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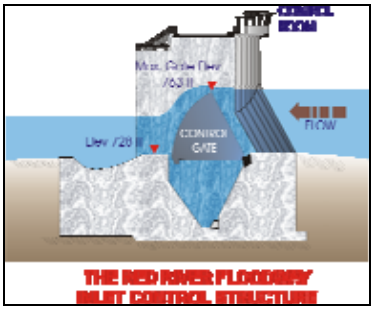
RED RIVER FLOODWAY OPERATION REPORT

SPRING 2009



Manitoba Water Stewardship

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RED RIVER FLOODWAY OPERATION REPORT

SPRING 2009

Ecological Services Division
Manitoba Water Stewardship

Printed on Recycled Paper

Manitoba

EXECUTIVE SUMMARY

The Red River spring flood of 2009 was the second highest in much of the Manitoba portion of the Red River basin since the start of official records in 1912. Only the flood of 1997 and the historical floods of 1776, 1826 and 1852 were greater.

Operation of the Red River Floodway in the spring of 2009, in concert with operation of the Portage Diversion and Shellmouth Reservoir, reduced the flood crest in the City of Winnipeg by 10 feet and is estimated to have prevented flood damages in the order of $10 billion.

During the spring of 2009, the Red River Floodway was operated for about 1100 hours over 47 days beginning at 1:15 PM on April 8 through to 6:00 PM on May 24. During this period of operation, 60 discrete gate adjustments were made as required at various times throughout any 24 hour period. In the spring of 2009, 2.67 million acre-feet of water was diverted around the City of Winnipeg with a peak flow of 43,600 cfs.

Between its completion in 1968 through to 2009, the Red River Floodway has been operated to prevent spring flooding in 27 out of the past 40 years. In 2009, conditions were unprecedented. In order to prevent imminent flooding in Winnipeg, operation of the floodway began with ice cover in place both at the inlet control structure and within the City of Winnipeg. This year's strong ice-cover was unique and had not been encountered previously. Typically, ice at the Floodway inlet begins to move freely when flows reach 35,000 to 40,000 cubic feet per second but in the spring of 2009, ice did not begin to move until flows were approximately 70,000 cubic feet per second or greater.

Despite the challenges of operating with ice cover on the river, which added an element of complexity and uncertainty to the real-time decisions on gate adjustments, this spring's operation of the Floodway was successful in protecting the City of Winnipeg while minimizing upstream impacts.

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INTRODUCTION

On April 20, 2005, *The Red River Floodway Act* was proclaimed in force. Clause 11(1) of this Act states that:

> "*On or before June 30 of any year in which the government operates the floodway during spring flooding to regulate the river level, the director must provide the minister with a report about the operation containing the information the minister requires.*"

The following report details operation of the Red River Floodway in the spring runoff period of 2009 as required by clause 11(1) of *The Red River Floodway Act*.

Within this report, all flows and levels are shown in imperial units. Flows can be converted from cubic feet per second (cfs) to cubic metres per second (m^3/s) by dividing by 35.3148. River levels can be converted from feet to metres by dividing by a factor of 3.28084. Water Survey of Canada is acknowledged for providing the provisional flows used in the report.

2009 SPRING FLOOD

The Red River spring flood of 2009 was the second highest in much of the Manitoba portion of the basin since the start of official records in 1912. Only the flood of 1997 and the historical floods of 1776, 1826 and 1852 were greater. The crest at Morris exceeded 1950 and 1979 crests by about half a foot but was 1.4 feet lower than that of 1997. The crest at the floodway inlet was 766.75 feet, 4.75 feet lower than 1997. The crest of 22.5 feet at James Avenue in the City of Winnipeg on April 16 was only two feet lower than that of 1997 and the second highest observed crest since operation of flood control works began in 1969.

The large runoff and high peak flows resulted from record-high soil moisture levels at freeze-up in 2008 followed by an above average snowpack in the United States portion of the basin and near normal spring precipitation. Soil moisture was also high in the Manitoba portion of the basin, but the snowpack in Manitoba was close to average. An early melt from March 20 to March 23 reduced most of the snow in the United States portion of the basin but was followed by two weeks of sub-zero temperatures which delayed runoff in the Manitoba portion. River ice was generally of average thickness but was unusually strong. The two week cold period from late March to early April kept river ice from deteriorating prior to spring runoff.

THE RED RIVER FLOODWAY

Following the historic flood of 1950 in the City of Winnipeg, work began on the design and construction of a series of flood control measures including Shellmouth Reservoir, Portage Diversion, and the Red River Floodway to protect the City from significant flood events. All were intended to be operated in concert to reduce flood flows and thus, minimize flood damages in the City of Winnipeg.

Operation of the floodway is guided by a set of rules (Appendix A) intended to provide balanced flood protection to the City of Winnipeg without artificially affecting properties south

or upstream of the inlet. Rule 1 requires that natural levels not be exceeded upstream of the floodway inlet structure as long as water levels within the City of Winnipeg are less than 24.5 James Avenue. The natural water level on the Red River at the Floodway entrance is defined as the water level that would have occurred at this location in the late 1950s if Shellmouth Reservoir, Portage Diversion, Assiniboine River dikes, and the Red River Floodway were not in place.

During the 2009 spring floodway operation, the natural water levels upstream of the inlet were calculated using the relationship developed by Acres Manitoba Limited in 2004 [*"Re-Computation of Natural Water Levels at the Floodway Inlet (Final Report)", April 2004*]. This relationship requires two input values: the natural flow in the Red River downstream of the Assiniboine River (at James Avenue) and the natural flow of the Assiniboine River into the Red River. These data along with the natural and actual water levels on the Red River at the floodway inlet are shown for the 2009 spring flood in Appendix B, Table 2. Real-time water level and flow data to guide the operations are obtained at a number of sites including the Red River at James Avenue or Chief Peguis Bridge, above and below the Inlet Control Structure, floodway channel, Assiniboine River at Headingley, Portage Diversion, Sturgeon Creek, and La Salle River along with estimates of un-gauged flow from small streams or overland runoff in the Winnipeg area.

OPERATION OF THE FLOODWAY IN SPRING 2009

Because water levels had reached a critical stage and flooding was imminent in the spring of 2009, a decision was made to begin a limited operation of the floodway while ice was still in place both at the inlet structure and within the City of Winnipeg - an unprecedented situation.

Consequently, the floodway was operated in the spring of 2009 under three distinct regimes, the first two of which presented significant operational challenges, many of which had not been previously experienced. Operation under the three regimes is briefly described below.

(1) Operation of the Red River Floodway Under Ice Cover

Since floodway operations began in 1969, ice has always moved before levels at James Avenue in Winnipeg exceeded 18.5 feet and at flow rates of around 35,000 to 40,000 cfs at the Floodway inlet. However, in 2009, ice did not move until the level at James Avenue had reached 20 feet on April 11 and at a flow rate of 70,000 cfs or greater at the Floodway inlet.

