

RED RIVER FLOODWAY OPERATION REPORT

SPRING 2023

July 14, 2023

Manitoba Transportation and Infrastructure
Hydrologic Forecasting and Water Management Branch
Engineering and Technical Services Division



Printed on Recycled Paper



EXECUTIVE SUMMARY

The 2023 Red River spring flood was influenced by a wide range of soil moisture and winter precipitation conditions across the Red River basin, with significant differences in conditions north and south of the border. The majority of the US portion of the basin had below normal soil moisture and a range of winter snowfall with some areas receiving well above normal amounts. The Manitoba portion of the basin had mostly near normal soil moisture and below normal winter precipitation. The March Outlook published by Manitoba's Hydrologic Forecast Center estimated that the peak flow at Emerson would be similar to the flow seen in the fall of 2019 under favorable conditions, and similar to the 2019 spring flood under normal conditions. Under unfavorable conditions, the 2023 flow at Emerson was forecast to be similar to 2020. Due to high winter precipitation in the U.S. portion of the basin, an early melt of the local tributaries and near normal spring precipitation, the observed peak at Emerson for the 2023 spring flood was approximately 50,145 cfs (1420 m³/s) and occurred on May 4. This is slightly higher than the peak forecast for favourable melt conditions published in the March Outlook. The 2023 peak flow measured at Emerson equated to a 1:7 year flood.

Ice was not a major concern on the Red or Assiniboine Rivers in 2023; however, some ice jamming did occur at various locations along the Assiniboine River both upstream and downstream of the Portage Diversion, and a significant ice run was observed on the Portage Diversion due to the mechanical failure of one of the control gates. Floodway operation began at 4:30 p.m. on April 20, and the gates were operated for 29 days ending at 7:29 p.m. on May 18. During the spring 2023 period of operation, 81 discrete gate adjustments were made, as required at various times, to regulate the water level at the floodway inlet. In the spring of 2023, approximately 429,000 acre-feet (529 million m³) of water was diverted around the City of Winnipeg by the Red River Floodway, with a peak flow of 10,710 cfs (303.3 m³/s). The Red River Floodway has been operated in 36 of the past 54 years to reduce high water levels in the City of Winnipeg since its first year of operation in 1969.

The Assiniboine River flow during the spring flood of 2023 was above average for the spring freshet. The natural (unregulated) peak flow along the Assiniboine River at Portage la Prairie occurred on April 28, and was computed to be 13,730 cfs (388.8 m³/s). The observed flow along the Assiniboine River at Headingley reached a maximum of 8,405 cfs (238.0 m³/s) due to the operation of the Shellmouth Dam and Portage Diversion.

In spring 2023, the operation of the floodway was successful in protecting the City of Winnipeg from flooding, while minimizing upstream impacts through normal floodway operation under Rule 1 of the Red River Floodway Rules of Operation, which sets out the conditions by which the floodway can be used to protect Winnipeg. Rule 1 requires that natural water levels are maintained on the Red River at the floodway inlet. On average, the operation of the Red River Floodway maintained river levels 0.41 ft (0.13 m) below computed natural water levels at the floodway inlet throughout the 29 days of floodway operation. In concert with the operation of the Portage Diversion and Shellmouth Dam, the operation of the floodway reduced the flood crest in the City of Winnipeg by 3.75 ft (1.14 m) at the natural flow crest. The recorded peak water level at James Avenue was 17.89 ft (5.45 m).

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	i
TABLE OF CONTENTS.....	ii
1.0 INTRODUCTION	1
2.0 2023 SPRING RUNOFF.....	1
3.0 THE RED RIVER FLOODWAY	2
4.0 OPERATION OF THE FLOODWAY IN SPRING 2023.....	2
4.1 General Observations	2
4.2 Public Communication in 2023 Flood.....	3
4.3 Ice Conditions in 2023.....	4
4.4 Assiniboine River Flow Contribution	4
4.5 Floodway Maintenance and Efficiency	5
5.0 CONCLUSIONS.....	5

TABLES

Table 1: 2023 Spring Floodway Gate Operations

FIGURES

Figure 1: Recorded and Natural River Levels at James Avenue 2023

Figure 2: Recorded and Natural Levels at Floodway Entrance 2023

APPENDICES

Appendix A: Red River Floodway Rules of Operation

Appendix B: Computation of Natural Flows and Levels

1.0 INTRODUCTION

On April 20, 2005, The Red River Floodway Act was proclaimed into 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 2023 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 the charts and tables in 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 35.3147. 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 Pumping Station Datum (JAPSD), which is based on the 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 727.57 ft (221.763 m).

This report refers to “natural” flows and water levels. Natural flows are the flows that would have occurred in the absence of flood control works (unregulated conditions). Natural water levels refer to the water levels that would have occurred in the absence of flood control and with the level of urban development in place at the time of the construction of these various works.

Manitoba Transportation and Infrastructure gratefully acknowledges Water Survey Canada for providing the provisional and approved flow data used in this report.

2.0 2023 SPRING RUNOFF

The 2023 Red River spring flood was influenced by a wide range of soil moisture and winter precipitation across the Red River basin, with significant differences in conditions north and south of the border. The majority of the US portion of the basin had below normal (50% - 85%) soil moisture, with some small pockets of well below normal (< 50%) and near normal (85% - 115%). The US portion of the basin saw a wide range of winter precipitation with well above normal (150% - 200%) at the southern point to below normal (50% - 85%) near the Manitoba-US Border. The Manitoba portion of the basin generally had normal (85% - 115%) soil moisture, with some pockets of above normal (115% - 150%) through the central portion of the basin, along with generally below normal (50% - 85%) winter precipitation. The March Outlook published by Manitoba’s Hydrologic Forecast Center estimated that the peak flow at Emerson could be similar to the flow seen in the 2019 fall flood under favorable conditions, and similar to the 2019 spring flood under normal conditions. Under unfavorable conditions, the 2023 flow at Emerson was forecast to be similar to the 2020 flow.

