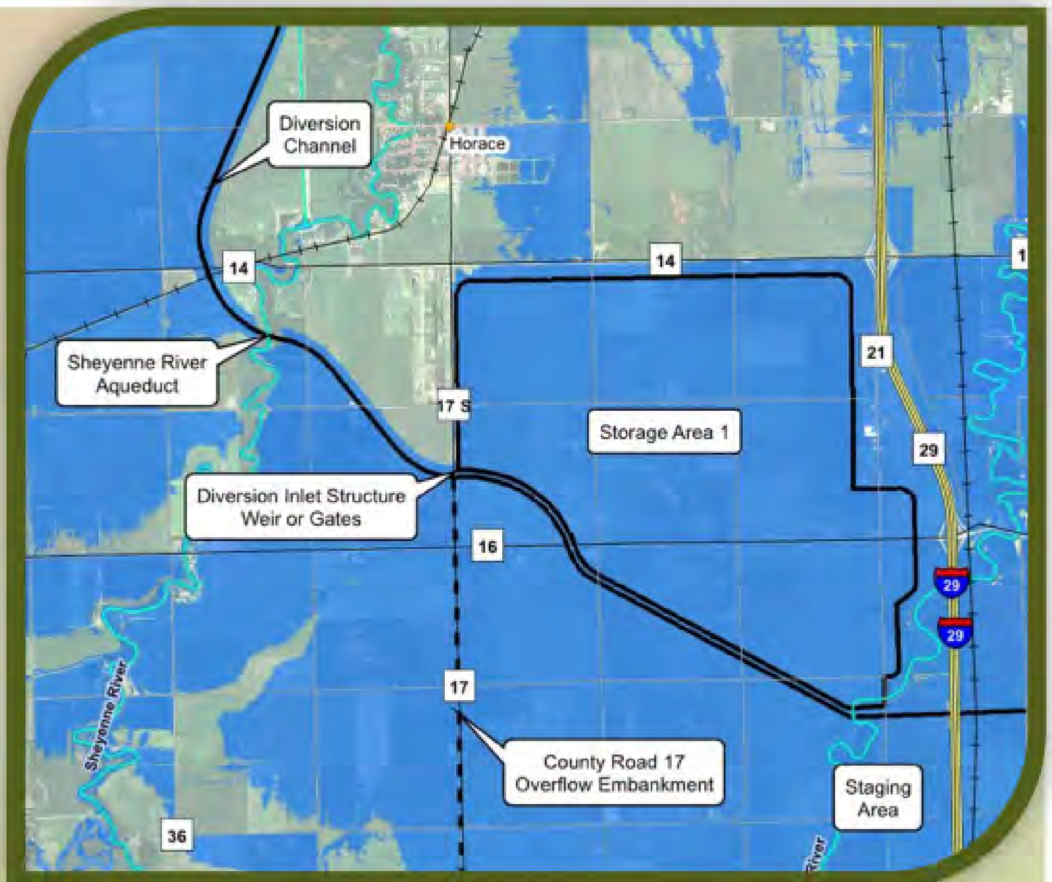
FINAL TECHNICAL MEMORANDUM

DIVERSION INLET GATE ANALYSIS

Final – January 10, 2013



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1 BACKGROUND AND OVERVIEW

The Fargo-Moorhead Area Diversion (FM Diversion) Project was developed as part of a feasibility study conducted by the U.S. Army Corps of Engineers to provide flood protection for the Fargo-Moorhead area. It is presented in the Integrated Final Feasibility Report and the Final Environmental Impact Statement (FR/FEIS) dated July 2011. The project consists of a 20,000 cfs diversion channel with upstream staging and storage and was referred to as the Locally Preferred Plan (LPP, a.k.a. North Dakota Diversion) in the FR/FEIS. This plan is now known as the Federally Recommended Plan (FRP).

The proposed FM Diversion begins approximately 4 miles south (upstream) of the confluence of the Red and Wild Rice Rivers and extends west around the cities of Horace, Fargo, West Fargo, and Harwood. The 36 mile long diversion channel crosses several rivers. The project includes gated control structures at the Red and Wild Rice Rivers. It has aqueducts at the Sheyenne and Maple Rivers that allow low tributary flows to enter the interior of the project area while larger flows would be passed into the diversion. The diversion channel also crosses the Rush and Lower Rush Rivers as well as several drains. The diversion channel ultimately discharges into the Red River downstream from the Red River's confluence with the Sheyenne River near the city of Georgetown, MN.

1.1 PURPOSE OF STUDY

Water entering the proposed FRP diversion channel is currently controlled with a concrete weir structure. **Figure 1** displays the project area including the staging area, Storage Area 1, diversion channel and inlet, and the County Road 17 Overflow Embankment. The FRP diversion inlet weir is approximately 130 feet long and is set at an elevation of 907.0 ft. This weir design prevents water from flood events less than a 28-percent chance event (3.6-year) from entering the diversion channel, while providing sufficient discharge capacity to effectively operate the diversion system during larger events. The passive weir provides limited flexibility for project operation. Therefore, the purpose of this study is to determine if a gated diversion inlet structure would provide benefits to the FRP such as increased operational flexibility and reduced staging elevations and durations.

2 MODELING

The Final "FM Diversion Post-Feasibility Southern Alignment Analysis: VE-13, North of Wild Rice River, South of Oxbow" Technical Memorandum was submitted on 10-October-2012. The baseline unsteady HEC-RAS model used in that analysis was also used in this analysis. The evaluations pertaining to this report were compared to the Phase 6 FRP with a diversion inlet weir. For comparisons in this report, the current Phase 6 FRP will be referred to as "FRP - Inlet Weir" and the plan associated with this analysis will be referred to as "FRP - Inlet Gate". The FRP project design utilized the 10-, 2-, 1-, and 0.2-percent chance flood events, commonly referred to as the 10-, 50-, 100-, and 500-year flood events, respectively. The Probable Maximum Flood (PMF) event and the 0.5 PMF event were used to size the staging area and Storage Area 1 embankments. The 0.5 PMF event has been assumed to be approximately equivalent to the Standard Project Flood (SPF). For this analysis, the 0.5 PMF and SPF are referred to as the 103k cfs event. **Table 1** presents the discharge for each of these events at USGS Gage 05054000, Red River at Fargo (Fargo Gage).

Table 1: USGS Gage 05054000 Red River at Fargo, ND - Event Based Discharges

Event	10%	2%	1%	0.2%	103k cfs (0.5 PMF)	PMF
Discharge (cfs)	17,000	29,300	34,700	61,400	103,000	205,000

3 DESIGN CONSIDERATIONS

The diversion channel provides flood risk reduction from flood events on the Red, Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers for properties in the Fargo-Moorhead area. Consequently, these rivers contribute to the with-project downstream impacts. For the FRP, the impacts have generally been a result of reduced natural floodplain storage in the Flood Damage Reduction Area (FDRA), and a shorter overall travel time for the with-project hydrograph to the downstream end of the project. This results in a with-project downstream hydrograph that peaks earlier and higher than the existing condition hydrograph. The upstream staging area provides a temporary flow reduction to the downstream reaches, through staging and storage, resulting in a lower peak discharge. However, the earlier timing still exists as the with-project hydrograph aligns with existing downstream tributaries resulting in minor, but measurable, impacts at some downstream locations.

