

Figure 5.3 shows that peak flows at Russell and St. Lazare are governed by the Shellmouth Reservoir, and peak flows at Miniota, Virden, Griswold, and Brandon are governed by the Qu'Appelle River.

The results discussed in the Section 5 are under scenario where the Brandon dike closure points are constructed. It is worth to mention that closure of the dike is a necessary step to protect the City of Brandon from a 50-year event. Without the closure, north Brandon would face flooding.

Consequently, this hydraulic model with inflow hydrographs can well represent the peak flow under a 50-year event.

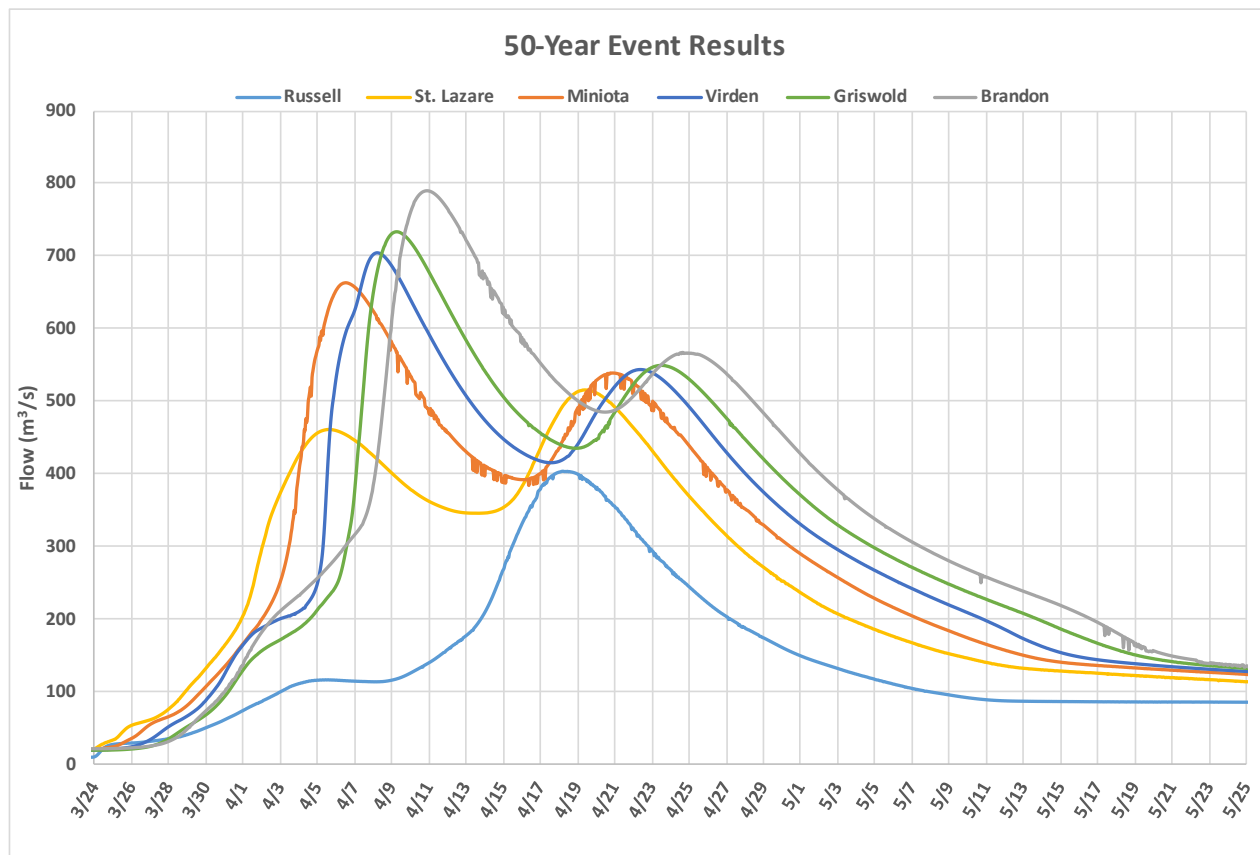


Figure 5.3 - Assiniboine River Dominant 50-Year Event Results

5.2.3 100-Year Event

Target and modelled flow at each compliance location under the 100-year event are shown in Table 5.4. The modelled results are shown to be within the required 5% for flow at five (5) compliance locations, while the result at St. Lazare is lower than the target peak flow.

