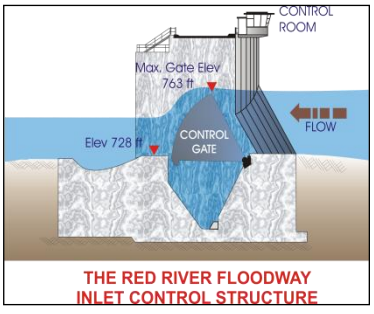
RED RIVER FLOODWAY OPERATION REPORT

SPRING 2017



THE RED RIVER FLOODWAY INLET CONTROL STRUCTURE

Manitoba Infrastructure

Manitoba

RED RIVER FLOODWAY OPERATION REPORT

SPRING 2017

June 29, 2017

Manitoba Infrastructure
Hydrologic Forecasting and Water Management Branch
Water Management and Structures Division

Manitoba

EXECUTIVE SUMMARY

The 2017 Red River spring flood resulted from well above normal winter snow fall in the Red River Valley, combined with above normal soil moisture going into freeze-up in the fall. The February Outlook published by the Manitoba Hydrologic Forecasting Center (HFC) estimated that the peak flow at Emerson could reach the level seen in the 2011 flood under unfavorable conditions, and the 2010 flood under normal conditions. This forecast was later downgraded to 2010 levels for the unfavorable condition, and 2013 levels for the normal condition. The observed 2017 peak flow measured at Emerson was approximately 36,410 cfs.

The 2017 Red River spring run-off event occurred earlier than is typical, and benefited from an unusual melt event in late February that reduced the snow pack in the southern portion of the basin. Ice was in place on the river until March 31, 2017 and delayed operation of the floodway by one day. Red River Floodway gate operations began on March 31 at 10:00 a.m. and the gates were operated for 28 days ending at 3:30 p.m. on April 27. Flow into the floodway ended in the evening of April 20. During this period of operation, 36 discrete gate adjustments were made as required at various times throughout any 24 hour period. In the spring of 2017, 558,700 acre-feet (689.1 million m^3) of water were diverted around the City of Winnipeg with a peak flow of 22,400 cfs (634.3 m^3/s). The Red River Floodway has been operated in 30 of the past 48 years to prevent spring flooding since its first year of operation in 1969.

The Assiniboine River flows in the spring flood of 2017 were quite high, and were calculated to be a 1:35 year flood event at Portage La Prairie. The natural Assiniboine River contribution at James Avenue peaked at 40,350 cfs (1142.6 m^3/s) on April 15. The observed flow along the Assiniboine River at Headingley reached a maximum of 15,360 cfs (434.9 m^3/s) due to operation of the Shellmouth Dam and Portage Diversion.

In spring 2017, operation of the floodway was successful in protecting the City of Winnipeg while minimizing upstream impacts through normal operation under Rule 1 of the Floodway Rules of Operation. Rule 1 requires that natural water levels are maintained on the Red River at the floodway inlet. The natural water level was exceeded briefly on April 11, but this occurred 1 week after the Red River has crested at the floodway inlet, and had no impact on the magnitude or duration of the flood event upstream. On average, operation of the Red River Floodway maintained river levels 0.29 ft (0.09 m) below natural throughout the 28 days of its operation in the spring of 2017. In concert with operation of the Portage Diversion and Shellmouth Reservoir, operation of the floodway reduced the flood crest in the City of Winnipeg by 8.94 feet (2.72 m) at the peak natural flow.

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1.0 INTRODUCTION

On April 20, 2005, The Red River Floodway Act was proclaimed in force. Subsection 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 2017 as required by section 11(1) of The Red River Floodway Act and includes the information specified in section 3(1) of The Red River Floodway Regulation.

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 levels within the City of Winnipeg reference the James Avenue datum, which is based on normal winter ice level in the city. This datum has been the traditional reference for water levels used by the City of Winnipeg, and is the datum used for reference water levels specified in the Red River Floodway Rules of Operation. Geodetic elevations can be converted to the James Avenue datum by subtracting 727.586 ft.

Manitoba Infrastructure (MI) gratefully acknowledges Water Survey Canada (WSC) for providing the provisional and approved flows used in the report.

2.0 2017 SPRING RUNOFF

The 2017 Red River spring flood resulted from well above (150% – 200 %) to extremely above (>200%) normal winter snow fall in the Red River Valley, combined with above (115% - 150%) normal soil moisture going into freeze-up in the fall. The February Outlook published by the Manitoba Hydrologic Forecasting Center (HFC) estimated that the peak flow at Emerson could reach the level seen in the 2011 flood under unfavorable conditions, and the 2010 flood under normal conditions.