The diversion system, including diversion channel and staging area, will operate differently for each flood event. The 10-, 2-, and 1-percent chance events were designed to allow discharges into the FDRA that produce a stage at the Fargo Gage of approximately 30 to 31 feet. The 0.2-percent chance event would be allowed to produce a stage of approximately 40 feet at the Fargo Gage. All four of these design events were evaluated to allow downstream impacts equivalent to those documented in the FR/FEIS. It was assumed that during the 103k cfs event, the Red River Control Structure (RRCS) and the Wild Rice River Control Structure (WRRCS) would regulate FDRA discharges to produce 40 feet at the Fargo Gage while leaving the diversion inlet gate wide open. The County Road 17 Overflow Embankment would also be used for the 103k cfs event. The County Road 17 Overflow Embankment elevation is based on the maximum of the 1-percent and 0.2-percent chance events' staging elevations. Based on this criterion, it is to be set at elevation 923.0 for the FRP – Inlet Weir plan. Even though the FRP-Inlet Gate Plan produces a lower 1-percent chance and 0.2-percent chance event staging elevations (Max = 922.2), the County Road 17 Overflow Embankment was assumed to remain at 923.0 to be consistent with the FRP – Inlet Weir Plan. The PMF event RRCS and WRRCS were designed to allow controlled discharges that produce a stage of approximately 40 feet at the Fargo Gage. PMF discharges through the diversion inlet and discharges over the County Road 17 Overflow Embankment occur in a similar fashion as with the 103k cfs operation. However, when the staging area reaches a given elevation (ex. 924.0), the RRCS and WRRCS would be opened further to allow additional flow as needed to protect the embankment structures.

Early in the FR/FEIS, two weir structures on the diversion channel near the WRRCS were included in the project. The crest of the west weir was set one foot higher than the east weir and served as the control weir to limit how much water could enter the diversion. The crest elevations for these weirs were originally set during Phase 2 when the east weir was set at the Red River 20-percent chance (5-year) flood elevation and the west weir was set at the Red River 20-percent chance flood elevation plus one foot. This ensured that the diversion was not put into use prior to exceeding a Phase 2 hydrology 20-percent chance event on the Red River. The flow that was associated with the 20-percent chance event was 9,600 cfs downstream of the confluence of the Red and Wild Rice Rivers. This flow level was established as a minimum flow to maintain in the rivers for environmental considerations. The hydrology was updated during Phase 3. With this, rather than establishing minimum flows based on local flow events, the 9,600 cfs flow was maintained as the benchmark. This flow is equal to approximately a 28-percent chance (3.6-year) flow on the Red River downstream of the Wild Rice River confluence with the Phase 3.1 hydrology. Based on this target flow, the east weir was left at the 28-percent chance flood elevation and the west weir was set one foot higher. With Phase 4, the targeted Red River flow through Fargo-Moorhead remained at 9,600 cfs and the crests of the weirs were adjusted based on the elevation associated with the 9,600 cfs discharge in the unsteady flow model. The crest elevation of the east weir at the Wild Rice River was lowered to 902.25, while the west weir was set one foot higher at an elevation of 903.25 that was 90' wide. Following the FR/FEIS analyses, the weir structure elevations and widths were modified based on updated unsteady flow modeling. The crest elevation of the west weir is set at 907.0 and is 130' wide.

3.1 FRP DIVERSION INLET WEIR OPERATION

3.1.1 FRP – INLET WEIR OPERATION OVERVIEW

The current operation (FRP - Inlet Weir) requires the RRCS and the WRRCS to restrict flow through the FDRA during the peak of the flood to offset the uncontrolled discharges flowing through the diversion channel from the Red, Wild Rice, Sheyenne, Maple, Rush and Lower Rush Rivers. This "de-coupling" offset effect reduces the downstream discharges, but in turn requires an upstream staging and storage component. Although the final design will include operation of both the RRCS and the WRRCS, modeling operations used for the FR/FEIS and for this analysis have been simplified to include releases only from the RRCS. This assumption was considered to be acceptable since the same staging area inundates both rivers' control structures equally.

During a flood, the gates on the Red and Wild Rice Rivers would restrict water entering the FDRA until the Wild Rice River water surface elevation at the diversion reaches an elevation of 907.0 ft. At this elevation, the diversion inlet weir would begin to pass water into the diversion channel. The peak of this diversion channel hydrograph would combine with the flows originating from the Sheyenne, Maple, Rush, and Lower Rush Rivers. The combined diversion flows would then be mitigated by the staging and storage area and the restriction that the Red and Wild Rice River gates have created. The Red and Wild Rice River gates would remain at a reduced release until the diversion hydrograph begins to recede. Then, the Red and Wild Rice River discharges would be increased to match the design through-town discharge. The FRP - Inlet Weir operation at the RRCS is presented in blue on **Figure 2**. It shows the discharges and stages at the RRCS for the FRP – Inlet Weir, FRP – Inlet Gate, and Existing Conditions alternatives. **Figure 3** displays the releases from the RRCS, how the flows attenuate and combine with local inflows throughout the FDRA, and the discharges on the Red River immediately upstream of the diversion outlet. It also shows the diversion inlet flows, outlet flows, and inflows to the diversion from the Sheyenne, Maple, Rush and Lower Rush Rivers. Lastly, it summarizes the with-project FRP – Inlet Weir hydrograph compared to the Existing Condition hydrograph downstream of the project area at Georgetown, MN.

3.1.2 FRP – INLET WEIR IMPACTS

The shape of the Red River hydrograph at Georgetown provides a good understanding of how the water passes through the project area and how the downstream impacts develop. In comparison to Existing Conditions, the FRP – Inlet Weir hydrograph is higher on the rising limb than Existing Conditions. This increase, although not at the peak at Georgetown, slowly transfers to a position later in the hydrograph as more tributaries enter the system and the flood wave moves downstream. These impacts become magnified toward Halstad, Thompson, and Grand Forks where the impact discharges transfer from the rising limb to the peak. The increase in discharge would pass to the receding limb of the hydrograph downstream of Grand Forks where it no longer creates an increase in peak stage. **Appendix A** presents the tabulated downstream impacts for the FRP – Inlet Weir concept compared to the FRP – Inlet Gate concept. **Appendix B** displays the FRP – Inlet Weir and FRP – Inlet Gate hydrographs for various locations downstream of the project. **Table 2** presents flow and elevation characteristics of the FRP – Inlet Weir operation for the events analyzed.