The floodway was first operated on April 8, 2009 beginning at 1:15 PM while ice cover remained on the Red River at the inlet and within the City of Winnipeg. This was an unprecedented procedure not previously experienced in the past 27 times over 40 years in which spring operation has occurred.

Operation with ice in place posed a risk of river ice being directed into the floodway channel and forming an ice jam in the channel. Ten tracked excavators with extended reach were used to facilitate ice movement in the area between the St. Mary's Road bridge and the floodway inlet. This action prevented serious ice jams from occurring. Ice began to move freely through the St. Mary's Road bridge during the early morning of April 10.

Operation of the floodway gates within the Rules of Operation is reliant upon accurate data. During normal open water periods, real-time water flow data are based on water level data obtained electronically from automatic gauging stations and verified with direct measurement by hydrometric technicians. However, when ice is in place, uncertainty associated with the data is greater than during open water.

The computation of natural water levels at the inlet control structure requires knowing the natural flow at James Avenue. Under open water conditions, the actual flow is estimated from the discharge rating curve for the Red River at James Avenue (Water Survey of Canada station 05OC015) during stable flow conditions. Under unstable ice conditions during the spring freshet, the actual flow is modelled to subtract the effects of the ice in the river system since it is too dangerous for hydrometric technicians to make direct flow measurements. When using models, the uncertainty is greater than when using real-time data that can be verified with direct measurement. The dam-like effect of ice jamming at various locations through the City caused an unusual steep river slope which added to the uncertainty in computing natural river levels at the floodway inlet.

(2) Operation of the Red River Floodway During Transition from Ice Cover to Open Water

Ice upstream of the floodway inlet did not begin moving freely until April 10, several days after levels in the City had exceeded flood stage. While Red River ice moved out of the City on April 11, river flows and levels in the City area were in a state of rapid change until April 13, causing difficulty in computing natural flows and levels. The additional water which had built up behind the ice jams in the City was released, causing a surge in flows at James Avenue, resulting in unpredictable flows from the morning of April 11 to the morning of April 12. This made it difficult to estimate flows at James Avenue at any given time or to forecast what the flows would be during the next 12 hours or so. Floodway operations to prevent natural levels from being exceeded at the floodway inlet caused a second surge of water through the City on April 12. Following any gate change, it takes the system between 6 and 12 hours to stabilize before the actual effect can be accurately estimated at James Avenue. With James Avenue flows and levels being in a rapid state of change, it was exceedingly difficult to determine the effect of gate changes and to compute natural river levels at the floodway inlet under these unprecedented conditions.

Despite these significant challenges during this transition period, the floodway was operated within the rules based upon real-time data provided by Water Survey of Canada and the use of modelling to estimate natural levels. However, subsequent to the conclusion of operations, Water Survey of Canada issued adjusted data. Natural levels were recalculated using the updated provisional data and it was found that natural levels had been briefly exceeded on April 13 during this transition period in which it was not possible to accurately estimate natural water levels. This brief exceedance of natural levels during the transition period would not have affected upstream properties since natural levels had been over two feet higher immediately before. Immediately after, actual levels continued to climb quickly well beyond those observed on the 13th and such levels persisted for several weeks during which time, no exceedance beyond natural occurred.

(3) Operation of the Red River Floodway During Open Water

Operation of the floodway during open water in 2009 followed normal protocol and was consistent with experience in past spring floods. A rain storm on May 13 produced a total of 40 to 60 mm of rain over Winnipeg, presenting a potential additional challenge and requiring additional gate changes. Fortunately, the event was spread over 15 hours and did not exceed the capacity of the pumping stations which protect the City.

The Red River at James Avenue reached its crest under open water at 22.5 feet on April 16, about 2 feet less than the crest in 1997, when an ice run on the Assiniboine River coincided with crests on local streams in the Winnipeg area and with high flows on the Red River at St. Norbert. The peak recorded level at the floodway entrance (Water Survey of Canada station 05OC026) was 766.75 feet at 10:00 AM on April 18 during open water operation and which was 0.4 feet lower than the computed natural peak level of 767.13 feet.

During operation in all three regimes, the floodway gates were adjusted in small increments to follow the natural rise in water levels. This was done to avoid large gate raises that may have caused sudden changes in water levels above and below the floodway control structure. Table 1 lists the gate operations that occurred during operation of the floodway in the spring of 2009. The average gate adjustment was 1.15 feet during the period of time that floodway flows were affected by gate operation.

Red River levels in Winnipeg at James Avenue during the period of operation are shown on Figure 1 and the recorded and natural levels at the floodway entrance are plotted in Figure 2 (from Appendix B, Table B-1).

Overall, in the spring of 2009, 2.67 million acre-feet of water was diverted around the City of Winnipeg with a peak flow of 43,600 cfs. The recorded river level at the floodway entrance was maintained below the computed natural level an average of 0.84 feet throughout the 47 days of floodway operation and up to 4 feet below natural at times.

CONCLUSIONS

It can be concluded that:

- During the spring of 2009, the Red River Floodway was operated for about 1100 hours over 47 days and, in combination with other related flood control measures such as operation of the Portage Diversion and storage of flood waters in Shellmouth Reservoir, reduced the flood crest in the City of Winnipeg by 10 feet, saving damages in the order of $10 billion;
- The Red River spring flood of 2009 was the second highest in much of the Manitoba portion of the basin since the start of official records in 1912, surpassed only by the flood of 1997 and the historical floods of 1776, 1826 and 1852;
- Operation of the Red River Floodway began at 1:15 PM on April 8, 2009, concluded at 6:00 PM on May 24, 2009 and during this period, 60 discrete gate adjustments were made as required at various times throughout any 24 hour period;
- Operation of the floodway in the spring of 2009 was unprecedented and began while ice cover was in place both at the inlet structure and within the City of Winnipeg, a situation not

previously experienced in the past 27 times over 40 years in which spring operation has occurred;

- Throughout its operation in the spring of 2009, recorded water levels upstream of the inlet were, on average, 0.84 feet less than natural;
- The crest at the floodway inlet was 766.75 feet, 4.75 feet lower than 1997 and the crest of 22.5 feet at James Avenue in the City of Winnipeg on April 16 was only two feet lower than that of 1997, and the second highest observed since operation of flood control works began in 1969;
- During spring 2009, 2.67 million acre-feet of water was diverted around the City of Winnipeg with a peak flow of 43,600 cfs.