The recorded peak flow was slightly higher than the forecast peak for favourable melt conditions published in the March Outlook. High winter precipitation in the U.S. portions of the Red River and

Souris River basins, an early melt of the local tributaries and near normal spring precipitation in the Red River basin balanced for near favourable conditions. Winter precipitation over the Red River Basin (November – March) was 113% of normal while the spring precipitation (April – May) was 83% of normal. The observed peak at Emerson for the 2023 spring flood occurred on May 4, and was approximately 50,145 cfs (1420 m³/s). The Red River crested at the floodway inlet on May 2, with a peak flow of approximately 53,275 cfs (1508.6 m³/s).

The 2023 natural spring flood was a modest event in the basin, with some substantial flooding and duration of heightened flows. The 2023 peak flow measured at Emerson equated to a 1:7 year flood. The peak natural flood flow at James Avenue equated to a 1:5 year flood.

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 the Shellmouth Dam and Reservoir, the Portage Diversion, and the Red River Floodway to protect the City of Winnipeg from significant flood events. All were intended to be operated in concert to reduce flood flows and thus, minimize flood damage within the City of Winnipeg.

Operation of the floodway is guided by the Red River Floodway Rules of Operation (Appendix A), a set of rules intended to provide balanced flood protection to the City of Winnipeg without artificially affecting properties south (e.g., upstream) of the inlet. Rule 1 requires that natural levels not be exceeded upstream of the Floodway Inlet Control Structure as long as water levels within the City of Winnipeg are less than 24.5 ft (7.47 m) at James Avenue or if the water level anywhere along the Red River within the City of Winnipeg is less than 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 the Shellmouth Reservoir, Portage Diversion, Assiniboine River dikes, Winnipeg dikes and Red River Floodway were not in place.

During the 2023 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 2023 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, Red River 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 2023

4.1 General Observations

Floodway operation began at 4:30 p.m. on April 20. Water had begun to spill into the floodway on April 19. 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 2023 followed normal protocol and was consistent with experience in past spring floods.

The computation of natural water levels at the Red River Floodway 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 an established water level-flow relationship for the Red River at James Avenue using water levels collected at Water Survey of Canada water monitoring station 05OC015, and considers the backwater influence of the Red River floodway at Lockport. This water level-flow relationship is verified multiple times throughout the spring through manual flow measurements.

The recorded instantaneous peak water level at James Avenue was 17.89 ft (5.45 m) under open water conditions on the afternoon of April 30. The peak natural flow at James Avenue in Winnipeg would have occurred on the morning of April 30, and was calculated to be approximately 67,600 cfs (1914.3 m³/s). This peak flow would have resulted in a James Avenue level of 21.60 ft (6.58 m). Operation of the floodway, Portage Diversion and Shellmouth Dam lowered the James Avenue water level during the peak natural flow by 3.75 ft (1.14 m), to a level of 17.85 ft (5.44 m).

Overall, in the spring of 2023, approximately 429,000 acre-feet (529 million m³) of water was diverted around the City of Winnipeg by the Red River Floodway, with a peak flow of 10,710 cfs (303.3 m³/s). The peak recorded level at the floodway entrance (Water Survey Canada station 05OC026) was 755.77 ft (230.36 m) on May 6, 0.12 ft (0.04 m) lower than the computed natural level of 755.89 ft (230.40 m). The water level at the floodway inlet did exceed natural for a brief period of time on the mornings of April 25 and April 26. These exceedances averaged 0.7" (1.8 cm) and did not impact the peak levels observed upstream of the floodway. The recorded river level at the floodway entrance was maintained at an average of 0.41 ft (0.13 m) below the computed natural level during the 2023 spring floodway operation.

After the raises that initiated 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 the operation of the floodway in the spring of 2023. On May 17, the floodway gates began lowering to their bedded position. The Red River was continuing to drop steadily and gate changes were no longer having an observable impact on the river level at James Avenue. The final gate operation occurred at 7:30 p.m. on May 18.

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 2023 Flood

During the 2023 flood, public communication was achieved by direct email to stakeholders, the publication of gate change notices and water level plots on Manitoba Transportation and Infrastructure's website, and through updates to the floodway operations info line.

MTI maintains an email database 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 Morris, 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 R.M. of Ritchot. Email notifications were distributed after each gate change operation. The first email was distributed April 19 at 8:25 a.m., providing notice of conditions at the floodway inlet, advising that flow had begun to enter the floodway naturally and operation of the floodway was likely to begin the following day. The initial operation notification was sent April 20 at 4:51 p.m. indicating that the gates had been raised. The final operation notification email was distributed on May 18 at 7:38 p.m., informing stakeholders on the contact list that floodway operations were complete for the spring 2023 flood.

Prior to the initial operation of the floodway, Manitoba Transportation and Infrastructure (MTI) hosted an annual pre-flood meeting of the Red River Floodway Operation Advisory Board.

MTI published the Red River Floodway gate change logs and hydrographs to the floodway information website (www.manitoba.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 (204-284-4550) was also maintained with the most recent information on the operation of the Red River Floodway.

