

**2011 Flood: Technical Review of
Lake Manitoba, Lake St. Martin
and Assiniboine River Water Levels**

Summary

October 2013

Introduction

Manitoba experienced unprecedented flooding in 2011. While flooding was severe across much of the province, the magnitude and duration of flooding on the Assiniboine River, Lake Manitoba and Lake St. Martin exceeded the capacity of Manitoba's flood control infrastructure. Extraordinary measures such as the Hoop and Holler controlled release on the Assiniboine River, increasing the capacity of the Portage Diversion, and the construction of the Lake St. Martin Emergency Channel were undertaken to protect Manitoba communities.

Following the spring runoff and melting of the snow pack, significant rainfall through parts of the province in spring and early summer contributed to extended flooding with the peak flow on the Assiniboine River near Portage la Prairie reaching 53,100 cubic feet per second (cfs), the highest flow on record. Water levels on Lake Manitoba peaked at 817.05 feet (wind eliminated level) in late July 2011, also the highest on record. A significant windstorm on May 31, 2011 produced waves reportedly up to four feet high and caused water levels in the south basin of Lake Manitoba to rise beyond 820 feet. This storm destroyed or damaged many of the homes and cottages on the south basin of the lake.

Finally, the water level on Lake St. Martin peaked at 805.6 feet in July of 2011, again the highest water level on record.

After the 2011 flood, a number of initiatives were undertaken to improve flood preparedness and water management in the province. This included the 2011 Flood Review Task Force, the Lake Manitoba and Lake St. Martin Regulation Review Committee, the Lake Manitoba and Assiniboine River Basin Flood Mitigation Study, and the Surface Water Management Strategy. In late 2011 Manitoba Infrastructure and Transportation (MIT) also began an extensive technical investigation of flooding on Lake Manitoba, Lake St. Martin and the Assiniboine River to determine how flood waters would have naturally flowed without flood infrastructure in place and examine how flood waters overwhelmed existing flood infrastructure. The methods and the results from this analysis were reviewed and validated by KGS Group, an independent engineering company skilled in this type of hydrologic and hydraulic analysis. The findings will guide plans for future flood control works.

Water Control Infrastructure

Manitoba has an extensive system of water control infrastructure much of which was built following the recommendations of the 1958 Royal Commission on Flooding. Major water control structures were designed to provide flood protection as part of a system and are not operated in isolation. Many of these structures are relevant to managing the Assiniboine River, Lake Manitoba and Lake St. Martin.

The Shellmouth Dam located approximately 24 km northwest of Russell, Manitoba was completed in 1972. The dam reduces peak flows on the Assiniboine River during floods by storing a portion of the Assiniboine River's flows in the reservoir. The Shellmouth Dam has provided significant flood protection for communities on the Assiniboine River including Brandon, Portage la Prairie and Winnipeg. In 2011, the Shellmouth Dam reduced flooding on the Assiniboine River, cutting peak flows at the dam by nearly half. The storage provided by the dam resulted in a peak flow of 12,100 cfs. If the dam did not exist, the flow on the Assiniboine River at the location of the dam would have peaked at 20,800 cfs. The operation of the Shellmouth Dam reduced peak flows at Portage la Prairie by 7,100 cfs.

There are a number of large dams located on the Souris River including the Rafferty and Alameda Dams in southern Saskatchewan and the Lake Darling Dam in North Dakota. During large floods such as 2011, these dams reduce flows and provide flood protection downstream. In 2011, the dams on the Souris River helped reduce the peak flow on the Assiniboine River at Portage la Prairie by approximately 4,500 cfs.

The Portage Diversion is a 29 km long channel completed in 1970 that diverts water from the Assiniboine River into Lake Manitoba. During the spring the diversion is operated to minimize ice jams along the lower Assiniboine River by holding flows at 5,000 cfs. Once the ice moves off the Assiniboine River the diversion is operated to provide flood protection to areas downstream of Portage la Prairie, including Winnipeg and along the Red River north of Winnipeg. The diversion was designed to divert flows of up to 25,000 cfs from the Assiniboine River. In spring 2011, it became clear that the forecasted Assiniboine River flows would exceed the combined flow capacity of the Assiniboine River channel and the Portage Diversion. Crews worked quickly and urgently to expand the capacity of the Portage Diversion to 34,000 cfs by building up the dikes on the diversion channel and reinforcing the operating structures.