The 2017 Red River spring run-off benefited from an unusual melt event that began in late February and lasted approximately two weeks. This greatly reduced the snow pack in the southern portion of the Red River basin where the greatest accumulation of precipitation had occurred. The peak flow at Emerson during this event was approximately 15,150 cfs (429.0 m^3/s). Due, in part, to this early melt event, the HFC revised the flood outlook for the Red River to 2010 levels for the unfavorable condition, 2013 levels for the normal condition, and 2014 for the favourable condition.

The spring melt in the northern portion of the Red River Basin began around March 20, and was very rapid. The observed peak at Emerson for the 2017 spring flood was approximately 36,410 cfs (1031.0 m^3/s), and occurred on April 3. This correlated with the favourable condition

forecast of 35,000 cfs (991.1 m^3/s) observed in 2014. The Red River crested at the floodway inlet on April 4, with a peak flow of approximately 62,300 cfs (1764.1 m^3/s).

Compared to recent flood events such as the 2009 and 2011 flood events, the 2017 natural spring flood was a relatively minor event. The 2009 peak flow measured along the Red River at Emerson was approximately 88,000 cfs (2491.9 m^3/s), and the 2017 peak flow measured at Emerson was approximately 45,000 cfs (1274.3 m^3/s).

3.0 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 (ex: 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 ft (7.47 m) James Avenue or if the water level anywhere along the Red River within the City of Winnipeg reaches two feet below the Flood Protection Level of 27.83 ft (8.48m). 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, Winnipeg dikes and the Red River Floodway were not in place.

During the 2017 spring floodway operation, the natural water levels upstream of the inlet were calculated with 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 2017 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.

4.0 OPERATION OF THE FLOODWAY IN SPRING 2017

4.1 General Observations

Floodway operation began the morning of March 31, subsequent to ice releasing upstream of the inlet control structure and floodway inlet areas during the evening on March 30. Water had begun to spill into the floodway on the 29, prior to operation of the gates, and the river level at James Ave was rising quickly. The presence of ice delayed the operation of the

floodway by approximately one day. The Red River Floodway gates were operated in accordance with normal operating procedures to reduce river levels in the City of Winnipeg. Operation of the floodway during open water in 2017 followed normal protocol and was consistent with experience in past spring floods.

The computation of natural water levels at the inlet control structure requires calculation of the natural flow at James Avenue. Natural flow is determined by adjusting the actual flow for the effects of the flood control works. Under open water conditions, the actual flow is determined from the discharge rating curve for the Red River at James Avenue using Water Survey of Canada levels collected at station 05OC015.

James Avenue water levels increased to a peak of 19.48 ft (227.71 m) under open water conditions on the morning of April 1st, and remained above 19.0 ft (5.8 m) for three days before being lowered in anticipation of high Assiniboine River flows entering the City. The peak natural flow at James Avenue in Winnipeg would have occurred on the evening of April 7th, and was calculated to be approximately 92,000 cfs (2605.1 m^3/s). This peak flow would have resulted in a James Avenue level of 27.34 ft (8.33 m). Operation of the floodway, Portage Diversion and Shellmouth Dam lowered the James Avenue water level during the peak natural flow by 8.98 ft (2.74 m) to 18.36 ft (5.60 m) and prevented millions of dollars of damage.

Overall, in the spring of 2017, approximately 556,400 acre-feet (689.1 million m^3) of water was diverted around the City of Winnipeg with a peak flow of 22,400 cfs (634.3 m^3/s). The peak recorded level at the floodway entrance (Water Survey Canada station 05OC026) was 760.33 ft (231.75 m)on April 4; 0.08 ft (0.02 m) lower than the computed natural level of 760.41 ft (231.77 m), and 0.91 ft (0.28 m) lower than the computed natural peak level of 761.24 ft (232.03 m), which occurred on April 6. The recorded river level at the floodway entrance was maintained an average of 0.29 ft (0.09 m) below the computed natural level throughout the 28 days of floodway operation; however, the level at the floodway entrance did exceed the computed natural level on April 11. A reduction in the Portage Diversion discharge caused the computed natural level at the inlet to drop approximately four inches below the regulated level. When this difference was observed, a gate adjustment was made to bring the regulated level below the computed natural level. This period above the computed natural level occurred seven days after the river had crested at the inlet, with no effect to the peak level or duration of the flood event.

After the initial operation, the floodway gates were adjusted in small increments to follow the natural rise and drop in water levels. This was done to avoid large gate raises and drops 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 2017. When flow into the floodway had ceased, and after consultation with the City of Winnipeg, the floodway gates were transitioned out of service over approximately one week. The final gate operation occurred at 3:30 pm on April 27.

Figure 1 shows the recorded and natural water levels for the Red River in Winnipeg at James Avenue during the period of operation. Figure 2 shows the recorded and natural water levels for the Red River upstream of the floodway entrance.

4.2 Public Communication in 2017 Flood

During the 2017 flood, public communication was achieved by direct email to stakeholders, publication of gate change notices and water level plots on Manitoba Infrastructure's website, and through updates to the floodway operations info line.