4.3 Ice Conditions in 2023

Ice was intact on the Red River immediately upstream of the floodway inlet until April 17. Ice was delayed in melt and break-up along the Red River, but it did not impact the timing of Floodway operation.

Minor ice jamming occurred at various locations along the Assiniboine River upstream of the Portage Diversion, and close to the City of Winnipeg. The Portage Diversion began operation on April 16, to maintain flows on the lower Assiniboine River to less than 5,000 cfs (141.6 m³/s) to mitigate the risk of ice jamming. An ice run on April 17 may have been a factor in the damaging of two gates, rendering them inoperable. The operation of the Portage Diversion was maintained with the remaining functional gates as investigations began to determine what would be required to repair the gates. A significant ice run took place on the Portage Diversion on April 24th due to the mechanical issues at the diversion control gates. The Portage Diversion began to transition out of operation for ice management on April 25.

4.4 Assiniboine River Flow Contribution

The Assiniboine River flows during the spring flood of 2023 were above average for the spring freshet. The computed peak natural Assiniboine flow at Portage la Prairie was 24,020 cfs (680.2 m³/s) on April 21. Due to minimal local inflows downstream of the Portage Diversion, the natural Assiniboine River contribution at James Avenue peaked at 23,085 cfs (653.7 m³/s). The recorded flow along the

Assiniboine River at Headingley reached a maximum of 8,405 cfs (238.0 m³/s) due to the operation of the Shellmouth Dam and Portage Diversion.

The greatest reduction in flow at James Avenue due to Shellmouth Dam operations occurred on May 8 and May 9, when the Red River flow at James Avenue was reduced by approximately 2,374 cfs (67.2 m³/s).

The flow at the Portage Diversion peaked with a surge in flow observed on April 19, at 19,650 cfs (556.4 m³/s). Combined with the impacts of the Shellmouth Dam, this resulted in a reduction in peak flow contribution to the Red River of 19,755 cfs (559.4 m³/s), two days later. Shellmouth Reservoir was only contributing a net reduction benefit of 105 cfs (3.0 m³/s) at Winnipeg during peak Portage Diversion Operation.

Due to the damage sustained by the two diversion gates, the flow into the Portage Diversion remained between 2,000-3,000 cfs (56.6-85.0 m³/s) through May and much of June. On June 16, work was undertaken to repair Gate 1, which was then closed. The second gate remained open 0.5 ft permitting approximately 500 cfs to enter the diversion channel until early July, when it was closed.

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 and Transportation regional maintenance staff. In 2023 the floodway showed slightly decreased efficiency of 2% when compared to the previous rating curve.

5.0 CONCLUSIONS

In summary:

- During the spring of 2023, the Red River Floodway was operated for 29 days. In combination with other related flood control infrastructure such as the Portage Diversion and Shellmouth Reservoir, the flood crest in the City of Winnipeg was reduced by 3.75 ft (1.14 m) during the peak natural flow. The recorded peak water level at James Avenue was 17.89 ft (5.45 m).
- The operation of the Red River Floodway began at 4:30 p.m. on April 20, and concluded at 7:29 p.m. on May 18. Over the course of the spring operation, 81 discrete gate adjustments were made as required.
- Recorded water levels upstream of the inlet were maintained below natural levels through the crest of the spring 2023 flood. However, it did exceed natural for a brief period of time on the rising limb, and did not impact the flood crest observed upstream of the floodway. On average, water levels were 0.41 ft (0.13 m) lower than natural levels during operation.
- The crest at the floodway inlet was 755.77 ft (230.36 m), 0.12 ft (0.04 m) lower than the computed natural level of 755.89 ft (230.40 m).
- Ice break-up did not impact floodway operations in 2023 and conditions upstream of the floodway inlet were ice free three days prior to operation.

- During the spring of 2023, approximately 429,000 thousand acre-feet (529 million m³) of water was diverted around the City of Winnipeg by the Red River Floodway, with a peak flow of 10,710 cfs (303.3 m³/s).