Table 1 –2009 Floodway Gate Operations

Date	Time*	Start of Operation	End of Operation	Date	Time*	Start of Operation	End of Operation
April 8, 2009	1:15 PM	728.00	737.28	May 3, 2009	2:20 PM	748.89	748.53
April 9, 2009	8:15 AM	737.28	740.14	May 3, 2009	7:30 PM	748.53	748.08
April 9, 2009	12:30 PM	740.14	747.99	May 7, 2009	7:00 PM	748.08	747.72
April 10, 2009	3:40 AM	747.99	749.42	May 9, 2009	7:20 PM	747.72	747.45
April 10, 2009	8:30 PM	749.42	753.46	May 10, 2009	10:30 AM	747.45	747.09
April 11, 2009	5:40 PM	753.46	750.20	May 10, 2009	7:15 PM	747.09	746.08
April 12, 2009	1:15 AM	750.20	744.41	May 11, 2009	7:45 PM	746.08	746.36
April 12, 2009	10:05 AM	744.41	746.54	May 12, 2009	1:05 PM	746.36	746.18
April 12, 2009	12:00 PM	746.54	749.94	May 12, 2009	7:55 PM	746.18	745.53
April 12, 2009	2:30 PM	749.94	751.48	May 13, 2009	3:15 AM	745.53	744.50
April 12, 2009	6:00 PM	751.48	752.07	May 13, 2009	12:30 PM	744.50	744.78
April 13, 2009	4:45 AM	752.07	750.63	May 13, 2009	8:25 PM	744.78	745.90
April 13, 2009	4:20 PM	750.63	749.15	May 14, 2009	11:15 AM	745.90	745.44
April 14, 2009	4:05 AM	749.15	750.81	May 14, 2009	7:55 PM	745.44	744.88
April 14, 2009	7:50 PM	750.81	750.55	May 16, 2009	11:00 AM	744.88	744.22
April 15, 2009	7:00 PM	750.55	750.38	May 16, 2009	7:40 PM	744.22	743.47
April 16, 2009	11:05 AM	750.38	751.31	May 17, 2009	7:45 PM	743.47	743.00
April 16, 2009	6:50 PM	751.31	752.40	May 18, 2009	11:10 AM	743.00	742.15
April 17, 2009	11:30 PM	752.40	752.15	May 18, 2009	7:40 PM	742.15	741.00
April 18, 2009	11:30 AM	752.15	751.65	May 20, 2009	11:00 AM	741.00	740.43
April 18, 2009	9:45 PM	751.65	751.14	May 20, 2009	9:00 PM	740.43	739.86
April 21, 2009	8:05 PM	751.14	750.89	May 21, 2009	1:30 PM	739.86	739.38
April 25, 2009	1:45 PM	750.89	750.72	May 21, 2009	8:45 PM	739.38	738.81
April 25, 2009	7:15 PM	750.72	750.38	May 22, 2009	12:50 PM	738.81	738.43
April 26, 2009	2:45 PM	750.38	750.12	May 22, 2009	9:10 PM	738.43	737.66
April 26, 2009	8:45 PM	750.12	749.86	May 23, 2009	10:50 AM	737.66	736.71
April 29, 2009	5:45 PM	749.86	749.68	May 23, 2009	7:00 PM	736.71	735.20
May 1, 2009	5:45 PM	749.68	749.42	May 24, 2009	10:10 AM	735.20	733.99
May 2, 2009	11:00 AM	749.42	749.24	May 24, 2009	5:00 PM	733.99	731.00
May 2, 2009	6:50 PM	749.24	748.89	May 24, 2009	6:00 PM	731.00	728.00
* Time of start of gate operation							

Figure 1 – Recorded River Levels at James Avenue 2009

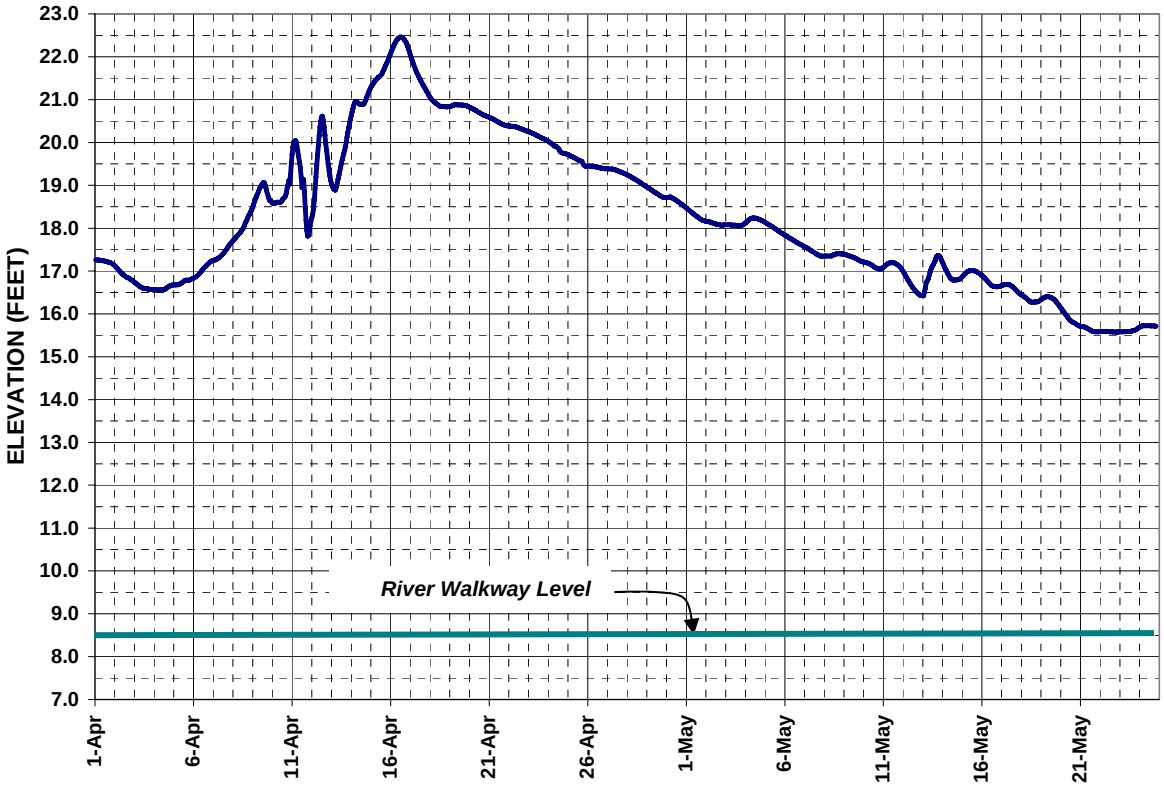
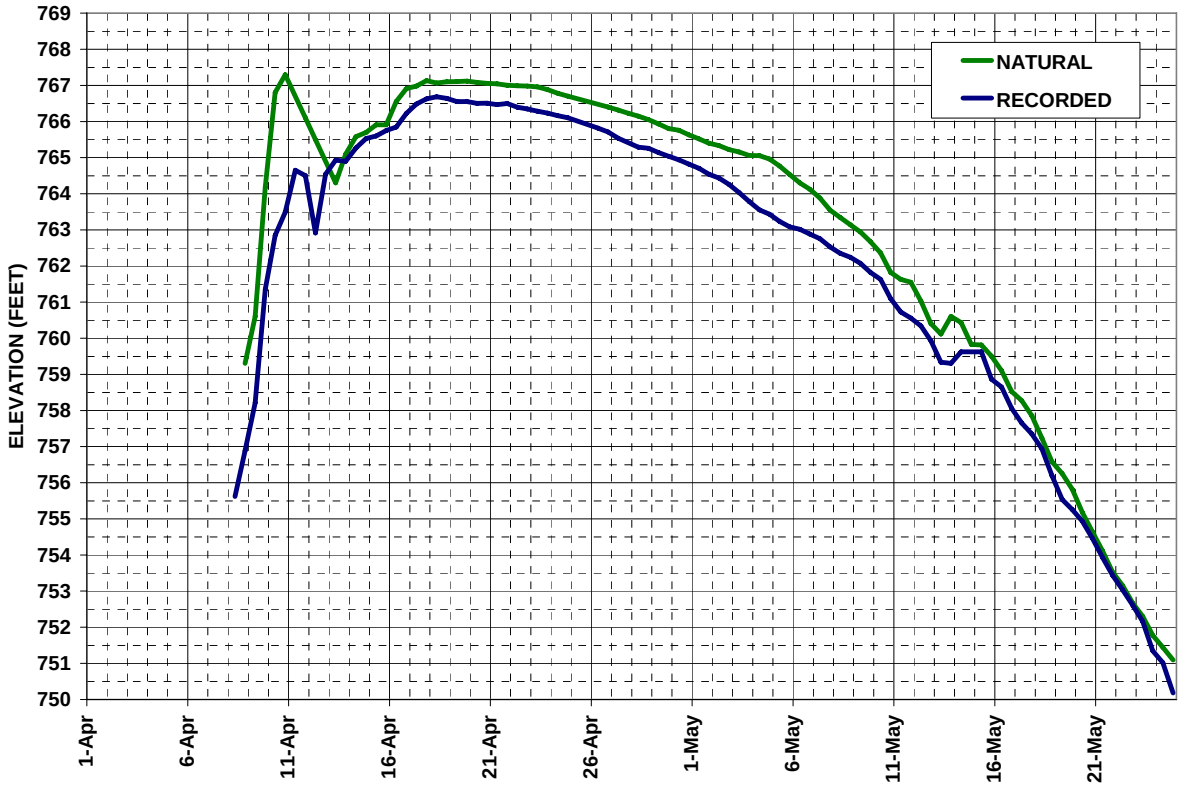