Table 5.4 - Assiniboine River Dominant 100-Year Event Results

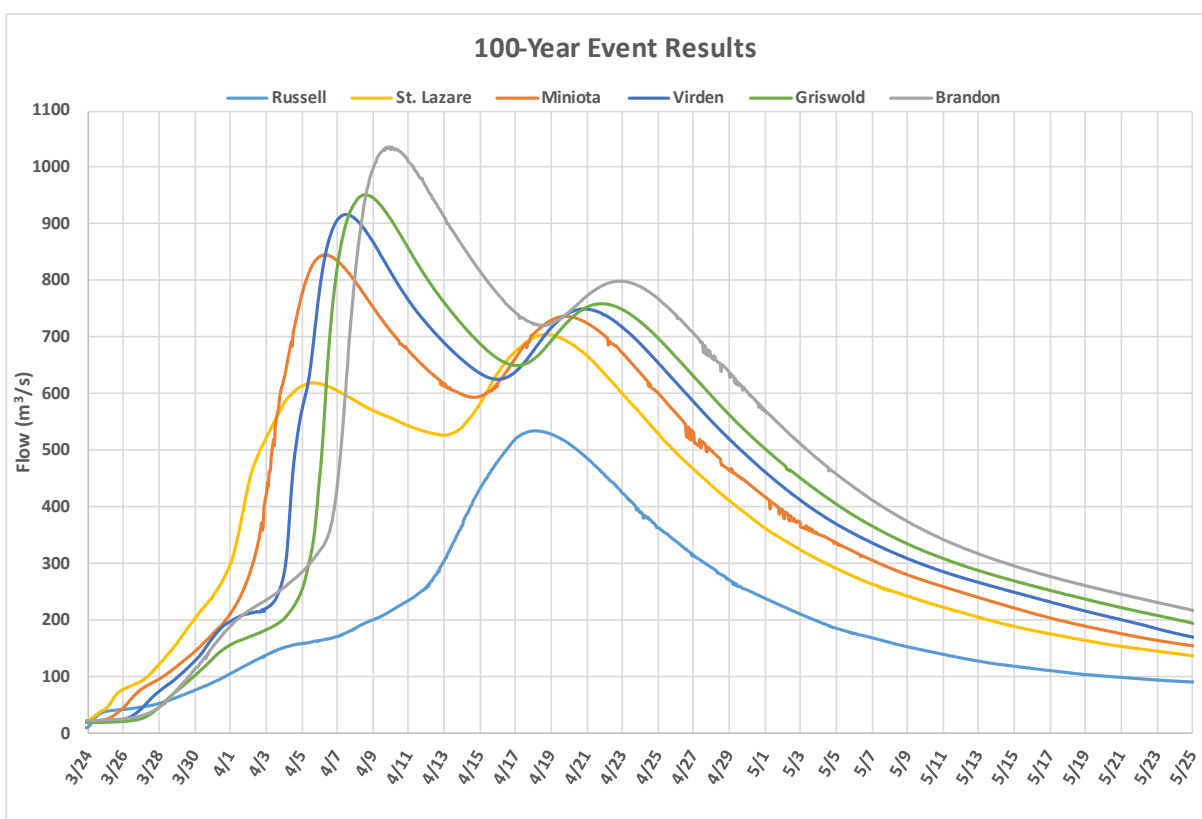
	Russell	St. Lazare	Miniota	Virden	Griswold	Brandon
Target Peak Flow (m³/s)	521.0	778.7	835.3	914.6	965.6	1025.1
Modelled Peak Flow (m³/s)	534.7	705.1	845.4	916.6	951.3	1036.6
Difference	+ 13.7 (2.6%)	- 73.6 (9.5%)	+ 10.1 (1.2%)	+ 2.0 (0.2%)	- 14.3 (1.5%)	+ 11.5 (1.1%)
Modelled Peak Water Surface Elevation (m)	412.79	393.34	380.43	372.17	367.35	363.82

Modelled flow hydrographs at six (6) compliance locations are shown in Figure 5.4. Two (2) peaks appear in hydrographs downstream of St. Lazare. The first peak is caused by flow from the Qu'Appelle River, and the second peak is caused by the Shellmouth Reservoir.

Figure 5.4 shows that peak flows at Russell and St. Lazare are governed by the Shellmouth Reservoir, and peak flows at Miniota, Virden, Griswold, and Brandon are governed by the Qu'Appelle River.

The results discussed in the Section 5 are under scenario where the Brandon dike closure points are constructed. It is worth to mention that closure of the dike is a necessary step to protect the City of Brandon from a 100-year event. Without the closure, north Brandon would face significant flooding.

Consequently, this hydraulic model with inflow hydrographs can well represent the peak flow under a 100-year event.

**Figure 5.4 - Assiniboine River Dominant 100-Year Event Results**

5.2.4 300-Year Event

Target and modelled flow at each compliance location under the 300-year event are shown in Table 5.5. The modelled results are shown to be within the required 5% for flow at St. Lazare, Virden, and Griswold, while the result at Russell, Miniota, and Brandon is slightly higher than the target peak flow.

Table 5.5 - Assiniboine River Dominant 300-Year Event Results

	Russell	St. Lazare	Miniota	Virden	Griswold	Brandon
Target Peak Flow (m³/s)	756.1	1138.3	1178.0	1302.6	1362.0	1438.5
Modelled Peak Flow (m³/s)	797.0	1104.3	1246.8	1347.0	1391.8	1515.5
Difference	+ 41.0 (5.4%)	- 34.0 (3.0%)	+ 68.8 (5.8%)	+ 44.4 (3.4%)	+ 29.8 (2.2%)	+ 77.0 (5.4%)
Modelled Peak Water Surface Elevation (m)	413.67	388.1	380.92	372.89	368.15	364.60

Modelled flow hydrographs at six (6) compliance locations are shown in Figure 5.5. Two (2) peaks appear in hydrographs downstream of St. Lazare. The first peak is caused by flow from the Qu'Appelle River, and the second peak is caused by the Shellmouth Reservoir.

Figure 5.5 shows that peak flows at Russell and St. Lazare are governed by the Shellmouth Reservoir, and peak flows at Miniota, Virden, Griswold, and Brandon are governed by the Qu'Appelle River.

Consequently, this hydraulic model with inflow hydrographs can well represent the peak flow under a 300-year event.