Table 1 - 2023 Floodway Gate Operations

Date*	Upstream Water Level		Gate Elevation	
	(ft)	(m)	(ft)	(m)
Storage Position	748.65	228.19	728.04	221.91
2023-04-20 4:30 PM	751.54	229.07	737.09	224.67
2023-04-20 7:51 PM	752.30	229.30	738.71	225.16
2023-04-20 11:06 PM	752.76	229.44	739.67	225.45
2023-04-21 11:09 AM	753.31	229.61	739.19	225.31
2023-04-21 2:57 PM	753.25	229.59	738.71	225.16
2023-04-21 7:00 PM	753.18	229.57	738.43	225.07
2023-04-21 11:14 PM	753.18	229.57	738.23	225.01
2023-04-22 7:13 AM	753.18	229.57	737.76	224.87
2023-04-22 11:23 AM	753.08	229.54	737.47	224.78
2023-04-22 10:53 PM	753.08	229.54	737.85	224.90
2023-04-23 2:59 PM	753.25	229.59	738.14	224.99
2023-04-23 6:55 PM	753.35	229.62	738.52	225.10
2023-04-23 11:07 PM	753.48	229.66	738.90	225.22
2023-04-24 2:57 PM	753.74	229.74	739.19	225.31
2023-04-25 7:07 AM	753.94	229.80	739.48	225.39
2023-04-25 11:07 AM	754.04	229.83	739.86	225.51
2023-04-25 3:31 PM	754.20	229.88	740.14	225.59
2023-04-25 7:05 PM	754.33	229.92	740.53	225.71
2023-04-26 7:04 AM	754.56	229.99	740.24	225.63
2023-04-26 10:55 AM	754.49	229.97	739.86	225.51
2023-04-26 2:57 PM	754.40	229.94	739.38	225.36
2023-04-26 10:55 PM	754.33	229.92	739.57	225.42
2023-04-27 2:50 PM	754.49	229.97	739.86	225.51
2023-04-27 7:07 PM	754.56	229.99	740.14	225.59
2023-04-27 11:03 PM	754.69	230.03	740.43	225.68
2023-04-28 6:51 PM	754.99	230.12	740.62	225.74
2023-04-28 11:00 PM	755.09	230.15	740.91	225.83
2023-04-29 2:55 PM	755.31	230.22	740.81	225.80
2023-04-29 10:48 PM	755.35	230.23	740.72	225.77
2023-04-30 7:30 AM	755.40	230.25	740.91	225.83
2023-04-30 2:53 PM	755.51	230.28	741.00	225.86
2023-04-30 6:51 PM	755.54	230.29	741.10	225.89
2023-05-05 10:58 PM	755.71	230.34	741.29	225.95
2023-05-06 11:15 AM	755.77	230.36	741.19	225.91
2023-05-06 3:12 PM	755.74	230.35	741.00	225.86
2023-05-08 2:50 PM	755.61	230.31	740.91	225.83
2023-05-09 7:45 AM	755.48	230.27	740.81	225.80
2023-05-09 10:58 AM	755.45	230.26	740.72	225.77
2023-05-09 2:54 PM	755.41	230.25	740.62	225.74
2023-05-10 7:38 AM	755.28	230.21	740.53	225.71
2023-05-10 3:02 PM	755.18	230.18	740.43	225.68
2023-05-10 7:00 PM	755.15	230.17	740.34	225.66

*Time at start of gate operation

Table 1 Continued – 2023 Floodway Gate Operations

Date *	Upstream Water Level		Gate Elevation	
	(ft)	(m)	(ft)	(m)
2023-05-10 11:02 PM	755.12	230.16	740.43	225.68
2023-05-11 7:00 AM	755.12	230.16	740.53	225.71
2023-05-11 3:03 PM	755.05	230.14	740.43	225.68
2023-05-11 6:55 PM	755.02	230.13	740.24	225.63
2023-05-11 11:06 PM	754.92	230.10	740.05	225.57
2023-05-12 7:51 AM	754.79	230.06	739.95	225.54
2023-05-12 2:54 PM	754.69	230.03	739.86	225.51
2023-05-12 6:56 PM	754.63	230.01	739.76	225.48
2023-05-12 11:13 PM	754.53	229.98	739.57	225.42
2023-05-13 7:40 AM	754.40	229.94	739.48	225.39
2023-05-13 11:01 AM	754.33	229.92	739.38	225.36
2023-05-13 3:09 PM	754.27	229.90	739.29	225.34
2023-05-13 6:57 PM	754.17	229.87	739.19	225.31
2023-05-13 11:13 PM	754.07	229.84	738.81	225.19
2023-05-14 7:43 AM	753.84	229.77	738.62	225.13
2023-05-14 10:53 AM	753.77	229.75	738.43	225.07
2023-05-14 3:14 PM	753.61	229.70	738.23	225.01
2023-05-14 7:53 PM	753.51	229.67	738.14	224.99
2023-05-14 11:02 PM	753.41	229.64	737.66	224.84
2023-05-15 7:16 AM	753.15	229.56	737.38	224.75
2023-05-15 10:59 AM	753.02	229.52	737.09	224.67
2023-05-15 3:03 PM	752.89	229.48	736.81	224.58
2023-05-15 6:59 PM	752.76	229.44	736.62	224.52
2023-05-15 11:05 PM	752.62	229.40	736.52	224.49
2023-05-16 7:10 AM	752.46	229.35	736.24	224.41
2023-05-16 11:09 AM	752.33	229.31	735.95	224.32
2023-05-16 2:57 PM	752.20	229.27	735.67	224.23
2023-05-16 6:55 PM	752.07	229.23	735.39	224.15
2023-05-16 11:03 PM	751.94	229.19	735.01	224.03
2023-05-17 7:45 AM	751.64	229.10	734.83	223.98
2023-05-17 11:01 AM	751.54	229.07	734.54	223.89
2023-05-17 2:51 PM	751.41	229.03	734.26	223.80
2023-05-17 7:01 PM	751.28	228.99	733.99	223.72
2023-05-17 11:07 PM	751.18	228.96	733.43	223.55
2023-05-18 7:34 AM	750.89	228.87	733.06	223.44
2023-05-18 10:20 AM	750.79	228.84	732.69	223.32
2023-05-18 1:38 PM	750.62	228.79	732.06	223.13
2023-05-18 4:25 PM	750.49	228.75	731.07	222.83
2023-05-18 7:29 PM	750.36	228.71	728.04	221.91