Figure 2 – Recorded and Natural Levels at Floodway Entrance 2009



APPENDIX A

Red River Floodway Rules of Operation

Rules of Operation
Red River Floodway Control Structure

Normal Operation:
1. Maintain natural[1] water levels on the Red River at the entrance to the floodway channel, until the water surface elevation at James Avenue reaches 24.5 feet (7.46 metres), or the river level anywhere along the Red River within the City of Winnipeg reaches two feet below the Flood Protection Level of 27.83 feet (8.48 m).

Major Flood Operation:
2. Once the river levels within Winnipeg reach the limits described in Rule 1, the level in Winnipeg should be held constant while levels south of the control structure continue to rise. Furthermore if forecasts indicate that levels at the entrance to the floodway channel will rise more than two feet (0.6 metres) above natural, the City of Winnipeg must proceed with emergency raising of the dikes and temporary protection measures on the sewer systems in accordance with the flood level forecasts within Winnipeg. The levels in Winnipeg should be permitted to rise as construction proceeds, but not so as to encroach on the freeboard of the dikes or compromise the emergency measures undertaken for protecting the sewer systems. At the same time the Province should consider the possibility of an emergency increase in the height of the floodway embankments and the West Dike. At no time will the water level at the floodway channel's entrance be allowed to rise to a level that infringes on the allowable freeboard on the floodway west embankment (Winnipeg side) and the West Dike.

Extreme Flood Operation:
3. For extreme floods, where the water level at the floodway channel's entrance reaches the maximum level that can be held by the floodway west embankment and the West Dike, the river level must not be permitted to exceed that level. All additional flows must be passed through Winnipeg.

Initial Gate Operation with Ice:
The floodway gates should not be operated until ice on the river is flowing freely, unless flooding in Winnipeg is imminent.

Final drop of Gates:
To minimize bank slumping along the river in Winnipeg and at the same time reduce the probability of sewer backup problems, final gate operations, once the level at the entrance to the floodway channel recedes to elevation 752 feet (229 metres), shall be carried out in consultation with the City of Winnipeg.

Operation of Horn:
The horn at the floodway structure shall only be operated once, before the first gate operation of the year. The horn should be sounded a half-hour before the first gate operation to alert residents that the floodway structure is being put into operation. For ongoing information a 1-800 number should be established that would provide current information of gate operations, potential impacts on water levels, and forecasts for the next few days. The information should also be included on the existing Water Stewardship internet site.

[1] The term natural refers to the level that would have occurred in the absence of the flood control works, with the level of urban development in place at the time of the construction of these works.

Emergency Operation to Reduce Sewer Backup in Winnipeg

4(1) This rule defines the circumstances under which the Minister of Water Stewardship ("the Minister") may determine that emergency operation of the floodway is necessary to prevent widespread basement flooding and resulting risk to health and damage to property within the City of Winnipeg.

4(2) This rule applies after the spring crest from snowmelt runoff at Winnipeg, whenever high river levels substantially impair the capacity of Winnipeg's combined sewer system.

4(3) As long as the Department of Water Stewardship ("the Department") forecasts that river levels for the next 10 days will be below 14 feet James Avenue Pumping Station Datum (JAPSD), the Department will not operate the floodway control structure.

