or assigned to it by the Minister.

EMO's mandate – The Emergency Measures Organization is responsible for:

- overseeing and coordinating all aspects of emergency preparedness in the province, and
- managing, directing and coordinating the response of all departments to a disaster or emergency, other than initial response and incident management at the site of the disaster or emergency.

EMO's emergency preparation duties – The Emergency Measures Organization must:

- prepare a provincial emergency preparedness program and a provincial emergency plan, and conduct regular reviews and revisions of the program and plan, and
- establish and maintain a registry containing a copy of every emergency plan and emergency management program in effect in the province.

7.5 Disaster Financial Assistance/Recovery Programs

7.5.1 Disaster Financial Assistance

The Government of Canada's primary instrument for responding to the financial needs of provinces and territories in the wake of major natural disasters is the Disaster Financial Assistance Arrangement (DFAA). Under that arrangement is the Disaster Financial Assistance (DFA) program. DFA is an assistance program, not a replacement, insurance or compensation program. There was a considerable amount of discussion and concern among those the Task Force consulted with around the interpretation of eligibility within the DFA application process.

The Province of Manitoba manages emergency events by following the guidelines as set out in the federal government's document "Emergency Management Framework for Canada". As such, the Province developed Manitoba's *Emergency Management Act* and the "Disaster Financial Assistance Policies and Guideline Regulations" that EMO follows when administering the DFA program within the province.

Beyond the regular DFA program, the Province chose to use Manitoba Agriculture, Food and Rural Initiatives (MAFRI)/ Manitoba Agricultural Services Corporation (MASC) programs to administer Lake Manitoba programs to provide enhanced assistance beyond DFA (e.g. The inclusion of secondary residences). This enhanced assistance was in response to the specific circumstances of Lake Manitoba.

The Province (MAFRI with support from EMO/local government and Manitoba Water Stewardship) developed separate program parameters, which may have been the cause of confusion for both government employees and those affected. The decision to separate the programs was made so as not to set precedents and raise expectations for DFA that cannot be sustained. It also allows the Province to maintain separation of claims for federal audit requirements. Individuals in certain geographic areas were eligible to apply for one or the other program, but never both. At least that is the way that it was/is supposed to work.

Manitoba Association of Native Fire Fighters (MANFF) are contracted by the federal government through Aboriginal Affairs Northern Development of Canada (AANDC) to administer the funds and programs for First Nations evacuation programs. The Province advises that they are not responsible for the operations of MANFF or the evacuation process for First Nations. Certain portions of these programs are cost-shareable with the federal government under the DFAA. EMO submits the DFA eligible expenses from all programs as one overall package to the federal government. This includes claims made from First Nations communities.

There are three full time DFA staff working out of the EMO office in Winnipeg. At the height of the flood, DFA hired 68 part time recovery advisers to assist with claims. Training and retention of these individuals appears to have been an issue during this event.

The Task Force heard, through the consultation process, difficulties persons had attending to claims offices, especially those persons who lived in remote areas including First Nations and NACC communities.

A province or territory may request Government of Canada disaster financial assistance when eligible expenditures exceed one dollar per capita (based on provincial or territorial population). Eligible expenses include, but are not limited to, evacuation operations, restoring public works and infrastructure to their pre-disaster condition, as well as replacing or repairing basic, essential personal property of individuals, small businesses and farmsteads.

The Government of Canada may provide advance and interim payments to provincial and territorial governments as funds are expended under the provincial/territorial disaster assistance program. All provincial or territorial requests for DFAA cost-sharing are subject to federal audit to ensure that cost-sharing is provided according to the DFAA guidelines. Each request for cost-sharing under the DFAA is processed once the affected province or territory provides the required documentation of expenditures.

On January 1, 2008, the revised guidelines for the DFAA came into effect. The guidelines spell out what provincial and territorial disaster expenses are eligible for federal cost-sharing and how the DFAA are administered. The new guidelines apply to natural disasters which occurred on or after January 1, 2008. The previous guidelines apply to earlier events for which Public Safety Canada is working with the provinces and territories on payments.

The revisions to the DFAA guidelines in 2008 include:

- clarifying the definition of eligible disasters,
- expanding the definition of eligible small businesses and farms to allow federal cost-sharing with provincial and territorial disaster financial assistance to business owners and part-time farmers,
- federal cost-sharing with provincial and territorial disaster financial assistance for charitable, non-profit or voluntary organizations, and
- federal cost-sharing with provinces and territories for enhancements to damaged infrastructure for the purpose of mitigation.

Table 7.1: Disaster Financial Assistance Arrangement (DFAA) per capita sharing formula

Eligible Provincial/Territorial Expenditures	Government of Canada Share
First $1 per capita	Nil
Next $2 per capita	50%
Next $2 per capita	75%
Remainder	90%

Source: Public Safety Canada

Example: ***For a disaster in a province with a population of one million where the total eligible expenses for responding to and recovering from a disaster are $10 million, the table below shows how eligible expenditures would be cost-shared through the DFAA.***

Table 7.2: Example for a disaster in a province with a population of one million

Eligible Expenditures	Provincial or Territorial Government	Government of Canada
First $1 per capita (100%) Provincial/Territorial	$1 million	Nil
Next $2 per capita (50%)	$1 million	$1 million
Next $2 per capita (75%)	$500,000	$1,500,000
Remainder (90%)	$500,000	$4,500,000
Total	**$3 million**	**$7 million**

Source: Public Safety Canada

Examples of provincial/territorial expenses that may be eligible for cost-sharing under the DFAA

- Evacuation, transportation, emergency food, shelter and clothing.
- Emergency provision of essential community services.
- Security measures including the removal of valuable assets and hazardous materials from a threatened area.
- Repairs to public buildings and related equipment.
- Repairs to public infrastructure such as roads and bridges.
- Removal of damaged structures constituting a threat to public safety.
- Restoration, replacement or repairs to an individual's dwelling (principal residence only).
- Restoration, replacement or repairs to essential personal furnishings, appliances and clothing.
- Restoration of small businesses and farmsteads including buildings and equipment.
- Costs of damage inspection, appraisal and clean up.

Examples of expenses that would NOT be eligible for reimbursement

- Repairs to a non-primary dwelling (e.g. cottage).
- Repairs that are eligible for reimbursement through insurance.
- Costs that are covered in whole or in part by another government program (e.g. production/crop insurance).
- Normal operating expenses of a government department or agency.
- Assistance to large businesses and Crown corporations.
- Loss of income and economic recovery.
- Forest fire fighting.

As of November, 2012, $362,171,268 has been paid out under the DFA program. MANFF has been provided with $63,398,692 in DFA payments for their ongoing support for more than 2000 evacuees.

The DFA program received 4488 private and 155 public sector applications.

73% of private claims files are closed, including rejected claims.
6% of public claims are closed.
1344 claims were deemed ineligible for DFA.

The main reasons for ineligible claims are:

- insurable losses,
- not a principal residence,
- no damage,
- business/farm under $10,000, and
- transferred to other program.

A total of 209 claims have appealed

- 34 of the claims are waiting for First Stage Appeal
- 175 of the claims have been completed to First Stage Appeal

A total of 61 claims have applied for Second Stage Appeal

- 49 of the claims are waiting on a hearing date
- 2 of the claims have been scheduled
- 10 of the claims have been completed to Second Stage Appeal

Estimated cost to repair or replace all damaged infrastructure is $129 million.

In spite of the large number of claims made under the DFA, a relatively small number of people attended the open houses to raise issues related to the program specifically.

Farm families and others living in the country felt that they were treated differently then city dwellers by Disaster Financial Assistance (DFA) staff. There was confusion over programs and the Task Force heard many concerns from flood victims about the differences of opinions on claims from DFA advisers. In many cases, having to travel long distances to meet with EMO officials was an issue.

7.5.2 MASC/MAFRI, BRAP, LMFAP, FRO, GO, DFA

Manitoba Agricultural Services Corporation (MASC) was appointed by the Minister of Agriculture, Food and Rural Initiatives (MAFRI) to administer a number of Building and Recovery Action Plan (BRAP) programs including Lake Manitoba Flood Assistance Program (LMFAP), Hoop and Holler Compensation Program, Dauphin River Flood Assistance Program (2011 and 2012), Lake Dauphin Emergency Flood Protection Program and the Lake St. Martin Commercial Fishers Flood Assistance Program.

A special unit within the Manitoba Agricultural Services Corporation, the Flood Recovery Office (FRO), was announced on May 2, 2011. The special unit manages the delivery of specific Lake Manitoba Flood Assistance Programs (Parts C and D), Dauphin Lake Emergency Flood Protection Program as well as the Hoop and Holler Compensation Program.

MAFRI Growing Opportunities (GO) offices, located in communities throughout the province, provided the delivery point for farm-related Lake Manitoba Flood Assistance Programs (Parts A and B). This approach was used to ensure farmers had a local contact with whom to discuss their programming needs.

Disaster Financial Assistance (DFA) programming is delivered by Emergency Measures Organization staff in those areas of Manitoba that do not fall within the geographic locations covered by the BRAP programs listed above. It is easy to understand, given all the programs and players, how confusion was experienced by some when dealing within this claims process.

In addition, many complaints were heard during the consultation process, of MASC/MAFRI/DFA losing original paperwork with no explanation given. The Task Force can only assume that this problem occurred as a direct result of limited full time trained staff within the different compensation programs.

Table 7.3: 2011 Flood Compensation Programs - September 30, 2012

	Number of Claims Received	Number of Claims Deemed Ineligible	Dollar Value of ClaimsPaid
Hoop and Holler Compensation Program	**683**	**46**	**8,358,740**
Lake Manitoba Financial Assistance Program			
Part A Pasture Flooding Assistance Component	356	78	2,692,478
Part B Agricultural Infrastructure, Transportation Crop/Forage Loss Component	543	37	28,764,819
Part C Business, Principal and Non-principal Residence Component	3263	527	40,720,117
Temporary Accommodations	288	39	4,187,790
Part D Flood Protection for Residences, Non-principal	2022	128	3,407,307
Sub-Total	**7155**	**855**	**88,131,251**
2011 Dauphin River Flood Assistance Program	**66**	**-**	**1,972,517**
Dauphin Lake Emergency Flood Protection Program	**101**	**41**	**286,376**
Sub-Total	**167**	**41**	**2,258,893**
Total	**7322**	**896**	**90,390,144**

Source: MAFRI

There are many reasons why applications were classified as ineligible, including administrative adjustments peculiar to the reporting software. These are listed below.

- It was determined the applicant was not in the program area and was then referred to the appropriate program.
- The applicant inadvertently registered for a program and it was subsequently determined they did not qualify (e.g. non-farmers registering for farm program). The client would have been referred to the appropriate program.
- The applicant/family members may have inadvertently submitted multiple applications. This was common especially during the early stages of the program.
- In the early stages of the program, the program administrator may have created duplicate claims for the same applicant.

Table 7.4: Listing of appeals requested and still being considered.

Appeals	Number of Appeals Requested	Number Still to be Considered
Hoop and Holler	16	11
LMFAP, Part A	3	3
LMFAP, Part B	14	12
LMFAP, Part C	215	179
LMFAP, Part D	8	3
Dauphin Lake	12	10
Dauphin River	0	0
Total	**268**	**218**

Source: EMO

As of September 30, 2012, there were 218 appeals waiting for a hearing. A full time Appeals Coordinator and Manager started the week of October 22, 2012 to assist with the scheduling of, and hearing of appeals.

The Province, through the EMO/DFA program held consultative meetings in several locations across the province. To their credit, the EMO website clearly outlines the program and all aspects of obtaining assistance. Even though EMO made many strides in communicating this program across the province, during the Task Force consultation meetings, the same comments continued to surface:

> ***"DFA is not understood well within government departments or outside within the general public."***
>
> ***"DFA needs to simplify their program communications so that the general public can better understand the entire program"***

The Task Force believes a lot of the clients' confusion has to do with following.

- There were instances where multiple adjusters ended up dealing with one claimant. (Temporary employees)
- There were no local offices for claimants to attend for information and assistance.
- There were not enough DFA staff (3 full time) to assist claimants in the claims process.
- The DFA recovery adviser changes during the claim process.
- There was a lack of training of elected officials, adjusters and individuals about DFA.
- Elected officials made promises to claimants which were not concurrent with the DFA programming.
- An ongoing DFA communications program post-2011 flood event was lacking, at the community and individual level.
- Time lines within the DFA program to settle claims was much too long. The shortage of staff likely added to this problem.
- The mental health of claimants and the stress issues faced daily during and after this event never appeared to be of concern within this provincial program.
- Claimants were often unable to contact adjusters, DFA or EMO staff, and there were long waiting periods for the return of phone calls.
- The Task Force heard from many DFA claimants that they had received a cheque in the mail with no explanation of the reason for the payment. Many concerned people contacted EMO about this, but with no resolution.
- The loss of paperwork from claimants within the DFA program was an issue. Many persons had to re-apply several times with no explanation of why or how their papers were lost.
- There was conflicting claim/DFA information from EMO, MASC and MAFRI.
- Rural Manitobans felt that they were treated like second-class citizens. They had issues with having to travel to major centres for DFA claims.

- The federal government's department responsible for DFA financial aid to First Nations communities, Aboriginal Affairs and Northern Development Canada (AANDC) puts little effort into working closely with the provincial EMO in ensuring First Nations communities understand the DFA program as it relates to disaster management.

7.6 First Nations

The Manitoba 2011 Flood Review Task Force undertook broad consultation with First Nation communities, Chiefs and Councils, political tribal organizations and individual First Nations members across the province. Though not within its original flood review mandate, the Task Force felt it would have been neglectful in its duties if it had not conducted this First Nations consultation process.

The issue of jurisdictions in EM situations, that is, who is responsible for First Nations emergency management during events such as the 2011 flood, was confusing to those living within the affected areas. Though most of the interviewees understood the federal government has responsibility, most felt that they had been left to look after themselves with little or no assistance from either the federal or provincial governments. The Task Force's consultation with the federal government department responsible for First Nation communities, AANDC, was even more confusing to the Task Force. The following are segments taken from AANDC/National Emergency Manual.

> ***"AANDC National Emergency Management plan is to provide a national framework for the roles and responsibilities of emergency management ; mitigation, preparedness, response and recovery activities in First Nation Communities across Canada.***
>
> ***The Provinces and Territories are responsible for activities related to Emergency Management within their respective jurisdictions. However, section 91(24) of the Constitution Act 1867 prescribes the legislative authority of the Government of Canada for "Indians, and lands reserved for the Indians." (The 1867 Constitution Act)***

Under the *Emergency Management Act*, AANDC is responsible for preparing emergency management plans in respect of EM risks, for maintaining, testing and implementing plans and for conducting exercises and training in relation to these plans.

First Nations are responsible for developing and implementing plans for their own communities. When an emergency occurs or may be imminent within a First Nation, it is the responsibility of the Chief and Council of the First Nation to utilize all available local resources to respond to any situation that results in a present or imminent threat to life, property or the environment in their community. The Chief and Council may declare a state of emergency through a Band Council Resolution and notify AANDC and Manitoba EMO if such a declaration is made. When a First Nation declares a state of emergency it signals its need for assistance.

AANDC policy continues on with the following:

> *" Manitoba EMO, with the Provincial Department of Infrastructure and Transportation , will work in cooperation with the Manitoba Association of Native Fire Fighters (MANFF) to deliver Emergency Management programs for Manitoba First Nations. During an emergency, Manitoba EMO will be responsible for coordinating emergency response assistance to First Nations when local resources are overwhelmed."*

This policy document also states that *" in October, 2009 the Government of Canada and the Province of Manitoba signed a Memorandum of Understanding (MOU) regarding the improved delivery of emergency management programs in First Nations communities. The MOU describes an agreement in principle to have Manitoba's Emergency Measures Organization (EMO) provide service to First Nations communities within Provincial boundaries on behalf of AANDC."*

The Task Force has been unable to substantiate that such a MOU exists between EMO, Manitoba and AANDC. The Province is not aware of this MOU and has asked AANDC to remove this information from their website on several occasions.

However, there is still a stable, on-the-ground working relationship between the Province and AANDC. But it should be noted that if there is confusion at the top level of the federal government agencies of what is in fact each others' areas of responsibilities during EM events are, this confusion will only be exacerbated at the community level.

During the 2011 flood, EMO did assist First Nations communities at the request of AANDC and provided the following services:

- EMO engaged MANFF under contract to undertake inspections on behalf of DFA.
- EMO agreed to evaluate the inspection reports, determine what was eligible and deal with the applicant.

EMO had to accept these responsibilities since AANDC has only one emergency manager on staff in Manitoba to service 63 First Nation communities.

The federal government, without any formal agreement, placed its responsibility for EM on First Nations communities on the Province. These services were provided under the provisions and guidelines of the DFA affecting reimbursement of provincial expenditures on First Nations. There was no standing agreement to do this, and it is subject to a case-by-case request from AANDC to the Province. The Province may have been placed in a position where it is liable for costs that the federal government may decline to absorb.