*Time at start of gate operation

Figure 1 - Recorded and Natural Levels at James Avenue 2023

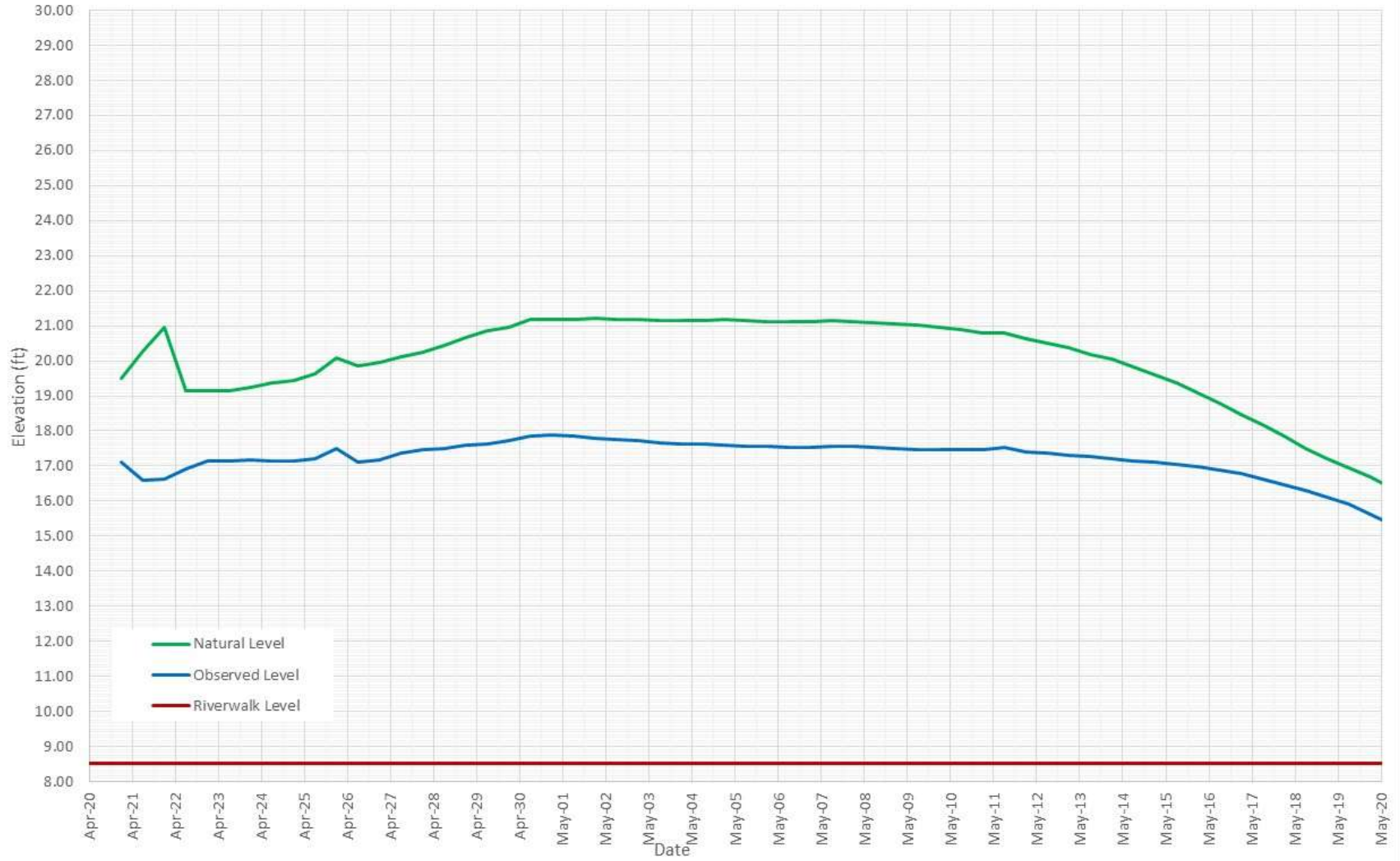
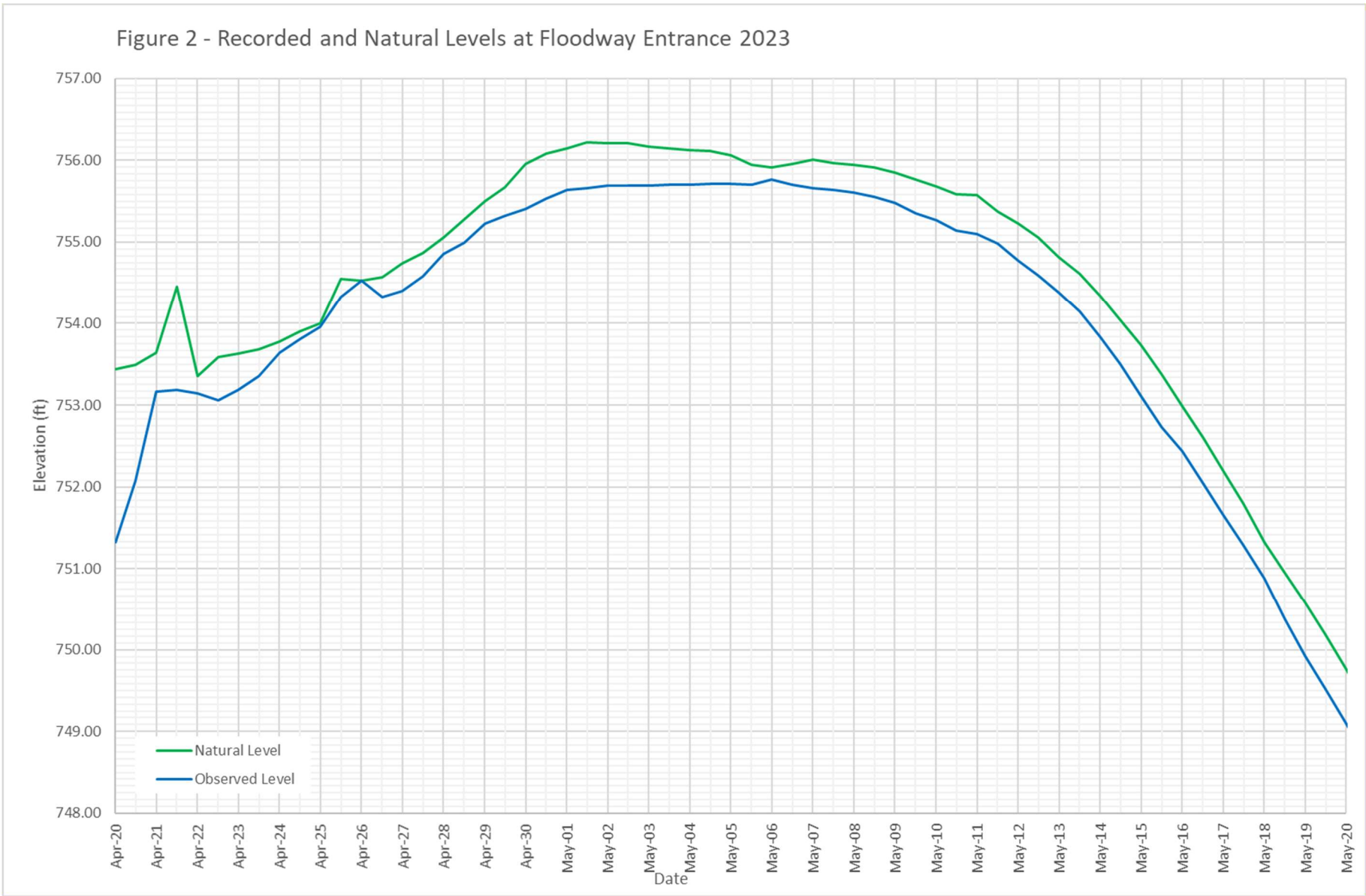