Table 2: Federally Recommended Plan - Inlet Weir Results

Event Frequency	Cass/Richland County Line Elevation (ft)	Oxbow Elevation (ft)	Staging Elevation (ft)	Fargo Gage Elevation (ft)	Diversion Inlet Flow (cfs) **	Overflow Embank-ment Flow (cfs)	Flow Through FDRA (cfs)
	RS 2582760	RS 2552977	RS 2531315	RS 2388223	RS 155289	CR 17	RS 2458511
10%	915.89	914.86	914.40	892.51 (29.77*)	4,590	0	10,337
2%	921.70	921.25	921.22	892.62 (29.88*)	16,740	0	10,337
1%	923.14	923.00	922.98	893.76 (31.02*)	20,070	0	12,284
0.2%	923.68	923.07	922.99	902.41 (39.67*)	20,640	0	27,976
103k cfs	925.85	925.48	925.40	902.78 (40.04*)	20,678	33,085	26,566
PMF	927.03	926.32	926.11	907.05 (44.31*)	12,564	83,678	116,060

* Flood Stage at USGS Gaging Station 05054000, Fargo, ND

**Diversion Inlet Flow at Peak Time

3.2 FRP DIVERSION INLET GATE OPERATION

3.2.1 FRP – INLET GATE OPERATION OVERVIEW

This proposed project operation (FRP – Inlet Gate) uses a diversion inlet gate to provide additional control of discharges entering the diversion channel from the upstream staging/storage area. The operation is generally opposite of the original FRP – Inlet Weir plan. Initially, the Red and Wild Rice River gates would remain open during the lead up to the flood and through the rising limb of the hydrograph to pass as much early flood water as possible. The gates would be operated to maintain a pre-determined target discharge and stage at USGS Gage 05054000 at Fargo (example: River Stage 31 feet). The diversion inlet gates would remain closed during this time to prevent staging/storage area water from adding to the uncontrolled discharges from the west (Sheyenne, Maple, Rush and Lower Rush Rivers). At this time, the staging area would begin to fill until the diversion discharges from the west begin to decrease. Then, the diversion inlet gates would open and allow water to pass into the diversion channel from the staging/storage area. Once the discharge hydrograph begins to crest at the downstream end of the project (near Georgetown, MN), the gates on the Red and Wild Rice Rivers could be opened further to reduce the duration of the upstream staging area without producing adverse downstream impacts. The extent of this additional release would be dependent on the designed level of protection within the FDRA. **Figure 4** shows the FRP – Inlet Gate operation hydrographs at Georgetown (same location as Figure 3). Notice how the diversion inlet gate releases do not align and contribute to the diversion discharges from the western rivers. The resulting shape of the FRP – Inlet Gate hydrograph at Georgetown matches Existing Conditions better than the FRP – Inlet Weir hydrograph. FRP – Inlet Gate vs. FRP – Inlet Weir mitigation and impact profile tables are shown in **Appendix A** and resulting hydrographs at select locations are presented in **Appendix B**.

3.2.2 FRP – INLET GATE IMPACTS

For this analysis, the FRP – Inlet Gate plan was operated to generally produce the same downstream impacts at USGS Gage 05070000, Red River near Thompson, ND as documented in the FR/FEIS. The operation also utilized similar maximum diversion discharges and similar maximum stage at the USGS Gage 05054000 at Fargo as in the FRP – Inlet Weir plan. For some events, matching exact downstream impacts as the FRP – Inlet Weir plan was difficult because many of the downstream results from the FRP – Inlet Weir plan showed benefits in some areas and impacts in further downstream areas. The FRP - Inlet Gate plan produced more uniform downstream impacts from Georgetown through Grand Forks than the FRP – Inlet Weir plan. This is because the gate flexibility allows for a better hydrograph match to Existing Conditions downstream of the project. **Table 3** presents flow and elevations correlating to the FRP – Inlet Gate option. **Table 4** presents a comparison of the upstream staging area elevations for the FRP – Inlet Weir option and the FRP – Inlet Gate option for the events analyzed. **Figure 5** shows the water surface profiles in the diversion and staging area for the 103k cfs Event for the FRP – Inlet Weir and the FRP – Inlet Gate options.

Table 3: Federally Recommended Plan – Inlet Gate Results

Event Frequency	Cass/Richland County Line Elevation (ft)	Oxbow Elevation (ft)	Staging Elevation (ft)	Fargo Gage Elevation (ft)	Diversion Inlet Flow (cfs) **	Overflow Embank-ment Flow (cfs)	Flow Through FDRA (cfs)
	RS 2582760	**RS 2552977**	**RS 2531315**	**RS 2388223**	**RS 155289**	**CR 17**	**RS 2458511**
10%	915.97	914.92	914.44	892.55 (29.81*)	6,432	0.00	10,337
2%	921.78	921.34	921.29	893.06 (30.32*)	22,000	0.00	10,373
1%	922.55	922.20	922.16	893.51 (30.77*)	20,000	0.00	11,407
0.2%	923.44	922.11	922.00	902.76 (40.02*)	22,000	0.00	29,151
103k cfs	925.48	924.96	924.89	902.76 (40.02*)	30,768	17,798	26,518
PMF	926.93	926.16	925.91	907.04 (44.30*)	12,201	81,013	115,733

* Flood Stage at USGS Gaging Station 05054000, Fargo, ND

**Diversion Inlet Flow at Peak Time

Table 4: Upstream Staging Elevations, FRP – Inlet Weir vs. FRP – Inlet Gates

Event Frequency	FRP - Inlet Weir	FRP - Inlet Gate	Difference
10	914.40	914.44	0.04
2	921.22	921.29	0.07
1	922.98	922.16	-0.82
0.2	922.99	922.00	-0.99
103k cfs	925.40	924.89	-0.51
PMF	926.11	925.91	-0.2

Note: Elevations obtained upstream from Red River Control Structure (RRN XS 2531315)

3.2.3 PASSING MORE WATER THROUGH FLOOD DAMAGE REDUCTION AREA

Intuitively, if the diversion operation is producing downstream impacts, one would anticipate that less diversion operation (passing more water through the FDRA) would reduce the downstream impacts. However, this is not the case in all circumstances since a storage component is included in the project. Storing water during the peak would typically produce less downstream impacts than releasing any amount of water whether it is through the diversion or through the FDRA. To make this concept more complex, either diversion inlet plan (gates or fixed weir) is capable of passing more water through the FDRA after the flood crest without producing adverse downstream impacts.

For the 1-percent chance event, passing more water through the FDRA (during the peak) reduces the staging area by 0.14 feet (922.16 FRP – Inlet Gate; 922.02 FRP – Inlet Gate passing more water) while maintaining the same downstream impacts. The flow through town cannot be increased any further during the peak of the flood without producing adverse downstream impacts.