The provincial program only allows private property owners and local authorities as eligible applicants. In the case of First Nations, AANDC is the local authority and therefore, for public sector issues AANDC must request DFA from the Province.

EMO, on behalf of AANDC, DFA programs, reports the following as of December, 2012:

- 920 private First Nations claims - $860,000 paid to date – 202 claims remain open
- 1 appeal process
- 30 First Nations bands/public sector claims - $29M paid to date, all remain open
- 1990 First Nations evacuees remain displaced

The Task Force consultation and research reviews clearly indicate that AANDC is not complying with its own policy in reference to First Nations communities but, without any formal approval process, has downloaded the EM programs to the Province.

The Task Force can find little evidence of mitigation, training or exercising programs within First Nations communities. The Province has opened its EM training to all interested parties but few First Nations participate. It is also clear that First Nations leadership are not aware of their responsibilities under the Federal Emergency Management Manual directives and this has led to very few communities being in a position to deal with EM events. The Task Force learned that some First Nations communities had part time EM positions within the band, but most had none.

AANDC advised the Task Force that *"they (federal government) believe EM training for First Nations is up to the Province, they don't have the resources."* There are no province-wide flood mitigation strategies for Manitoba First Nations communities. This is a federal government responsibility.

An issue faced by EMO was that not all First Nations will work with MANFF.

7.7 Recommendations

Emergency Measures Organization

45. The Province increase the Emergency Measure Organization's (EMO) full time staff to be better able to deal with present and future emergency management events, training, exercising and mitigation projects.

46. EMO enhance its strategic provincial annual training program with a goal that training be mandatory for all newly elected officials trained in emergency management. This would also include programs oriented to First Nations communities.

47. EMO develop a comprehensive training program that would instruct municipalities, First Nations communities and individuals on how to make sandbags, how to operate machinery and how to properly build flood protection dikes.

48. EMO and Manitoba Infrastructure and Transportation (MIT) develop a strategic program aimed at stockpiling dike building construction material around the province in known flood prone areas with the view toward using this material for other projects once the flood threat has passed.

49. EMO ensure ICS (Incident Command System) training/awareness in all emergency management (EM) training programs.

50. EMO develop an EM data base to be utilized by all partners involved in the EM response.

51. EMO's after-action report should be released in a more timely fashion.

52. EMO consider the development of a provincial "reserve" group, trained to supplement the EM office with its demands during EM events.

53. EMO consider the development of an advisory committee made up of flood victims and responders to look at the response to this flood and future EM events, outside of DFA issues, to assist EMO with its strategic planning.

54. EMO work with universities, organizations, individuals and industry, assisting them with federal and provincial support with their flood mitigation projects.

55. EMO develop an EM training program for the construction industry involved in EM response. This would include management and "on the ground" workers.

56. EMO invite a representative from the construction industry to join their monthly EM meetings and be part of the operational command centre during EM events.

57. EMO, jointly with MIT, host a conference for the construction industry involved in flood response and include items such as training availability, expectations, cooperation and coordination during EM events, tender process, permit issues and call out procedures.

58. EMO establish an on-site training program for isolated, Northern Association of Community Councils (NACC) communities specifically, that would assist them in mitigating and managing future events.

59. EMO develop an advance "Disaster Response Team" to assist municipalities at very short notice during these events.

60. EMO develop a training program that is tailored to rural, smaller centres versus larger municipalities that have more resources.

61. The Emergency Management Organization's head office, located on the 15th floor of 405 Broadway in downtown Winnipeg needs to be relocated to an appropriate location that meets the operational and administrative needs and accessibility of its staff and EM partners.

Disaster Financial Assistance Program

62. The Province take immediate steps to increase the number of DFA's full time employees within the Emergency Measures Organization.

63. The EMO/DFA office develop an easy to understand and use communications package that can be sent out to elected officials, First Nations, business, farmers and individuals.

64. The EMO/DFA office develop a DFA education/training program that is delivered province-wide, not just in Winnipeg, and set training targets and goals as part of EMO's annual program initiatives.

65. EMO undertake a comprehensive review of the provincial and federal DFA program and how it was implemented in 2011, and how can it be done better in future. Develop an easy to understand and comply-with program for individuals.

66. EMO establish a mental health component as part of its strategies and programs within DFA.

67. The Province encourage the federal government to enhance its DFA program within First Nations communities and work more cooperatively with the Province in assisting with DFA/First Nations programming.

68. The DFA/recovery programs should remain within EMO, or an appropriate government department, having control over all compensation programs, provide one-stop shopping for all claimants, reducing confusion.

69. EMO develop a one-window consent information/application/assessment form that can be utilized by agencies, alleviating multiple forms/paper work.

70. EMO consider developing a DFA advisory group made up of those administering the program and those who have been directly affected by disasters and have utilized the program, to assist both sides in understanding and developing training and communications programs to assist in future EM events.

71. EMO, through its DFA programs, develop a communications plan that explains all aspects of the assistance payments, reasons for and outstanding balance issues, when distributing payments to clients.

First Nations

72. The Province strongly urge the federal government (AANDC) to develop a national strategic, overall emergency management plan that would encompass all of their responsibilities in administering and operationalizing their EM plan within the province. This would include all aspects such as mitigation (in Manitoba, flood mitigation is of particular significance), strategies, training, exercising, communications and resources to accomplish these goals.

73. The leadership of Manitoba First Nations communities make emergency management programs within their communities a priority, including the establishment of full time emergency management coordinators, training and exercising programs. First Nations leadership should also address the issue of province-wide First Nations EM mitigation strategies within First Nations communities with the federal government/AANDC.

8. Adequacy of Existing Flood Control Infrastructure

The adequacy of existing flood protection infrastructure and the need for additional works.

8.1 Background

There was significant flood damage throughout Manitoba during the 2011 flood, despite the operation of the existing water control structures and other infrastructure designed to mitigate flood damages. An assessment of the adequacy of existing flood protection infrastructure and identification of additional infrastructure that would provide improved water management capability within the province was conducted for each of the water control structures addressed in *Section 4: Evaluation of the Operation of Water Control Structures.* Prospective new flood control works would be identified based on a review of previous basin studies, input from the general public and the Task Force's own evaluation.

The Task Force fully understands that the Province is faced with financial and human resource limitations, and acknowledges that it will not be possible to address all of the recommendations regarding new flood control infrastructure. Recommendations will have to be prioritized, with due consideration for the findings of the Assiniboine River and Lake Manitoba Basins Flood Mitigation Study which is now underway. Some recommendations such as adding gates to the Shellmouth Dam, are already being studied or implemented. Others, such as those regarding the need to upgrade existing infrastructure, should be implemented in the short to medium term. And others, such as developing additional reservoir storage capacity or additional outlet capacity from Dauphin Lake and Lake Manitoba, will require long term study to establish feasibility.

The 2011 flood was a very extreme and rare event and it would not have been possible to prevent flood damages in all cases. In addition, scientific evidence is increasingly suggesting that global warming and climate change could lead to greater variability in the weather and possibly more extreme drought and flood events in the future.

8.2 Dauphin Lake Basin – Mossy River Control Structure

Mossy River is the only outlet from Dauphin Lake. The Mossy River Control Structure has been effective in stabilizing lake levels and preventing very low levels during periods of sustained low runoff. However, it has no capability to prevent very high lake levels, such as occurred in 2011, because of the limited channel capacity of the Mossy River. Two possible measures for limiting high water levels on Dauphin Lake during periods of high runoff were identified by stakeholders, namely reducing inflow by changing land use or providing storage in watersheds draining into the lake, and increasing outflow by improving or augmenting the capacity of the Mossy River.

8.3 Upper Assiniboine River – Shellmouth Dam and Lake of the Prairies Reservoir

Shellmouth Dam was originally designed and constructed for flood control and water supply, and is currently operated as a multipurpose project to reduce downstream flood damages, to augment low flows for water supply and instream flow requirements along the Assiniboine River and to provide recreational and fisheries benefits on the reservoir. The operating guidelines have evolved over the years to meet these objectives.

Recommendations like adding gates to Shellmouth Dam are being considered.

Every year, the operation of the Shellmouth Dam has resulted in some reduction in downstream peak flow – by 22 percent at Russell in 2011, from 540 m^3/s to 420 m^3/s (19,500 cfs to 14,100 cfs).

The Shellmouth Dam controls only 11 percent of the Assiniboine River basin. But, its operation has provided significant benefits to communities, farmers and other downstream interests by reducing the magnitude and duration of peak flows that would have otherwise occurred without the dam. Any time peak flows are reduced downstream by increasing reservoir storage, outflows must eventually be greater than inflows to allow reservoir drawdown by releasing water from the reservoir. In most years these additional outflows can be controlled within the downstream river channel. However, during high runoff events when the reservoir level rises above the crest of the spillway, it is not possible to control these outflows and the duration of downstream flooding can be extended, resulting in what is termed "artificial flooding". Options to reduce flood damages downstream of the Shellmouth Dam such as a buy-out of flood-prone valley bottom lands and constructing dikes along the margins of the Assiniboine River below the Shellmouth Dam should be examined.

The flood control potential of the Shellmouth Reservoir is limited by the storage volume between the target minimum winter drawdown elevation 422.45 m (1386.0 ft) and the crest of the spillway elevation 429.31 m (1408.5 ft). This volume is approximately 340 000 dam^3 (276,000 acre-ft) as compared to the average annual inflow of roughly 460 000 dam^3 (373,000 acre-ft) and the 2011 annual inflow of 2 200 000 dam^3 (1,784,000 acre-ft). There is some concern that the magnitude of inflows may be increasing over time as a result of continued agricultural drainage activities in Saskatchewan. In addition, flood control benefits of dam operation may be offset by the additional inflows that enter the Assiniboine River below the dam also due to the more intensive drainage activities in Saskatchewan. Increased runoff volumes destabilize tributary channels, resulting in extensive bed degradation, bank instability and deepening and widening of the channel. The ultimate outcome is a loss of productive lands along the margins of these tributaries, increased difficulties maintaining culverts and bridges and excessive sedimentation (and potential reduction in conveyance capacity) of the Assiniboine River channel.

In cooperation with the Province of Saskatchewan, Manitoba should work to identify and control drainage activities in both provinces, and to gain a better understanding of the impact of agricultural drainage on the hydrology of the Assiniboine River.

The Province of Manitoba has been investigating the merits of adding 1.8-metre (six-foot) gates to the presently ungated spillway crest of the Shellmouth Dam to increase the flood control benefits of the reservoir. The Province should continue to pursue the installation of these spillway gates, but examine and quantify the flood control benefits and assess any impact on other uses served by the reservoir.

8.4 Portage Diversion and Assiniboine River Dikes

The Portage Diversion weir and headgate structure, the Portage Diversion channel and associated drop and outlet structures, and the Assiniboine River dikes are operated as an integrated system to manage flood flows on the lower Assiniboine River. Any change to upgrade or increase the capacity of one component of the system must consider the impact on the other components.

The Portage Diversion weir and headgate structure have been in service for more than 40 years, and were severely tested during the 2011 flood. Several individuals commented that the structure is being used with increasing frequency in recent years, allegedly to accommodate water level requirements at the Forks in Winnipeg rather than to mitigate high spring water levels on the Red River within Winnipeg and/or prevent overbank flooding between Portage la Prairie and Winnipeg. An examination of historic diversion records would support the view that the use of the Portage Diversion has become more frequent, and extended for longer periods, in most years since 1995. But it must be recognized that these diversions have been occurring during a wet period with repeated high flows on the Assiniboine River.

All of the components of the Portage Diversion system require upgrading including the headgate structure, the outlet structure at Lake Manitoba and the wasteway (fail safe). The upgrades made to the dikes along the Portage Diversion channel in 2011 should be retained and maintained as a contingency for future large flood events. Drop structures and bridge crossings should be upgraded where necessary.

The integrity of the Assiniboine River dike system is highly variable.

To reduce the frequency of operation and the magnitude of diversions through the Portage Diversion, additional storage on the Assiniboine River (such as the Holland Dam) upstream of Portage la Prairie, and storage on tributaries to the Assiniboine River should be studied. In addition to providing additional flood control benefits, this storage could also provide water supply benefits to the region and reduce the reliance on Shellmouth Dam for low flow augmentation in the lower Assiniboine River.

The Assiniboine River dikes are an important component of the flood control system for Winnipeg and the farmland and communities located between Portage la Prairie and Headingly. The location of the dikes varies with the local topography, and in some locations local road and/or railway grades are used as surrogate dikes where feasible. Typically, dikes are placed as far away as is practicable from the active river channel to minimize the potential for undermining due to bank erosion. But in many locations the dikes or surrogate dikes are situated relatively close to the river channel because of local constraints.

Given the age of the dikes and the various agencies which have been responsible for their construction and maintenance over the years, the integrity of the dikes varies significantly. The newer dikes are in better condition than the oldest dikes and the overall integrity of the dike system has been improved over time. However, in some locations the dikes are constructed of unsuitable and/or poorly compacted material that is porous and subject to piping and slumping when exposed to high water for long periods.

The geotechnical performance of the dikes was a critical limiting factor in managing the 2011 flood in the Portage la Prairie area. There was concern a sustained flow higher than 510 m^3/s (18,000 cfs) could result in an uncontrolled failure of the dikes in some locations. The shortfall in accommodating the forecast flow upstream of the Portage Diversion through the enhanced Portage Diversion channel, given the maximum tolerable flow down the Assiniboine River, resulted in the decision to construct a controlled breach of the Assiniboine River dike at Hoop and Holler Bend. Actual flows at the diversion peaked lower than expected, so flows through the Hoop and Holler breach were much lower than initially anticipated. Nevertheless, it is clear that the system capacity was challenged in 2011.

The Assiniboine River dikes need upgrading. In addition, as one component of a properly engineered dike system, a permanent controlled wasteway (either north or south of the Assiniboine River), should be constructed to pass Assiniboine River flows in excess of the combined capacity of the Portage Diversion and the lower Assiniboine River channel when the need arises.

8.5 Lake Manitoba – Fairford River Water Control Structure

In most years the major source of inflow to Lake Manitoba is the Waterhen River, which conveys outflow from Lake Winnipegosis. The Waterhen River experiences multi-year cycles of dry and wet periods, which can be attributed to the large storage volume in Lake Winnipegosis and the relatively limited channel capacity of the river channel. These same multi-year cycles were mirrored in Lake Manitoba before 1961, when the construction and operation of the Fairford River Water Control Structure (FRWCS) and expansion of the Fairford River channel allowed Lake Manitoba levels to be maintained within a narrower range. However, this operation resulted in wider and more frequent fluctuations on Lake St. Martin, which is located downstream of the structure.

Since 2003, the FRWCS has been operated in accordance with the report of the Lake Manitoba Regulation Review Advisory Committee, which recommended that Lake Manitoba water levels be regulated to reflect a more natural regime. When both Lake Manitoba and Lake St. Martin are within a "normal" range no adjustments are made to the control structure, but when either or both lakes are outside of their desirable ranges, the lakes are regulated to balance the impact on both lakes.

The Fairford River Water Control Structure operated at maximum capacity during the flood.

Outflows through the FRWCS are limited by the hydraulic capacity of the Fairford River channel. In 2011, large differences between inflows and outflows contributed to a substantial increase in water levels on Lake Manitoba. Such rises in lake level can be mitigated by either limiting the inflow to Lake Manitoba, or by increasing the outlet capacity from the lake. Any increase in outflow capacity from Lake Manitoba would require a similar increase in outflow capacity from Lake St. Martin to prevent surcharging of that lake.

Stakeholders made a number of recommendations regarding possible actions to better manage the water levels on Lake Manitoba which would reduce or preclude the need for additional outlet capacity from Lake Manitoba and Lake St. Martin. Options suggested included a diversion from Lake Manitoba to Lake Winnipeg, a diversion from Lake Winnipegosis to Lake Winnipeg and an outlet control structure on the Waterhen River to control outflow from Lake Winnipegosis.

Throughout the review process, the Task Force and the Lake Manitoba and Lake St. Martin Regulation Review Committee held joint open houses at communities around Lake Manitoba, and have collaborated on the issues related to Lake Manitoba and Lake St. Martin. As well, the Committee has conducted extensive consultations and analyses on water levels and outlet capacity needs of Lake Manitoba and Lake St. Martin, and has made specific recommendations on these matters. These recommendations should be adopted with due consideration for the findings of engineering studies now underway.

8.6 Red River Floodway

In response to the disastrous flood of 1950, the Red River Floodway was constructed in 1968 to provide flood relief for the city of Winnipeg. The combined operation of the floodway, the Shellmouth Dam and the Portage Diversion now protect Winnipeg against a 700-year flood event.

Rules for operation of the floodway are under the general authority of *The Water Resources Administration Act* and are a condition of the license issued under *The Manitoba Environment Act* on July 8, 2005. The rules dictate how the floodway gates are to be used under normal, major and extreme water flows. The Red River Floodway has proven to be very effective in protecting Winnipeg from flood damages, and the Task Force has no recommendations for additional flood control infrastructure in the Red River Valley.