4(4) When the Department forecasts that river levels for the next 10 days are expected to rise to 14 feet JAPSD or higher, the Department will prepare a report that describes:

(a) The basis of the Department's river level forecasts and its risk assessment;

(b) The risk of basement flooding in Winnipeg, including the following factors:

(i) The predicted peak river level in the next 10 days;

(ii) The length of time the Department forecasts the river level will be at 14 feet JAPSD or higher;

(iii) The risk of an intense rainfall event in Winnipeg in the next 10 days;

(c) The benefits and costs of floodway operation, including:

(i) The extent of basement flooding and damage to property expected from various combinations of intense rainfall events and high river levels;

(ii) The risk to the health of Winnipeg residents from sewer back-up;

(iii) Economic loss and damage caused by artificial flooding south of the inlet control structure;

(iv) Impacts of operation on fish and wildlife and their habitat and on water quality;

(v) The risks and potential costs of riverbank instability that may be caused by artificial river level changes, both upstream and downstream of the inlet control structure;

(vi) During construction of the floodway expansion, costs and risks associated with any resulting delays of that construction, including the potential average annual expected damages associated with an additional period of risk of a flood event that would exceed the current capacity of the floodway;

(vii) Such other benefits and costs of operation of which the Department is aware at the time of the preparation of the report, excluding benefits associated with recreational or tourism activities or facilities; and

(d) measures that may be taken to mitigate the costs and impacts of the operation under consideration, including:

(i) minimizing the rate at which river levels are changed both upstream and downstream of the floodway inlet control structure;
(ii) providing means to assure fish passage.

4(5) The Department will present a draft of the report prepared under rule 4(4) to the Floodway Operation Review Committee and provide an opportunity for the Committee to provide input, before finalizing the report and making recommendations respecting floodway operation.

4(6) The Department will not recommend operation of the floodway unless the expected benefits of doing so clearly and substantially outweigh the expected costs.

4(7) The Department will present its report and recommendations to the Minister, who, subject to rule 4(8), will make a decision respecting floodway operation based on his or her consideration of the report.

4(8) The Department will not operate the floodway control structure under this rule:

(a) to raise river levels immediately upstream of the control structure to an elevation higher than 760 feet above sea level;

(b) to achieve a river level of less than 9 feet JAPSD; or

(c) except in circumstances of extreme urgency, to lower river levels more than one foot per day.

4(9) The Department will issue a news release announcing a decision to operate the floodway at least 24 hours before commencing operation.

4(10) The Department will ensure every reasonable effort is made to personally notify landowners who may be directly affected by flooding due to floodway operation in advance of the operation.

4(11) The Department will sound the horn at the floodway inlet control structure one-half hour before operation commences.

4(12) The Department will maintain a program of compensation for damages suffered by landowners arising from flooding caused by floodway operation under this rule.

APPENDIX B

Computation of Natural Flows and Levels

Computation of Natural Flows and Levels
On the Red and Assiniboine Rivers

Table 2 in the main report lists the natural flows on the Red River below the confluence with the Assiniboine River and on the Assiniboine River at the Forks. This Appendix describes how those flows were determined, and explains how the relationships developed in the Acres 2004 study were applied to compute the natural level at the floodway entrance.

Table B-1 lists the recorded and computed flows and levels for each time step. Columns 1 to 7 list the flows used in computing the natural flows on the Assiniboine River, and columns 8 to 10 list the flows used for computing the natural flows on the Red River.

NATURAL ASSINIBOINE RIVER FLOW

The natural flows on the Assiniboine River are altered by operation of the Shellmouth Dam, the Portage Diversion, and by the presence of dykes along the Assiniboine River.

The Shellmouth Dam can decrease flows below natural by adjusting the control gates so that reservoir outflows are lower than the inflows. In this case the reservoir levels rise, and excess water is stored behind the dam.

The Portage Diversion can be used to reduce flows in the lower Assiniboine River by diverting some of the river flow north to Lake Manitoba.

The Assiniboine River dykes were constructed to prevent overflows from the river onto the surrounding lands. Because of the height of the river and the slope of the land much of this overflow did not return to the Assiniboine River. Therefore the dykes have the effect of increasing flows entering Winnipeg on the Assiniboine River during periods of high flow.

Referring to Table B-1, column 1 lists the flow reductions at Winnipeg resulting from storage behind the Shellmouth Dam. It is important to recognize that these flow changes at the dam take some time to reach Winnipeg. The Department uses the Muskingum routing procedure to compute this flow attenuation.

Column 2 shows the flows diverted to Lake Manitoba via the Portage Diversion. Again the flows are routed to Winnipeg to apply the time delay.

Column 3 shows the recorded flows at the hydrometric station at Headingley. These first three columns are summed to determine the total natural flow before applying the natural breakouts that would have occurred if the dykes were not in place.

Column 4 lists the computed breakouts that would have occurred at those flows if the dykes had not been constructed.

Column 5 lists the computed natural flows at Headingley. These are computed by adding the three adjustments to the recorded flows at Headingley.

There is some additional local inflow entering the Assiniboine River between Headingley and the Forks. Most of this flow is recorded on Sturgeon Creek. In column 6 the recorded flows on Sturgeon Creek are increased to include unmeasured local inflows.

Finally columns 5 and 6 are added together to give the computed natural flows of the Assiniboine River at the Forks, as listed in column 7.

NATURAL RED RIVER FLOW

On the Red River the primary flow adjustment is caused by the Red River Floodway. During periods of extensive flooding there can also be a flow change resulting from changes in the storage of floodwaters on the land, but as long as flood levels at the floodway entrance are held at natural that change would be negligible.

Column 8 lists the recorded flows in the floodway channel, and column 9 shows the recorded flows at James Avenue. Column 10 sums the flows in those two columns and adds the three flow adjustments on the Assiniboine River to give the total natural flow on the Red River at James Avenue, which is downstream of the Forks.

NATURAL RIVER LEVELS AT THE FLOODWAY INLET

Table B-2 is a reproduction of Table 4-7 from the Acres report "*Re-Computation of Natural Water Levels at the Floodway Inlet (Final Report), April 2004*". The table provides natural elevations at the inlet based upon the relative contribution of natural flow at the Forks from the Red and Assiniboine Rivers. The *combined* flow is represented by the values in the left-hand column entitled Red River at James Avenue. The Assiniboine River Contribution amount is shown across the top and is the flow in the Assiniboine River at the Forks.

The natural water level at the inlet can vary by a few feet dependent upon the amount of flow coming from the Assiniboine River (Assiniboine River Contribution). This phenomenon is referred to as a variable backwater effect.

This concept can be illustrated by using the example of 100,000 cfs flow for the Red River at James Avenue in various combinations of Red and Assiniboine River flows. One combination could have 95,000 cfs as Red River flow upstream of the Forks and 5,000 cfs as Assiniboine River Contribution; this combination results in a level at the inlet of 765.6 feet as shown in Table B-2. Similarly, another combination, while still yielding a total James Avenue flow of 100,000 cfs, could be 70,000 cfs as Red River flow upstream of the Forks and 30,000 cfs as Assiniboine River Contribution; the resulting inlet level would be 762.9 feet. The difference in the inlet water elevation between these two flow combinations is 2.7 feet, with the lower elevation occurring when there is relatively more flow on the Assiniboine River.