An email database has been developed and maintained in accordance with the recommendations of the 2010 Public Review of the Red River Floodway Rules of Operation. The database includes municipal staff from the City of Winnipeg, Town of Morris, R.M. of East St. Paul, R.M. of West St. Paul, City of Selkirk, R.M. of St. Clements, R.M. of St. Andrews, R.M. of Springfield, R.M. of MacDonald, and the R.M. of Richot. Email notifications were distributed after each gate change operation. The first email was distributed March 31 at 10:30 a.m. providing notice of the initial floodway operation at 10:00 a.m. that morning. The final email was distributed at 3:30 p.m., April 27, informing the stakeholders on the contact list that floodway operations were complete for the Spring 2017 flood.

This year MI published the Red River Floodway gate change logs and hydrographs to the floodway information website (http://www.gov.mb.ca/mit/wms/rrf/information.html). The hydrographs showed natural and observed water levels at the floodway inlet, flow in the Red River upstream of the inlet, and flow in the floodway. These plots were updated on a daily basis during the operating period. The gate change logs were updated as gate changes were made.

An information phone line (1-204-284-4550) was also maintained with the most recent information on the operation of the Red River Floodway.

4.3 Ice Conditions in 2017

Ice was intact on the Red River upstream of the floodway inlet until March 31. Despite the early melt event and associated high river flows, ice break-up was late relative to the flow peak during the 2017 spring flood, occurring only four days before the flood crest arrived at the inlet. Ice had cleared on the Red River in most parts of the City and north of the City by March 30. South of Winnipeg, ice break-up was reported on the 31 along the Red River in regions near St. Jean, Aubigny, and Morris. The presence of ice at the floodway inlet had the potential to significantly impact the regulation of river levels in the City by delaying Floodway operations; however, while it did delay the initial operation of the floodway, it did not affect the floodway's ability to reduce the peak water level at James Avenue.

Ice jamming was not a major issue along the Assiniboine River upstream of the Portage Diversion. A surge of water (8,300 cfs or 235 m^3 peak) was allowed through the bascule gates on the 4 as a major ice run into the Portage Diversion reservoir temporarily increased discharge through the bascule gates. Ice on the Lower Assiniboine, however, was still intact until April 6. Minor ice jamming occurred downstream of Portage la Prairie but did not cause any damages.

4.4 Assiniboine River Flow Contribution

The Assiniboine River flows during the spring flood of 2017 were quite high, though manageable when compared to the 2011 event. The spring 2017 flood event on the Assiniboine at Portage has been calculated to be a 1:36 year event. The computed peak natural Assiniboine flow at Portage la Prairie was 40,350 cfs (1142.6 m^3/s) on April 15. The natural Assiniboine River contribution at James Avenue peaked at 32,740 cfs (927.1 m^3/s). The observed flow along the Assiniboine River at Headingley reached a maximum of 15,360 cfs (434.9 m^3/s) due to operation of the Shellmouth Dam and Portage Diversion.

The greatest reduction in flow at James Avenue due to Shellmouth Dam operations occurred on April 22, when the Red River flow at James Avenue was reduced by approximately 3,100 cfs (87.8 m^3/s).

The Portage Diversion peaked on April 14, at 24,700 cfs (699.4 m^3/s). Combined with the impacts of the Shellmouth Dam, this resulted in a reduction in peak flow contribution to the Red River of 25,540 cfs (723.2 m^3/s).

4.5 Floodway Maintenance and Efficiency

The floodway channel is maintaining acceptable levels of efficiency due to annual brush clearing in the floodway channel by Manitoba Infrastructure regional maintenance staff.

5.0 CONCLUSIONS

In summary:

- During the spring of 2017, the Red River Floodway was operated for 28 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 8.94 ft (2.72 m) during the peak natural flow.

- Operation of the Red River Floodway began at 10:00 a.m. on March 31, 2017, and concluded at 3:30 p.m. on April 27, 2017. During this period, 36 discrete gate adjustments were made as required.

- Recorded water levels upstream of the inlet were maintained below natural levels throughout floodway operation in the spring of 2017, with the exception of April 11 when the water level briefly exceeded natural by approximately four inches (100 mm). This had no effect on the peak level or duration of flooding upstream of the inlet. On average, water levels were 0.29 ft (0.09 m)lower than natural levels.

- The crest at the floodway inlet was 760.33 ft (231.75 m); 0.91 ft (0.28 m) lower than the computed natural peak level of 761.24 ft (232.03 m).

- The presence of ice delayed floodway operation by one day.

- During spring 2017, 556,400 acre-feet (689.1 million m^3) of water were diverted around the City of Winnipeg with a peak flow of 22,400 cfs (634.3 m^3/s).