8.7 Souris River Basin

The high snowmelt runoff combined with spring and summer rainfall in 2011 resulted in a prolonged period of extensive flooding and saturated field conditions that led to the loss of agricultural productivity throughout much of the Souris River basin in Manitoba. In the communities of Melita, Souris and Wawanesa, the existing permanent dikes were enhanced using various forms of emergency temporary dike protection, and major flood damage in those communities was largely avoided. Manitoba Hydro managed to maintain electricity and natural gas services throughout the flood. A number of bridges sustained damages or were closed, and both the Wawanesa Dam and Oak Lake Dam were damaged from flood waters.

The major storage reservoirs in the Souris River basin are located upstream in Saskatchewan (Boundary, Rafferty, Alameda and Moosomin dams) and in North Dakota (the U.S. Fish and Wildlife Service dams in the Upper Souris, J. Clark Salyer and Des Lacs national wildlife refuges).

In June 1978, the Canada-Manitoba-Saskatchewan Souris River Basin Study identified prospective structural and non-structural flood damage reduction measures on the main stem of the Souris River in Manitoba to reduce both agricultural and urban flood damages. Agricultural flood protection measures included diking, channel enlargement, a combination of diking and channel enlargement, cleaning debris from bridges and dams and channel realignment. Urban flood protection measures included alternative diking schemes for the towns of Melita and Souris and the village of Wawanesa. In addition, headwater storage was examined on tributaries to the Souris River in Manitoba (Antler River, Gainsborough Creek, Graham Creek and Jackson Creek) and Souris River main stem storage was also examined (Coulter Bridge Dam, Lauder Dam, High Souris Dam and Nesbitt Dam). Other structural measures included removal of all existing dams on the main stem of the Souris River, improvement of discharge capacities at road and railway crossings and flood proofing to render buildings, contents and property less vulnerable to flood damages.

After a detailed engineering and economic evaluation of all of these alternatives, the only structural mitigation measures in Manitoba that were recommended involved diking and flood proofing at Melita, Souris and Wawanesa. There was one basin-wide recommendation in the 1978 report regarding the need to better control agricultural land drainage. The Task Force supports this recommendation, given the concern expressed by residents about the effect of drainage in tributary basins to the Souris River in Manitoba.

8.8 Water Control Structures Operated by Others

The Task Force heard from several individuals that water control structures owned by Ducks Unlimited Canada have been poorly maintained. Even so, these structures could possibly have been operated during 2011 to control flood waters and reduce the magnitude and extent of local flooding. The Province should approach Ducks Unlimited Canada with a view to cooperating in this matter.

8.9 Community and Private Dikes

There are a number of private and community or municipal diking projects throughout Manitoba, with Ochre River, Brandon, Souris, Miniota and St. Lazare as examples. Many of these projects have been designed locally and are being maintained on an ad hoc basis. Some of these dikes appear to be in various states of disrepair and/or have not been brought up to current design standards. Many stakeholders indicated that there are insufficient local resources to maintain the dikes properly, and that local expertise is insufficient to assess the integrity and reliability of the dikes. In concert with local municipalities and individuals, the Province should develop an inventory of these dikes, determine ownership, and clarify and communicate responsibility for ongoing maintenance and liability.

8.10 Non Structural Alternatives – Wetland Retention and Restoration

Several individuals and non-government organizations have suggested that the magnitude of flooding in 2011 would have been substantially reduced if unmitigated drainage had not taken place in the headwaters of the Souris and Assiniboine rivers. Alternatively, the effects of this drainage could have been mitigated by actively working to store floodwaters on the landscape, rather than letting them flow uncontrolled to streams and water bodies. In response, the Task Force has conducted a brief review of the state of knowledge and practice regarding the impact of drainage and restoration of wetlands on hydrology (Appendix E).

In short, the impacts of draining prairie wetlands vary from year to year and are dependent on hydrological conditions. To understand the impacts of wetland drainage, it is necessary to understand the hydrological processes as they relate to the generation of runoff, and the hydraulic characteristics of both the natural and manmade drainage systems. Such an understanding is developed through the use of hydrologic modelling that simulates runoff processes. These models must address both the generation and conveyance of runoff while adequately representing the spatial distribution and connectivity of intact and drained wetlands within a watershed. While significant advances have been made in the hydrologic modelling of prairie watersheds with intact and drained wetlands, more work is needed to develop an understanding of the implications of specific drainage projects on the runoff regime.

Wetland drainage leads to increases in peak flows and run off volumes causing stream erosion and sedimentation.

The modelling of wetlands is data-intensive and requires spatial elevation data (LiDAR, for example) that is of sufficient resolution to capture the shallow depressions of wetlands and the hydraulic features of the wetlands and receiving streams. The large volume of data that is required for this process has limited runoff modelling to only relatively small watersheds. Scaling up the results from small watersheds to larger basins is complex and quite non-linear because the location of wetlands within a basin affects their ability to control floods. For instance, if the wetlands are all located in the upper portion of the watershed and drain only a small percentage of the total contributing area, they may have little impact on the downstream flood peak and only contribute to the runoff volume on the recession of the flood.

Nevertheless, on the whole, hydrologic modelling suggests that local wetland drainage leads to increases in peak flows and runoff volumes during low to moderate flood events. During major floods that occur in response to abnormally wet conditions, nearly filled or full natural wetlands would have less of an impact as they have little remaining flood storage and would effectively behave like a drained wetland. In 2010, southern Manitoba experienced well above normal summer and fall precipitation that filled many natural wetlands and saturated the soil, significantly reducing the natural storage available to accommodate the 2011 spring snowmelt and rainfall runoff events.

8.11 Alternative Land Use Services (ALUS) Pilot Project

While attending meetings in Miniota and Oak Lake, Task Force members visited a farm where wetlands had been restored under a pilot project known as the Alternative Land Use Services (ALUS). ALUS is an ecological goods and services program, conceived from a paper released by the Delta Waterfowl Station and the Keystone Agricultural Producers that proposed a voluntary incentive-based wetland restoration program. In 2006 an ALUS pilot project was launched in the Rural Municipality of Blanshard in southwestern Manitoba. The three-year project offered landowners the opportunity to sign contracts on a voluntary basis for wetland, riparian area and grasslands habitat restoration. Payments to landowners were based on acreage and quality of habitats under agreement. An advisory group that included local agricultural producers had a significant role in the development of ALUS program options.

The level of interest in the pilot project was reflected in its funding base which included the governments of Canada and Manitoba, the Delta Waterfowl Foundation, Keystone Agricultural Producers, the Rural Municipality of Blanshard, the Little Saskatchewan River Conservation District and private donors. Since the ALUS project, the Province has been working on the development of a surface water management strategy.

8.12 Closed Drainage Basins – Whitewater Lake

The last of the Pleistocene continental glaciers retreated from the Prairie region between about 17,000 and 10,000 years before present, and left numerous small and large topographically closed depressions in the Prairie landscape. The existence of these depressions, together with the dry climate, has resulted in a large proportion of the landscape being internally drained within closed drainage basins that rarely, or never, spill runoff water to a major river system. The lakes within such hydrologically closed basins are sensitive to changes in climate and land use.

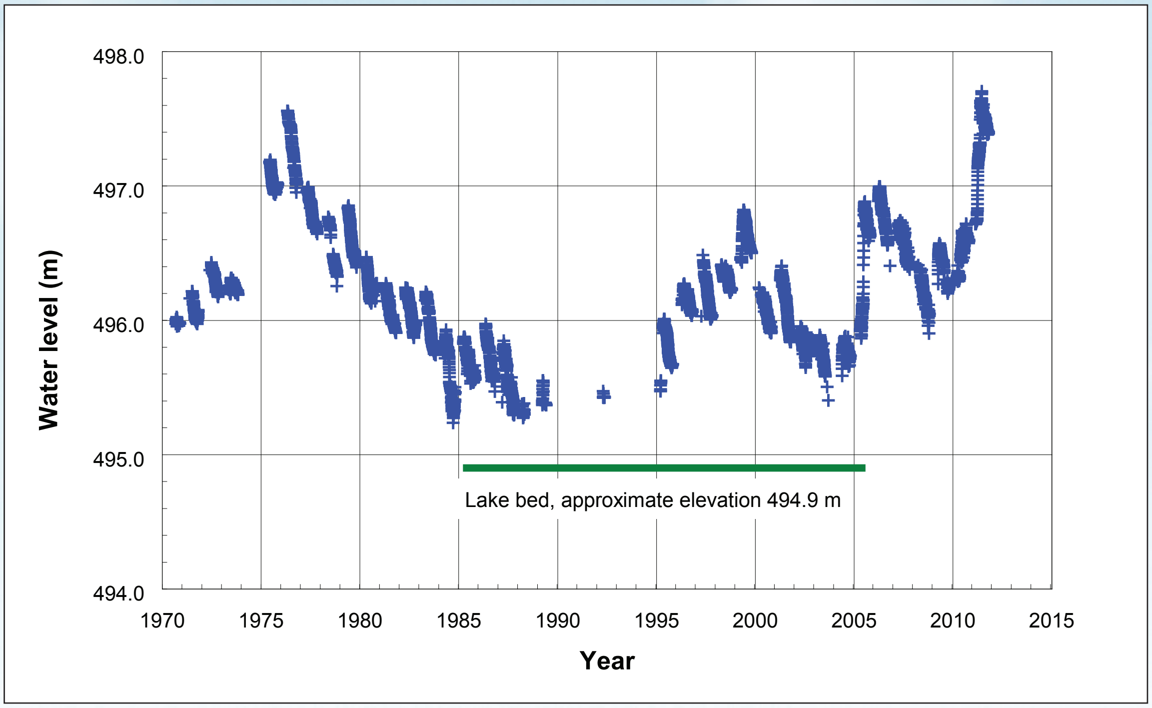
There are generally considered to be five major closed drainage basins in the Canadian Prairies: Bigstick Lake (Maple Creek), Old Wives Lake and Quill Lakes in Saskatchewan, and Pakowki Lake and Sounding/Eyehill Creeks in Alberta. Smaller examples in Manitoba include North Shoal Lake and Whitewater Lake. The Task Force was approached by stakeholder groups who were concerned about the very high water levels on Whitewater Lake.

Whitewater Lake is typically less than 1.5 metres (5 ft) deep, with a drainage area of 684 km^2 (264 $miles^2$) located in an agricultural area of southwestern Manitoba. The Turtle Mountain is the dominant feature within the watershed. It rises to a height of 213 m (700 ft) above the adjacent plain over a distance of 10 km (six miles) in the southern portion of the basin. Intermittent streams on the north slope of Turtle Mountain drain into swampland bordering Whitewater Lake. As they flow down the slopes, the streams are entrenched in well-developed ravines cut into the landscape. At the foot of the mountain the stream gradients decrease and the ravines disappear. There are no direct surface inlets entering the lake. There is no natural outlet from the lake, but field surveys completed in 1976 indicated that at lake levels higher than 497.70 m (1632.8 ft) the lake would drain west to Medora Creek which eventually enters the Souris River near Napinka.

Water levels on Whitewater Lake have historically fluctuated over wet and dry cycles in response to precipitation, surface runoff from the Turtle Mountain and evaporation losses from the lake surface (Figure 8.1). Water levels have ranged from dry (lake bottom elevation 494.90 m, or 1623.7 ft) in the 1930s to a maximum recorded level of 497.66 m (1632.8 ft) on June 28, 2011. The flooded area was roughly 11 300 hectares, or 28,000 acres. The median water level has been about 496.2 m (1628 ft), which corresponds to a flooded area of 7800 hectares (19,200 acres). Various studies have been completed over the years to assess proposals to stabilize lake levels, including schemes to import water during low runoff periods and to construct drainage channels to either or both Medora Creek and Elgin Creek that would operate during periods of high runoff. None of these proposals have been implemented due to high capital costs and difficulty in reaching consensus among the various stakeholders in the region which include the rural municipalities of Arthur, Whitewater, Winchester and Morton, and various wildlife management groups, including Ducks Unlimited Canada.

The Task Force was approached by some of these stakeholder groups as well as by the Turtle Mountain Conservation District, and was asked to immediately address the very high Whitewater Lake levels which were flooding extensive areas of agricultural land. Turtle Mountain Conservation District has attempted to find a solution acceptable to all parties, but has not been successful. The Task Force advised these groups that it had neither the mandate nor the authority to recommend or approve any specific action, but would note their concerns and would include the issue in its report to government.

Figure 8.1 Water levels on Whitewater Lake, 1970-2011.



8.13 Recommendations

74. Examine and adopt means to accommodate any impact on hydrology of global warming and climate change when planning, designing and implementing future water use projects.

75. Investigate the feasibility of developing storage on the major tributaries that contribute runoff to Dauphin Lake including the Valley River, Vermillion River, Ochre River and Turtle River.

76. Investigate the feasibility of developing a second controlled outlet from Dauphin Lake into Lake Winnipegosis. Local residents suggest that a possible location for this additional outlet channel would be east of, and parallel to, the Mossy River.

77. Investigate alternative means to prevent or reduce flood damages on the Assiniboine River below Shellmouth Dam:
    - Continue to pursue the installation of spillway gates on Shellmouth Dam, but examine and quantify the flood control benefits and assess any impact on other uses served by the reservoir.
    - Investigate the merits of a buy-out of flood-prone valley bottom lands downstream of Shellmouth Dam, which would increase the operational flexibility of Shellmouth Dam and eliminate future downstream flood damages and liability.
    - Investigate the feasibility of constructing dikes along the margins of the Assiniboine River below Shellmouth Dam to reduce future flood damages on flood prone valley bottom lands and increase operational flexibility.

78. Continue to work with the Province of Saskatchewan to better understand the impact of agricultural drainage on the hydrology of the Assiniboine River, and to identify and control drainage activities in both Saskatchewan and Manitoba.

79. Retain and maintain the upgraded dikes along the Portage Diversion channel, as a contingency for future large flood events. Upgrade drop structures and bridge crossings where necessary.

80. Upgrade the outlet structure on the Portage Diversion channel where it enters Lake Manitoba, to improve the hydraulic performance during passage of the design flow.

81. Investigate means to reduce damages which result from spills through the wasteway (fail safe) on the Portage Diversion:
    - Raise both the east embankment and the crest elevation of the wasteway.
    - Acquire any additional land control that may be required to accommodate spills through the wasteway.

82. Upgrade and modernize the Portage Diversion headgate structure.

83. Examine the feasibility of developing additional storage on the Assiniboine River (such as the Holland Dam) upstream of Portage la Prairie, which would reduce the frequency of operation and the magnitude of diversions through the Portage Diversion, provide water supply benefits in the region and reduce the reliance on Shellmouth Dam for low flow augmentation in the lower Assiniboine River.

84. Examine the feasibility and effectiveness of developing storage on tributaries to the Assiniboine River.

85. Develop and implement a program to upgrade the Assiniboine River dikes between Portage la Prairie and Headingly. The optimal design capacity should be determined from detailed engineering studies now underway.

86. As one component of a properly engineered dike system, determine the optimum location and capacity of a permanent controlled wasteway (either north or south of the Assiniboine River), and construct such a structure to pass Assiniboine River flows in excess of the combined capacity of the Portage Diversion and Assiniboine River channel and dikes. The facility should be sized with due consideration of the potential flood risks/benefits and the capacity of the landscape to accommodate the design flow through the breach.

87. Adopt the recommendations of the Lake Manitoba and Lake St. Martin Regulation Review Committee regarding additional outlet capacity requirements for Lake Manitoba and Lake St. Martin, with due consideration for the engineering studies that are being conducted.

88. Examine the feasibility of alternative schemes suggested to the Task Force by local residents to reduce or control inflow to Lake Manitoba and thereby reduce or preclude the need for additional outlet capacity from Lake Manitoba and Lake St. Martin:
    - A diversion from Lake Manitoba to Lake Winnipeg.
    - A diversion from Lake Winnipegosis to Lake Winnipeg.
    - An outlet control structure on the Waterhen River to control outflow from Lake Winnipegosis.

89. Identify and better control agricultural drainage activities in tributary basins to the Souris River in Manitoba.

90. Compel Ducks Unlimited Canada to 1) operate its water control infrastructure to provide flood control benefits when necessary and where possible, with local input into the development of appropriate operating guidelines; and 2) develop a long term strategy to decommission structures which no longer meet the needs of the organization and which cannot be transferred to another entity.

91. Require as a condition of its license that Ducks Unlimited include a plan, with funding, for the eventual decommissioning of its water control infrastructure.

92. In concert with local municipalities and individuals, develop an inventory of community and private dikes, determine ownership, and clarify and communicate responsibility for ongoing maintenance and liability.

93. In concert with the Association of Manitoba Municipalities, develop a mechanism to provide technical assistance to local authorities for assessing dike integrity and ensuring that all community and private dikes are constructed and maintained to established industry standards.

94. Continue to monitor and support research to develop tools to better understand and assess the impact on runoff of wetland drainage, and conversely wetland retention and restoration.