The lower Assiniboine River, from approximately Portage la Prairie downstream to Headingley has a limited natural channel capacity estimated between 10,000-15,000 cfs. Flows that exceed this capacity will overflow from the river and spread out across the relatively flat prairie. The Assiniboine River dikes are built on each side of the river, and consist of approximately 77 km on the north bank and 71 km on the south bank of the river (a total of 148 km of dikes) starting just east of Portage la Prairie and extending downstream east of Baie St. Paul. The dikes effectively increase the capacity of the Assiniboine River channel and, in conjunction with the Shellmouth Dam and the Portage Diversion, prevent the Assiniboine River from overflowing its banks.

Historical records show that before modern flood control infrastructure was in place, the Assiniboine River overflowed its banks during other large floods, and water naturally flowed into Lake Manitoba by way of old river channels. Large volumes of water have also been documented overflowing into the La Salle River system, reaching the Red River and the City of Winnipeg. The Assiniboine River flows in 2011 were the highest ever recorded and without the Portage Diversion and the Assiniboine River dikes, the river would have overflowed its banks. Before the flood MIT reinforced the dikes, raising them by two feet as early flood forecasts indicated the potential for significant flooding on the Assiniboine River. During the 2011 flood the dikes allowed for sustained flows of 18,000 cfs on the lower Assiniboine River for an extended period of time. Without the dikes, the river's capacity would have been considerably lower, requiring more flow to be diverted into Lake Manitoba or causing significant flooding downstream of Portage la Prairie.

The Fairford River is the natural outlet from Lake Manitoba, flowing into Lake Pineimuta and then on to Lake St. Martin. Outflows from Lake St. Martin are through the Dauphin River to Lake Winnipeg. The Fairford River Water Control Structure (FRWCS) was completed in 1961 and consists of a concrete stop-log control structure. The project also included enlargement of the natural river channel and excavation of the lake

bottom leading up to the channel. This allows for higher flows out of Lake Manitoba than would naturally occur. When water levels are high or significant inflows are predicted, all of the stop-logs can be removed from the structure to increase outflows from Lake Manitoba to help lower the lake before, during and after periods of high inflow.

Lake St. Martin experienced record high water levels in the summer of 2011 due to high inflows from Lake Manitoba. The Dauphin River, the outlet from Lake St. Martin, has a limited outflow capacity and a history of developing frazil ice jams which restrict the river channel and further reduce outflows from Lake St. Martin. When water levels on Lake St. Martin are high, outflows from Lake Manitoba through the Fairford River Water Control Structure are typically reduced in the late fall to lower the chances of frazil ice jams forming on the Dauphin River. To provide for maximum outflows from Lake Manitoba and Lake St. Martin, the Manitoba government built the Lake St. Martin Emergency Channel. The channel allowed for maximum outflows on Lake Manitoba throughout the winter of 2012 while at the same time, increasing the outflows from Lake St. Martin and reducing the consequences if frazil ice were to develop. The Lake St. Martin Emergency Channel had an immediate impact and lowered levels on Lake St. Martin, which allowed for higher outflows from Lake Manitoba.

Regulated and Unregulated Flows

The recorded water levels are referred to as regulated levels, while the levels that would have occurred without flood control structures are referred to as unregulated levels. Unregulated levels are sometimes referred to as natural levels, and must be computed for water bodies by removing the effect that all flood control structures had on flows and/or levels.

Lower Assiniboine River

In May of 2011, flows on the Assiniboine River near Portage la Prairie exceeded the capacity of Manitoba's extensive system of flood control infrastructure. If more water wasn't diverted into Lake Manitoba, it was possible that the Assiniboine dikes would have been breached leading to widespread, uncontrolled flooding. As discussed, the capacity of the Portage Diversion was increased on an emergency basis to handle 34,000 cfs, almost 10,000 cfs more than the design capacity. Even with the expanded diversion, flows on the Assiniboine River began to exceed the combined capacity of the enlarged Portage Diversion and the main channel of the Assiniboine River. The decision was made to make a controlled release at the Hoop and Holler site and prevent an uncontrolled and potentially catastrophic breach of the Assiniboine River dikes.

Emergency flood mitigation measures implemented by the Manitoba government in 2011 prevented

an estimated \$300 million in damage on the lower Assiniboine River. Under unregulated conditions, without the benefit provided by the Portage Diversion and other flood protection infrastructure, the potential damage on the lower Assiniboine River has been estimated to be \$2.2 billion.