3.2.4 DIVERSION CHANNEL IMPROVEMENT

For the latest Phase 6 evaluations, the FRP – Inlet Weir was set at 907.0 to keep flood waters up to a 28-percent chance event (3.6-year) from entering the diversion channel from the upstream staging area. Since the proposed diversion inlet gates can be operated to hold or release any discharge at any event frequency (up to the design limitations), they can be constructed at a lower elevation while meeting the same 28-percent chance event diversion flow objectives. It was assumed that the invert of the diversion inlet gates would be constructed to 901.0 for this analysis. This is equivalent to the elevation of the diversion channel upstream of the diversion inlet and the top of the drop structure weir at the Wild Rice River. See the green dashed lines on **Figure 6**. It is also near the elevation of the interconnecting channel between the Red and Wild Rice Rivers. Therefore, this configuration would not require additional excavation of the diversion channel between the inlet structure and the Wild Rice River when compared to the FR/FEIS layout. As presented on **Tables 2 and 3**, the reduction in the staging elevation for the FRP – Inlet Gates compared to the FRP – Inlet Weir is 0.51 feet (925.4 - 924.89) for the 103k cfs event.

Another option was evaluated in an attempt to obtain additional benefits. This option included lowering the diversion inlet gate invert to the bottom of the diversion channel as measured on the downstream side of the diversion inlet (approximate elevation of 886.0). This would require additional channel excavation between the diversion inlet structure and the Wild Rice River when compared to the FR/FEIS plan and the previously described gate plan with the gate set at 901.0. This plan would reduce the drop across the gate structure and create a positive slope from the Wild Rice River to the diversion inlet gate. The red dashed lines on **Figure 6** represent the bottom of the diversion channel for this option. Lowering the diversion inlet structure to 886.0 produced an additional 0.27 feet of reduction in the staging area resulting in an overall staging elevation of 924.62 for the 103k cfs event. **Figure 6** shows the channel configurations and water surface elevations associated with the FRP – Inlet Gates and with the FRP – Inlet Gates with the sloping channel modification. This option should be evaluated further during final project design.

3.3 GATE CONFIGURATION

3.3.1 BACKGROUND

The FR/FEIS analysis subjectively compared advantages and disadvantages of eight different gated and non-gated configurations for the RRCS and the Diversion Inlet Structure (Appendix F, Exhibit B). The recommended RRCS configuration included three identical 50 foot-wide by 50 foot-tall radial gates. The FR/FEIS ultimately recommended a concrete weir with an ogee crest elevation of 903.25 and an effective flow width of 90 feet for the diversion inlet structure. This was chosen in the FR/FEIS because it was deemed the best option in terms of hydraulic performance, handling flood flows and low flows, potential environmental impacts, permitting, and operation and maintenance. In the Phase 6 modeling efforts, the weir was revised to have a crest elevation of 907.0 and a width of 130 feet as described in the beginning of "Section 3 – Design Considerations". The concrete weir and apron structure is confined between vertical abutment walls. Upstream and downstream concrete wing walls extend at right angles from the ends of the abutment walls and tie the structure to the upstream and downstream channel banks. The entire structure is supported on a pile foundation. Because the Diversion Inlet Structure is situated at an intermediate high point in the channel bottom profile, there is no requirement for a low flow pilot channel or local drainage opening.

3.3.2 PRELIMINARY OPERATIONS FOR 103K CFS EVENT AND PMF EVENT

Although the sloping diversion inlet channel produced an additional staging area reduction of 0.27' for the 103k cfs event, the overall benefits vs. costs for this added improvement is unknown. Items to consider with this option are the benefits from the reduced staging area elevation and the costs associated with larger gates such as the gates themselves, a larger foundation, and an increase in channel excavation between the inlet structure and the Wild Rice River. Therefore for this analysis, it was assumed that the proposed FRP – Inlet Gates are set to have an invert elevation of 901.0 which is just above the invert of the diversion inlet channel. This configuration was evaluated with the 103k cfs Event and the PMF event to determine the gate sizing. The results of the preliminary analysis were subsequently used to formulate the gated structure.

3.3.3 LAYOUT, TYPE, NUMBER, AND SIZE OF GATES

The best value and utility of the gated structure will be obtained if it can:

- efficiently pass flood flows up to the PMF with minimal backwater effects (with overflow embankment)
- facilitate maximum utilization of upstream staging and storage capacity
- effectively regulate both the discharge and upstream profile of flood events to influence the peaks and timing of diversion hydrographs
- integrate well with other project gated structures to optimize project operation and decouple downstream hydrographs
- offer flexibility for operational scenarios

A gated configuration was developed to incorporate the defined effective length and crest elevation of the weir. The following additional assumptions were used in selecting the type, size, and number of gates:

- gated structure should reasonably fit the existing site weir layout
- gates type should generally be consistent with other project gate systems
- gates must not negatively obstruct 103k cfs Event and PMF Event profiles
- gates must be controllable through their full range of operation
- gate size should be reasonable and consistent with industry standards
- gates should have reasonable height to width ratios
- gate number should be as low as practical while remaining efficient

A configuration of three identical radial gates was selected based on reasoning similar to that used for the RRCS and WRRCS – reasonable width for passing ice and debris, and redundancy of gates for operation and maintenance issues. Symmetry was also a consideration to keep flows generally centered in the upstream and downstream channels. **Figure 7** presents a general schematic of the RRCS from the FR/FEIS which is expected to be similar to the diversion inlet gate structure.

For this analysis, gate width was obtained by dividing the total effective weir length by three and then rounding up for unknown entrance and pier losses. The conservative gate width selected equals 45 feet, but may be reduced during more detailed design. The selected width for the two gate piers is 8 feet (consistent with the RRCS and WRRCS).

A gate height of 25 feet was selected to avoid overtopping by the highest flood profile; however it may be reduced during more detailed design.

In summary, the proposed gated Inlet Diversion Structure is a down-scaled version of the RRCS. The FRP – Inlet Gate Structure will consist of three (3) – 45' Wide x 25' High gates, and will have a similar superstructure, hoist system, operating bridge, heating elements, and controls as the RRCS. Operating and maintenance issues will also be similar between the two, except for the fact that the Diversion Inlet Gate will be closed and dry most of the time because this reach of the diversion channel will remain dry during non-flood events.

For this conceptual analysis, the gate structure mimics the previous inlet weir design for the foundation and basic structural design, except that it is wider and has the gate structure superimposed above it. The weir crest will become the gate sill at the diversion inlet gate invert elevation. Similarly, the abutment walls and wing walls will remain largely unchanged. However, the upstream approach channel will need to be flared and warped to fit the 151 foot width of the Gated Diversion Inlet Structure.

Addition of the gated structure will have no geotechnical implications other than to reevaluate the pile foundation design. Similarly, there are no significant environmental implications because the structure is not on a natural watercourse and will be dry most of the time.