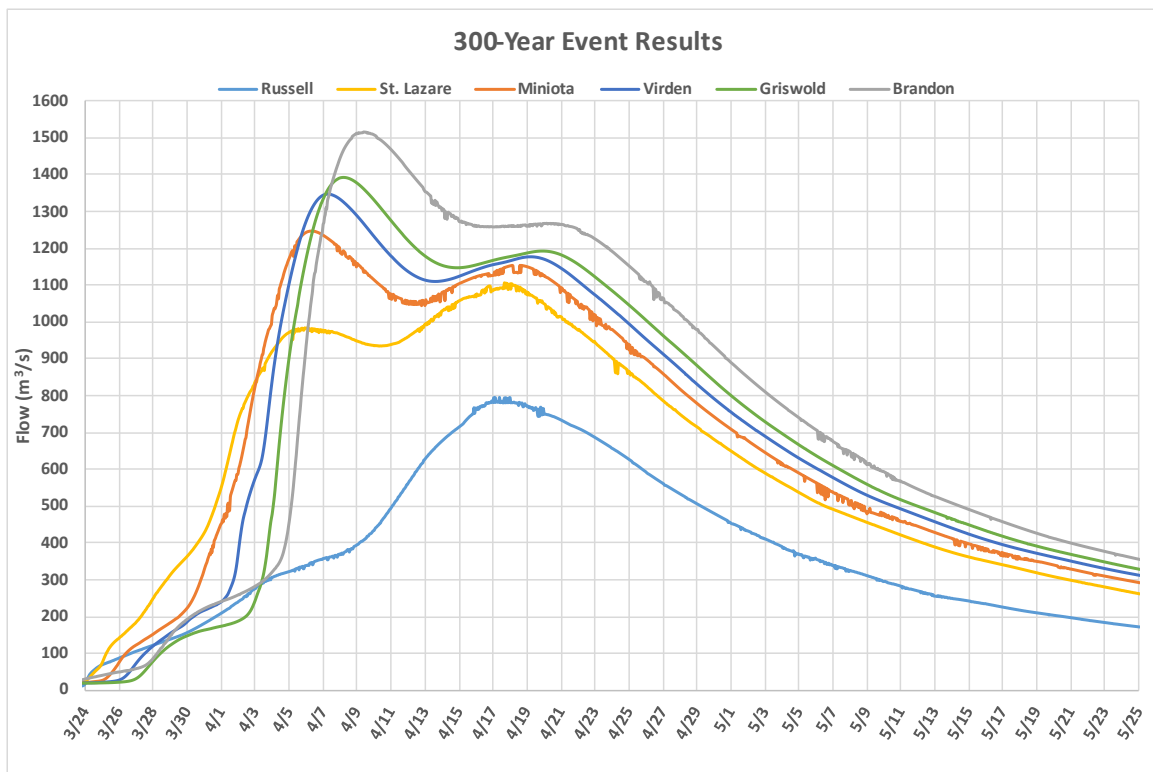


Figure 5.5 - Assiniboine River Dominant 300-Year Event Results

5.2.5 500-Year Event

Target and modelled flow at each compliance location under the 500-year event are shown in Table 5.6. The modelled results are shown to be within the required 5% for flow at St. Lazare, Virden, and Griswold, while the result at Russell, Miniota, and Brandon is slightly higher than the target peak flow.

Table 5.6 - Assiniboine River Dominant 500-Year Event Results

	Russell	St. Lazare	Miniota	Virden	Griswold	Brandon
Target Peak Flow (m³/s)	860.8	1305.4	1359.2	1515.0	1585.7	1673.5
Modelled Peak Flow (m³/s)	913.4	1295.2	1459.0	1575.2	1625.2	1764.3
Difference	+ 52.6 (6.1%)	- 10.2 (0.8%)	+ 99.8 (7.3%)	+ 60.3 (4.0%)	+ 39.4 (2.5%)	+ 90.8 (5.4%)
Modelled Peak Water Surface Elevation (m)	414.01	394.31	381.15	373.26	368.55	364.96

Modelled flow hydrographs at six (6) compliance locations are shown in Figure 5.6. Two (2) peaks appear in hydrographs downstream of St. Lazare. The first peak is caused by flow from the Qu'Appelle River, and the second peak is caused by the Shellmouth Reservoir.

Figure 5.6 shows that peak flows at Russell and St. Lazare are governed by the Shellmouth Reservoir, and peak flows at Miniota, Virden, Griswold, and Brandon are governed by the Qu'Appelle River.

Consequently, this hydraulic model with inflow hydrographs can well represent the peak flow under a 500-year event.

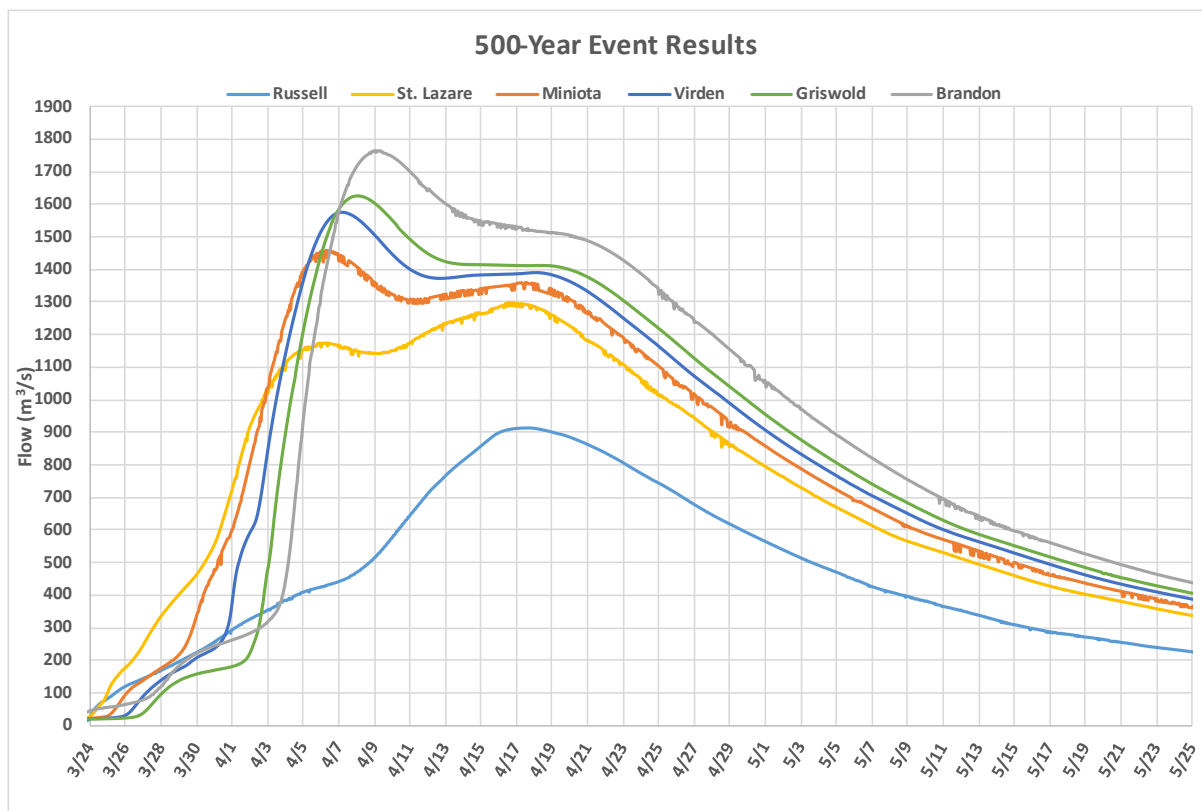


Figure 5.6 - Assiniboine River Dominant 500-Year Event Results

5.3 Qu'Appelle River Dominant 200-Year Event Results

Several scenarios with varying Shellmouth peak flows and downstream boundary conditions were evaluated to simulate the 200-year (0.5%) Qu'Appelle River dominant flow condition and to explore the backwater effect of the Assiniboine River on the Qu'Appelle River.