Under unregulated conditions the peak flow at Portage la Prairie was estimated at 64,200 cfs, compared to the recorded flows of 53,100 cfs. Detailed hydrodynamic modelling was undertaken to estimate the overflows that would have reached Lake Manitoba and the extent of the flooded area under unregulated conditions with a pre-development landscape. Figure 1 shows the results of the modelled overflows, the study area is indicated by the green polygon. Downstream from the study area, the extent of the overflows was estimated to provide an approximation of inundated areas downstream to Winnipeg.

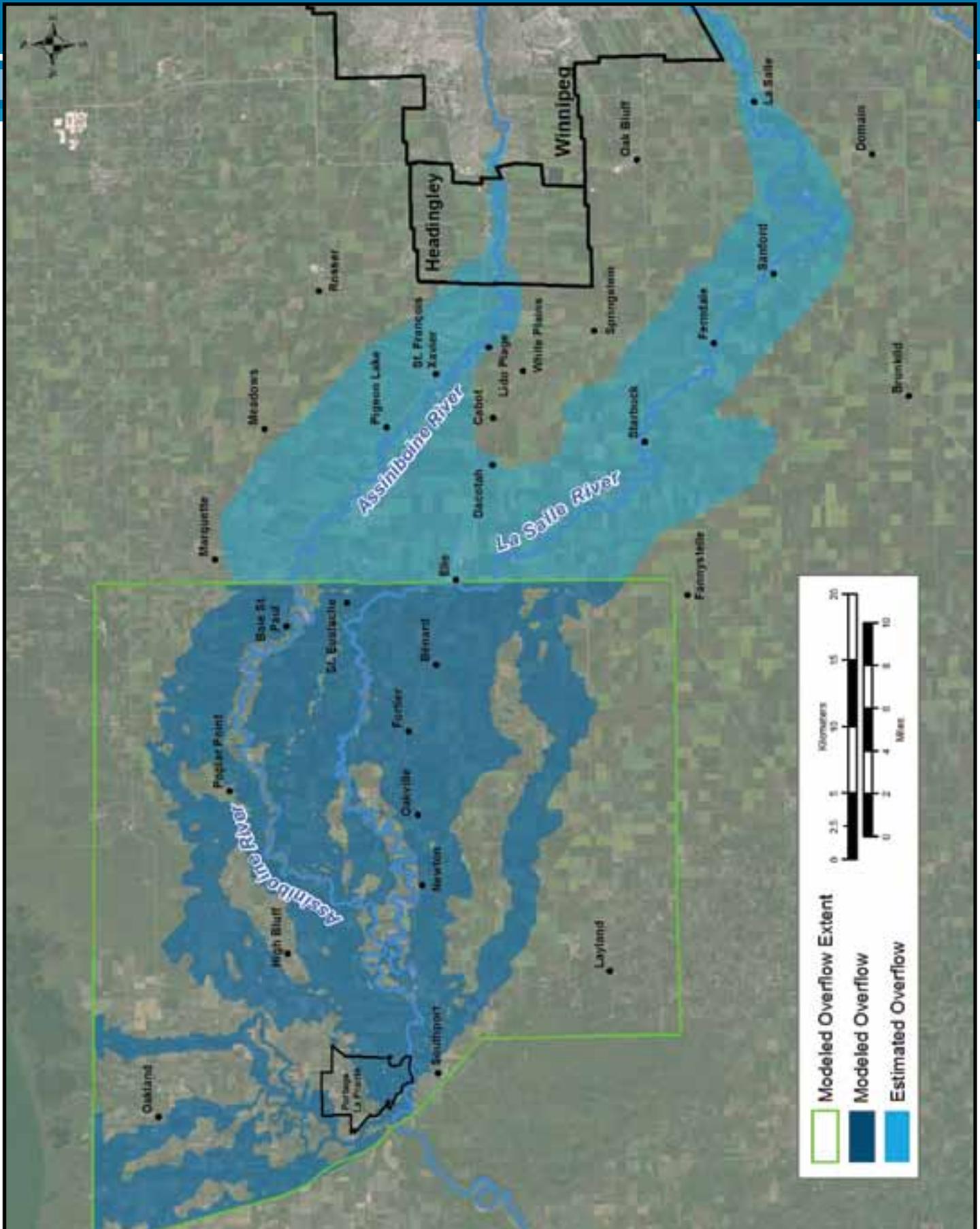


Figure 1: Map showing the modelled overflows within the study area (green box) under unregulated flows and pre-development topographic conditions. The extent of overflows downstream to Winnipeg was estimated based on limited topographic information.