95. Consider development of a wetland retention and preservation program with defined goals, possibly in partnership with non-governmental organizations. Such a project could be modelled on the Alternative Land Use Services (ALUS) pilot project.

96. Continue to consult with local stakeholders and interest groups, and attempt to find a water management solution that is in the best interests of all parties affected by closed basins such as Whitewater Lake.

9. Environmental Impacts

The environmental, social, water quality and human health impacts related to flooding of environmentally sensitive developments such as sewage lagoons, landfill sites and gasoline, oil and farm chemical sites.

9.1 Background

The Task Force worked with a local environmental consulting firm to examine potential environmental impacts of the items listed in the Term of Reference. Since time and budget constraints did not allow for a comprehensive review of the environmental impacts in flooded areas across the entire province, representative sites for each of the items were selected for study. These sites were selected on the basis of input from Task Force members and the response of participants in an on-line survey conducted by the Task Force relating to environmental issues. It should be noted the number of respondents to the survey was a relatively small sample of the total number of Manitobans impacted by the flood. However, the survey results revealed concerns worthy of consideration. In discussions between the consultant and the Task Force, it was agreed to also examine the impacts to domestic water supplies and the impacts to riparian zones and related erosion.

The effects of the 2011 flood on the environment will be felt for some time.

9.2 Wastewater Lagoons

The potential impacts of flooded wastewater lagoons was seen by many respondents to the Task Force survey, and confirmed by later field visits, to be one of the major issues. This was a concern because of the proximity of lagoons to surface water bodies throughout Manitoba. Almost 70 percent of respondents to the survey indicated that they had witnessed flooding issues with lagoons. Further discussion was focused around the Glenboro lagoon, although many other lagoons were identified and visited.

The effects of flooded lagoons tended to be of a local impact during the flood and of short duration, although potential for medium to long term impacts existed. This is particularly true when considering the ongoing impacts to water quality being observed in water bodies such as Lake Winnipeg. However, for the most part, the large volume of water associated with the flooding served to dilute the concentrations of the raw sewage. Impacts to groundwater and potentially human health from the 2011 flood remain unknown.

9.3 Hazardous Materials Storage Sites

Commercial hazardous materials sites were not considered an issue during the study. This is because existing regulations and business practices effectively protect these types of sites, and make them resistant to flood events. Hazardous materials issues related to the flood were limited to the domestic quantities that were stored throughout the flooded area. Paints, solvents, gasoline, chemicals and other items were frequently noted as having entered the environment during the 2011 flood. The impacts from hazardous products that entered the environment during the 2011 flood may be long term because of the integrity of the storage containers containing such items and the overall volume of the substances that were released during the flood. The effects to natural systems and human health are unknown.

9.4 Landfill Sites

Flood issues with landfill sites were only reported at one location – Strathclair, Manitoba. However, a subsequent field visit could not determine the extent of the concern. Other active landfill sites that were visited were deliberately set away from surface water bodies to comply with regulations. It is probable that there were a number of abandoned landfill sites that were impacted by the flood, but locating and evaluating these was not possible during this study.

9.5 Domestic Water Supplies and Wastewater Facilities

A common issue throughout the extent of the 2011 flood was the effect of flooding of domestic water systems, including wells and septic fields or holding tanks. Groundwater sources became susceptible to contamination by sewage from flooded tanks, lagoons and outdoor latrines. Likewise, agricultural pesticides entered the groundwater supply through flooded wells. The area of Twin Beaches was selected for further study, due to the widespread impacts reported and observed at that location.

Destruction of domestic water systems including flooding of wells and individual wastewater collection systems will likely impact the local surface water quality for a short period. However, the long term effects to groundwater supplies, and the potential for impacts to human health, are unknown. By excluding further development on land subject to flooding, the impacts of wastewater facilities on water quality could be reduced. However, this may reduce or eliminate future recreational opportunities in areas like Twin Beaches.

9.6 Riparian Zones and Erosion

This item was not included in the Term of Reference and originally was not planned to be studied. However, riparian zones are environmentally sensitive areas, and serve to protect water quality. This issue had the potential to be one of the longest term impacts of the 2011 flood, and one of the most severe impacts to the natural environment. The area around Lake St. Martin and Grahamdale was selected for further evaluation.

The loss of riparian zones led to severe erosion and downstream impacts to systems and infrastructure. This will produce the most complex impacts over time. While the zones themselves may recover in the medium term, the long term implications to natural ecosystems is unknown. Over this medium term, it is expected that aquatic life will potentially be significantly impacted, although the extent of the impacts is unknown.

9.7 Other Issues

The overall environmental impact of the 2011 flood will not be known for many years. In the case of Lake Manitoba in particular, measuring the effects of the flood on fish, wildlife and riparian areas over time will be difficult and costly. Periodic testing may not tell the whole story and may not paint the truest picture of the impacts. Long-term, ongoing monitoring and observations are necessary to identify changes that may be happening to the flooded areas over the years to come. The local knowledge of First Nations elders, commercial fishers and residents along the lake can provide valuable insight into the impacts of the flooding and changes to the natural balance of the ecosystem.

Throughout the areas along and surrounding Lake Manitoba that were flooded in 2011, and within the lake itself, debris has accumulated as a result of the flood. These areas include Delta Marsh, recognized internationally as a Wetland of International Significance, and other shoreline marshes along the lake. Some of the debris contains hazardous materials such as 45 gallon drums with fuel and/or oil, herbicide and pesticide containers from private properties and similar materials detrimental to the environment. Some communities in the area have initiated clean-up campaigns on their own, but the overall task of cleaning up the problem is beyond what they can be expected to accomplish using volunteers and local funding. More support to this effort is required for the benefit to the environment as a whole.

That being said, the Province needs to take a proactive role in cleaning the debris from flood-affected areas. All provincial lands should be made a priority by the Province and cleaned up to reduce the damage that is evident.

Measuring the effects on fish and wildlife will be difficult and costly.

9.8 Conclusion

In assessing the 2011 flood effects there were many instances where either the scope or significance of impacts were unknown. For more detailed discussion, see the entire report provided by the consultant in Appendix F.

9.9 Recommendations

97. Protect the integrity of the province's groundwater supply by instituting an annual water quality monitoring program, and by investigating the various pathways to groundwater contamination that may arise during a flood. Mitigation measures for protecting groundwater supplies in flood prone areas must be investigated and implemented.

98. Establish a water quality monitoring program for surface water to identify any future impacts of hazardous materials in flood zones. Implement an educational program to discourage the storage of these materials on land subject to flooding.

99. Enhance the existing monitoring program for the impacts on fish and wildlife as a result of the 2011 flood , including habitat and physical environment (riparian areas).

100. Establish public consultation procedures and protocols for environmental issues for flood events including public education seminars, news releases and open house events.

101. Implement a program to receive and document public input from First Nations elders and other community members, commercial fishers, lakeshore residents and others to monitor the long-term impacts of the 2011 flood on Lake Manitoba.

102. The Province develop and take a lead role in participating, and supporting local efforts, in a program to remove from Lake Manitoba, its shorelines, shoreline marshes and surrounding areas deleterious and hazardous materials that have accumulated as a result of the 2011 flood.

10. Land Use Policies and Zoning

Land use policies and zoning criteria relative to areas of the basin that are vulnerable to flooding.

10.1 Background

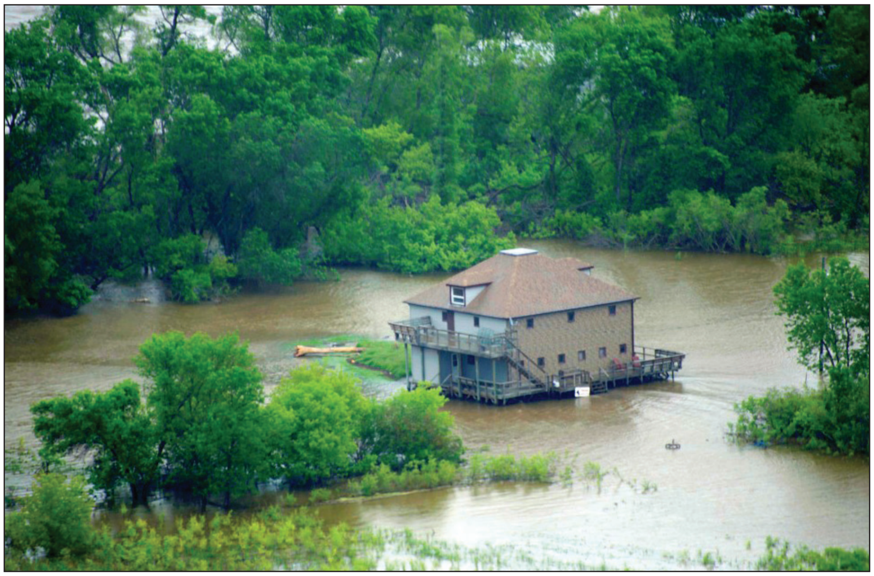
The Lake Manitoba and Lake St. Martin Regulation Review Committee (the Committee) was asked by the Province to "consider and provide recommendations on land use policies and zoning criteria relative to areas vulnerable to flooding around Lake Manitoba and Lake St. Martin". Since the Term of Reference for the Manitoba 2011 Flood Review Task Force (Task Force) in this regard was similar, although broader in geographic scope, the Task Force and the Committee worked cooperatively in addressing this matter.

The Committee commissioned a land use planning study in cooperation with the Task Force focusing on Lake Manitoba and Lake St. Martin. While the conclusions and recommendations from that report relate primarily to Lake Manitoba and Lake St. Martin, they have broader implications throughout the province. Additional work undertaken by the Task Force included interviews and discussions in the Assiniboine River watershed to confirm and broaden the findings. The study was structured to provide an understanding of approaches to land use policies and regulations, and to develop general principles and arrive at conclusions that would assist both the Committee and the Task Force in developing related recommendations.

Work on the land use study took place from early June to the end of August 2012. There were follow-up interviews by the Task Force in November and December 2012. Meetings were held with community leaders and research was conducted into land use planning policies and regulations and "best practices" elsewhere. Structured interviews were conducted in each community to seek more detailed information directly from individual First Nations communities, planning districts and municipalities. A half-day workshop was held to examine experiences in this area of planning across Canada and the United States.

When properly applied, land use planning can improve the situation for future generations. It can result in a sustainable community that meets the needs of the present without compromising the ability of future generations to meet their needs. To be effective, this planning should be done through a process that balances ecological, cultural, historical and aesthetic values with economic development. Municipal governments, with a regional focus along the watershed area, should be implementing integrated community sustainable plans.

Communities use planning to direct development and public projects, and to ensure their land use regulations meet the community's needs. Land use planning can prevent many hazard-related problems by directing poorly conceived new developments and post-disaster rebuilding away from dangerous locations. When it comes to what individuals, families and communities will experience in the future related to floods, proper planning can have a significant impact by determining where new development should or should not be allowed.



Properly applied land use planning can improve the situation for future generations.

10.2 Land Use Planning and Floods in Manitoba

When planning, communities generally employ five strategies for managing growth and development in flood prone areas:

- designating hazard lands,
- dedicating shoreline reserves,
- maintaining and enhancing shoreline vegetation,
- defining flood protection levels, and
- establishing development setbacks from water bodies.

The study conducted on behalf of the Committee and Task Force found that all the municipalities that were examined employ these five strategies, to varying degrees, in their development plans and zoning by-laws. In fact, planning seems to be relatively well organized and managed at the provincial and municipal levels. The limited data made available through the study suggests that, for a variety of reasons, such is not the case on First Nations communities in Manitoba, at least not for those that were examined.

However, the need for better, more effective coordination of efforts between jurisdictions is evident when comparing the results of decisions that have been made in Manitoba with those made in Saskatchewan. Saskatchewan is the most relevant case in point as it is most similar to Manitoba in many respects, and much of the water flowing into Manitoba originates in Saskatchewan.

To assist in ensuring the safety and security of individuals, communities and property from natural and human-induced threats, the Province of Saskatchewan requires all planning decisions, insofar as is practical to:

- identify potential hazard lands and address their management,
- limit development on hazard lands to minimize the risk to public or private infrastructure,
- prohibit the development of new buildings and additions to buildings in the floodway of the 500-year flood on any watercourse or water body, and
- require flood proofing of new buildings and additions to buildings to an elevation of 0.5 metres (1.6 feet) above the 500-year flood elevation of any watercourse or water in the flood fringe.

In comparison, the Provincial Land Use Policy in Manitoba states that land subject to flooding must be identified, and is land that:

- is inundated by floods up to and including the design flood (100-year flood),
- has a known history of flooding, or
- experiences flooding during a flood event of a magnitude specified by the Province in areas protected by flood control works, or
- is identified under the Designated Flood Area regulation.

Development of land subject to flooding in Manitoba may be permitted only if the risks are eliminated or ways are identified to ensure that:

- no additional risk to life, health or safety is created as a result of the development,
- buildings and other infrastructure such as septic fields are protected from the risks related to flooding, erosion and bank instability, and
- water flow, velocities and flood levels would not be adversely altered, obstructed or increased as a result of the development.

To implement provincial land use policies, municipalities rely on the Province to determine what 'land subject to flooding' means. That means the Flood Protection Level (FPL) must be identified and expressed as minimum building elevations in feet/metres above sea level that can be understood and used by homeowners and contractors. Flood Protection Levels (FPLs) vary from location to location.

The provincial interpretation of the Provincial Land Use Policy, as applied in practice since at least 1980 to determine minimum building elevations, is that the FPL is the higher of the 100-year flood or the flood of record.

The Flood Protection Level must be identified and expressed in elevations that can be understood and used by homeowners and contractors.

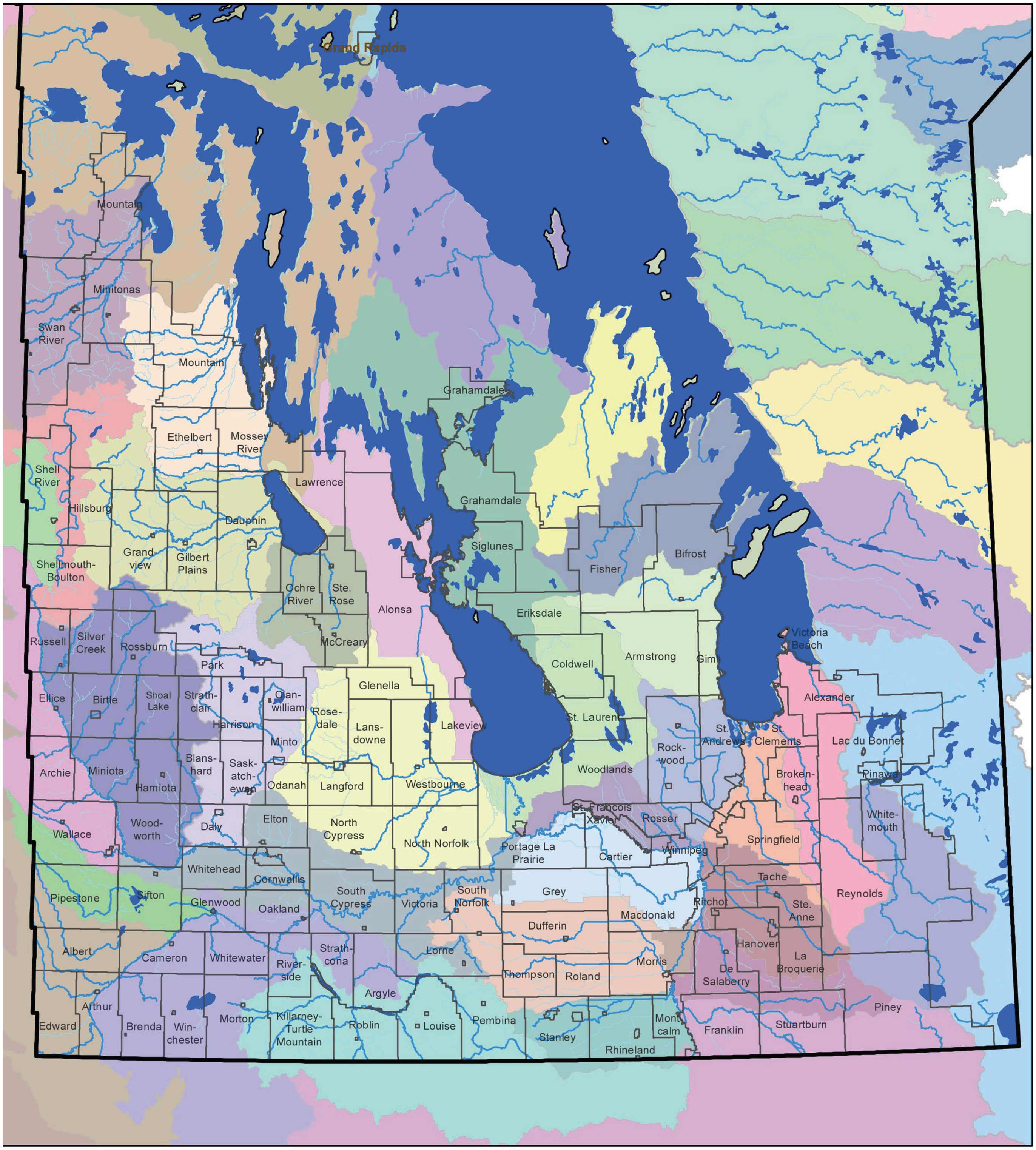
10.3 Existing Provincial Policy: Development Guidelines and Standards

Even though provincial flood protection policy requires flood protection to the higher of the 100-year flood level or the flood of record, flood damages continue to occur in Manitoba. The standard response of water managers has been to re-compute the 100-year flood level based on the latest flood or to raise the FPL to the flood of record, as was done for Lake Manitoba after the 2011 flood. These new levels determine the Province's flood protection requirements that municipalities must include in their planning documents, but this site-specific practice has resulted in uneven flood risk geographically and has created considerable confusion.