Figure 2 - Recorded and Natural Levels at Floodway Entrance 2023



APPENDIX A

Red River Floodway Rules of Operation

Rules of Operation

Red River Floodway Control Structure

Normal Operation:

1. Maintain natural¹ water levels on the Red River at the entrance to the floodway channel, until the water surface elevation at James Avenue reaches 24.5 ft (7.46 m), 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 ft (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 m) 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 ft (229 m), shall be carried out in consultation with the City of Winnipeg.

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 ft James Avenue Pumping Station Datum (JAPSD), the Department will not operate the floodway control structure.

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.

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 ft 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 backup;
 - (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 ft above sea level;
 - (b) to achieve a river level of less than 9 ft 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

Figure 1 and Figure 2 in the main report show the natural and observed levels at the floodway inlet and James Avenue. This Appendix describes how these levels 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 (unregulated) 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 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. Much of this overflow would not return to the Assiniboine River because of the height of the river and the slope of the land. 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.

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 values in columns 1 to 3 (Shellmouth flow reduction, recorded Portage Diversion flow, and recorded Headingley flow) and subtracting by the computed Assiniboine River natural breakouts.

There is some additional local inflow entering the Assiniboine River between Headingley and the Forks. Most of this flow is recorded on Sturgeon Creek. However, in column 6 the recorded flows on Sturgeon Creek are increased to include the estimated 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 columns 1, 2, 8 and 9, and subtracts column 4 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 Natural Red River at James Avenue Flow. The Natural Assiniboine River Flow 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 the Assiniboine River Contribution. This combination results in a level at the inlet of 765.6 ft 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 the Red River flow upstream of the Forks, and 30,000 cfs as the Assiniboine River Contribution. The resulting inlet level would be 762.9 ft (232.53 m). The difference in the inlet water elevation between these two flow combinations is 2.7 ft (0.82 m), with the lower elevation occurring when there is relatively more flow on the Assiniboine River.

Natural water 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 2023 Flows and Levels