The recommended gate structure is consistent with the gated control structures on the Red River and the Wild Rice River. Other potential gate types that might work for this application were briefly considered and dropped. Vertical steel lift gates do not offer any particular advantage in this size range and they do require different hoisting systems and maintenance procedures. Hydraulically operated bottom-hinged steel crest gates could also be used, but may not be economical at the 25 foot height. In addition they require completely different operating systems and maintenance procedures than the other control structures on the Red and Wild Rice Rivers. A pneumatically operated steel crest gate system (Obermeyer) was not considered sufficiently robust for this application.

3.4 INLET GATE VS. INLET WEIR

Several advantages exist for either diversion inlet option. The primary objective of the controlled diversion inlet, whether it is a weir or a gate, is to be able to regulate discharges entering the diversion for proper system operation. The objective of the diversion project is to provide flood mitigation while minimizing impacts (matching downstream existing condition hydrographs). Either option would require adequate stream gaging technology to accurately define an estimated existing condition hydrograph for determining potential impacts.

3.4.1 DIVERSION INLET WEIR ADVANTAGES

- A fixed concrete weir is a completely passive structure that is reliable and is an inoperable obstruction to flow. It provides a fixed crest elevation over which water can flow without further regulation when it rises above the crest elevation. This may be an advantage when considering the number of structures requiring operation.
- A fixed concrete weir has a lower upfront cost than the inlet gates.
- A fixed concrete weir would require less maintenance, and would therefore have lower maintenance costs than a gated structure.
- A fixed concrete weir automatically prevents discharges from entering the diversion channel at stages less than a 3.6-year event (dependent on RRCS and WRRCS operation).

3.4.2 DIVERSION INLET GATE ADVANTAGES

- A full height, multiple bay, radial gate structure provides a range of flow control attributes. The gate structure can be used to;
  - detain appropriate quantities of water for later release
  - vary flow releases to maintain a desired upstream water elevation
  - release desired flows of water as needed for downstream purposes
  - release variable flows of water according to a specific defined program or in response to real-time dynamic data input
  - drain the diversion channel if necessary during the flood to make emergency repairs.
- Proper operation of the gate structure can produce similar downstream hydrographs as existing conditions, which results in consistent impacts from Georgetown to Grand Forks.

A full height, multiple bay, electric hoist operated, radial gate structure is a complex facility. However, this gate type of water control system has been proven over many decades to be reliable for countless applications. This is why it was recommended for the gated control structures on the Red River and the Wild Rice River. With proper design, construction, maintenance and operation, these structures will serve the project reliably.

3.4.3 DIVERSION INLET WEIR AND GATE UNCERTAINTIES

- An evaluation has not been completed to determine the cost and cost savings associated with incremental staging. This would include, but may not be limited to, earthwork, transportation, and real estate costs.

3.5 SHEYENNE RIVER AQUEDUCT

Based on the FR/FEIS design, an aqueduct is proposed where the diversion channel crosses the Sheyenne River. The diversion flows pass under the Sheyenne River through a box type culvert structure (aqueduct). Sheyenne River low flows pass over the diversion channel via a concrete channel, while residual Sheyenne River high flows enter the diversion channel downstream from the aqueduct. Since the large 103k cfs Event controls the design height of the upstream staging area embankment, the question arose whether or not the Sheyenne River aqueduct was creating elevated backwater effects that contribute to the staging area elevation. To determine whether this is the case, the 103k cfs Event was computed using both diversion inlet options (FRP – Inlet Weir and FRP – Inlet Gate) to determine any potential benefits or impacts related to the diversion inlet structure in combination with increased capacity for the Sheyenne River Aqueduct.

The FR/FEIS Sheyenne River aqueduct structure was used as a baseline for this analysis. This has an opening that is approximately 10’ high x 300’ wide (with interior piers). To bookend the evaluation, the entire structure was removed leaving the diversion channel “as-is” to show no restriction at the structure. A configuration with an opening that is approximately 10’ high x 500’ wide was also used in the analysis to create a mid-point.

As expected, widening the Sheyenne River Aqueduct to 500’ reduced the stage increase across the Sheyenne River structure, but the stage reduction did not carry through into the staging area for the FRP – Inlet Gates or FRP – Inlet Weir. Also, completely removing the Sheyenne River Aqueduct eliminated the stage increase across the Sheyenne Structure. Again, this stage reduction did not carry through the inlet to the staging area. Therefore, on large events where discharge capacity is of concern, the Sheyenne River Aqueduct does not appear to create adverse conditions on the upstream staging area because the diversion inlet structure is controlling the capacity of releases from the staging area into the diversion channel.

Sheyenne River Aqueduct Analysis water surface profiles for the 103k cfs Event along the diversion channel are displayed in **Figure 8** for the FRP – Inlet Weir option and **Figure 9** for the FRP – Inlet Gate option.

4 COST COMPARISON

Preliminary comparative costs for the diversion inlet structures were derived by extracting and scaling the diversion inlet weir and the Red River Control Structure cost elements found in Phase 4 (FR/FEIS), Appendix G, Exhibit B and in the Phase 4 Total Project Cost Summary (TPCS).

Diversion inlet weir costs from the FR/FEIS were based on a concrete weir structure that is 90 feet wide with a crest elevation of 903.25 feet. The equivalent diversion inlet weir structure documented in Phase 6 (FRP) includes a 130 foot wide weir at elevation 907.0 feet. The costs for the FRP diversion inlet weir were developed using a direct ratio of its foundation width over the FR/FEIS foundation width. The foundation for the FRP – Inlet Gate option was prorated in a similar fashion as the FRP diversion inlet weir. To account for the gated structure portion of the FRP diversion inlet gate total cost, a ratio was applied to the gated structure line item in the FR/FEIS Red River Control Structure cost estimate based on the cross sectional area of the gate openings.

The values derived are imprecise and they are indicative of the relative cost relationship between the alternative structures. For this reason, a contingency of 30% was applied to the base costs. Costs and benefits outside the scope of this analysis must also be considered. These include values generally associated with operational flexibility, reduction in staging area elevation, uniform downstream impacts, and benefits associated with less frequent operation of the diversion channel. Detail pertaining to the cost estimate is provided in **Appendix C**.

The total costs (including site work) for the diversion inlet weir structure from FR/FEIS and Phase 6, and the Phase 6 diversion inlet gate structure are presented below. The gated structure option would add approximately $12M to the current base weir option.

The comparative diversion Inlet Weir/Gate Structure costs are as follows:

Locally Preferred Plan (FR/FEIS, 90’ Weir)	**$13M**
Federally Recommended Plan (Phase 6, 130’ Weir)	**$18M**
Federally Recommended Plan – (Phase 6, (3) - 45’ x 25’ Gates)	**$30M**
Estimated Additional Cost for Diversion Inlet Gate Structure	**$12M**

As a comparison, the diversion inlet structure costs were compared to the FR/FEIS Red River Control Structure and the Wild Rice River Control Structure. To make a direct comparison, the site work (dewatering) and fish passage were removed from the FR/FEIS cost estimates. Therefore, the FR/FEIS costs for the Red River Hydraulic Structure (3) – 50’ x 47’ gates and the Wild Rice Hydraulic Structure (2) – 30’ x 25’ gates were approximately $33M and $19M respectively compared to $26M cost for the proposed diversion inlet gate structure (no site work).