The total volume of overflow from the Assiniboine River to Lake Manitoba was found to be relatively small, however, the modelled overflow results are considered conservative because the modelling could not account for erosion and topographic data was incomplete. The analysis confirmed that overflows from the Assiniboine River to Lake Manitoba would have occurred under unregulated conditions. This means that during a large flood, a portion of the flows on the Portage Diversion are not artificial flows, as they would have occurred anyway under unregulated conditions.

Finally, the Assiniboine River has a documented history of abandoning its channels and following new courses in the reach below Portage la Prairie.

At various points since the retreat of the last glacier, the Assiniboine River has flowed to the Red River via different channels, including the present La Salle River channel, and it has also flowed north to Lake Manitoba. Without operation of the Portage Diversion in 2011, the huge volume of flows on the Assiniboine River would have overtopped or caused a failure of the human-made dikes. This could have resulted in the Assiniboine River abandoning its present channel to follow a new course. The existing water control works not only provide flood protection but also provide a measure of stability to help maintain the Assiniboine River's present course in a naturally unstable and dynamic reach of the river.

Lake Manitoba

Lake Manitoba is a large lake with numerous inflows. In 2011, the Portage Diversion was not the only source of significant inflows to the lake. Record inflows in 2011 were also recorded on the Waterhen River, the largest tributary to the lake. The Waterhen River has also had higher than average flows over much of the last decade.

The results of analysis of water levels on Lake Manitoba are provided in Table 1 below and displayed in Figure 2

Table 1: Summary of Lake Manitoba levels under different scenarios

	March 31	May 31	June 30	July 31	August 31	September 30	2011 Peak Level (date)
Regulated (Recorded)	812.80	815.72	816.87	816.93	816.22	815.35	817.05 (July 23)
Regulated (Portage Diversion limited to 25,000 cfs)	812.80	815.61	816.70	816.78	816.09	815.24	816.96
Unregulated – pre-development overflows	814.66	816.24	816.72	816.56	816.21	815.63	816.75 (July 1)
Unregulated – no Assiniboine overflows	814.66	816.08	816.52	816.35	816.02	815.46	816.55 (July 1)

Note: all lake levels in the table above are wind-eliminated levels

The hydrograph in Figure 2 shows that before the spring runoff began in 2011, Lake Manitoba was 1.9 feet below the unregulated level due to the operations of flood control infrastructure. The regulated level on March 31, 2011 was 812.80 feet, and under unregulated conditions without flood control works the water level would have been 814.66 feet. The regulated water level of 812.80 feet is still very high and above the desirable range

of 810.5-812.5 feet. However, the unregulated level would have been even higher because the years preceding 2011 were also very wet, and without Fairford River Water Control Structure the natural outflows would have been lower, resulting in higher lake levels. The operation of the Fairford River Water Control Structures in preceding years provided a substantial benefit before the 2011 spring runoff started.