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Date	Assiniboine River							Red River									
	Shellmouth Flow Reduction (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 flow U/S of Floodway	Red River Floodway flow	La Salle flow	Red River flow at James Ave.	Natural Red River flow at James Avenue	Natural water level on Red R. At James Ave (feet)	Recorded Water level on Red R. at James Ave (feet)	Natural water level on Red R. at Floodway Inlet (feet)	Recorded Water level on Red R. at Floodway Inlet (feet)	Below Natural at Floodway Inlet (feet)
	Recorded	Recorded	Recorded	Computed	=1+2+3-4	Rec. & Est.	=5+6	Computed	Recorded	Recorded	Recorded	=1+2-4+9+10	Computed	Recorded	Computed	Recorded	Computed
April 20, 2023 AM	82	7,144	5,859	975	12,109	1,180	14,185	38,971	1,193	3,107	47,924	55,258	18.88	17.08	753.44	751.33	2.11
April 20, 2023 PM	87	9,623	5,708	1,068	14,350	929	16,225	39,518	1,236	3,143	48,062	57,940	19.51	17.12	753.49	752.08	1.41
April 21, 2023 AM	93	13,790	5,452	1,728	17,608	784	19,375	39,884	3,201	3,054	45,974	61,330	20.27	16.59	753.64	753.16	0.48
April 21, 2023 PM	105	15,978	5,263	2,302	19,044	686	20,730	42,025	4,675	2,851	46,151	64,607	20.97	16.64	754.45	753.19	1.26
April 22, 2023 AM	116	5,256	5,890	1,000	10,262	628	11,890	42,751	4,728	2,631	47,173	56,273	19.14	16.90	753.35	753.14	0.21
April 22, 2023 PM	138	4,429	5,532	1,000	9,099	519	10,618	44,196	4,557	2,438	48,127	56,252	19.13	17.15	753.58	753.06	0.52
April 23, 2023 AM	156	4,197	5,795	1,000	9,148	429	10,577	44,455	4,906	2,319	48,092	56,352	19.16	17.14	753.62	753.19	0.44
April 23, 2023 PM	193	4,095	6,308	1,000	9,596	401	10,998	44,552	5,249	2,219	48,232	56,769	19.25	17.18	753.68	753.35	0.33
April 24, 2023 AM	220	4,105	6,622	996	9,950	403	11,349	44,795	5,860	2,116	48,075	57,263	19.37	17.14	753.77	753.64	0.13
April 24, 2023 PM	275	4,042	6,459	954	9,822	414	11,190	45,398	6,172	1,954	48,054	57,588	19.45	17.13	753.91	753.81	0.10
April 25, 2023 AM	313	4,059	7,373	912	10,832	411	12,156	45,266	6,554	1,900	48,397	58,410	19.64	17.22	754.00	753.96	0.04
April 25, 2023 PM	389	4,060	7,673	854	11,268	378	12,500	46,733	7,261	1,951	49,474	60,329	20.07	17.50	754.55	754.32	0.23
April 26, 2023 AM	438	4,012	6,152	812	9,789	364	10,965	47,258	7,747	1,968	47,995	59,379	19.86	17.12	754.53	754.53	0.00
April 26, 2023 PM	536	4,348	6,098	754	10,227	374	11,355	47,281	7,472	1,869	48,151	59,751	19.94	17.16	754.57	754.33	0.24
April 27, 2023 AM	595	4,260	6,612	712	10,754	376	11,842	47,746	7,472	1,671	48,932	60,547	20.12	17.36	754.74	754.40	0.34
April 27, 2023 PM	713	3,913	7,114	654	11,086	384	12,124	48,149	7,778	1,508	49,376	61,126	20.25	17.48	754.87	754.58	0.29
April 28, 2023 AM	781	3,963	7,394	612	11,526	414	12,552	48,626	8,378	1,406	49,462	61,972	20.43	17.50	755.05	754.86	0.20
April 28, 2023 PM	916	4,075	7,645	554	12,081	442	13,077	49,166	8,733	1,325	49,845	63,014	20.65	17.60	755.28	755.00	0.28
April 29, 2023 AM	989	4,297	7,803	516	12,573	410	13,498	49,745	9,210	1,233	49,981	63,961	20.85	17.64	755.50	755.23	0.27
April 29, 2023 PM	1,135	3,886	7,993	500	12,514	398	13,412	50,422	9,654	1,144	50,302	64,478	20.97	17.72	755.67	755.32	0.35
April 30, 2023 AM	1,210	4,074	8,033	496	12,821	386	13,703	51,350	9,899	1,010	50,880	65,568	21.19	17.86	755.96	755.40	0.56
April 30, 2023 PM	1,361	3,426	7,825	454	12,157	366	12,978	52,186	10,262	839	50,954	65,549	21.19	17.88	756.08	755.54	0.55
May 1, 2023 AM	1,434	3,284	7,554	416	11,856	339	12,611	52,640	10,451	703	50,784	65,538	21.19	17.84	756.15	755.64	0.51
May 1, 2023 PM	1,581	3,234	7,327	400	11,742	315	12,458	53,029	10,650	614	50,636	65,701	21.22	17.80	756.22	755.66	0.56
May 2, 2023 AM	1,650	3,175	7,113	396	11,542	299	12,237	53,143	10,599	536	50,493	65,519	21.18	17.77	756.21	755.69	0.52
May 2, 2023 PM	1,787	3,135	6,913	354	11,480	266	12,100	53,231	10,609	472	50,273	65,449	21.18	17.73	756.21	755.70	0.52
May 3, 2023 AM	1,847	3,086	6,777	316	11,394	236	11,946	53,153	10,602	417	49,983	65,201	21.15	17.68	756.16	755.69	0.47
May 3, 2023 PM	1,967	3,096	6,655	300	11,418	218	11,936	53,134	10,665	369	49,711	65,139	21.16	17.63	756.14	755.71	0.44
May 4, 2023 AM	2,016	3,085	6,555	300	11,356	210	11,866	53,138	10,662	322	49,563	65,026	21.16	17.61	756.12	755.71	0.42
May 4, 2023 PM	2,115	3,098	6,491	300	11,404	203	11,907	53,125	10,661	287	49,444	65,018	21.17	17.59	756.11	755.71	0.40