FIGURES

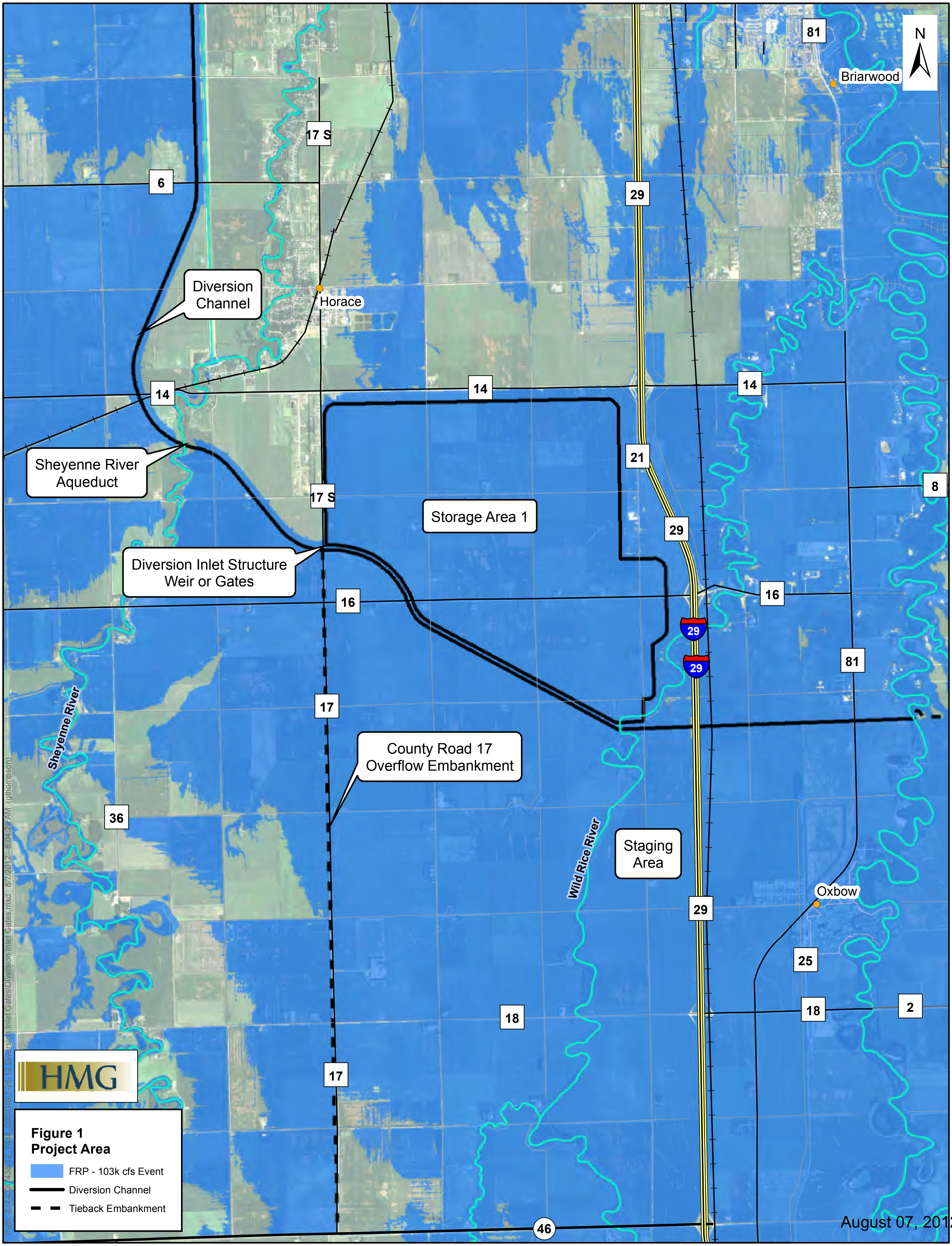
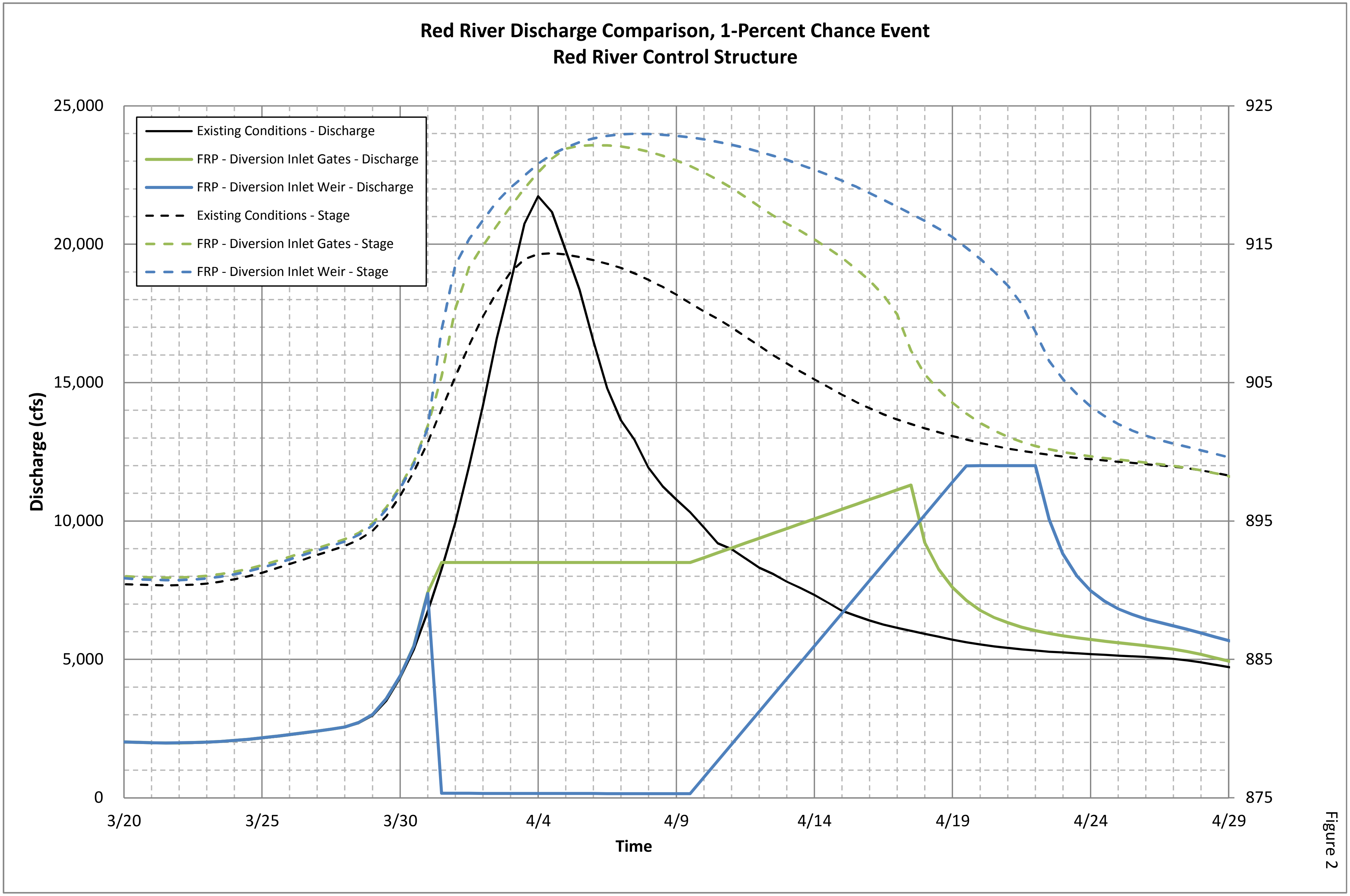