Table 1 –2017 Floodway Gate Operations

Date	Time *	Gate Elevation	
		Start of Operation	End of Operation
March 31, 2017	10:00 AM	728.04	738.04
March 31, 2017	4:00 PM	738.04	739.95
April 1, 2017	7:15 AM	739.95	742.90
April 1, 2017	3:30 PM	742.90	744.78
April 1, 2017	10:20 PM	744.78	745.16
April 2, 2017	8:20 AM	745.16	745.53
April 2, 2017	4:40 PM	745.53	745.81
April 2, 2017	10:20 PM	745.81	746.27
April 3, 2017	4:30 PM	746.27	746.63
April 3, 2017	9:30 PM	746.63	747.09
April 5, 2017	4:30 PM	747.09	747.54
April 6, 2017	5:00 PM	747.54	747.81
April 6, 2017	10:00 PM	747.81	748.08
April 8, 2017	10:00 PM	748.08	747.72
April 10, 2017	10:30 AM	747.72	747.27
April 10, 2017	8:30 PM	747.27	746.82
April 11, 2017	8:30 AM	746.82	745.99
April 11, 2017	8:30 PM	745.99	745.44
April 12, 2017	4:00 PM	745.44	744.97
April 14, 2017	8:30 PM	744.97	744.41
April 15, 2017	2:00 PM	744.41	743.66
April 16, 2017	10:15 AM	743.66	743.00
April 16, 2017	8:55 PM	743.00	742.15
April 17, 2017	10:15 AM	742.15	741.29
April 18, 2017	11:45 AM	741.29	740.43
April 19, 2017	3:30 PM	740.43	739.95
April 20, 2017	8:15 AM	739.95	739.09
April 21, 2017	2:30 PM	739.09	738.23
April 23, 2017	8:30 AM	738.23	737.38
April 24, 2017	8:30 AM	737.38	736.43
April 25, 2017	8:30 AM	736.43	735.48
April 25, 2017	4:00 PM	735.48	734.73
April 26, 2017	8:15 AM	734.73	733.71
April 26, 2017	4:15 PM	733.71	732.69
April 27, 2017	8:15 AM	732.69	730.71
April 27, 2017	3:30 PM	730.71	728.04