Water levels were checked at three (3) selected locations, ranging from the middle of the Saskatchewan-Manitoba border to St. Lazare to the downstream of the Qu'Appelle River and the Assiniboine River junction, as shown in Figure 5.7.

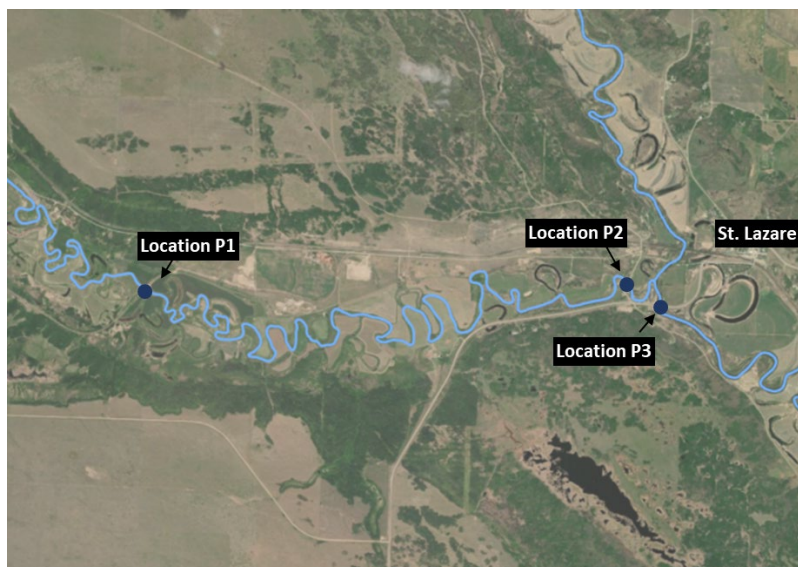


Figure 5.7 - Compliance Locations on the Qu'Appelle River

Six (6) scenarios are evaluated, as described in Table 5.7.

Table 5.7 - Scenarios for the Qu'Appelle River Dominant Events

Version	Shellmouth Reservoir Peak Flow (m ³ /s)	Downstream Boundary Condition	
		Catchment Reference	Peak Day Timing Reference
V12	671	2017 Event	2017 Event
V15	400	2017 Event	2017 Event
V16	400	2005 Event	2017 Event
V17	400	2005 Event	2005 Event
V18	400	2005 Event	2005 Event with Adjustments
V19	Constant Flow of 85	2005 Event	2005 Event

Water level results for the six (6) scenarios are shown in Table 5.8. The peak flow of the Shellmouth and downstream hydrographs have minimal impact on the Qu'Appelle River water level upstream of location P1. However, altering the Shellmouth Reservoir's peak flow influences the water level near the Qu'Appelle River and Assiniboine River junction. Changes to the downstream hydrographs' peak flow and timing do not significantly impact the Qu'Appelle River water level.

Table 5.8 - Qu'Appelle River Water Levels under Various Events

Location	Qu'Appelle River Water Level (m)					
	V12	V15	V16	V17	V18	V19
P1: Middle of SK-MB Border and St. Lazare	396.32	396.32	396.29	396.29	396.31	396.30
P2: Upstream of the Qu'Appelle River and the Assiniboine River junction	394.31	394.20	394.16	394.14	394.16	394.21
P3: Downstream of the Qu'Appelle River and the Assiniboine River junction	393.99	393.80	393.75	393.72	393.75	393.82

Consequently, the V19 setup was used as the Qu'Appelle River dominant 200-year (0.5%) event for flood mapping purposes.

Table 5.8 and Table 5.9 show the V19 water levels and peak flows under the Qu'Appelle River dominant 200-year event. The target peak flows and modelled peak flows were assessed at five (5) compliance locations, except for Russell, which is not influenced by the Qu'Appelle River. The modelled results are within the required 5% for flows at St. Lazare, Virden, and Griswold, while the results at Miniota and Brandon slightly exceed the target peak flows.

Modelled flow hydrographs at five (5) compliance locations are shown in Figure 5.8. One (1) peak caused by flow from the Qu'Appelle River appears in hydrographs. Peak flows are governed by the Qu'Appelle River.

Consequently, this hydraulic model with developed inflow hydrographs can well represent the peak flow under a Qu'Appelle River dominant 200-year event. However, it should be noted that the modelled 1:200 year values at the gauge locations shown in Table 5.9 were not developed for producing the Assiniboine River flood maps, but to confirm that the downstream boundary along the Assiniboine River as representative when producing the 1:200 year flood maps along the Qu'Appelle River. The Flood Maps (see Section 6 for further discussion) developed for the 1:200 year flood maps along the Assiniboine River used the Assiniboine River Dominant flows as described in Section 5.1.

Table 5.9 - Qu'Appelle River Dominant 200-Year Event Results

	St. Lazare	Miniota	Virden	Griswold	Brandon
Target Peak Flow (m³/s)	996.8	1044.9	1141.2	1197.8	1262.9
Modelled Peak Flow (m³/s)	970.1	1137.1	1196.9	1229.4	1329.2
Difference	- 26.7 (2.7%)	+ 92.2 (8.8%)	+ 55.7 (4.9%)	+ 31.6 (2.7%)	+ 66.3 (5.3%)
Modelled Peak Water Surface Elevation (m)	393.82	380.80	372.64	367.86	364.31