Figure 1
Project Area



Red River Discharge Comparison, 1-Percent Chance Event
Red River Control Structure
Existing Conditions - Discharge
FRP - Diversion Inlet Gates - Discharge
FRP - Diversion Inlet Weir - Discharge
Existing Conditions - Stage
FRP - Diversion Inlet Gates - Stage
FRP - Diversion Inlet Weir - Stage
Discharge (cfs)
25,000
20,000
15,000
10,000
5,000
0
925
915
905
895
885
875
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

Figure 2

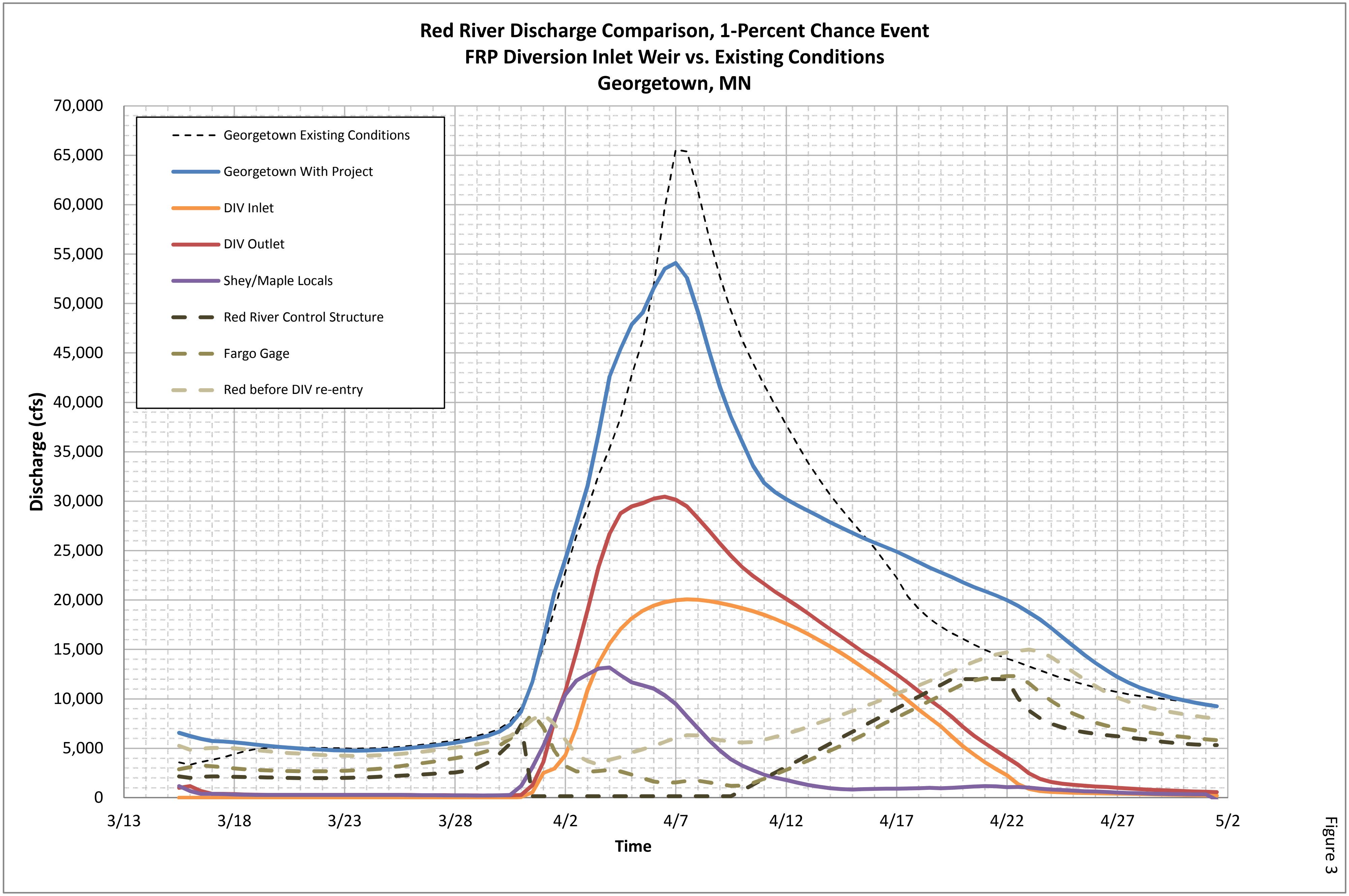