* Time at start of gate operation

Figure 1 – Recorded and Natural River Levels at James Avenue Gauge 2017

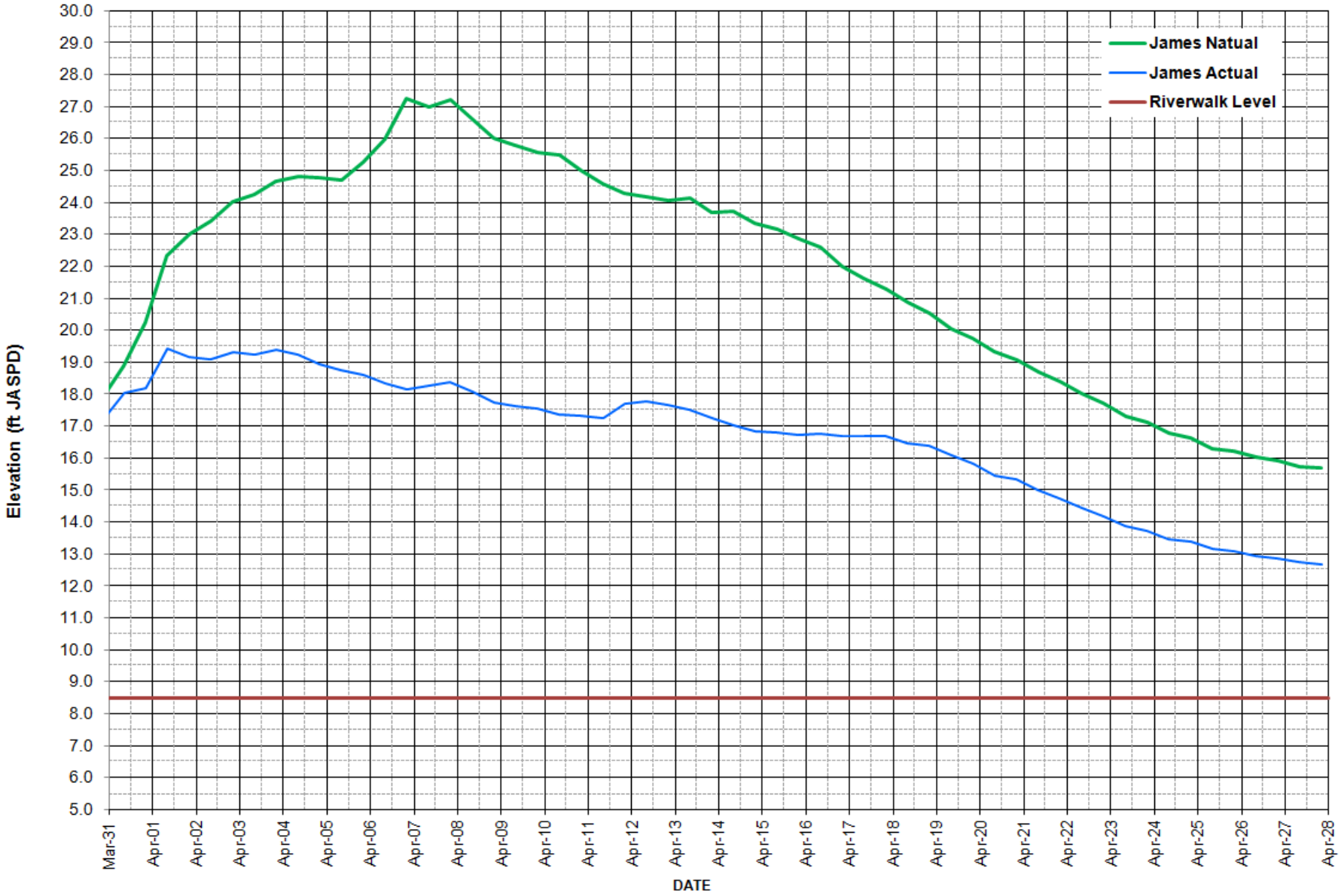
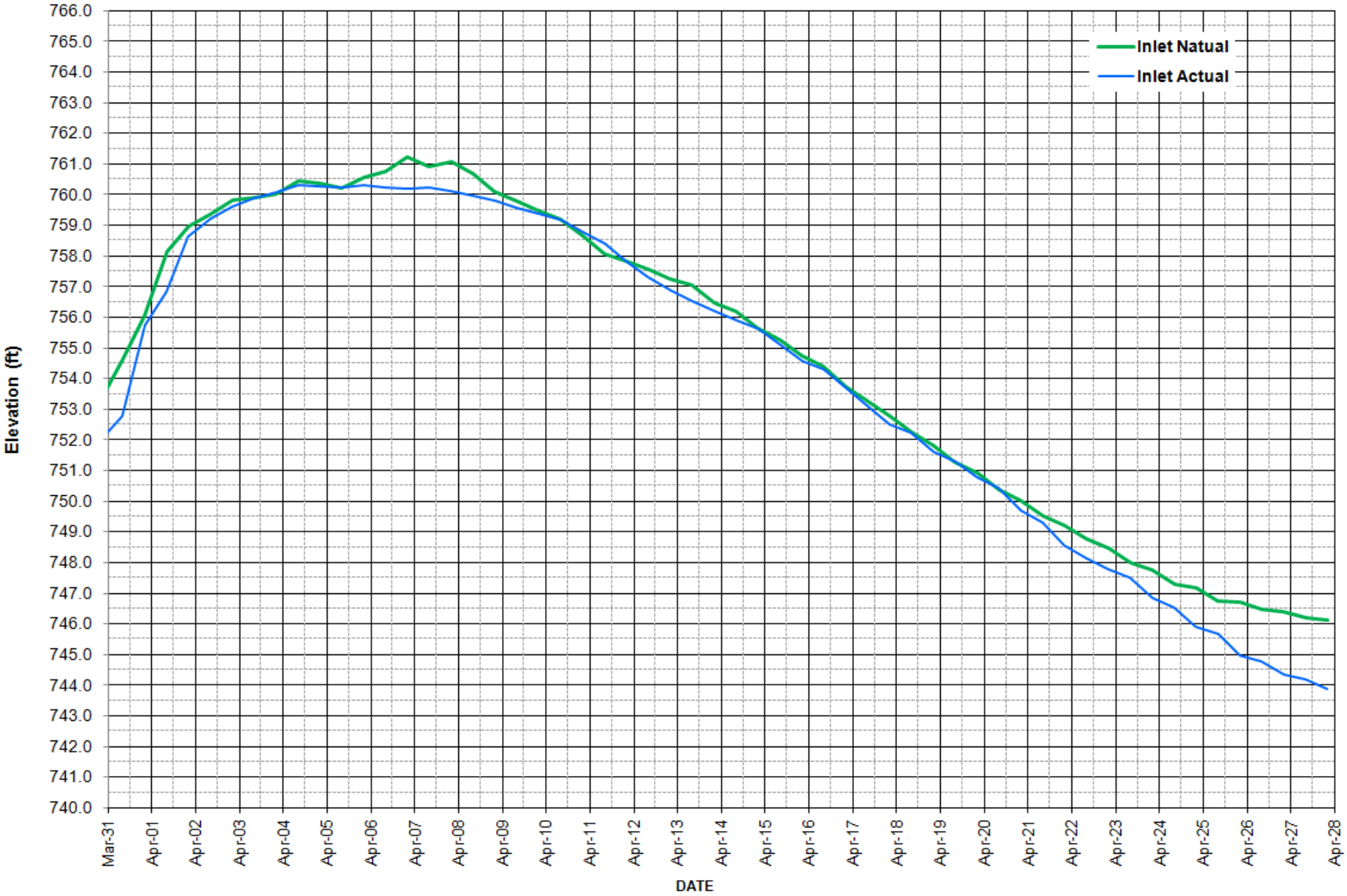