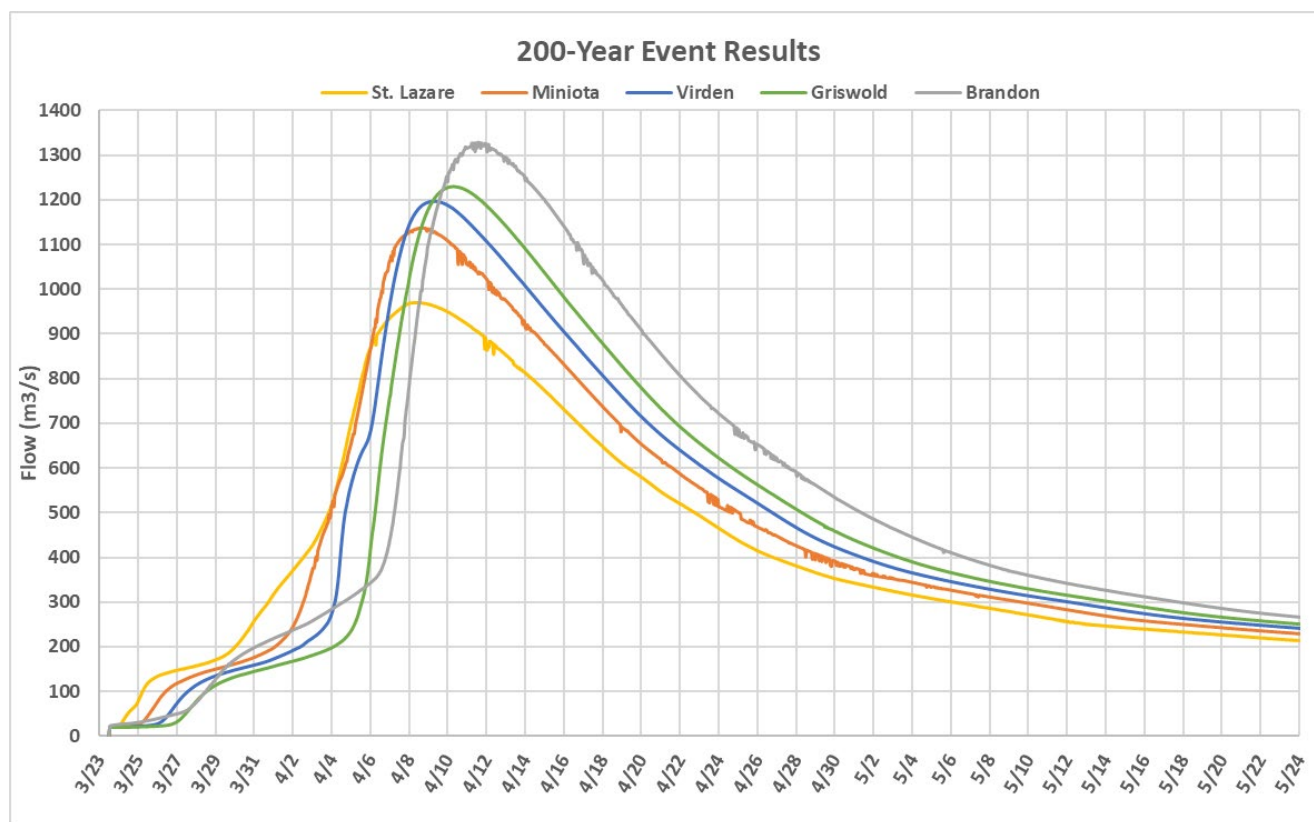


Figure 5.8 - Qu'Appelle River Dominant 200-Year Event Results

5.4 Results Comparison of the 200-Year Assiniboine River and Qu'Appelle River Dominant Events

The 200-year Qu'Appelle River dominant scenario results in higher peak flows at downstream locations compared to the 200-year Assiniboine River dominant scenario, as shown in Table 5.11. This occurs despite the Assiniboine River dominant scenario having higher inflow data (Table 5.10).

The difference is due to the flow control dynamics in each scenario: in the Qu'Appelle River dominant scenario, peak flows downstream are consistently governed by the Qu'Appelle River's peak, along with a steady flow of 85 m³/s from the Shellmouth Dam. In contrast, under the Assiniboine River dominant scenario, only the St. Lazare location is influenced by the peak flow from the Shellmouth Dam with minor flow contributions from the Qu'Appelle River. All other downstream locations are still primarily governed by the Qu'Appelle River, which has a lower peak flow under the Assiniboine River dominant event compared to its peak under the Qu'Appelle River dominant event.

Table 5.10 - Assiniboine River and Qu'Appelle River Dominant Events Inflow Peak Flows

	Shellmouth Dam	Qu'Appelle River
200-Year Assiniboine River Dominant Event Inflow Peak Flow (m ³ /s)	671	430
200-Year Qu'Appelle River Dominant Event Inflow Peak Flow (m ³ /s)	85	665

Table 5.11 - Assiniboine River and Qu'Appelle River Dominant Events Results Comparison

	St. Lazare	Miniota	Virden	Griswold	Brandon
Target Peak Flow (m3/s)	996.8	1044.9	1141.2	1197.8	1262.9
200-Year Qu'Appelle River Dominant Event Modelled Peak Flow (m3/s)	970.1	1137.1	1196.9	1229.4	1329.2
200-Year Assiniboine River Dominant Event Modelled Peak Flow (m3/s)	949.2	1062.0	1156.0	1200.1	1308.3
Flow Difference Between Two Scenarios (m3/s)	20.9	75.1	40.9	29.3	20.9
200-Year Qu'Appelle River Dominant Event Modelled Peak Water Surface Elevation (m)	393.82	380.80	372.64	367.86	364.31
200-Year Assiniboine River Dominant Event Modelled Peak Water Surface Elevation (m)	393.77	380.71	372.58	367.81	364.29
Water Surface Elevation Difference Between Two Scenarios (m)	0.05	0.09	0.06	0.05	0.02

6. Flood Mapping

Flood maps for the Assiniboine River dominant 200-year (0.5%) event were created using exported results from the HEC-RAS RAS Mapper and ArcGIS Pro.

Thirty-seven (37) flood maps are generated and shown in Appendix D, including one (1) index map, thirty-two (32) rural area maps with a scale of 1:10,000 along the Assiniboine River from the Shellmouth Reservoir to downstream of Brandon, and four (4) urban area maps with a scale of 1:5,000 focusing on St. Lazare and Brandon.