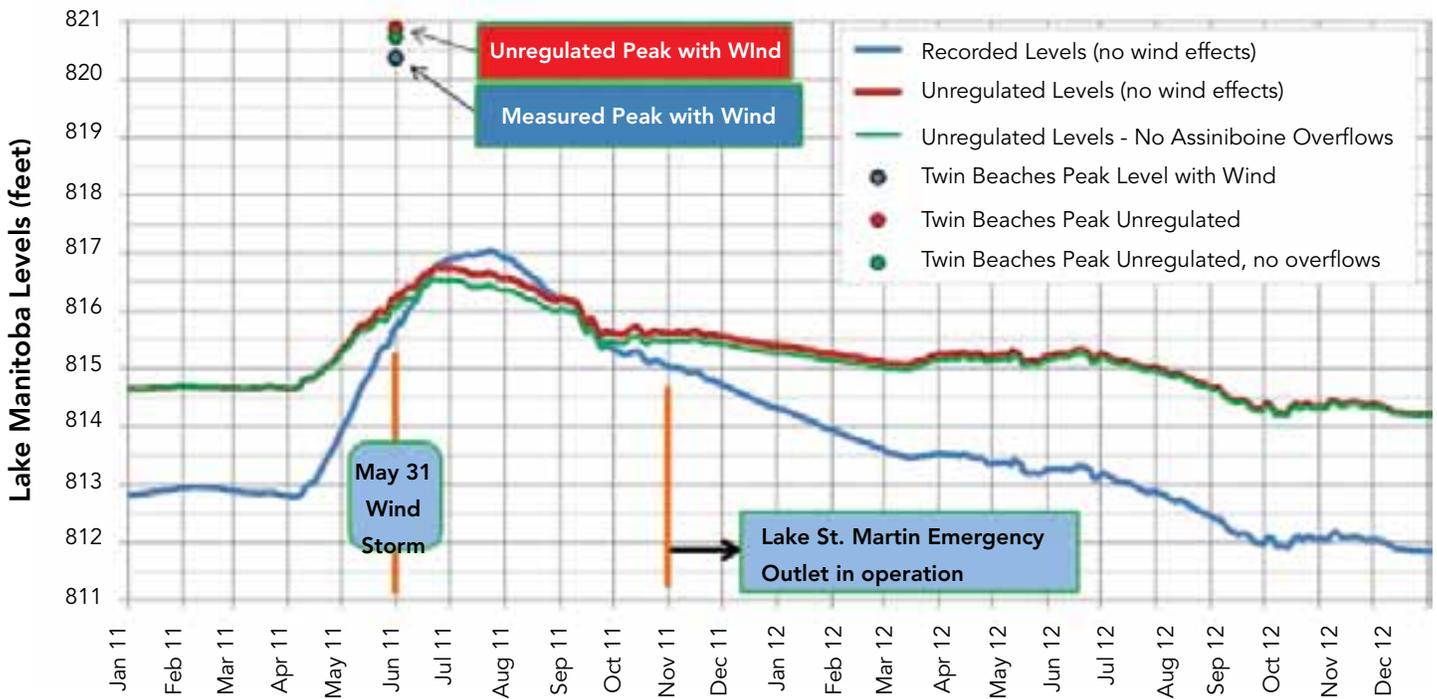


Figure 2: Hydrograph showing recorded, and unregulated Lake Manitoba Levels, with and without overflows from the Assiniboine River. The effect of the May 31 wind event on water levels at Twin Beaches, representative of the south basin, is illustrated by the points.

When the major storm hit Lake Manitoba on May 31, 2011 causing significant damage, the recorded wind-eliminated water level was 815.72 feet. Under unregulated conditions the wind-eliminated lake level would have been higher at 816.24 feet. Flood control works reduced lake levels by 0.5 feet compared to expected water levels in an unregulated environment. The peak wind and wave affected water level at Twin Lakes Beach was 820.37, this instantaneous water level is shown as a point in Figure 2. Although the recorded, wind-eliminated water levels on Lake Manitoba peaked on July 23 at 817.05 feet, the south basin of Lake Manitoba actually experienced wind-affected water levels during the May 31 storm more than three feet higher than the July peak. This means that flood damage to property was caused by the higher water levels associated with the May 31 wind storm, rather than any subsequent high water periods.

The analysis further shows that water levels on Lake Manitoba were higher than the estimated unregulated peak from June 22 to August 30, 2011. The regulated peak water level was 817.05 feet on July 23, 2011 versus the computed unregulated peak water level of 816.75 feet on July 1, 2011. The artificial increase in peak water level of 0.3 feet resulted in an estimated 24,000 additional acres around the lake being flooded. Figure 3 shows the estimated incremental area that was flooded at the maximum water level. Property damage or economic losses incurred as a result of flooding below the unregulated peak water level are due to natural causes, since under unregulated conditions the water level would have reached that level anyway. In other words, flood damage that occurred below the unregulated peak water level was not made worse by artificial flooding.