Figure 2 – Recorded and Natural Levels at Floodway Entrance 2017



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 Province of Manitoba 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 Manitoba Infrastructure ("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 Manitoba Infrastructure ("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 dikes along the Assiniboine River.

The Shellmouth Dam can decrease flows below natural levels 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 dikes were constructed to prevent overflows from the river onto the surrounding lands and becauseof the height of the river and the slope of the land much of this overflow did not return to the Assiniboine River. Therefore, the dikes 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 dikes were not in place.

Column 4 lists the computed breakouts that would have occurred at those flows if the dikes 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 (232.53 m)The difference in the inlet water elevation between these two flow combinations is 2.7 feet (0.82 m), 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 13 of Table B-1. For comparison, column 14 of Table B-1

lists the recorded levels at the floodway inlet (station 05OC026). Similar levels for James Avenue in Winnipeg are provided in columns 11 and 12.

Table B-1 Spring 2017 Flows and Levels

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine Flows							Red River Flows						
Date / Time	Shellmouth Flow Reduction (Routed to Headingley) Recorded	Portage Diversion flow (Routed to Headingley) Recorded	Actual Assiniboine R. flow at Headingley Recorded	Natural breakouts from river Computed	Natural Assiniboine River flow at Headingley =1+2+3-4	Sturgeon Cr. Flow plus other local inflows Rec. & Est.	**Natural Assiniboine R. flow into Red River Computed**	Red River Floodway flow Recorded	Red River flow at James Ave. Recorded	**Natural Red River flow at James Avenue =1+2-4+8+9**	Natural water level on Red R. At James Ave (feet) Computed	Recorded Water level on Red R. at James Ave (feet) Recorded	Natural water level on Red R. at Floodway Inlet (feet) Computed	Recorded Water level on Red R. at Floodway Inlet (feet) Recorded
29-Mar-2017 8:00 AM	-14	0	2,775	0	2,761	954	3,715	0	38,940	38,926	13.85	13.87	749.08	749.08
29-Mar-2017 8:00 PM	-14	0	3,091	0	3,077	1,112	4,190	1,423	41,371	42,780	15.30	14.97	750.36	750.24
30-Mar-2017 8:00 AM	-13	0	3,444	0	3,431	1,388	4,818	2,069	44,646	46,702	16.28	15.79	751.59	751.53
30-Mar-2017 8:00 PM	-13	0	3,837	0	3,823	1,803	5,626	2,785	49,621	52,392	17.87	17.13	753.34	751.98
31-Mar-2017 8:00 AM	-12	0	4,274	0	4,262	1,920	6,181	3,760	53,012	56,759	18.89	18.05	754.63	752.78
31-Mar-2017 8:00 PM	-12	0	4,762	0	4,749	1,923	6,672	8,490	53,155	61,633	20.21	18.19	756.05	755.76
01-Apr-2017 8:00 AM	-11	0	5,305	0	5,293	1,973	7,267	12,277	56,747	69,013	22.34	19.41	758.14	756.85
01-Apr-2017 8:00 PM	-11	14	5,910	0	5,912	1,929	7,841	16,610	55,597	72,209	23.03	19.14	758.96	758.64
02-Apr-2017 8:00 AM	-10	78	6,584	0	6,651	2,141	8,792	18,672	55,386	74,126	23.41	19.10	759.35	759.23
02-Apr-2017 8:00 PM	-10	1,082	7,335	0	8,406	2,102	10,508	19,421	56,271	76,763	24.02	19.30	759.82	759.60
03-Apr-2017 8:00 AM	-8	1,356	8,087	0	9,435	2,039	11,473	20,333	55,930	77,610	24.24	19.22	759.91	759.90
03-Apr-2017 8:00 PM	-8	2,015	10,352	0	12,359	1,948	14,307	20,779	56,613	79,398	24.66	19.38	760.02	760.07
04-Apr-2017 8:00 AM	-5	2,653	8,402	0	11,050	1,817	12,867	21,488	56,011	80,148	24.81	19.24	760.43	760.30
04-Apr-2017 8:00 PM	-5	3,895	7,583	0	11,473	1,674	13,147	21,461	54,659	80,011	24.79	18.93	760.36	760.28
05-Apr-2017 8:00 AM	2	4,331	7,640	0	11,973	1,494	13,467	21,348	53,913	79,594	24.70	18.76	760.20	760.23
05-Apr-2017 8:00 PM	2	6,913	7,644	0	14,559	1,350	15,909	22,415	53,136	82,466	25.28	18.58	760.58	760.30
06-Apr-2017 8:00 AM	16	12,384	7,623	1,080	18,944	1,247	20,191	22,210	52,194	87,884	25.96	18.33	760.76	760.24
06-Apr-2017 8:00 PM	16	23,096	8,619	6,292	25,440	1,058	27,585	22,074	51,542	103,020	27.25	18.15	761.24	760.21
07-Apr-2017 8:00 AM	45	21,663	11,047	6,853	25,901	958	28,239	22,144	51,995	102,700	26.99	18.27	760.90	760.23
07-Apr-2017 8:00 PM	45	22,889	10,591	7,289	26,236	841	28,684	21,794	52,303	104,320	27.21	18.36	761.07	760.11
08-Apr-2017 8:00 AM	98	20,772	9,419	5,532	24,758	751	26,201	21,370	51,227	99,000	26.61	18.07	760.68	759.96
08-Apr-2017 8:00 PM	98	19,594	9,282	4,871	24,103	683	25,133	20,760	50,053	95,376	26.02	17.75	760.10	759.81
09-Apr-2017 8:00 AM	189	19,778	9,445	5,088	24,324	607	25,391	20,009	49,596	94,659	25.79	17.63	759.78	759.56
09-Apr-2017 8:00 PM	189	19,765	9,852	5,285	24,520	512	25,595	19,386	49,241	93,865	25.56	17.54	759.46	759.37
10-Apr-2017 8:00 AM	328	20,880	10,309	6,176	25,341	418	26,785	18,778	48,602	94,764	25.47	17.38	759.19	759.17
10-Apr-2017 8:00 PM	328	19,554	10,738	5,703	24,917	324	26,022	17,702	48,406	91,693	25.00	17.33	758.65	758.80