It is the Task Force's opinion that the 100-year flood standard is too low when one considers risk over the longer term. With a 100-year flood, there is a one percent chance that it will occur in any one year, but in any one location the probability that the 100-year flood will be exceeded at least once in a 10-year period is 10 percent and the probability over a 50-year period is 40 percent. This longer term risk is considered too high and is generally not understood by Manitobans. It is suggested the 200-year flood may provide an appropriate level of long term risk tolerance, given the economic damages resulting from floods, the economic costs of building to higher FPLs and the uncertainty with estimation of FPLs from limited hydrologic data.

The Task Force recognizes the benefits of restricting development close to shorelines, not only because of flooding but also because shorelines by their very nature move over time. However, a more balanced approach would be to set the FPL based on an appropriate return period, and to address future shoreline erosion by means of development set-backs. However, whatever guidelines or standards the Province adopts for new construction in areas subject to flooding, they should be transparent, clearly communicated, equitable, consistent in their application, enforceable and developed such that outcomes flowing from them generally are predictable.

Figure 10.1: Rural municipal and watershed boundaries in southern Manitoba.



Kilometers
0 10 20 40 60 80 100

0 5 10 20 30 40 50
Miles

Manitoba
Infrastructure and Transportation
Water Management & Structures

Projection: NAD 83 UTM Zone 14
Map Generated: January 3, 2013

10.4 Municipal Planning

Information that is available on the location and extent of areas subject to flooding, such as flood risk maps developed under the Canada-Manitoba Flood Damage Reduction Program and Flood Protection Levels established by the Province, is not being effectively applied by many communities. On the other hand, digital elevation maps suitable for planning are not widely available and are not contiguous.

Although most property owners and developers do comply with the planning policies and regulations that restrict development in flood prone areas, there needs to be a mechanism for dealing with non-complicance.

10.5 Planning with First Nations

A key issue identified through the study is that there are insufficient initiatives or planning structures to ensure an effective coordination of efforts between municipalities and First Nations communities. There are exceptions, such as a recent initiative between the Province, the Fisher River and Peguis First Nations and neighbouring municipalities concerning livestock and hog barn operations. Also, there have been reciprocal arrangements regarding land use between the Rural Municipality of Headingly and the Swan Lake First Nation. But, other than that, there have been few initiatives undertaken to coordinate land use planning between municipalities and adjacent First Nations communities in Manitoba. Similarly, there seems to be little effective coordination between neighbouring municipalities when it comes to drainage. The Task Force also noted that First Nations lack the resources to undertake planning for their communities, and there is a need to facilitate the development of a collaborative approach to planning between First Nations and adjacent municipalities.

First Nations point out that when neighboring municipalities improve their land drainage systems, they can often aggravate flooding on reserves by directing additional water though reserves. An effective mechanism is needed to ensure drainage systems are designed on a watershed basis, without consideration of administrative boundaries, and without creating adverse effects downstream.

10.6 Designated Flood Areas and Pilot Project for Lake Manitoba

Water follows natural topography regardless of political boundaries or local jurisdictions. Development plans and zoning regulations are developed and enforced by municipalities on geographic boundaries. Figure 10.1 illustrates how watershed boundaries and those of the various political and administrative jurisdictions differ.

Geographic areas created by treaties with First Nations also need to be taken into consideration, as the Province has no authority to enforce land use planning policies and regulations on reserve lands. First Nations, municipalities and the Province should have an interest in resolving issues such as road access and drainage along common boundaries. In spite of these challenges, significant progress has been made in Manitoba in terms of planning and the regulation of development based on watersheds.

Most Manitobans, including those living around lakes, recognize that action is required to ensure that the kind of devastation experienced in 2011 is not repeated. In this regard, the Lake Manitoba and Lake St. Martin Regulation Review Committee recommended that “Designated Flood Areas” be established in the Lake Manitoba/Lake St. Martin area in a similar fashion to those in the Red River Valley. Designated Flood Areas are enacted through regulations under *The Water Resources Administration Act*.

It is difficult to estimate the return period of the 2011 event on Lake Manitoba.

In interviews conducted with municipalities and First Nations around Lake Manitoba as part of its land use study, the Lake Manitoba and Lake St. Martin Regulation Review Committee found that all interviewed answered “yes” to the following question:

“Assuming that adequate resources would be made available to do it properly, would your community be open to participating in a Pilot Project/planning process involving neighbouring municipalities and others to establish a “Special Planning Area” or authority to develop and enforce an Integrated Watershed Management Plan?”

Recognizing the challenges inherent in establishing a new institution, the Committee recommended that consideration be given to expanding the mandate of an existing institution(s) to undertake the pilot project.

The Integrated Watershed Management Plan would be subject to a consultation process and would ultimately be approved and adopted by the Province pursuant to *The Water Protection Act*. The Province would then require that planning districts and municipalities incorporate the geographically relevant flood-specific planning elements into their development plans and encourage First Nations communities to do likewise. The Province, through Conservation and Water Stewardship, could be responsible for implementing and enforcing the drainage provisions.

Among other things, this pilot project would need to:

- hire new staff or second existing qualified provincial staff to form a coordinating body which would define the scope of the pilot project, prepare the plan for the area, and assist planning districts, municipalities and First Nations to incorporate the flood-related land use policies into their development plans,
- acquire topographic maps (e.g. LiDAR) and other data needed for planning,
- engage with the local community and the Province in defining Designated Flood Areas around the lakes and rivers within the pilot project, and
- develop incentives to encourage landowners to take positive action to protect shorelines and restore wetlands.

A watershed-based Designated Flood Area on Lake Manitoba and/or Lake St. Martin would facilitate the establishment of higher FPLs than in other areas of the province, consistent with the principles and recommendations of the Task Force. The interim Flood Protection Level for Lake Manitoba has been computed based on the May 31, 2011 wind event (248.5 metres, or 815.3 feet wind eliminated water level) plus wind setup (0.6 m to 1.5 m, or 2 to 5 feet) plus wave uprush (0.3 to 0.6 m, or 1 to 2 feet), resulting in flood protection levels that could potentially be as high as 250.6 m (822.3 ft). The probabilities of such lake levels recurring on Lake Manitoba are unknown, but considered very rare. Under this FPL, communities around Lake Manitoba would likely have the highest standard of flood protection in the province, based on this single event. On the other hand, if structures are built based on this FPL, there would likely be very little structural flood damage in future.

10.7 Activities by the Governments of United States and Canada

10.7.1 United States of America

It is apparent that land use planning and flood management systems in the U.S.A. are far from perfect. In fact, over the years, these systems have resulted in increased flood losses, created a false sense of security regarding building in a flood plain, and disconnected citizens and local governments from the financial consequences of developing in hazard areas. However, the lessons learned from these outcomes have led to significant changes in the approach taken. Of note is *The Disaster Mitigation Act* of 2000, which requires more intergovernmental cooperation and the development of detailed local land use and flood mitigation plans. Perhaps more importantly, this Act makes federal funding available for pre-disaster mitigation planning as well as post-disaster mitigation works.

State flood plain managers in the U.S.A. have also learned from past mistakes and are advocating a new approach – "No Adverse Impact" – which calls for the actions of one property owner to have no adverse effect on the rights of other property owners, either upstream or downstream. Under this concept, the adverse effects or impacts would be measured in terms of increased flood peaks, increased flood stages, higher flood velocities, increased erosion and sedimentation or other impacts the community considers important.

10.7.2 Canada

Since the early 1990s, the Government of Canada, through disaster assistance funding, has been paying hundreds of millions of dollars "to pick up the pieces" after a flood, but unlike its American counterpart, has not been engaged at the front end working toward mitigating potential damage due to floods.

However, the current Canadian government has concluded that "an ounce of prevention is worth a pound of cure" with its recent announcement of the Financial Support to Provinces and Territories for 2011 Flood Mitigation Investments, which will reimburse some provincial costs for mitigation measures implemented in advance of the 2011 flood. Consideration is being given to making this initiative a permanent national program. Eligible costs to date have been limited to approved permanent flood protection measures, such as permanent dikes. A case should be made that federal contributions should also go toward assisting provincial and local authorities (including First Nations) to undertake land use planning along watersheds in a more effective and coordinated manner, and toward hiring staff with the requisite expertise to ensure that regulations are enforced.

10.8 Recommendations

103. Develop maps which delineate land subject to flooding for various probabilities of exceedence, and consult with local authorities to ground-truth the results. These maps should be made available through the Internet for convenient use by the public and local administrations for zoning purposes and for developing flood mitigation projects.

104. Implement clear policy measures to ensure future development does not knowingly occur on land subject to flooding without appropriate mitigation. Possibilities include:
    - the development of mechanisms through district planning boards to prevent future developments below the FPL, and
    - expansion of Designated Flood Areas into regions that experience chronic flooding of developed properties.

105. Develop and adopt a uniform Flood Protection Level (FPL) throughout the province. Such a standard should strike a balance between long term risk tolerance, the economic damages resulting from flooding, the economic costs of building to higher FPLs, and the uncertainty in the estimated FPLs due to limited hydrologic data.

106. Permit local developers and institutions to adopt a risk-based approach for determining a higher standard of flood protection where appropriate, to be implemented locally where justified from a benefit-cost analysis or where facilities are of a critical nature. The minimum standard would be enacted through regulation and the higher risk-based approach would be at the discretion of the authority or proponent investing in the new capital works.

107. Engage the Government of Canada and First Nations in a process that will lead to improved planning and coordination among municipalities and First Nations.

108. Accept and implement the recommendation from the Lake Manitoba and Lake St. Martin Regulation Review Committee that the Province establish a five-year pilot project involving the Government of Canada, planning districts, municipalities, conservation districts and First Nations to develop an Integrated Watershed Management Plan within the Lake Manitoba or Lake St. Martin basin. The plan would define Designated Flood Areas within the watershed, develop appropriate land use policies and regulations relating to flood control and mitigation including land drainage and incorporate the principles associated with "No Adverse Impact".

109. Encourage Public Safety Canada to develop a new program to financially support proactive flood mitigation works by the provinces, as a more cost effective alternative to ongoing, and often repeated, payments of compensation for flood damages through existing programs.

11. Communications to the Public

Adequacy of communications to the public about information such as flood forecasts, emergency response, disaster recovery and flood-mitigation programs.

11.1 Background

Communications is a common thread running throughout this report. Discussion under most of the previous sections dealing with specific Terms of Reference express the need for better communication, not just to the public, but also within the provincial government and among various agencies and jurisdictions involved in fighting the flood. Recommendations related to communications in those sections are specific to those Terms of Reference, whether it be the operation of the flood control structures, flood forecasting or Disaster Financial Assistance, as examples. This chapter focuses on the adequacy of communications with the general public.

11.2 Communications Activities

Manitoba has an Emergency Public Information Plan, which applies to all emergencies requiring a provincial level response as defined by the Manitoba Emergency Plan. The objective, as stated in the plan, is that "prompt, effective and coordinated public information is provided by the provincial government to the affected segments of the population and the public as a whole". Communication is essential to avoiding or minimizing loss of life and harm to people, property, businesses and other affected interests.

Communications by the Province of Manitoba during the 2011 flood was led by Communications Services Manitoba (CSM) within Manitoba Culture, Heritage and Tourism. The Province and CSM provided Manitobans with a comprehensive communications program throughout this event. While the effort was sometimes delayed by policial process in some of this information being released, as time passed, communications became streamlined and more effective in keeping Manitobans up to date.

CSM worked in collaboration with Manitoba Water Stewardship (MWS), Manitoba Infrastructure and Transportation (MIT), Emergency Measures Organization (EMO), Manitoba Health, Office of the Fire Commissioner and Manitoba Conservation. EMO had a full time communications specialist with them in the command centre. While CSM provided information directly to the public or to the public via the media, MWS, MIT and EMO were the government departments responsible for getting information to municipalities and First Nations communities, which in turn, were providing information to their residents through local media.

The Task Force heard of some problems in communications between the Province and the affected municipalities. For instance, one municipality reported that during the flood, the media was receiving updated information before the municipality did. Communication with the municipality in question improved over time but the oversight caused hardship for those managing the event initially. Another point raised by municipal officials is that flood bulletins often covered a wide geographic area, and would have been more helpful to local officials and residents if they had been more site-specific. Also, there were instances where government departments confused the names of towns or cities with neighbouring rural municipalities - the City of Portage la Prairie and the Rural Municipality of Portage la Prairie, for example.

Media sometimes received information before the municipalities

Many government departments worked together to get daily forecasts to the public.

CSM also supported provincial programs such as Disaster Financial Assistance (DFA), Building and Recovery Action Plan (BRAP), and Manitoba Agricultural Services Corporation (MASC) and they developed after-flood booklet information posted on their website. Materials were also prepared for psychosocial teams who were undertaking outreach work in flooded areas, and many other projects.

The Task Force consulted with local media to determine how well information was being provided to them. Those media personnnel that responded expressed no concerns with the way the Province or CSM provided information or in their dealings with EMO responding agencies.

CSM employed a variety of media to deliver the Province's message to the public before, during and after this event and the communications effort continues as this review is being undertaken. Before the flood, the Province issued three flood outlooks and held 20 other media events between January and early March, 2011. The latter provided updates on what the Province, municipalities and First Nations communities were doing to prepare for the flood such as the purchase of equipment, technical briefings and notifications of where and why equipment will be working in key areas as well as flood safety and volunteer information. The information communicated was also intended to provide Manitobans with actions that they could take to prepare and protect themselves.

During the flood, the Province undertook significant and frequent dissemination of information. These actions included:

- 98 flood bulletins,
- 75 media briefings,
- over 50 media tours,
- 364,806 visits and 930,926 flood page views to the flood website, and
- 2900 followers on twitter.

CSM also provided on-site professional communications support to four municipalities while they were responding to the flood emergency and experiencing significant media attention.

CSM advised the Task Force that they would like their staff to receive emergency management training to better understand the emergency management process.

During the 1997 flood, a 24-hour television broadcast provided residents of the Red River Valley with up-to-date and continuing flood-related information. Those consulted thought this was an excellent communications tool. The Task Force feels that, when the Province is under a state of emergency, a public service television channel, radio station or similar media should be dedicated to communicate the details of the emergency at hand to the general public. In the case of a flood event, information provided should include flood bulletins, needs for volunteers, comments on road status and road closures and other relevant information. In addition, the Province should educate the public on the use and importance of the toll-free 511 road conditions information line and website. Many people were apparently not aware of this service.

Although the media interacted extensively with both the Province and municipal officials, television and radio coverage was not necessarily focused on providing local residents with the critical information they needed. There is a big difference between a sensational media story that may make the national news and the communication of vital information to residents, such as details regarding road closures. There is a need for a one source/one story communication tool focused on the information needs of flood-affected residents.

The office for DFA also rolled out a communications program in several locations across the province. They also used the Internet as their main source of comprehensive information outlining the programs and processes for applicants for DFA benefits. While the Internet is a valuable tool, and is taken for granted by most Manitobans, the Province cannot rely exclusively on the Internet to disseminate information. Many people who talked with the Task Force, primarily those from more remote areas, do not have access to the Internet. A number of First Nations communities operate their own radio stations. These could provide a useful service, especially in those communities with no Internet access.

Social media played a role in communications during the 2011 flood like no other flood event before. Facebook, Twitter and blogs all provided information and comments available to anyone tapped into those sources. However, there appeared to be insufficient awareness regarding the availability of these information sources. Many who might have found these media useful, such as municipal officials, were unaware of them.

It should be noted that information available through social media may not always be reliable. In some cases, information being provided may be predicated on rumour and be misleading. Social media can be a valuable tool, but for the reasons described, it can have risks. The Province should consider developing this avenue of communication further to make it a more effective tool in the future.

The Task Force heard that for some Manitobans, trust became a significant issue. In 2011 the information the Province was distributing was changing daily, sometimes hourly, and often coming from different sources. After years of one familiar face providing Manitobans with flood information, the introduction of a new voice for flood forecasting was a real challenge in terms of trust and credibility. A single spokesperson for the Province would help to instill a level of comfort in the public.

Many municipalities and First Nations communities consulted felt they were left out when CSM was developing its communications plan for the 2011 flood. Involvement of these entities would very valuable in developing a comprehensive plan.