Natural levels are determined by using the natural Red River flows at James Avenue listed in column 10 of Table B-1, and the natural Assiniboine River flows listed in column 7 of Table B-1 and interpolating between the values listed in Table B-2 to determine the natural levels. These natural levels are listed in column 11 of Table B-1. For comparison, column 12 of Table B-1 lists the recorded levels at the floodway inlet (station 05OC026).

Table B-1 Spring 2009 Flows and Levels

Column =>	1	2	3	4	5	6	7	8	9	10	11	12
			Assiniboine Flows					**Red River Flows**				
	Shellmouth Flow Changes (Routed to Headingley)	Portage Diversion flow (Routed to Headingley)	Actual Assiniboine R. flow at Headingley	Natural breakouts from river	Natural Assiniboine River flow at Headingley	Sturgeon Cr. Flow plus other local inflows	**Natural Assiniboine R. flow into Red River**	Red River Floodway flow	Red River flow at James Ave.	**Natural Red River flow at James Avenue**	Natural water level on Red R. at Floodway Inlet (feet)	Recorded Water level on Red R. at Floodway Inlet (feet)
Date / Time	*Recorded*	*Recorded*	*Recorded*	*Computed*	*=1+2+3-4*	*Rec. & Est.*	***=5+6***	*Recorded*	*Recorded*	***=1+2-4+8+9***	*Computed*	*Recorded*
08-Apr-2009 8:00 AM	-400	1,941	2,727	0	4,268	228	**4,496**	6,260	41,060	**48,862**	757.98	755.62
08-Apr-2009 8:00 PM	-400	2,180	2,502	0	4,283	296	**4,579**	6,354	41,474	**49,608**	759.30	756.89
09-Apr-2009 8:00 AM	-396	1,988	2,330	0	3,922	268	**4,190**	6,354	42,179	**50,125**	760.60	758.21
09-Apr-2009 8:00 PM	-350	2,897	2,351	0	4,899	344	**5,243**	16,684	42,963	**62,194**	764.17	761.35
10-Apr-2009 8:00 AM	-350	2,749	2,452	0	4,851	463	**5,314**	25,609	43,318	**71,327**	766.80	762.85
10-Apr-2009 8:00 PM	-325	3,306	2,608	0	5,589	644	**6,232**	28,967	41,665	**73,613**	767.30	763.49
11-Apr-2009 8:00 AM	-300	3,405	2,821	0	5,927	706	**6,633**	33,669	46,614	**83,389**	766.70	764.66
11-Apr-2009 8:00 PM	-275	3,401	3,205	0	6,331	985	**7,316**	33,422	43,275	**79,823**	766.10	764.50
12-Apr-2009 8:00 AM	-250	3,224	3,904	0	6,878	1,289	**8,167**	27,483	55,430	**85,887**	765.50	762.91
12-Apr-2009 8:00 PM	-210	3,648	4,543	0	7,982	1,428	**9,410**	33,204	55,113	**91,756**	764.90	764.54
13-Apr-2009 8:00 AM	-190	3,460	5,832	0	9,102	1,930	**11,032**	34,710	57,798	**95,778**	764.30	764.93
13-Apr-2009 8:00 PM	-155	4,453	6,538	0	10,836	2,252	**13,088**	34,676	62,041	**101,016**	765.10	764.90
14-Apr-2009 8:00 AM	-120	3,955	7,277	0	11,112	2,270	**13,382**	36,160	65,806	**105,801**	765.58	765.27
14-Apr-2009 8:00 PM	-70	4,249	7,877	0	12,056	2,729	**14,785**	37,556	66,248	**107,983**	765.70	765.53
15-Apr-2009 8:00 AM	-50	4,494	8,509	0	12,952	3,016	**15,969**	38,323	67,914	**110,681**	765.91	765.60
15-Apr-2009 8:00 PM	-50	4,600	11,512	136	15,927	3,124	**19,050**	38,799	69,358	**112,571**	765.91	765.75
16-Apr-2009 8:00 AM	0	14,100	12,531	3772	22,860	3,153	**26,012**	39,120	71,888	**121,336**	766.56	765.85
16-Apr-2009 8:00 PM	10	16,750	11,139	4276	23,623	3,108	**26,731**	41,000	71,674	**125,158**	766.91	766.22
17-Apr-2009 8:00 AM	76	19,899	9,353	4607	24,720	3,066	**27,786**	42,289	68,675	**126,332**	766.98	766.49
17-Apr-2009 8:00 PM	138	22,088	6,779	4531	24,474	3,051	**27,525**	42,993	66,891	**127,579**	767.13	766.63
18-Apr-2009 8:00 AM	201	19,299	5,132	2911	21,720	2,988	**24,709**	43,316	65,629	**125,534**	767.07	766.69
18-Apr-2009 8:00 PM	223	19,014	4,052	2324	20,965	2,819	**23,784**	43,241	65,275	**125,429**	767.10	766.64
19-Apr-2009 8:00 AM	247	18,056	3,579	1736	20,146	2,694	**22,841**	42,967	65,452	**124,985**	767.11	766.56
19-Apr-2009 8:00 PM	312	17,373	3,275	1394	19,567	2,490	**22,057**	43,026	65,393	**124,710**	767.12	766.55
20-Apr-2009 8:00 AM	377	16,520	2,929	1018	18,808	2,172	**20,980**	42,962	64,905	**123,746**	767.09	766.50
20-Apr-2009 8:00 PM	464	15,641	2,689	721	18,074	1,907	**19,981**	43,093	64,330	**122,807**	767.05	766.51
21-Apr-2009 8:00 AM	555	15,261	2,484	593	17,707	1,761	**19,468**	43,200	63,872	**122,295**	767.05	766.47
21-Apr-2009 8:00 PM	677	14,849	2,278	474	17,329	1,599	**18,929**	43,014	63,311	**121,377**	767.01	766.50
22-Apr-2009 8:00 AM	798	14,414	2,081	363	16,931	1,357	**18,287**	42,602	63,163	**120,615**	766.99	766.39
22-Apr-2009 8:00 PM	953	14,001	1,859	267	16,547	1,229	**17,775**	42,556	62,794	**120,037**	766.98	766.35