Flood maps for the Qu'Appelle River dominant 200-year (0.5%) event were also generated using exported results from the HEC-RAS RAS Mapper and ArcGIS Pro.

Three (3) flood maps are generated and shown in Appendix E, including one (1) index map and two (2) rural area maps with a scale of 1:10,000 along the Qu'Appelle River from the Saskatchewan-Manitoba border to St. Lazare.

7. Conclusion

AECOM undertook the hydrodynamic modelling study for the Assiniboine River from Shellmouth Dam to Brandon to develop a two-dimensional (2D) model for various flood scenarios.

The 2D hydraulic model uses a terrain surface which is a combination of four (4) data sources covering the Assiniboine River from the Shellmouth Dam to downstream of the City of Brandon and the Qu'Appelle River from eastern Saskatchewan to St. Lazare. Thirty-three (33) inflow boundaries, including two (2) main flows from Shellmouth Reservoir and Qu'Appelle River and thirty-one (31) ungauged tributaries, are added to the model as internal and external boundaries. Twenty-seven (27) hydraulic structures, including twenty-six (26) bridges and one (1) culvert, are added to the model.

The hydraulic model is calibrated and validated against six (6) historical events (1995, 1976, 2005, 2011, 2014, 2017) to reproduce the published rating curves, peak flow, and peak water level at the three (3) compliance locations (Russell, Miniota, Brandon). Calibration was accomplished by modifying the Manning's roughness assigned to each land use category. The calibration events input hydrographs are generated by three (3) approaches.

The modelled rating curve at Russell and Brandon were both found to match the published rating curve particularly well, while the curve at Miniota did not provide as good of a match, which might be affected by changes within the river channel itself, potentially through riverbed erosion since the rating curve development in 2017.

Modelled flows and peak water levels match well with the recorded data for the 1976 and 1995 events. Modelled water levels match well but miss the 5% for peak flow for the 2005 event. As for the 2011, 2014, and 2017 events, almost all compliance locations satisfy or are very near to the criteria, except Miniota in the 2011 event.

Six (6) frequency flow scenarios under the Assiniboine River dominant condition and one (1) 200-year (0.5%) event under the Qu'Appelle River dominant condition are run using the calibrated model and inflows established through unit hydrographs, peak flows, and time of rise relationships.

The hydraulic model with inflow hydrographs can well represent peak flows under the Assiniboine River dominant 200-year event, with the modelled flow matching well with the target flows at all six (6) compliance locations. The hydraulic model with inflow hydrographs is more suitable for larger events than for the 20-year event. Almost all compliance locations satisfy the 5% flow criteria under the 50-year and 100-year events, except for St. Lazare, which shows lower flow. Modelled flows satisfy or are very near to the 5% criteria under the 300-year and 500-year events.

The hydraulic model with inflow hydrographs can well represent peak flows under the Qu'Appelle River dominant 200-year event, with the modelled flow matching well with the target flows at three (3) compliance locations and slightly exceeding the 5% criteria at two (2) compliance locations.

Flood maps for the Assiniboine River dominant 200-year (0.5%) event and Qu'Appelle River dominant 200-year (0.5%) event are created using exported results from the HEC-RAS RAS Mapper and ArcGIS. Thirty-seven (37) Assiniboine River dominant flood maps are generated, including one (1) index map, thirty-two (32) rural area maps with a scale of 1:10,000 along the Assiniboine River from Shellmouth Reservoir to downstream of Brandon, and four (4) urban area maps with a scale of 1:5,000 covering two (2) communities of St. Lazare and Brandon. Three (3) Qu'Appelle River dominant flood maps are generated, including one (1) index map and two (2) rural area maps with a scale of 1:10,000 along the Qu'Appelle River from the Saskatchewan-Manitoba border to St. Lazare. Consequently, this 2D hydraulic model with developed inflow hydrographs is more suitable for frequency flow events larger than the 20-year and can well represent peak flows and the flood extent under the 200-year event.

Appendix A - Unit Hydrographs and Calibration Results

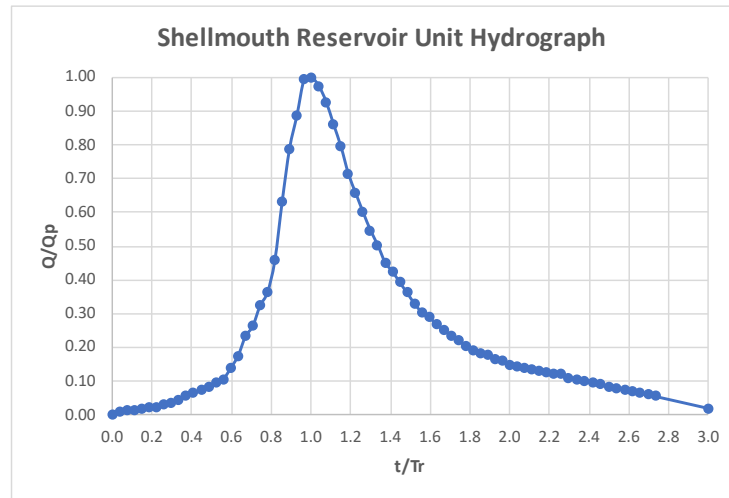
A decorative graphic consisting of a thick, dark green wave-like shape that starts from the left edge of the page, dips slightly, and then rises to curve upwards towards the right edge, creating a modern, flowing background element.