11.3 Conclusion

The Task Force recognizes that some Manitobans were unhappy with communications related to the flood, as noted in the previous discussion. Overall, it is the Task Force's opinion that to the Province's and Communications Services Manitoba's credit, they provided Manitobans with an effective, comprehensive communications program throughout this event. Considering the emergency situation, the communication of the level of risk was, for the most part, effectively conducted by the Province.

However, the Task Force heard one distinct message throughout its travels and consultation.

> *"Communications to the public and emergency management responders needs to be more timely in order to be accurate enough to respond to."*

The information conveyed by the official government site was factual but not always timely, and the usefulness of the information was often compromised by its delayed arrival.

Throughout the 2011 flood, some municipalities faced serious challenges related to communication. Manitoba Water Stewardship offered direct support to affected municipalities, but in some instances, municipalities chose not to collaborate because of mistrust. This lack of collaboration is problematic in events where a strategic approach to communications is key to informing the public. It is essential for an official communications agency to foster alliances with the municipalities based on the provision of accurate, timely and factual information.

Information changed daily, sometimes hourly, as events unfolded.

The communications challenges faced by the Province during the flood were exacerbated at times by members of the media who undertook to sensationalize the situation, resulting in coverage focusing on psychological hardships and emotional reactions. Such coverage often emphasized negative images and difficult experiences. Unfortunately, in many instances, some media had their own agenda during the event of the 2011 flood. The climate leading up to a provincial election gave them an interesting platform to spur antagonistic views that in many instances made the situation worse.

Members of the media are not agents of governments. Nevertheless, in an emergency context, it is important to work together toward the provision of accurate and useful information. In a large-scale disaster, it is imperative to find a balance between human interest stories and the communication of factual information. All stakeholders should engage in an ethical way to provide a dynamic delivery of the information that is pertinent to Manitobans.

11.4 Recommendations

110. The Emergency Measures Organization (EMO), in concert with Communications Services Manitoba (CSM) update the training program specific to CSM and EMO requirements for emergency management events.

111. A 24-hour dedicated television channel, and perhaps a radio service, be established to provide up-to-date information on flood conditions, forecasts and outlooks, road closures, as well as contact information for the public during an emergency.

112. The Province develop an information program to increase awareness among Manitobans regarding the value and usefulness of the toll-free 511 road conditions information line and website during an emergency.

113. A protocol be established to improve communication between the Province and affected municipalities and First Nations communities during an event such as the 2011 flood.

114. The Province take steps to ensure communications to the public and emergency management responders is accurate and disseminated in a more timely fashion to allow those “on the ground” to respond to the situation appropriately.

115. Designate a credible, skilled and knowledgeable spokesperson(s) to provide a “one face” approach to communicating information to the public in a language the public can understand.

12. Impacts on Road Networks and Bridges

Impacts on road networks and bridges to businesses and public access.

12.1 Background

The road network throughout agricultural Manitoba is a product of the first surveys conducted under the Dominion Land Survey that began in 1871 and extended through that decade. The system is common throughout the Prairies. The landscape was divided into a grid of one-mile square sections. Surrounding each section was a road allowance. As settlement progressed, and the number of farms increased, roads were established along most of these allowances to provide settlers access to their farmsteads and to allow them to deliver their goods to market. In the beginning it was not uncommon for as many as four farmsteads to locate on one section, each farming 160 acres. As a result, the road network became very intricate.

Along this network of roads, bridges were necessary to cross gullies, creeks and rivers. Over the decades with the advent of larger machinery and trucks, and a deepened concern for safety, bridges and crossings were built to a higher standard to meet these needs. The cost of maintaining most of this infrastructure is the responsibility of local rural municipalities.

An efficient and well-maintained transportation system is still critical to agriculture, commerce, rural residents and the economy of the Province. In addressing this Term of Reference, the Task Force sought to identify important transportation infrastructure of concern by consulting with municipalities, First Nations communities and provincial government departments. The input gathered from residents and businesses was important in identifying locations for more detailed consideration. The Task Force took several questions under consideration.

- What was the impact of the 2011 flood on regional roadways and bridges?
- What was the impact of flooding from the perspective of First Nations, individual homeowners and cottage owners, local businesses or agricultural producers?
- Could these impacts have been lessened?
- Are there changes that could be made to reduce flood-related impacts on public roads and bridges in future years?

The toll of the 2011 flood on roads and low-level crossings was accentuated by the length of time they were under water or surrounded by water. The damage to bridges was more a result of the high flows on the rivers and streams during flood crests that occurred from April through July. At the time of the writing of this report, significant repair work has been completed but much is left to be done. Some bridges still need to be replaced and there are roads still to be repaired. Citizens and businesses are still having to use alternative routes to reach their destinations at considerable cost and time. The impacts are felt by school divisions and their students, the agricultural industry, the oil industry and the entire trucking industry. In addition, the safety of some rural communities was compromised as a result of reduced access for emergency service vehicles.

The length of time roads were under water prolongued the damage.

12.2 Jurisdictional Context and Issues

In order to fully understand the issues associated with the impacts of the 2011 flood on roads and bridges, it is important to understand the jurisdictional context under which provincial road repair and maintenance is governed.

Provincial roads are the responsibility of the Province, whether passing through an urban area or a rural municipality. All costs associated with these roads are the Province's expense. The same applies for provincial bridges and other structures. However, municipal roads are the responsibility of the individual municipality and all costs associated with repairing and maintaining these roads are the municipality's expense. First Nations are responsible for their own roads and bridge structures. Any provincial infrastructure in a First Nations community is the responsibility of the Province. However, there may be instances where agreements among the federal and provincial governments and the First Nations may exist for the maintenance of roads and bridges on First Nations.

There are times when provincial roads are closed due to sink holes, such as on Provincial Trunk Highway (PTH) 83 or deliberate cuts, on Provincial Road (PR) 331 for example, and/or bridge closures such as PR 227 over the Portage Diversion and PR 251, the Coulter bridge over the Souris River. During these road closures, municipal roads by necessity are used as detours. In some cases, provincial roads are built to withstand heavier, more frequent traffic than municipal roads. When normal provincial road traffic is detoured on to a municipal road, increased repairs and maintenance are often required, largely in part because the municipal road was not designed to handle the resulting extra traffic flow.

Municipal budgets are being decimated by maintenance costs on roads that were not built, nor intended to be used, for the increased heavier traffic due to detours around damaged bridges and roads. Municipalities need assistance from the Province in maintaining and rebuilding these damaged roads. The Province should have a negotiated policy/agreement in place with the municipality covering regular road maintenance and repairs in these situations. The municipality should not be expected to bear these costs on its own.

12.3 Actions Taken by the Province

Throughout its investigations and consultation process, the Task Force heard of many instances in which roads, bridges and related infrastructure were damaged or otherwise impacted as a result of the 2011 flood. Damage or access issues were reported across the province including Russell, Ochre River, Dauphin River First Nation, Siglunes, St. Laurent, Morris, Cornwallis, Fairford First Nation and Melita. The impacts to infrastructure, people and businesses ranged in severity from location to location, but overall were very significant.

Many problems can arise when roads are exposed to water for long periods of time. Erosion can occur along shoulders and banks of the road. Water under pressure penetrates the roadways causing increased cracking, potholes and sink holes. Washouts can develop depending on the force and flows of the water. Bridges can be subjected to scouring, erosion and washouts depending on the force and longevity of the flows of water. In early spring, ice damage can be very destructive as well. The true effects of the water damage on roads and bridges may not be known for years to come. Regular monitoring of the affected infrastructure needs to be conducted over time to ensure the integrity of these structures has not been compromised.

As of the date this report was prepared, the 2011 flood affected 154 provincial roads and highways, 500 municipal roads, 73 damaged highway provincial structures and 500 municipal bridges. The current estimated value of repairs to bridge sites on the provincial highway network that were impacted by the Souris and Assiniboine river basins flooding alone is $70 million. This is based on current inspection information and could increase once additional inspection data is evaluated. Current estimates of provincial roads and highways that were impacted predict $42 million in damages. This number may rise upon further review and inspection.

No value has been placed on municipal infrastructure damage at this time.

The Task Force believes a comprehensive list of damaged roads and bridges now exists and repairs have been completed, or are underway on many. In recognition of that, there is still much to be done. Rather than presenting a complete list of all infrastructure that was impacted by the flood, a few examples are highlighted here to illustrate the damage that occurred and the scope of the associated impacts.

Manitobans were impacted in a variety of ways by closure of roads and bridges.

In the Rural Municipality of Westbourne, approximately 200 flooded sites were repaired in 2011, with repair costs ranging from small-scale to huge. The municipality's public works staff continued to repair sites through 2012. In addition, even into the summer of 2012, the municipality continued to discover plugged culverts and debris on road allowances. The cost of this clean-up represented a significant portion of the municipality's budget. The 2011 flood was not an isolated event for Westbourne, which has been impacted by flooding in eight of the last ten years. The municipality needs permanent flood mitigation measures that will enable its infrastructure to better withstand future floods. Other municipalities faced similarly long lists of sites to be repaired due to washouts, slope failures and other impacts of flooding.

In St. Lazare, the community-owned bridge over the Qu'Appelle River was damaged and remained out of service for a period of two to three weeks. This required the use of a 40 to 50 kilometre detour, and prevented direct emergency vehicle access. Manitoba Infrastructure and Transportation has since repaired the bridge.

Dauphin River First Nation was severely impacted as a result of the only access road into the community being flooded. The road was closed for a two-week period in early April, then closed again on May 20 and did not reopen until October. The community was isolated and its residents, if they chose not to evacuate, had to travel 60 kilometres by boat on a fast-moving, debris-filled river to get in and out. All businesses in Dauphin River were closed in March, 2011 and the many commercial fishers in the community could not get their product to market. Repairs to the road did not begin until July, 2012. However, the road is now being raised and it is felt that it will provide much better access to the community in the future.

Many beach and cottage areas around Lake Manitoba were isolated during the flood due to roads being flooded and closed. This resulted in residents and cottagers being forced to take long detours in some cases, such as in the Rural Municipality of Grahamdale when the Township Line Road was damaged. Further, such access issues can also have financial implications for municipalities, as some cottagers may either decide or be forced to stay away. This can affect community businesses dependent on cottager traffic. In some cases, businesses were forced to close, such as the St. Ambroise store and the ice cream shop in St. Laurent. In addition, a cottager from the Twin Lakes Beach area reported that lost access to their property meant that they were unable to try to save their home or its contents.

Residents, farmers and businesses across Manitoba were impacted in a variety of ways by damage to, and closures of, flooded roads and bridges. Perhaps the most obvious impact is lost access, but other significant impacts included interrupted delivery of lumber and gravel supplies and septic services. Farmers were impacted by being unable to access farmland in some areas or being unable to transport their goods. Many farmers were forced to use alternate routes to gain access to their land which at times put them on major highways with large, slow moving equipment. Not only did this increase the travel time between land locations but it also caused safety concerns insofar as it led to the mixing of slow moving equipment with fast moving traffic.

Local communities were forced to detour around washed out bridges, causing increased travel time for farmers, businesses and school children.

Businesses servicing farmers were unable to reach their clients in some cases causing delays in planting, spraying, harvesting and other similar issues. Other business owners who were required to use detours to service their clients faced losses due to considerably increased travel time for both them and their customers. Children were impacted in many areas due to school bus route detours. Safety issues also came into play when residential traffic, gravel trucks and construction vehicles were forced to share either secondary roads or roads that had been temporarily raised, such as on Venice Road in the Twin Lakes Beach area. In addition, vehicles were at risk of being damaged by the material such as gravel and stone used to build up roads.

Many municipalities faced significant financial hardship as a result of the damage caused to roads and bridges by the flood. Even cleaning out ditches of silt and debris can present enormous costs to a municipality. This can be an issue not only in terms of the actual costs associated with repair and building materials and equipment, but also in terms of other resources such as staff time. In the Rural Municipality of Westbourne, for example, public works staff are not able to carry out routine maintenance activities on a regular basis because as they are still dealing with the flood and the aftermath. In addition to the expenses associated with flooded roads and bridges and culvert repairs, municipalities are often faced with costs resulting from the use, or over-use, of soft roads and additional traffic on secondary roads that are used as detours. In some cases, the damage to roads is made worse by drivers not abiding by imposed road restrictions. At a Task Force meeting in Oak River, a number of municipalities reported that roads in their communities were damaged as a result of being used as alternate routes during the flood, and as of the summer of 2012 these roads had not yet been repaired. The costs to repair such “collateral damage” are often not recognized by the Province.

As an example, the impact of damage to PTH 21 at Hartney, in southwest Manitoba, was described to the Task Force as extremely significant. A temporary, single-lane bridge was put in place. This temporary bridge cannot accommodate heavy truck traffic and wide loads. This resulted in municipal roads and bridges in the area receiving considerable extra heavy traffic and wide loads. The issue was magnified due to there being no provincial roads east of PTH 21 that cross the Rural Municipality of Cameron.

Another case in point is the Coulter bridge which spanned the Souris River south of Melita on PR 251. It was deemed unsafe after the 2011 flood and subsequently dismantled. This road was a major artery linking the oilfields of Pierson and Lyleton areas to Waskada, the hub of the oil producing area. Heavy traffic now has to travel north to Melita and east on PTH 3 and then south to Waskada. Other commercial traffic including agriculture is affected as well as school bus routes. People who live on the west side of the river but work in or around Waskada have a much longer commute and vice-versa. Fortunately, the Province has fast-tracked the replacement of this bridge.

12.4 Making Decisions on Repairs and Reconstruction

Municipal and provincial officials must make many decisions regarding repairs both during and after a flood. During the flood, priorities must be identified in terms of which roads and bridges must be kept open, whether through sandbagging, diking or raising the road. In the case of damage to infrastructure, officials must also immediately begin the process of determining what will be repaired, to what condition, using what funds, and when.

Currently, the Province prioritizes recovery efforts using factors such as traffic volumes, length of detour, impact on emergency services, impact on provincial/regional economy and other factors. In determining repair and replacement of infrastructure, the Province should consult with each affected municipality. Municipalities must have the opportunity to express how the infrastructure affects their citizens and businesses. This information sharing could be beneficial in helping the Province understand the effects on the municipalities of its infrastructure rebuilding plan. It could also help municipalities to better plan to meet their own needs going forward.

It is recognized that difficult decisions have to be made during an event such as the 2011 flood. Protecting 18th street in Brandon helped maintain the flow of approximately $45 million of trade flow. Protecting the Trans Canada Highway and its bridges helped to keep $145 million worth of trade moving daily along that route.

An assessment of decisions made by Province regarding provincial trunk highways and provincial roads should be conducted. This could include:

- how decisions were made in 2011, and how were they made in prior floods,
- identifying repair and reconstruction priorities by region,
- developing a timeframe for reconstruction – short and long-term. Also identify actions taken before, during, and after the flood, and
- designating essential routes/vital road network.

Existing policies and regulations led to several challenges for municipalities in their attempts to address their own infrastructure needs during and after the 2011 flood. In some cases, the Disaster Financial Assistance (DFA) program required that engineering assessments be conducted before municipalities could proceed with infrastructure repairs or reconstructions. This added costs and caused delays to the process, and in some cases, resulted in recommendations for expensive replacements despite the fact that, from the municipal perspective, less costly options were available that would have been quicker to implement. In addition, if a municipality proceeded on its own to repair roads that required immediate attention, it risked losing financial assistance for other claims. If a municipality chose to repair its damaged infrastructure using its own equipment, reimbursement from DFA would only be 65 percent of actual costs. A municipality was not entitled to recover employee costs unless it was considered overtime. As a result, municipalities turned to contractors to do the work instead, because that cost would be fully recoverable. However, contractors were not always readily available to do the work in a timely manner.

Other issues resulted from municipalities requiring approval and licensing from the Province in order to replace or add culverts, even in situations where the necessary action required only replacing a culvert of the same size as the one that was in place prior to the flood.

The Task Force recognizes that not all bridges damaged by the 2011 flood can be repaired or replaced. In some cases it is not practical, or it may not be economically justified. One method to determine which repair or replacement projects should be funded is to undertake a cost benefit analysis of each project. This must be balanced by considering the importance of such a road or bridge to the municipality. Vital routes must be indentified and given priority.

It is very important that the rationale behind any decisions regarding changes to the level of service provided by infrastructure in an area be communicated to the local officials first and then communicated to the public. It is reasonable to expect that people who may be inconvenienced by such changes feel put out if not consulted. However, in some situations a cost benefit analysis or other such decision-making process may well demonstrate that inconvenience is an unfortunate consequence of taking the most justified course of action. If this is thoroughly communicated to those affected, the change may be more palatable.