Column =>	1	2	3	4	5	6	7	8	9	10	11	12
			Assiniboine Flows					**Red River Flows**				
	Shellmouth Flow Changes (Routed to Headingley)	Portage Diversion flow (Routed to Headingley)	Actual Assiniboine R. flow at Headingley	Natural breakouts from river	Natural Assiniboine River flow at Headingley	Sturgeon Cr. Flow plus other local inflows	**Natural Assiniboine R. flow into Red River**	Red River Floodway flow	Red River flow at James Ave.	**Natural Red River flow at James Avenue**	Natural water level on Red R. at Floodway Inlet (feet)	Recorded Water level on Red R. at Floodway Inlet (feet)
Date / Time	*Recorded*	*Recorded*	*Recorded*	*Computed*	*=1+2+3-4*	*Rec. & Est.*	***=5+6***	*Recorded*	*Recorded*	***=1+2-4+8+9***	*Computed*	*Recorded*
23-Apr-2009 8:00 AM	1108	13,974	1,614	245	16,450	1,165	**17,616**	42,552	62,381	**119,770**	766.96	766.29
23-Apr-2009 8:00 PM	1295	13,665	1,433	191	16,202	1,021	**17,223**	42,293	61,864	**118,926**	766.88	766.24
24-Apr-2009 8:00 AM	1481	13,671	1,322	205	16,269	898	**17,167**	41,942	61,227	**118,116**	766.78	766.16
24-Apr-2009 8:00 PM	1668	13,596	1,222	207	16,279	788	**17,067**	41,864	60,523	**117,444**	766.70	766.11
26-Apr-2009 8:00 AM	2362	13,209	1,091	239	16,423	507	**16,930**	40,972	59,295	**115,599**	766.47	765.82
26-Apr-2009 8:00 PM	2583	12,858	1,062	210	16,293	438	**16,731**	40,562	59,154	**114,946**	766.40	765.71
27-Apr-2009 8:00 AM	2804	12,851	1,024	242	16,436	423	**16,859**	39,869	59,065	**114,347**	766.32	765.53
27-Apr-2009 8:00 PM	3003	12,220	948	154	16,018	406	**16,423**	39,609	58,732	**113,410**	766.23	765.41
28-Apr-2009 8:00 AM	3202	12,020	915	148	15,989	389	**16,378**	39,421	58,271	**112,767**	766.15	765.29
28-Apr-2009 8:00 PM	3365	11,832	890	140	15,947	372	**16,319**	39,196	57,696	**111,948**	766.05	765.26
29-Apr-2009 8:00 AM	3527	11,256	865	73	15,575	311	**15,886**	39,039	57,029	**110,778**	765.93	765.14
29-Apr-2009 8:00 PM	3645	11,032	851	56	15,472	305	**15,777**	38,714	56,394	**109,729**	765.81	765.04
30-Apr-2009 8:00 AM	3763	10,446	859	0	15,072	296	**15,368**	38,481	56,307	**109,002**	765.76	764.94
30-Apr-2009 8:00 PM	3834	10,043	844	0	14,721	290	**15,011**	38,083	55,629	**107,589**	765.63	764.82
01-May-2009 8:00 AM	3905	9,820	827	0	14,552	279	**14,831**	37,896	54,806	**106,427**	765.52	764.70
01-May-2009 8:00 PM	3933	9,634	823	0	14,390	272	**14,662**	37,569	54,041	**105,177**	765.40	764.54
02-May-2009 8:00 AM	3961	9,390	817	0	14,168	235	**14,403**	37,233	53,781	**104,366**	765.33	764.44
02-May-2009 8:00 PM	3952	9,223	821	0	13,996	233	**14,229**	36,490	53,507	**103,172**	765.22	764.26
03-May-2009 8:00 AM	3943	9,390	810	0	14,143	201	**14,344**	35,836	53,521	**102,690**	765.16	764.03
03-May-2009 8:00 PM	3905	9,192	781	0	13,878	194	**14,072**	35,008	53,478	**101,583**	765.06	763.78
04-May-2009 8:00 AM	3867	9,201	779	0	13,847	219	**14,066**	34,226	54,200	**101,494**	765.05	763.55
04-May-2009 8:00 PM	3808	9,201	777	0	13,785	211	**13,997**	33,555	54,012	**100,576**	764.96	763.44
05-May-2009 8:00 AM	3748	9,307	767	0	13,822	196	**14,019**	32,899	53,435	**99,389**	764.76	763.23
05-May-2009 8:00 PM	3674	9,289	724	0	13,687	185	**13,872**	32,444	52,827	**98,234**	764.53	763.08
06-May-2009 8:00 AM	3600	9,320	720	0	13,640	187	**13,827**	31,953	52,305	**97,178**	764.30	763.02
06-May-2009 8:00 PM	3518	9,615	702	0	13,835	184	**14,020**	31,509	51,795	**96,437**	764.12	762.88
07-May-2009 8:00 AM	3436	9,620	702	0	13,758	205	**13,963**	30,974	51,297	**95,328**	763.89	762.76
07-May-2009 8:00 PM	3351	9,119	875	0	13,345	191	**13,536**	30,280	50,812	**93,562**	763.55	762.53
08-May-2009 8:00 AM	3266	9,153	1,063	0	13,482	170	**13,652**	29,451	50,812	**92,681**	763.34	762.35
08-May-2009 8:00 PM	3183	8,382	1,389	0	12,954	162	**13,116**	28,901	50,982	**91,448**	763.14	762.24
09-May-2009 8:00 AM	3100	8,463	1,550	0	13,113	163	**13,276**	28,307	50,775	**90,646**	762.95	762.07
09-May-2009 8:00 PM	3021	8,408	1,554	0	12,983	144	**13,128**	27,576	50,375	**89,380**	762.67	761.82