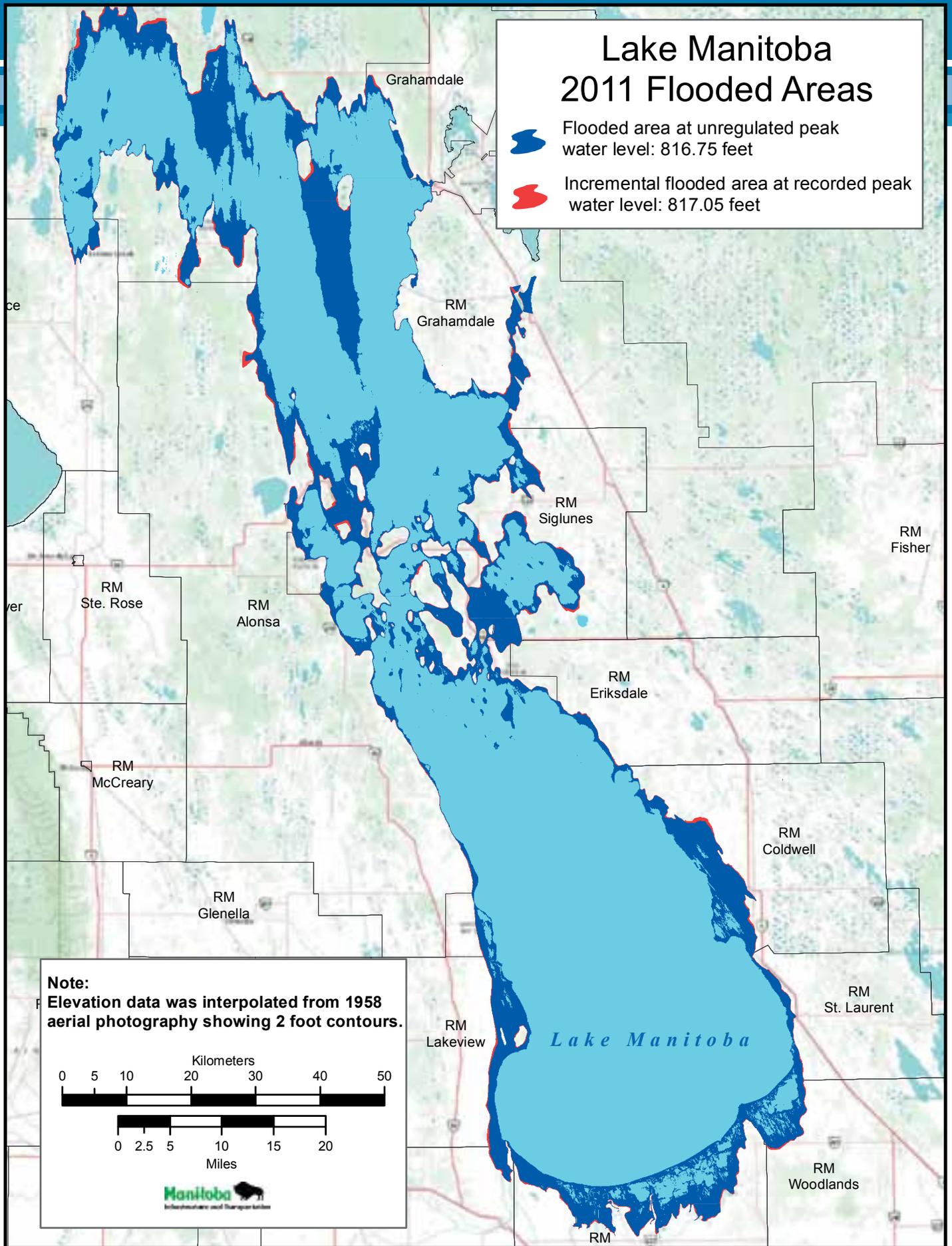


Figure 3: Map illustrating the inundated areas at the computed unregulated peak level and the incremental artificial flooding at the recorded peak level.

It is noteworthy that in spite of the significant artificial inflow to Lake Manitoba from the Portage Diversion, there was only a nominal artificial effect on the Lake Manitoba water level. This was due to the significantly enhanced outflow from the Fairford River Water Control Structure (FRWCS). As discussed above, lake levels were 1.9 feet lower than unregulated conditions before the 2011 flood event. This additional storage capacity combined with the increased outflows through the Fairford River Water Control Structure during the flood almost fully mitigated the impact of the Portage Diversion inflows to the lake. The net

effect of inflows, outflows, and the starting water level under regulated and unregulated conditions is illustrated in Figure 4. The FRWCS provided enhanced outflows from Lake Manitoba before, during and after the flood event. It is also notable that increasing the capacity of the Portage Diversion from 25,000 cfs to 34,000 cfs had a negligible effect on Lake Manitoba water levels. As shown in Table 1, restricting the flows on the Portage Diversion to the design capacity of 25,000 cfs would have resulted in a peak water level that was only 0.09 feet lower than the peak recorded water level.