12.5 Standards/Level of Service

Consideration must be given to the standard to which roads and bridges should be repaired or rebuilt. It is notable that homes, cottages and other such structures are required to meet different standards, or flood levels, than roads and related infrastructure. Should policies allow an important road to be lower than the flood level? In 2011, some Manitobans had to evacuate not because their homes were below the flood plain, but because the roads servicing their homes would not be able to support emergency vehicles. It is obviously very important that emergency road access be available to all communities at all times. This may require the development or designation of a full-time vital road network, with all involved routes being located above the flood level, where feasible. This could also be a part of the Province's business continuity plan to ensure business carries on during a flood such as 2011.

Also, the Task Force has noted difficulties in differentiating between what is considered flood mitigation and what is considered upgrading infrastructure to handle the new flood of record. Too often, the decision is made to repair damaged infrastructure to a prior standard. This can be acceptable in some circumstances but not when it is a frequent event such as what has occurred in the Red River Valley in recent years.

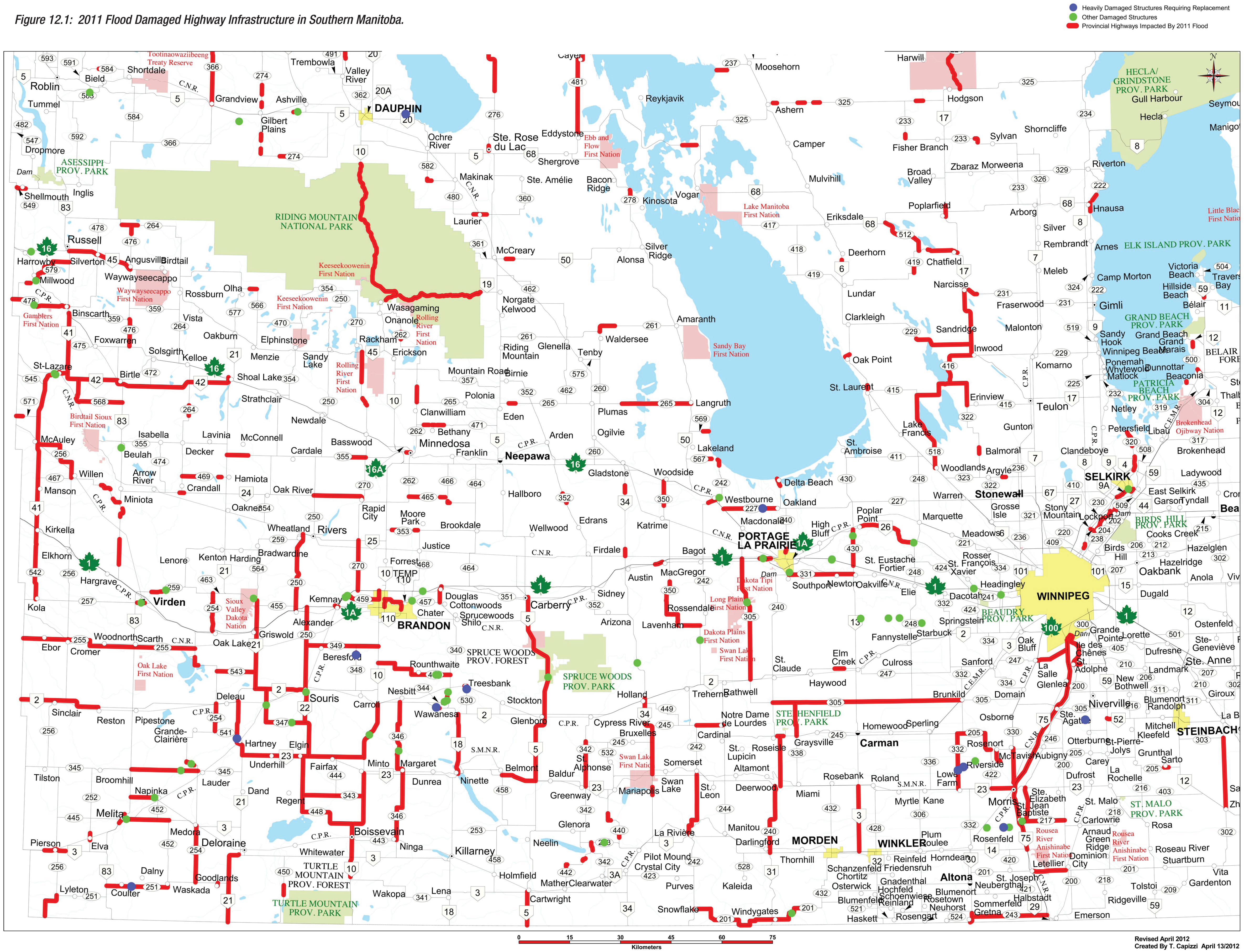
Funding should be invested in remedying the problem, rather than re-establishing the status quo so structures in question can be inundated again during similar floods in subsequent years. With a little extra funding, improvements to the road or structure in question can be brought to a better standard to alleviate the recurring problem instead of having to rebuild it to the old standard repeatedly after each flood event.

The Task Force noted that municipalities are frustrated by compensation rules requiring infrastructure to be repaired to the same standard after each flood event, rather than implementing an upgrade which would prevent the damages from reoccurring. As an example, King Street in Emerson requires a substantial amount of repairs after each significant flood, but these damages, and their associated costs, could potentially be avoided if new, appropriately-sized culverts were installed.

Another such situation occurred southwest of Dauphin, where a private road was washed out by the Vermillion River. Through the use of federal disaster assistance funding, the road was restored to its pre-flood condition. However, the road remained impassable and actually required more expensive repair in order to be useable. Funding for this level of repair was not available from federal disaster assistance funding. Municipalities cannot absorb the burden of upgrading their flood-damaged infrastructure on their own. Instead of investing in temporary solutions, the three levels of government - federal, provincial and municipal - need to work towards a permanent solution.

In some cases municipalities face the opposite problem. There can be a disconnect between the amount of funding available for a repair and the standards which that repair is required to meet. In these scenarios, it may be appropriate to apply a "minimum standard" approach to make decisions on what degree of repair should be undertaken. Standards must be compatible with municipal resources – imposing Provincial standards on municipalities is impractical if the municipalities do not have the funds available to comply.

Figure 12.1: 2011 Flood Damaged Highway Infrastructure in Southern Manitoba.



12.6 Recommendations

116. The Province review its five-year Highway Capital Plan in light of the 2011 flood and the fast-tracking of certain pieces of vital infrastructure and roadways. A five-year plan of reconstruction be developed and published by the Province in consultation with local municipalities involved.

117. Identify key transportation routes and protect them so that commerce can continue uninterrupted during a flood.

118. Review the possibility of providing flood-proof emergency access to communities that could be affected by flooding.

119. Jurisdictional issues among federal, First Nations, provincial and municipal authorities be resolved so that roadway and drainage infrastructure on First Nations can be addressed.

120. The Province recognize all the costs incurred with road/culvert/bridge reconstruction required due to alternate route usage (detour) when major roadways are closed due to the flood.

121. The Province continue to study and monitor the effects of the 2011 flood on all affected provincial roads and bridges, and be prepared to address any additional costs that may arise as a result of the flood.

122. Consult with local officials before making decisions on the permanent closure of provincial roads or non-replacement of bridges.

123. Review, with the Government of Canada, alternative options with Disaster Financial Assistance's policy of replacing structures to the standard that existed prior to the flood as opposed to making permanent improvements to these structures to mitigate damages in the long term.

124. Review, with the Government of Canada, a policy to allow municipalities and First Nations communities who are completing repair works on infrastructure damage due to flooding using their own equipment and staff, to be reimbursed at the same rate as contractors who would be conducting similar work.

125. Decisions made by the Province regarding the closing or decommissioning of provincial infrastructure that would impact a particular municipality be communicated to local officials in a timely manner to allow them to review the situation, examine the municipal perspective on the decision and prepare a response.

13. First Nations and Flooding

13.1 Background

First Nations' experiences of the 2011 flood are distinct from other Manitobans.

During the course of its work, the Manitoba 2011 Flood Review Task Force (Task Force) came to understand that differences in governance, relationship to the Crown and history with flooding have meant First Nations' experiences of the 2011 flood have been distinct from other Manitobans. As a result, the Task Force has determined that First Nations' concerns require separate commentary.

This section focuses on the historical background relevant to First Nations' experiences and provides an overview of key issues encountered by the Task Force. It is intended to substantiate and explain the assertion of the Task Force that important issues related to flooding as experienced by First Nations people require further investigation. It should be noted that other sections of this report also contain significant information about First Nations' experiences relevant to the 2011 flood.

In addressing the First Nations' experience, the Task Force is aware that it cannot speak on behalf of First Nations communities. The issues noted are presented from the perspective of the Task Force. Further, the discussion of First Nations' issues in this section and throughout the report is by no means exhaustive. Additional investigation would likely highlight other areas worthy of examination.

The First Nations communities that were impacted by flooding in 2011 are illustrated in Figure 13.1. There was a substantial variation in the degree of flooding and related damage among these communities.

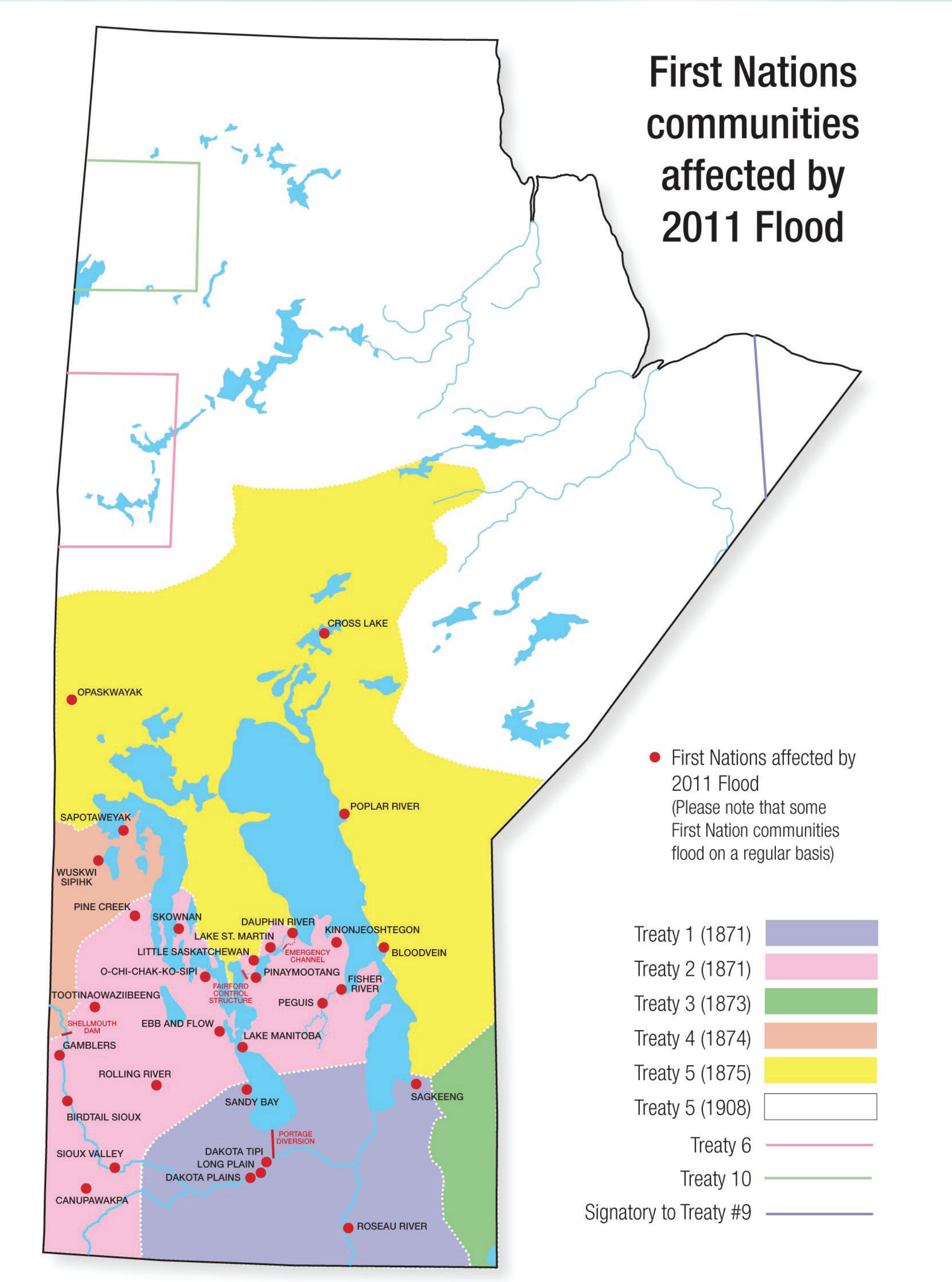
13.2 History and Treaties

From time immemorial, Aboriginal people have lived in the region that is now Manitoba. In the immediate pre-settlement period, the major Aboriginal groups of the region were Ojibway/Anishinaabe, Cree, Dakota and Metis.

The Task Force finds the description below from the Treaty Relations Commission of Manitoba to be a helpful introduction to the history of treaties in Canada.

> *Canada understands treaties between the Crown and First Nation people to be solemn agreements that set out promises, obligations and benefits for both parties. The First Nations understand the Treaties to be a series of negotiations through which they safeguarded their languages, traditions and cultures, while also agreeing to share the land with Canadians.*
>
> *Indigenous North America, like Europe, was populated by many nations of people with different languages, cultures, religions, ways of life and traditional territories. When First Nations met with each other they negotiated alliances that were mutually beneficial. These alliances established peaceful relationships among them which included trade, passage, peace and friendship, and other obligations and responsibilities.*

Figure 13.1: First Nations communities impacted by flooding in 2011



Starting in 1701, in what was to eventually become Canada, the British Crown entered into solemn treaties to encourage peaceful relations between First Nations and non-Aboriginal people. Over the next several centuries, treaties were negotiated and signed to define, among other things, the respective rights of First Nation people and governments to use and enjoy lands that First Nations people traditionally occupied. (Treaty Relations Commission of Manitoba: www.trcm.ca/about_treaties.php.)

Treaties were signed on the Canadian Prairies in a particular social, political and economic context. By the late 19th century, Aboriginal people across the Prairies were experiencing economic hardship related to the decline of the fur trade and the near-extinction of the bison. At the same time, the Canadian government was looking to establish non-Aboriginal agricultural settlement across the Prairies. In these contexts, the two parties came together to negotiate what have become known as the numbered treaties. Contemporary Manitoba includes lands involved in Treaties 1 (signed in 1871), 2 (signed in 1871), 3 (signed in 1873), 4 (signed in 1874) and 5 (signed in 1875), as well as in later adhesions to these treaties and to Treaty 9.

In seeking treaties, the Canadian government was motivated in part by the Royal Proclamation of 1763, which prohibited settlers from occupying territory that Aboriginal people had not officially surrendered. According to this way of thinking, it was necessary to conclude treaties in advance of extensive settlement of the Prairies by newcomers. The government was particularly keen to secure lands that were especially desirable, such as good farmland and important transportation routes. For their part, Aboriginal people were, as described by historian Sarah Carter, "interested in entering into agreements that could assist them to acquire economic security in the face of a very uncertain future."[1]

From the perspective of the Canadian government, the numbered treaties involved an agreement by Aboriginal people to surrender their claims to large areas of land in return for small reserves, annual payments and a variety of other considerations, such as the establishment of on-reserve schools or the provision of farming equipment. In retrospect, it is clear that Aboriginal people and the Canadian government differed substantially in their views of the agreements that were signed. A basic point of divergence related to what had been arranged with respect to land. While the Canadian government was convinced it had secured absolute control over much of the Canadian West, Aboriginal people felt they had agreed to share the land in peaceful coexistence.

One of the key commitments Aboriginal people believed they had secured through treaty was the right to continue to hunt and fish across the region, even outside of reserve lands. But as settlement increased in Manitoba, their ability to access traditional foods became increasingly constrained. Even reserve lands proved vulnerable, as the early 20th century policy of reserve surrender facilitated the removal of Aboriginal people from reserves located in desirable areas and their re-establishment in remote locations. For instance, the community that today occupies Peguis Reserve was, until surrender, located in what are now valuable lands immediately north of the city of Winnipeg, in the vicinity of Selkirk.

While First Nations maintain their primary relationship with the Government of Canada, over time they have developed important connections with provincial authorities and have come to participate in and be served by provincial programs and services. Additionally, First Nations communities live side-by-side with Manitoba's rural municipalities and share many local concerns derived from geographical proximity.

It was in the context of historical relationships with the Government of Canada rooted in treaties, increasingly significant involvement with the Government of Manitoba and important practical concerns shared with rural municipalities that self-governing First Nations communities experienced the 2011 flood. The Task Force has come to understand that many difficulties encountered by First Nations through the 2011 flood related to lack of clarity surrounding the division of powers among levels of government.

[1] *Aboriginal People and the Colonizers of Western Canada to 1900, p. 120.*

13.3 Jurisdiction

The question of who has the responsibility to do what in relation to First Nations communities and reserve lands contributed to difficulties related to the 2011 flood. Jurisdictional problems exist between the federal and provincial governments, and are also evident at the municipal level. While in many cases divisions of responsibility may seem clear in the abstract, it appears in practice there is often confusion among the parties involved.