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine Flows							Red River Flows						
Date / Time	Shellmouth Flow Reduction (Routed to Headingley) Recorded	Portage Diversion flow (Routed to Headingley) Recorded	Actual Assiniboine R. flow at Headingley Recorded	Natural breakouts from river Computed	Natural Assiniboine River flow at Headingley =1+2+3-4	Sturgeon Cr. Flow plus other local inflows Rec. & Est.	**Natural Assiniboine R. flow into Red River Computed**	Red River Floodway flow Recorded	Red River flow at James Ave. Recorded	**Natural Red River flow at James Avenue =1+2-4+8+9**	Natural water level on Red R. At James Ave (feet) Computed	Recorded Water level on Red R. at James Ave (feet) Recorded	Natural water level on Red R. at Floodway Inlet (feet) Computed	Recorded Water level on Red R. at Floodway Inlet (feet) Recorded
11-Apr-2017 8:00 AM	518	18,851	11,337	5,748	24,959	277	26,039	16,546	48,075	89,739	24.59	17.24	758.07	758.39
11-Apr-2017 8:00 PM	518	17,062	11,947	5,145	24,382	253	25,125	15,051	49,813	87,590	24.28	17.68	757.82	757.81
12-Apr-2017 8:00 AM	759	17,591	12,361	5,750	24,961	234	26,000	13,772	50,111	87,984	24.16	17.77	757.54	757.30
12-Apr-2017 8:00 PM	759	19,153	12,605	6,721	25,796	217	27,324	12,690	49,706	89,029	24.06	17.66	757.23	756.87
13-Apr-2017 8:00 AM	1,041	21,405	12,803	8,301	26,947	203	29,284	11,860	49,100	91,708	24.14	17.50	757.05	756.52
13-Apr-2017 8:00 PM	1,041	21,452	13,138	8,533	27,097	186	29,538	11,141	48,098	90,263	23.70	17.25	756.46	756.20
14-Apr-2017 8:00 AM	1,350	23,813	13,594	10,528	28,230	178	31,700	10,471	47,221	93,382	23.74	17.03	756.20	755.91
14-Apr-2017 8:00 PM	1,350	23,564	14,097	10,698	28,314	155	31,852	9,880	46,404	91,897	23.36	16.83	755.64	755.63
15-Apr-2017 8:00 AM	1,675	23,839	14,514	11,389	28,640	148	32,529	8,785	46,295	91,983	23.17	16.80	755.26	755.13
15-Apr-2017 8:00 PM	1,675	23,732	14,919	11,595	28,732	157	32,737	7,645	46,042	90,689	22.85	16.74	754.73	754.59
16-Apr-2017 8:00 AM	2,001	22,468	15,315	11,221	28,563	170	32,388	7,065	46,160	88,915	22.61	16.76	754.41	754.28
16-Apr-2017 8:00 PM	2,001	21,257	15,353	10,430	28,180	197	31,620	5,820	45,809	85,318	22.01	16.68	753.72	753.71
17-Apr-2017 8:00 AM	2,313	20,633	15,298	10,188	28,056	201	31,374	4,493	45,809	83,437	21.63	16.68	753.25	753.09
17-Apr-2017 8:00 PM	2,313	20,388	15,136	9,922	27,915	189	31,082	3,097	45,835	81,555	21.29	16.68	752.80	752.51
18-Apr-2017 8:00 AM	2,595	19,424	14,862	9,310	27,571	181	30,412	2,430	44,929	78,687	20.86	16.46	752.25	752.22
18-Apr-2017 8:00 PM	2,595	19,171	14,610	8,993	27,383	169	30,046	1,419	44,579	76,756	20.52	16.37	751.81	751.60
19-Apr-2017 8:00 AM	2,829	18,256	14,366	8,424	27,028	163	29,388	1,052	43,479	74,041	20.04	16.09	751.29	751.28
19-Apr-2017 8:00 PM	2,829	18,176	14,073	8,199	26,879	149	29,109	992	42,339	72,535	19.74	15.81	750.92	750.79
20-Apr-2017 8:00 AM	3,003	17,814	13,815	7,933	26,699	135	28,776	699	40,954	70,404	19.33	15.45	750.37	750.43
20-Apr-2017 8:00 PM	3,003	17,587	13,568	7,654	26,503	123	28,423	0	40,561	68,805	19.06	15.35	750.02	749.68
21-Apr-2017 8:00 AM	3,109	17,134	13,399	7,356	26,286	114	28,041	0	39,179	66,778	18.70	14.98	749.54	749.29
21-Apr-2017 8:00 PM	3,109	16,720	13,219	7,018	26,030	105	27,600	0	38,265	65,111	18.41	14.74	749.21	748.56
22-Apr-2017 8:00 AM	3,144	16,119	13,074	6,622	25,715	102	27,076	0	37,171	63,056	18.01	14.43	748.79	748.12
22-Apr-2017 8:00 PM	3,144	15,886	12,976	6,440	25,565	97	26,826	0	36,283	61,753	17.73	14.18	748.48	747.77
23-Apr-2017 8:00 AM	3,112	15,221	12,848	5,997	25,184	87	26,205	0	35,166	59,495	17.32	13.86	747.98	747.50
23-Apr-2017 8:00 PM	3,112	14,806	12,678	5,690	24,906	81	25,761	0	34,657	58,265	17.12	13.72	747.76	746.84
24-Apr-2017 8:00 AM	3,019	14,169	12,578	5,265	24,501	76	25,129	0	33,729	56,182	16.76	13.44	747.30	746.55
24-Apr-2017 8:00 PM	3,019	13,744	12,484	5,006	24,241	73	24,732	0	33,576	55,345	16.65	13.39	747.19	745.91