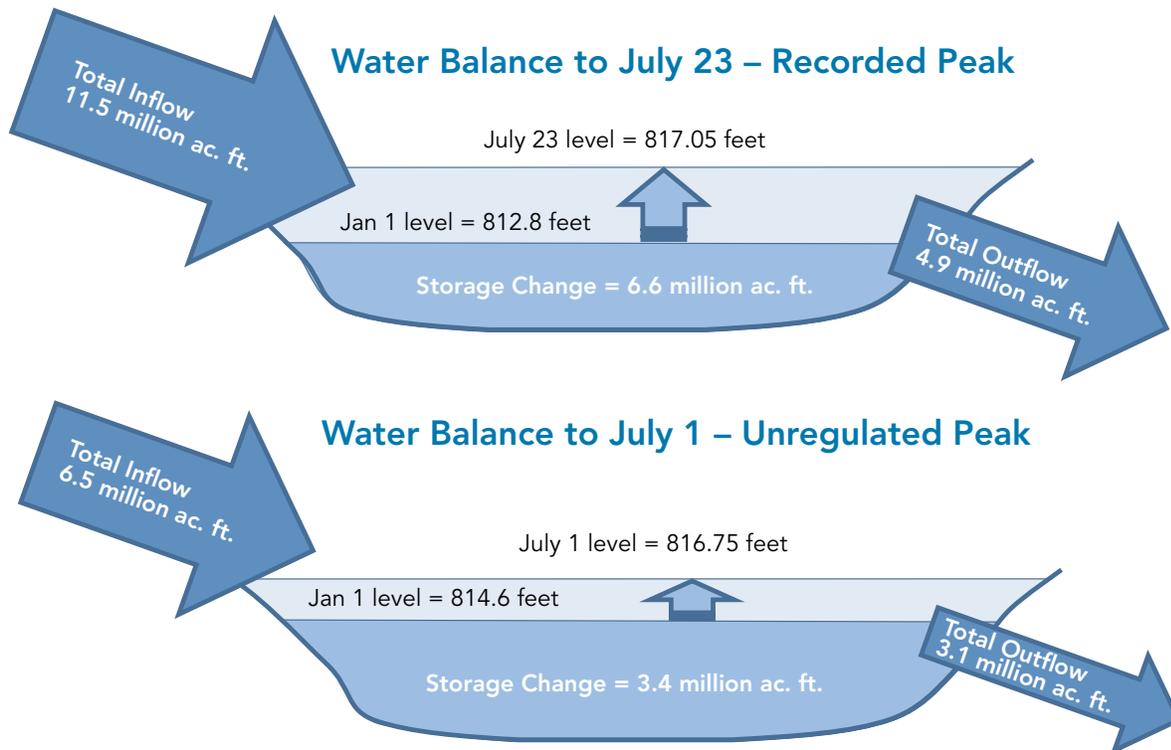


Figure 4: Lake Manitoba inflows and outflow to date of recorded peak water level and unregulated peak water level.

The operation of the Fairford River Water Control Structure reduced water levels after the 2011 flood more rapidly than would have occurred under unregulated conditions. This can be seen in Figure 2 as the regulated water level dropped lower than the unregulated water level as soon as September, 2011. The increased outflow capacity meant that under regulated conditions, Lake Manitoba dropped below flood stage (814 feet) by February 2012. Under unregulated conditions the lake would have peaked slightly lower but remained above flood stage well into 2013.

Analysis of the predicted natural overflows from the Assiniboine River to Lake Manitoba showed that the effect on the Lake Manitoba water level was to raise it by 0.2 feet. This is illustrated in Figure 2 which shows the unregulated lake levels that would have occurred both with the computed overflows from the Assiniboine River and assuming that overflows did not reach the lake. Note that this is a conservative estimate of overflows and further work is planned to refine the modelling.

Lake St. Martin

The results of analysis of water levels on Lake St. Martin are displayed in Figure 5 below. The November 1, 2011 opening date for the Lake St. Martin Emergency Channel is shown as the vertical orange line. The winter of 2012 was very mild and as a result frazil ice did not develop on the Dauphin River. The warm weather conditions are reflected in the recorded water levels as well as the unregulated water levels (purple and green lines) in Figure 5 below. The red line in the hydrograph illustrates the expected lake levels under normal weather conditions where frazil ice would have greatly restricted outflow from the lake. It is this scenario that necessitated construction of the Lake St. Martin Emergency Outlet Channel that allowed increased outflows from Lake St. Martin and Lake Manitoba to continue throughout the winter of 2012.