Roseau River just was one of many First Nations communities affected in 2011.

13.3.1 Federal-Provincial

The Task Force heard presentations from officials involved with First Nations flood issues on behalf of both the provincial and federal governments. All individuals seemed concerned with First Nations' well-being and offered examples of their efforts to address First Nations' issues, both during the flood itself and in the months since. The Task Force recognizes the significant human and financial resources invested in coping with flooding on First Nations lands. But evidence suggests that even well-meaning attempts by individuals often failed to amount to real improvements in the lives of First Nations people affected by flooding.

Both the federal and provincial governments have occasionally overstepped what they perceive as their strict spheres of responsibility in relation to First Nations flooding. From their perspectives, they do so as a matter of grace rather than responsibility. First Nations require cooperation from other governments in dealing with issues such as flooding. Aboriginal people would benefit from greater clarity regarding which government has responsibility for which flood-related problems.

The Task Force is aware that jurisdictional difficulties of this sort are hardly new. In fact, they have plagued First Nations since treaty. Jurisdictional issues that seem to have been particularly significant during the flood of 2011 include the following points.

1. The federal government is under an obligation, deriving at least in part from treaty, to provide a wide range of services and resources to First Nations. Recognizing this, the provincial government often resists undertakings that may seem to encroach on the federal sphere of responsibility. Provincial officials do so out of concern for their lack of jurisdictional authority and also to avoid expenditures of provincial resources. Task Force members heard, however, that in recent years the Province has increasingly adopted the attitude that 'a Manitoban is a Manitoban,' with the result that the Province has extended a greater number of programs and services to First Nations communities.

2. Reserve lands are held in trust by the Crown for First Nations people. Provincial legislation respecting land use planning and zoning does not apply. Whatever flood protection measures derived from such legislation for the province as a whole are therefore not available on-reserve. Further, the Task Force has observed that First Nations communities often lack the resources to undertake effective land use planning and flood mitigation under their own auspices.

3. The Task Force has observed that the federal responsibility to provide services has been devolved to a great extent to individual First Nations. This includes infrastructure, housing, education, social assistance, band administration and economic development, and all the financial and personnel management associated with such activities. Particularly in times of crisis, communities are overwhelmed by these extensive obligations.

13.3.2 Municipal

The Task Force also heard evidence of jurisdictional issues involving municipal governments. There appears to be a lack of coordination between First Nations and local governments on water management issues. Neither municipalities nor First Nations communities seem to have structures in place to ensure cooperation in water management or land use planning activities that may bear on the other community. Some First Nations people feel they are subject to flooding due to the actions of upstream neighbours. The maintenance of municipal roads that primarily serve First Nations communities is another issue deriving from the problematic relationship between municipalities and First Nations.

The Task Force feels that confusion over the division of powers between the federal, provincial, municipal and First Nations governments complicated the handling of aspects of the 2011 flood that bore on First Nations people and/or reserve lands. Evidence suggests that variations in how jurisdictional issues have been resolved have contributed to uneven outcomes among First Nations communities.

13.4 Other Issues

While jurisdiction seems to be the root of many problems, the Task Force has also become aware of some other key issues for First Nations people deriving from the 2011 flood. While the below list is not exhaustive, it does suggest the range of concerns that have come to the attention of the Task Force.

13.4.1 Long-Term Evacuations of Large Proportions of the Population

The length of time their peoples have been forced to spend away from their homes is distressing to Aboriginal leaders. Notably, as people moved from an Aboriginal reserve to an urban centre, these evacuations resulted in immersion in a dramatically different social and cultural environment. While some individuals found opportunities in this situation, it has been very distressing for others. The Task Force heard concerns that the evacuation may have a long-term detrimental impact on First Nations communities, particularly in terms of its impact on the very young or the very old.

According to First Nations people, specific effects of displacement included:

- stress on communities due to culture shock,
- negative effects on social relationships and personal well-being,
- loss of time in school for students,
- difficulties derived from media stories that reflected negatively on displaced First Nations, and
- insufficient support.

13.4.2 Lack of Resources

The Task Force recognizes that First Nations communities faced with allocating limited resources are obliged to make difficult choices. Basic needs such as housing tend to be addressed before seemingly less pressing issues such as land use planning and flood risk mapping. This has contributed to a situation in which many reserves are ill-prepared to cope with high water.

The emergency channel from Lake St. Martin to Lake Winnipeg.

13.4.3 Flood-Related Environmental Damages

Aboriginal leaders expressed distress over flood damage to areas of recreational and spiritual significance. The Task Force heard from some First Nations communities that water contamination has, in some places, impeded the ability of First Nations people to make use of the waters close to their community without risking boils or skin sores. Such losses may be more significant in the context of isolated communities without access to alternative recreational outlets and spiritual gathering areas.

Aboriginal leaders also shared their concern with the Task Force over fish and bird kills they believed to be connected to the 2011 flood. In this regard, it is important to recognize the continuing importance of traditional foods in the diets of First Nations communities. There may be health consequences related to replacement foods, particularly in the context of high rates of illnesses such as diabetes among First Nations people. It is also important to recognize the cultural significance to First Nations people of participating in the harvesting of birds and fish. Any flood-related effect on fish and bird populations is experienced much more severely by First Nations people than by many other Manitobans, even considering the personal and economic interest of some non-Aboriginal Manitobans in hunting and fishing.

13.4.4 Impact on Band Finances

The Task Force heard that some First Nations lack the sophisticated accounting and management skills necessary to deal with the complexities of large-scale flood protection measures, particularly in times of personal and community distress and dislocation. As a result, some First Nations have been unable to fulfil the conditions under which monies expended on flood fighting may be reimbursed. While some municipalities experienced similar issues, the Task Force feels that First Nations communities were disproportionately affected.

13.4.5 On-Reserve Drainage

A number of First Nations have concerns about lack of on-reserve drainage. Visits to a number of reserves allowed some Task Force members to observe the situation first-hand. In some instances, while the 2011 flood waters from adjacent rivers and other water bodies did not directly damage houses, water backed up behind the dikes that were intended to provide flood protection. This resulted in flooded basements and soaked crawl spaces that contributed to mould problems sufficiently severe to render some homes uninhabitable. First Nations people expressed concerns that, with reference to programs to repair or replace housing, homes damaged in this way may be dealt with differently from houses directly affected by flood waters.

13.4.6 Emergency Management on First Nations Lands

The Task Force heard concerns over the effectiveness of emergency management on Aboriginal reserves. The Manitoba Association of Native Fire Fighters played a significant role in 2011, but there seems to be disagreement among Aboriginal people regarding the effectiveness of this organization. Flood response efforts may have been hampered by lack of clarity regarding the relationship between Manitoba's Emergency Measures Organization (EMO) and on-reserve communities. The problem may stem from how EMO is structured to integrate with the municipal level of government. Insofar as First Nations represent distinct governments not equivalent to rural municipalities, the integration between Aboriginal communities, Aboriginal Affairs and Northern Development Canada (AANDC) and Manitoba's EMO could be improved. There seems to be a lack of awareness of emergency management training opportunities that may be available to Aboriginal people, or some difficulties related to organizing and funding appropriate training.

13.5 Conclusions

The Task Force feels that its mandate was insufficient to adequately address the full scope of First Nations issues related to the 2011 flood. As a result, this summary offers only a limited discussion of key issues that became apparent to the Task Force in the course of its wider study of the 2011 flood. Also, the Task Force has become aware of a variety of other water management issues affecting First Nations communities including surface water flooding and on-reserve wastewater management. Further investigation into these matters in a cooperative effort among provincial, federal, municipal (insofar as appropriate) and First Nations governments should be undertaken.

The Task Force recognizes that, for a variety of geographical, social, political, economic, jurisdictional and historic reasons, flooding affects First Nations communities in distinct ways. Any future investigation into matters, flood-related or otherwise, that affects First Nations should be adequately equipped to take into account this distinctiveness.

The Task Force has been heartened by what it sees as a willingness on the part of many First Nations communities to collaborate on solutions to persistent flooding and related water management problems. There is an understanding that all residents of Manitoba form part of a broader community in relation to water management. Many First Nations people expressed to the Task Force their desire to be party to broader regional discussions oriented to finding solutions to water management problems.

13.6 Recommendation

126. Future reviews conducted by the Province of issues that affect First Nations communities must include a mandate adequate to encompass the distinctive nature of First Nations' issues, including geographically and gender balanced representation by members of affected First Nations communities.

14. Conclusions

The effort put forth by the Province, and indeed all who were involved in fighting the 2011 flood, was commendable. The Province generally did a good job of constructing new dikes and raising and strengthening existing dikes both on its own and when working with affected rural municipalities, cities, towns and First Nation communities. Flood forecasters were able to give water managers, communities and residents time to prepare by virtue of their early assessment of the severity of the impending flood. The operation of the Province's flood control infrastructure was managed as well as it could have been, given the severity of the flood and the condition of some of the flood control infrastructure. The entire system was operated without failure due to the skill and determination of the operating personnel. The fact that there was no loss of life underscores the role played by the technologists and engineers who operate the system.

The Task Force has identified a number of concerns that need to be addressed by the Province. The most pressing are presented in the following discussion.

While the Hydrologic Forecasting Centre (HFC) provided adequate early warning of the severity of the impending flood through its spring flood outlook reports, it had difficulty keeping abreast of the changing flood conditions and providing accurate operational forecasts over the summer period. The forecasting model employed by the HFC was not able to provide reliable rainfall runoff forecasts. Furthermore, the lack of a flood operations room where forecasters could work collaboratively made their task more complicated. There was no data management system for handling large volumes of hydroclimatic data nor were there dedicated software programs for use by the forecast centre during critical forecasting periods. In spite of the challenges, the HFC displayed a high level of commitment and professionalism under very trying circumstances.

The inadequacy of succession planning within the provincial government was particularly evident during the 2011 event. Relatively inexperienced forecasters had to deal with a flood far beyond anything they had ever faced, using tools that in some cases were not up to the task at hand. It is clear that the capabilities of the young forecasters need to be reconciled with the tools that they are using in preparing flood forecasts.

The condition of the Province's flood control infrastructure, outside of the Red River Valley, created some serious issues. All of the components of the Portage Diversion system require upgrading and repair. While increasing the storage at the Shellmouth Dam would not have provided significant relief in 2011, it would have positive flood control benefits along the entire Assiniboine River system in years when less severe flooding occurs. Furthermore, Manitobans living around Lake Manitoba have the expectation that an effective method of managing water levels on Lake Manitoba needs to be examined, to develop a solution that provides sufficient outflow capacity to match prospective inflows.

But perhaps the most significant infrastructure issue is the condition of the dikes along the Assiniboine River from Portage la Prairie to Headingly. The inability of those dikes to convey flows for sustained periods of time at their original design capacity resulted in a need to shunt far more water out of the Assiniboine River into Lake Manitoba than what would have been otherwise necessary. This resulted in higher water levels on Lake Manitoba (by about 10 centimetres). Also, the poor performance of the dikes increased anxiety levels about the potential implications of their failure on the safety of residents living adjacent to the Assiniboine River between Portage la Prairie and Winnipeg. Finally, the questionable state of the dikes added to the need to construct and ultimately operate a controlled breach at Hoop and Holler Bend. The need to construct a controlled breach would be justified as a precautionary measure to prevent overtopping of the dikes. The actual operation of the breach appears to have been undertaken in as a judicious manner as possible given the circumstances at the time and based on information available. The utility of such a controlled breach in 2011 suggests that construction of a permanent wasteway at some location on the Assiniboine River dikes to act as a relief valve for future major floods would be an important addition to the Portage Diversion system. A long term plan of investment in the flood control infrastructure in the Assiniboine River basin is required.

Task Force members spent a considerable amount of time checking out the condition of flood control infrastructure throughout southern Manitoba.

Staffing was identified as an issue with the Emergency Measures Organization (EMO). Several individuals "on the ground" expressed their sincere appreciation for the efforts and assistance of EMO, but said that there were simply not enough EMO personnel available to deal with an event of this magnitude. In addition to increasing the number of personnel, it is clear that greater effort must be put into training and preparation at all levels of emergency management including response and recovery, with a greater focus on preparedness than there has been in the recent past. This training should cut across all levels of government. The current location of the Manitoba Emergency Control Centre is inconvenient and vulnerable for a number of reasons. The Centre should be relocated to a site that meets the Centre's operational and administrative needs and accessibility requirements, and provides a more secure venue for the management of emergencies.

The physical strain and the emotional stress before, during and after the flood was too much for many individuals to bear. The Regional Health Authority of Manitoba established a Psychosocial Recovery Team to help people with the issues they were facing. While this action was a step in the right direction, more emphasis is required on programs dealing with people impacted by events of this nature.

During the flood, more than 650 roads and nearly 600 bridges were damaged, disrupting transportation networks across the province. The cost of repairing the provincial roads and bridges damaged by the flood is enormous and most of it would be borne by the Province. However, significant costs due to both direct damage and "collateral damage" (from over-use when used to detour around damaged provincial infrastructure) of municipal infrastructure have placed an immense burden on municipalities. The costs to repair these damages must be offset by the Province. Municipalities cannot afford to absorb the burden of upgrading their flood-damaged infrastructure on their own, especially when the damage was caused by circumstances beyond their control.

Policies related to what the Disaster Financial Assistance program will or will not cover for municipal repairs and activities related to those repairs must be re-examined. Standards for repair or replacement of damaged infrastructure should be re-evaluated with an eye toward investing in the future, rather than staying with the status quo. With a little extra funding, roads and structures can be improved to a better standard to alleviate the recurring problem instead of repeatedly having to rebuild them to the old standard after each flood event.

With respect to the Disaster Financial Assistance programs, there was a considerable amount of confusion among flood victims and program administrators alike concerning the variety of programs available, the number of agencies involved and what types of damage claims were eligible. A concerted effort must be put forth by both the federal and provincial governments to communicate program details to the public and to simplify the methods by which applicants can submit damage claims.

Continued and enhanced cooperation with other jurisdictions in water management matters will produce benefits to Manitoba. Land drainage activities in upstream jurisdictions need to be addressed on a watershed basis with our neighbours. The sharing of water management data among all upstream jurisdictions should be improved and formalized.

The Task Force report addresses First Nations' concerns in various sections of the report. It is clear that flood response on the part of federal, provincial and First Nations governments was hampered by confusion over jurisdictional responsibilities and uncertainty over how to work together. These matters need to be addressed. The Task Force recognizes that Manitoba First Nations were disproportionately subject to long-term flood-related evacuations. As of December 2012, an estimated 2000 people were still evacuees of the 2011 flood. The 2011 flood served to further exacerbate pre-existing social, environmental or financial problems in some First Nations communities.

In the course of the Task Force's investigations and through site visits some of these problems were seen first hand. More specifically, the Task Force observed the environmental aspects and the limitations that financial constraints has on some of these First Nation communities (i.e. over-land flooding, culvert sizing, road damage, flood affected homes, etc). Site visits took place in the following First Nation communities: Opaskwayak, Tootinaowaziibeeng Treaty Reserve (Valley River First Nation), Dauphin River First Nation, Lake Manitoba First Nation, Peguis First Nation and Pinaymootang First Nation (Fairford). Joint open houses were held in Pinaymootang First Nation and Winnipeg by the Task Force and the Lake Manitoba and Lake St. Martin Regulation Review Committee. The 2011 flood-affected First Nations communities are displayed in Figure 13.1. It must be noted, while the Task Force invested significant time and effort in examining First Nations' experiences, Task Force members feel that the Task Force mandate was insufficient to adequately investigate many of the distinctive concerns of First Nations people.

The recommendations presented in this report have been developed on the basis of data gathered from a number of provincial agencies and after extensive discussions with a wide range of Manitobans. Recommendations relating to operating strategies and forecasting are based on a rigorous assessment of the 2011 flood characteristics and a quantitative analysis of 2011 forecasting outcomes. Other recommendations have been formulated on the basis of what the Task Force heard, on individual members' knowledge and expertise and by drawing on experiences in other jurisdictions.

Some of the recommendations in this report have already been acted on while others are being studied or are in the process of being implemented. The Task Force fully understands that the Province of Manitoba is faced with financial and human resource limitations, and acknowledges that it will not be possible to address all of the recommendations in this report in the short term. The recommendations presented will have to be prioritized, and a long term plan for implementation developed.

Looking into the future, Manitobans need to cultivate an understanding of the province's ongoing vulnerability to flooding. Science suggests that the 2011 flood, while a monumental event in our relatively short history, may not prove to be such a rare event as time advances. The potential impacts of climate change are uncertain, and it is possible the 2011 flood will prove to be a harbinger of events still to come. As Manitobans, we need to be prepared. We need to stop being surprised by high water. We need to find ways to sustain an awareness of our vulnerabilities in both communities and individuals, and to incorporate this awareness into how we structure our lives, our communities and the landscape. We must not set our memories aside when the immediate threat has passed and we are in a relative state of calm.