Unit Hydrographs and Calibration Results

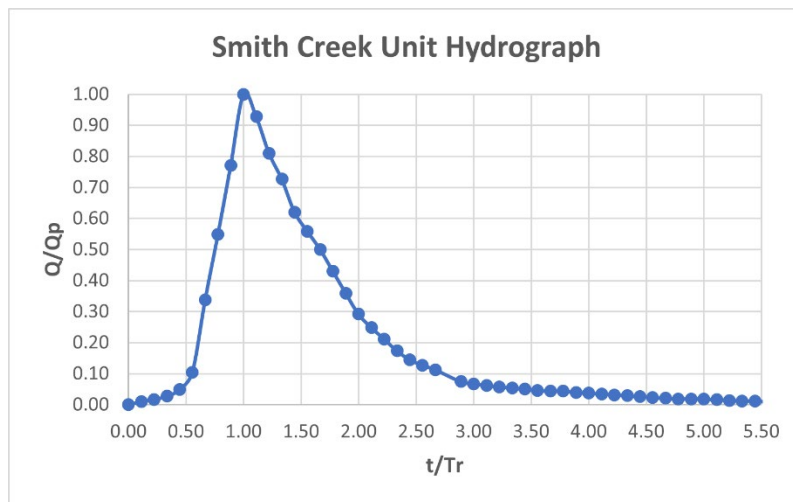
This appendix shows the unit hydrographs of twelve (12) catchments and calibration results of eleven (11) catchments comparing the recorded hydrographs and synthetic hydrographs generated from unit hydrographs, as the Shellmouth Reservoir's hydrograph is analyzed in the main body.

Unit Hydrographs

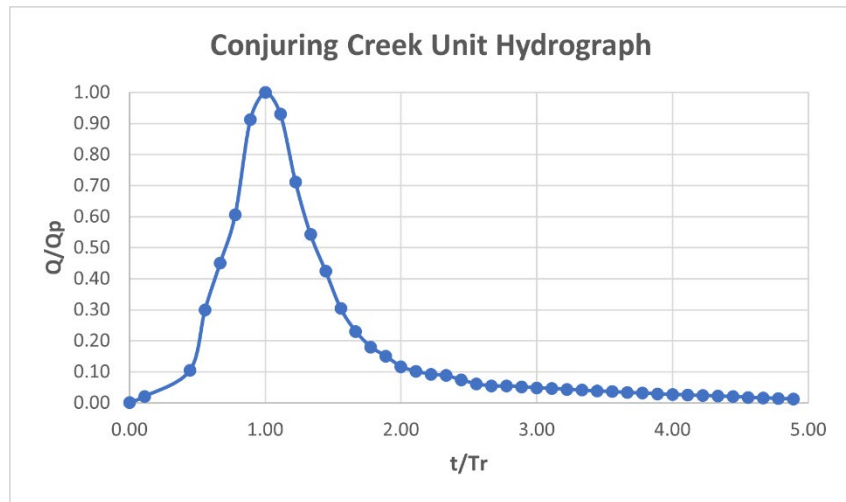
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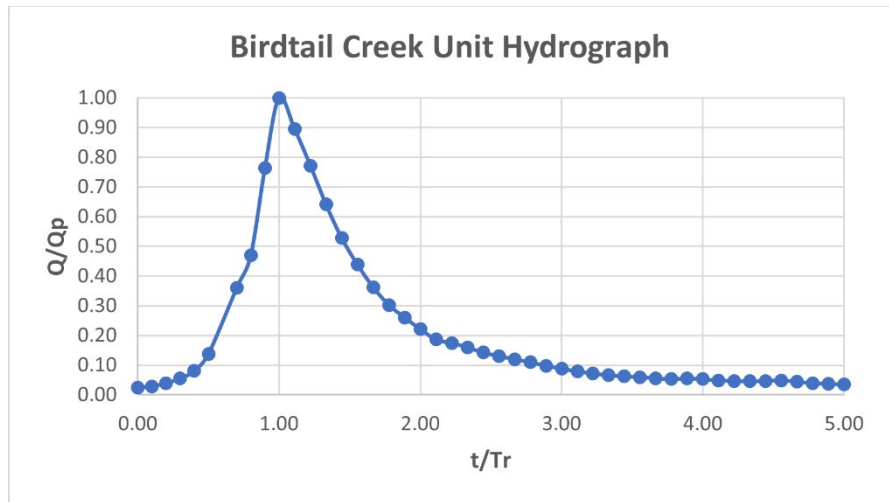
2. Smith Creek