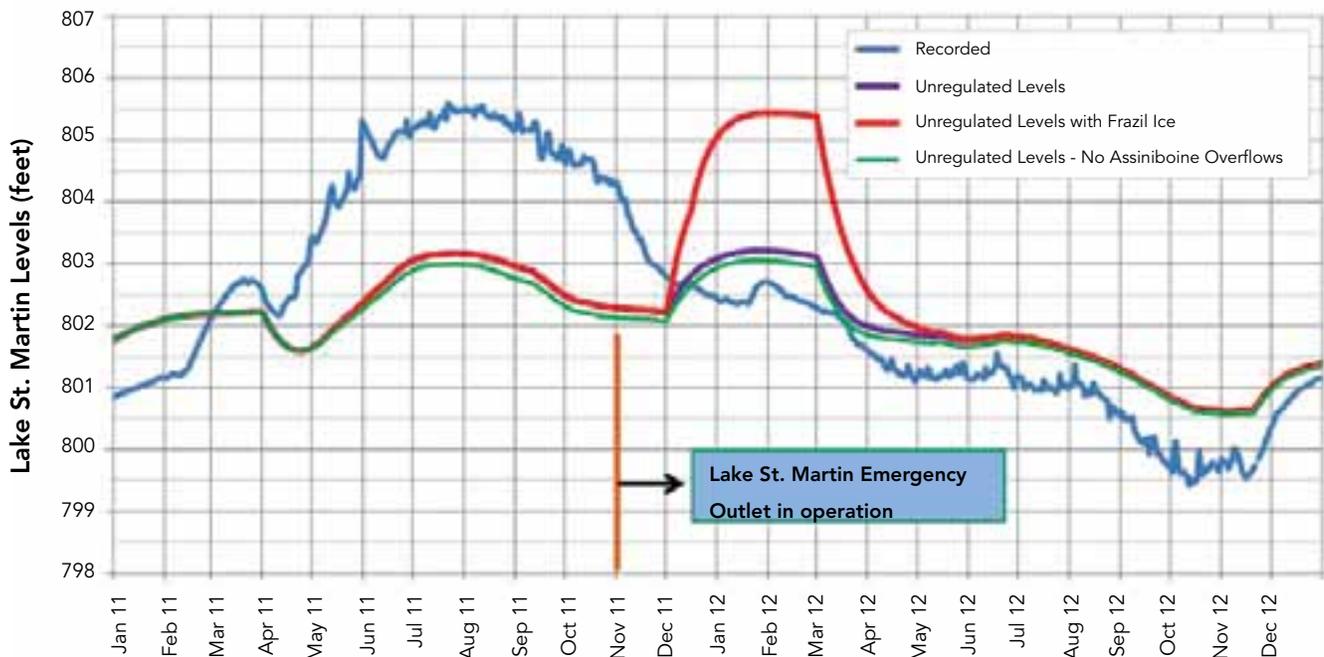


Figure 5: Hydrograph showing recorded, and unregulated Lake St. Martin Levels, with and without overflows from the Assiniboine River.

It is noteworthy that from January until late February 2011, prior to spring runoff, the recorded Lake St. Martin water level was approximately one foot below the unregulated water level, although this benefit was quickly negated when the flows through Fairford River Water Control Structure were increased. The operation of the Fairford River Water Control Structure, which lowers water levels on Lake Manitoba during high water periods, serves to artificially increase inflows and causes artificially high water levels on Lake St. Martin. The Portage Diversion, by increasing inflows to Lake Manitoba, also artificially adds to the total volume of water that flows through Lake St. Martin. As a result of the operation of these two structures, the water levels on Lake St. Martin were artificially

high from early March until early December, 2011. Lake St. Martin reached a maximum level of 805.60 feet versus an unregulated peak level of 803.17 feet, meaning that water levels on Lake St. Martin were artificially high by up to 2.4 feet.

The Lake St. Martin Emergency Channel helped to significantly reduce water levels on Lake St. Martin much faster than they would have dropped under unregulated conditions. This is illustrated by the steeper decline in recorded lake levels beginning on November 1, 2011, the date that the emergency channel began operation. As a result of operation of the Lake St. Martin Emergency Channel, the recorded water level on Lake St. Martin dropped below the unregulated water level in mid-December 2011.