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Assiniboine Flows							**Red River Flows**						
Date / Time	Shellmouth Flow Reduction (Routed to Headingley) Recorded	Portage Diversion flow (Routed to Headingley) Recorded	Actual Assiniboine R. flow at Headingley Recorded	Natural breakouts from river Computed	Natural Assiniboine River flow at Headingley =1+2+3-4	Sturgeon Cr. Flow plus other local inflows Rec. & Est.	**Natural Assiniboine R. flow into Red River Computed**	Red River Floodway flow Recorded	Red River flow at James Ave. Recorded	**Natural Red River flow at James Avenue =1+2-4+8+9**	Natural water level on Red R. At James Ave (feet) Computed	Recorded Water level on Red R. at James Ave (feet) Recorded	Natural water level on Red R. at Floodway Inlet (feet) Computed	Recorded Water level on Red R. at Floodway Inlet (feet) Recorded
25-Apr-2017 8:00 AM	2,874	12,970	12,335	4,487	23,692	67	23,906	0	32,752	53,083	16.27	13.14	746.76	745.69
25-Apr-2017 8:00 PM	2,874	12,857	12,174	4,357	23,547	61	23,688	0	32,600	52,687	16.22	13.09	746.72	744.99
26-Apr-2017 8:00 AM	2,689	12,457	11,999	4,004	23,140	59	23,199	0	32,063	51,213	16.01	12.93	746.47	744.79
26-Apr-2017 8:00 PM	2,689	12,112	11,832	3,772	22,860	47	22,907	0	31,825	50,399	15.92	12.85	746.39	744.33
27-Apr-2017 8:00 AM	2,479	11,625	11,674	3,396	22,382	46	22,428	0	31,417	48,917	15.74	12.73	746.19	744.20
27-Apr-2017 8:00 PM	2,479	11,399	11,542	3,242	22,178	37	22,215	0	31,233	48,353	15.68	12.67	746.13	743.90

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)