Column =>	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Date	Assiniboine River							Red River									
	Shellmouth Flow Reduction (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 flow U/S of Floodway	Red River Floodway flow	La Salle flow	Red River flow at James Ave.	Natural Red River flow at James Avenue	Natural water level on Red R. At James Ave (feet)	Recorded Water level on Red R. at James Ave (feet)	Natural water level on Red R. at Floodway Inlet (feet)	Recorded Water level on Red R. at Floodway Inlet (feet)	Below Natural at Floodway Inlet (feet)
	Recorded	Recorded	Recorded	Computed	=1+2+3-4	Rec. & Est.	=5+6	Computed	Recorded	Recorded	Recorded	=1+2-4+9+10	Computed	Recorded	Computed	Recorded	Computed
May 5, 2023 AM	2,153	3,086	6,463	300	11,403	197	11,899	52,987	10,589	255	49,312	64,841	2115	17.58	756.06	755.71	0.35
May 5, 2023 PM	2,229	3,119	6,514	300	11,562	191	12,052	52,574	10,358	229	49,149	64,555	2111	17.55	755.94	755.70	0.24
May 6, 2023 AM	2,255	3,107	6,559	298	11,623	183	12,104	52,477	10,473	205	48,950	64,487	2111	17.51	755.91	755.76	0.15
May 6, 2023 PM	2,307	3,021	6,599	277	11,650	157	12,084	52,616	10,572	185	48,984	64,607	2113	17.52	755.95	755.70	0.25
May 7, 2023 AM	2,323	2,974	6,557	258	11,596	133	11,987	52,830	10,525	168	49,163	64,727	2116	17.57	756.01	755.66	0.35
May 7, 2023 PM	2,354	2,850	6,497	250	11,451	119	11,821	52,767	10,456	154	49,082	64,492	2111	17.55	755.96	755.64	0.33
May 8, 2023 AM	2,361	2,908	6,419	248	11,440	117	11,805	52,723	10,412	143	48,990	64,422	2109	17.52	755.95	755.61	0.34
May 8, 2023 PM	2,374	2,849	6,371	227	11,366	116	11,709	52,637	10,331	134	48,926	64,253	2106	17.51	755.91	755.55	0.36
May 9, 2023 AM	2,373	2,855	6,322	208	11,342	114	11,664	52,438	10,206	125	48,794	64,020	2101	17.47	755.85	755.48	0.36
May 9, 2023 PM	2,370	2,809	6,321	200	11,301	113	11,614	52,196	9,950	119	48,799	63,729	20.94	17.47	755.77	755.35	0.41
May 10, 2023 AM	2,363	2,820	6,321	204	11,300	116	11,619	51,918	9,709	111	48,757	63,445	20.88	17.46	755.68	755.27	0.41
May 10, 2023 PM	2,347	2,661	6,347	246	11,109	168	11,523	51,695	9,495	122	48,837	63,094	20.81	17.48	755.59	755.14	0.44
May 11, 2023 AM	2,333	2,621	6,357	280	11,030	191	11,501	51,648	9,345	173	49,023	63,042	20.79	17.53	755.57	755.10	0.47
May 11, 2023 PM	2,305	2,592	6,315	254	10,958	167	11,379	51,087	9,156	130	48,543	62,342	20.64	17.40	755.38	754.98	0.39
May 12, 2023 AM	2,285	2,545	6,229	216	10,843	127	11,186	50,678	8,733	108	48,409	61,755	20.52	17.37	755.23	754.77	0.46
May 12, 2023 PM	2,246	2,618	6,143	200	10,806	108	11,115	50,135	8,287	101	48,201	61,151	20.39	17.31	755.06	754.59	0.46
May 13, 2023 AM	2,221	2,534	6,059	198	10,616	108	10,922	49,437	7,701	88	47,991	60,249	20.19	17.26	754.81	754.38	0.43
May 13, 2023 PM	2,171	2,557	5,966	177	10,517	107	10,802	48,870	7,268	75	47,750	59,569	20.04	17.19	754.62	754.15	0.47
May 14, 2023 AM	2,142	2,526	5,898	158	10,408	107	10,672	48,057	6,539	68	47,590	58,639	19.82	17.15	754.34	753.83	0.51
May 14, 2023 PM	2,084	2,497	5,862	150	10,293	106	10,550	47,152	5,771	69	47,418	57,621	19.59	17.10	754.04	753.51	0.53
May 15, 2023 AM	2,051	2,500	5,839	150	10,239	104	10,493	46,253	5,037	67	47,226	56,663	19.36	17.05	753.74	753.11	0.63
May 15, 2023 PM	1,985	2,494	5,815	150	10,144	84	10,378	45,160	4,133	70	46,996	55,458	19.09	16.99	753.38	752.73	0.64
May 16, 2023 AM	1,949	2,488	5,792	150	10,078	64	10,293	43,982	3,304	67	46,601	54,191	18.78	16.88	752.99	752.43	0.55
May 16, 2023 PM	1,877	2,498	5,792	150	10,017	55	10,222	42,825	2,563	66	46,174	52,962	18.48	16.77	752.60	752.05	0.56
May 17, 2023 AM	1,839	2,488	5,792	150	9,969	54	10,174	41,589	1,818	60	45,676	51,672	18.16	16.64	752.20	751.66	0.54
May 17, 2023 PM	1,764	2,513	5,792	150	9,919	56	10,124	40,319	1,167	59	45,059	50,353	17.84	16.48	751.79	751.28	0.50
May 18, 2023 AM	1,725	2,521	5,792	149	9,888	54	10,092	39,024	514	55	44,411	49,021	17.50	16.30	751.32	750.88	0.44
May 18, 2023 PM	1,648	2,510	5,796	139	9,815	54	10,007	38,024	218	53	43,710	47,946	17.22	16.11	750.94	750.38	0.56
May 19, 2023 AM	1,609	2,499	5,803	129	9,781	54	9,964	37,070	34	48	42,941	46,954	16.96	15.90	750.58	749.93	0.65
May 19, 2023 PM	1,531	2,514	5,802	125	9,722	53	9,900	36,026	0	47	41,929	45,849	16.68	15.63	750.19	749.52	0.67
May 20, 2023 AM	1,493	2,497	5,818	125	9,683	53	9,861	34,881	0	44	40,796	44,661	16.37	15.32	749.76	749.09	0.66
May 20, 2023 PM	1,418	2,504	5,828	125	9,624	53	9,802	33,713	0	44	39,637	43,434	16.03	15.00	749.32	748.66	0.66

Table B-2 - Red River Floodway Inlet Natural Water Level Rating Table

		NATURAL ASSINIBOINE RIVER FLOW CONTRIBUTION (cfs)										
cfs		0	5,000	10,000	15,000	20,000	25,000	30,000	35,000	40,000	45,000	50,000
NATURAL RED RIVER AT JAMES AVENUE FLOW (cfs)	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)