Column =>	1	2	3	4	5	6	7	8	9	10	11	12
			Assiniboine Flows					**Red River Flows**				
	Shellmouth Flow Changes (Routed to Headingley)	Portage Diversion flow (Routed to Headingley)	Actual Assiniboine R. flow at Headingley	Natural breakouts from river	Natural Assiniboine River flow at Headingley	Sturgeon Cr. Flow plus other local inflows	**Natural Assiniboine R. flow into Red River**	Red River Floodway flow	Red River flow at James Ave.	**Natural Red River flow at James Avenue**	Natural water level on Red R. at Floodway Inlet (feet)	Recorded Water level on Red R. at Floodway Inlet (feet)
Date / Time	*Recorded*	*Recorded*	*Recorded*	*Computed*	*=1+2+3-4*	*Rec. & Est.*	***=5+6***	*Recorded*	*Recorded*	***=1+2-4+8+9***	*Computed*	*Recorded*
10-May-2009 8:00 AM	2942	8,175	1,562	0	12,679	174	**12,853**	26,797	50,083	**87,998**	762.37	761.63
10-May-2009 8:00 PM	2868	8,060	1,556	0	12,484	175	**12,659**	25,087	49,671	**85,685**	761.82	761.10
11-May-2009 8:00 AM	2794	7,948	1,310	0	12,052	157	**12,209**	23,701	50,217	**84,660**	761.63	760.73
11-May-2009 8:00 PM	2722	9,139	919	0	12,780	157	**12,937**	23,003	49,877	**84,741**	761.55	760.56
12-May-2009 8:00 AM	2651	8,746	673	0	12,070	155	**12,226**	22,408	48,412	**82,217**	761.03	760.34
12-May-2009 8:00 PM	2579	8,636	582	0	11,797	155	**11,952**	21,088	47,283	**79,586**	760.41	759.93
13-May-2009 8:00 AM	2507	8,420	593	0	11,520	1,578	**13,097**	19,109	49,107	**79,143**	760.12	759.33
13-May-2009 8:00 PM	2432	8,302	789	0	11,523	1,625	**13,147**	19,441	50,812	**80,987**	760.60	759.31
14-May-2009 8:00 AM	2357	8,195	904	0	11,456	846	**12,302**	20,135	49,173	**79,860**	760.44	759.63
14-May-2009 8:00 PM	2279	6,995	1,411	0	10,684	759	**11,443**	19,341	48,687	**77,302**	759.83	759.63
15-May-2009 8:00 AM	2200	7,720	1,644	0	11,564	638	**12,203**	18,287	49,461	**77,668**	759.82	759.63
15-May-2009 8:00 PM	2120	7,257	1,752	0	11,129	541	**11,670**	17,543	49,370	**76,289**	759.50	758.87
16-May-2009 8:00 AM	2039	7,485	1,788	0	11,312	464	**11,776**	16,887	48,543	**74,954**	759.10	758.65
16-May-2009 8:00 PM	1959	7,380	1,785	0	11,123	393	**11,516**	15,409	48,044	**72,791**	758.53	758.06
17-May-2009 8:00 AM	1880	7,823	1,781	0	11,484	367	**11,851**	14,181	48,228	**72,112**	758.27	757.65
17-May-2009 8:00 PM	1801	7,507	1,730	0	11,038	328	**11,367**	13,452	47,598	**70,359**	757.86	757.35
18-May-2009 8:00 AM	1723	6,895	1,674	0	10,292	280	**10,572**	12,338	46,916	**67,872**	757.24	756.94
18-May-2009 8:00 PM	1647	6,543	1,623	0	9,813	251	**10,063**	10,647	46,614	**65,451**	756.58	756.20
19-May-2009 8:00 AM	1571	6,185	1,564	0	9,320	221	**9,541**	9,240	47,099	**64,095**	756.25	755.54
19-May-2009 8:00 PM	1499	6,180	1,515	0	9,194	206	**9,399**	8,448	46,482	**62,609**	755.82	755.26
20-May-2009 8:00 AM	1427	5,574	1,553	0	8,554	194	**8,748**	7,841	45,249	**60,091**	755.18	754.93
20-May-2009 8:00 PM	1355	5,840	1,588	0	8,783	185	**8,967**	6,870	44,488	**58,553**	754.64	754.46
21-May-2009 8:00 AM	1283	5,460	2,034	0	8,777	184	**8,961**	5,986	44,160	**56,889**	754.11	753.93
21-May-2009 8:00 PM	1214	4,390	2,475	0	8,079	186	**8,265**	5,187	43,832	**54,624**	753.53	753.44
22-May-2009 8:00 AM	1146	4,507	3,028	0	8,681	161	**8,842**	4,320	43,845	**53,818**	753.15	753.03
22-May-2009 8:00 PM	1077	3,511	3,425	0	8,014	160	**8,174**	3,496	43,792	**51,877**	752.67	752.61
23-May-2009 8:00 AM	1010	3,648	3,900	0	8,558	158	**8,716**	2,572	43,845	**51,075**	752.30	752.16
23-May-2009 8:00 PM	946	2,616	4,485	0	8,047	156	**8,203**	1,615	44,042	**49,219**	751.78	751.35
24-May-2009 8:00 AM	889	1,718	5,099	0	7,706	150	**7,855**	1,087	44,396	**48,090**	751.44	751.02
24-May-2009 7:50 PM	832	1,584	5,597	0	8,013	144	**8,157**	545	44,356	**47,317**	751.10	750.18

Table B-2 Red River Floodway Inlet Natural Rating Table

RED RIVER AT JAMES AVENUE (cfs)	ASSINIBOINE RIVER CONTRIBUTION (cfs)										
cfs	0	5,000	10,000	15,000	20,000	25,000	30,000	35,000	40,000	45,000	50,000
20,000	742.1	740.4	738.7	737.4							
30,000	746.6	745.2	743.9	742.6	741.5						
40,000	750.4	749.2	748.0	746.9	745.8	744.9					
50,000	753.8	752.7	751.7	750.7	749.7	748.8	747.9				
60,000	756.8	755.9	754.9	754.0	753.1	752.2	751.4				
70,000	759.7	758.8	758.0	757.1	756.3	755.5	754.7				
80,000	762.4	761.6	760.8	760.1	759.3	758.5	757.8				
90,000		763.9	763.2	762.6	761.9	761.2	760.6	759.9			
100,000		765.6	765.3	764.8	764.1	763.5	762.9	762.3			
110,000		766.7	766.3	765.9	765.5	765.2	764.7	764.2			
120,000		767.6	767.5	767.2	766.8	766.5	766.1	765.7	765.4		
130,000		768.5	768.2	768.0	767.7	767.5	767.3	767.0	766.6		
140,000			768.7	768.7	768.6	768.4	768.1	767.9	767.6	767.4	
150,000			769.1	769.0	768.8	768.7	768.6	768.5	768.5	768.3	
160,000			769.6	769.4	769.2	769.1	768.9	768.8	768.7	768.5	768.5
170,000			770.1	769.9	769.8	769.6	769.5	769.3	769.2	769.0	768.8
180,000			770.5	770.4	770.3	770.2	770.0	769.9	769.7	769.5	769.4
190,000				770.5	770.5	770.5	770.5	770.3	770.2	770.1	769.9
200,000				770.7	770.6	770.6	770.5	770.5	770.5	770.5	770.5
210,000				770.9	770.8	770.7	770.7	770.6	770.6	770.5	770.5
220,000				771.1	771.0	770.9	770.8	770.7	770.7	770.6	770.5
230,000				771.2	771.2	771.1	771.0	770.9	770.8	770.7	770.7
240,000					771.5	771.4	771.3	771.2	771.1	771.0	770.9
250,000					771.8	771.7	771.6	771.6	771.5	771.4	771.3
260,000					772.1	772.0	772.0	771.9	771.8	771.7	771.6
270,000					772.4	772.4	772.3	772.2	772.1	772.1	772.0
280,000					772.8	772.7	772.6	772.5	772.5	772.4	772.3
290,000					773.1	773.0	772.9	772.8	772.8	772.7	772.6
300,000					773.3	773.3	773.2	773.1	773.1	773.0	772.9

Note: Open water conditions under steady state (no ice)