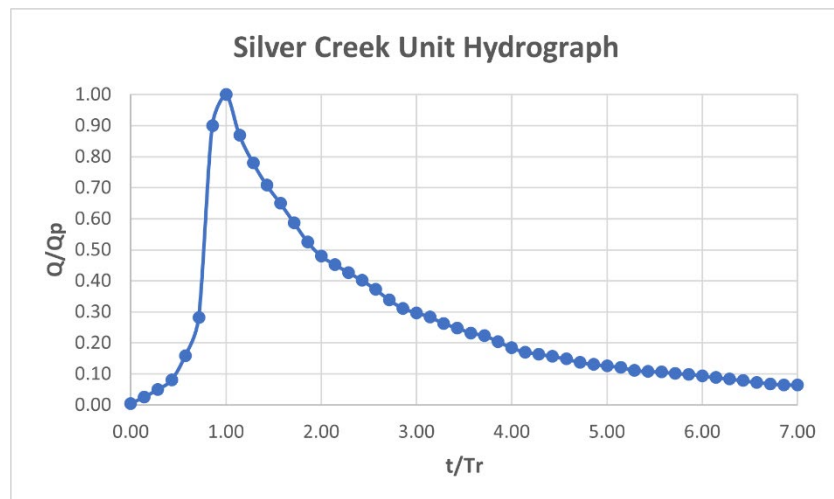
3. Conjuring Creek



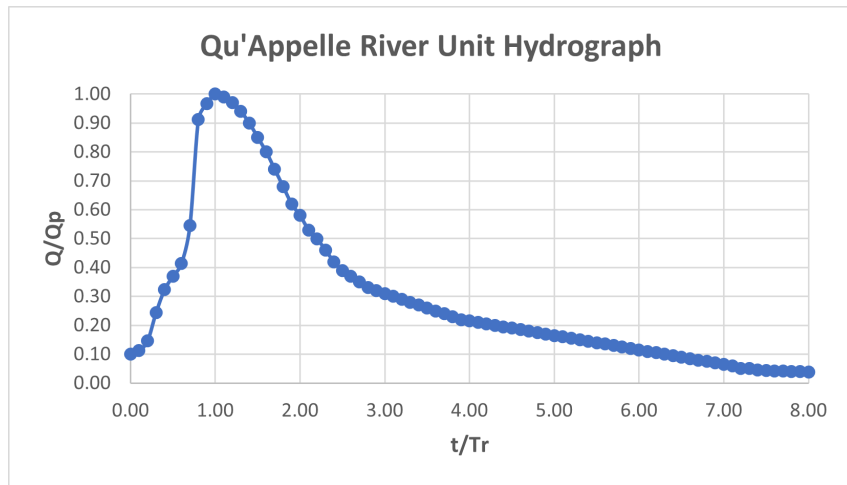
4. Birdtail Creek



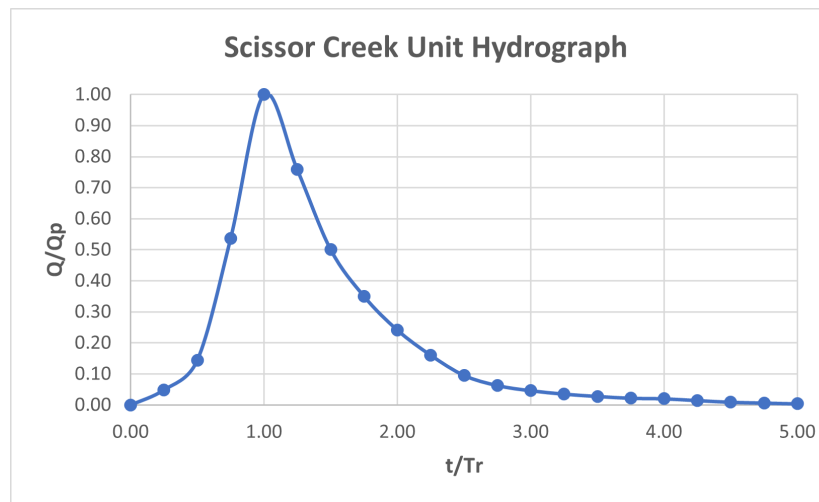
5. Silver Creek



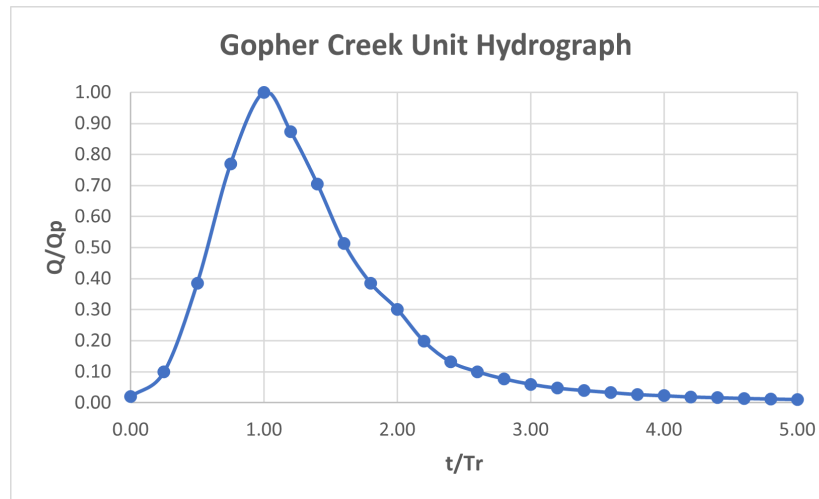
6. Qu'Appelle River



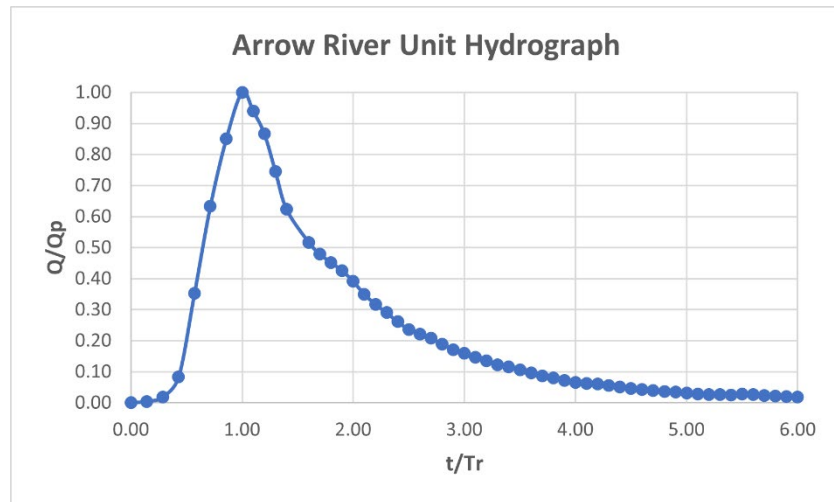
7. Scissor Creek



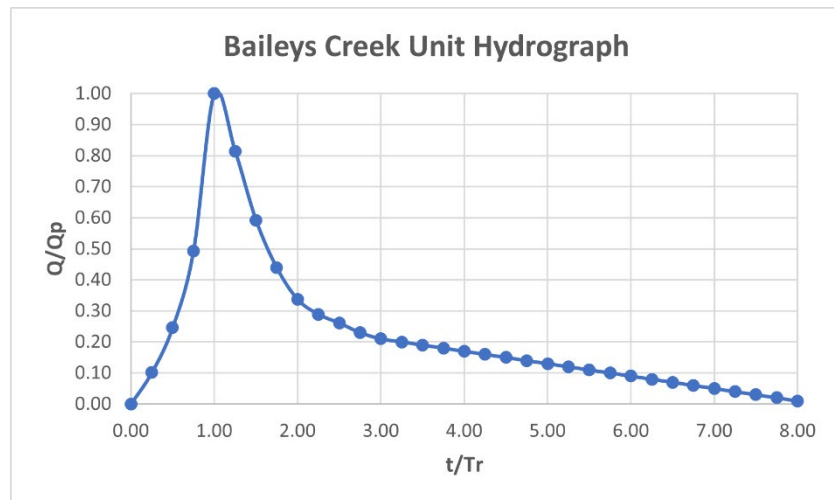
8. Gopher Creek



9. Arrow River



10. Baileys Creek



11. Oak River