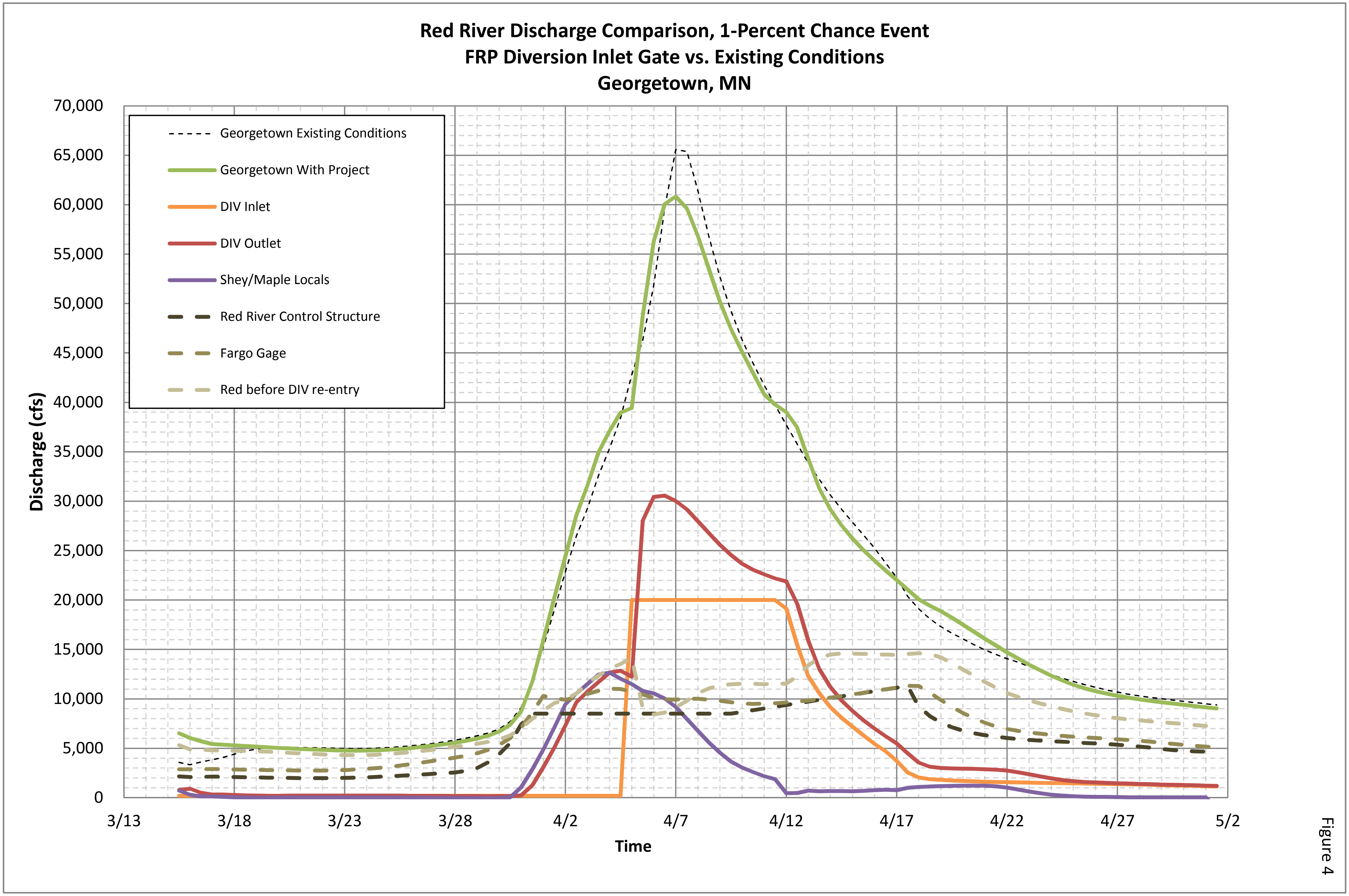
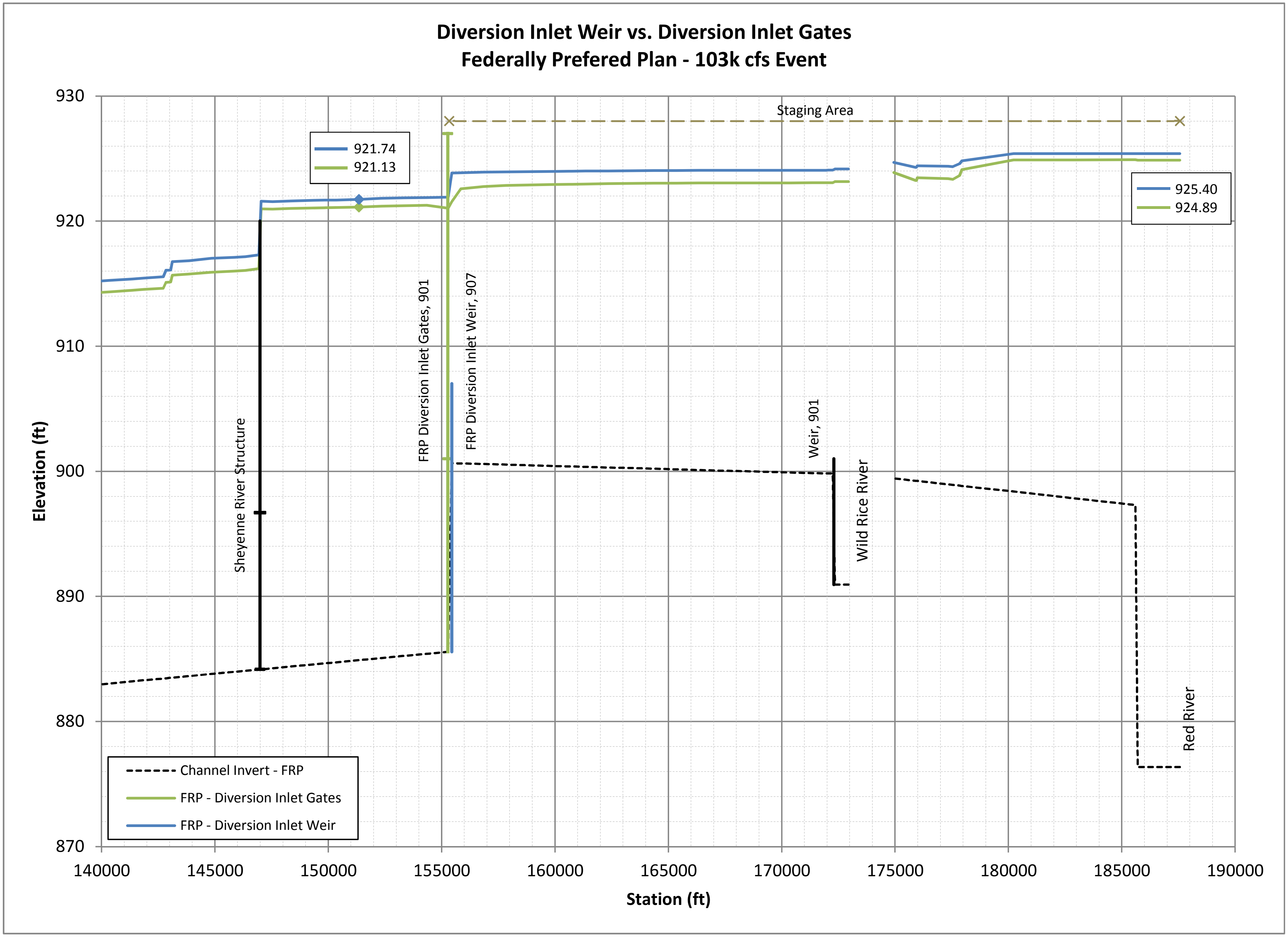

Red River Discharge Comparison, 1-Percent Chance Event
FRP Diversion Inlet Weir vs. Existing Conditions
Georgetown, MN
Georgetown Existing Conditions
Georgetown With Project
DIV Inlet
DIV Outlet
Shey/Maple Locals
Red River Control Structure
Fargo Gage
Red before DIV re-entry
Discharge (cfs)
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/13
3/18
3/23
3/28
4/2
4/7
4/12
4/17
4/22
4/27
5/2
Time

Figure 3



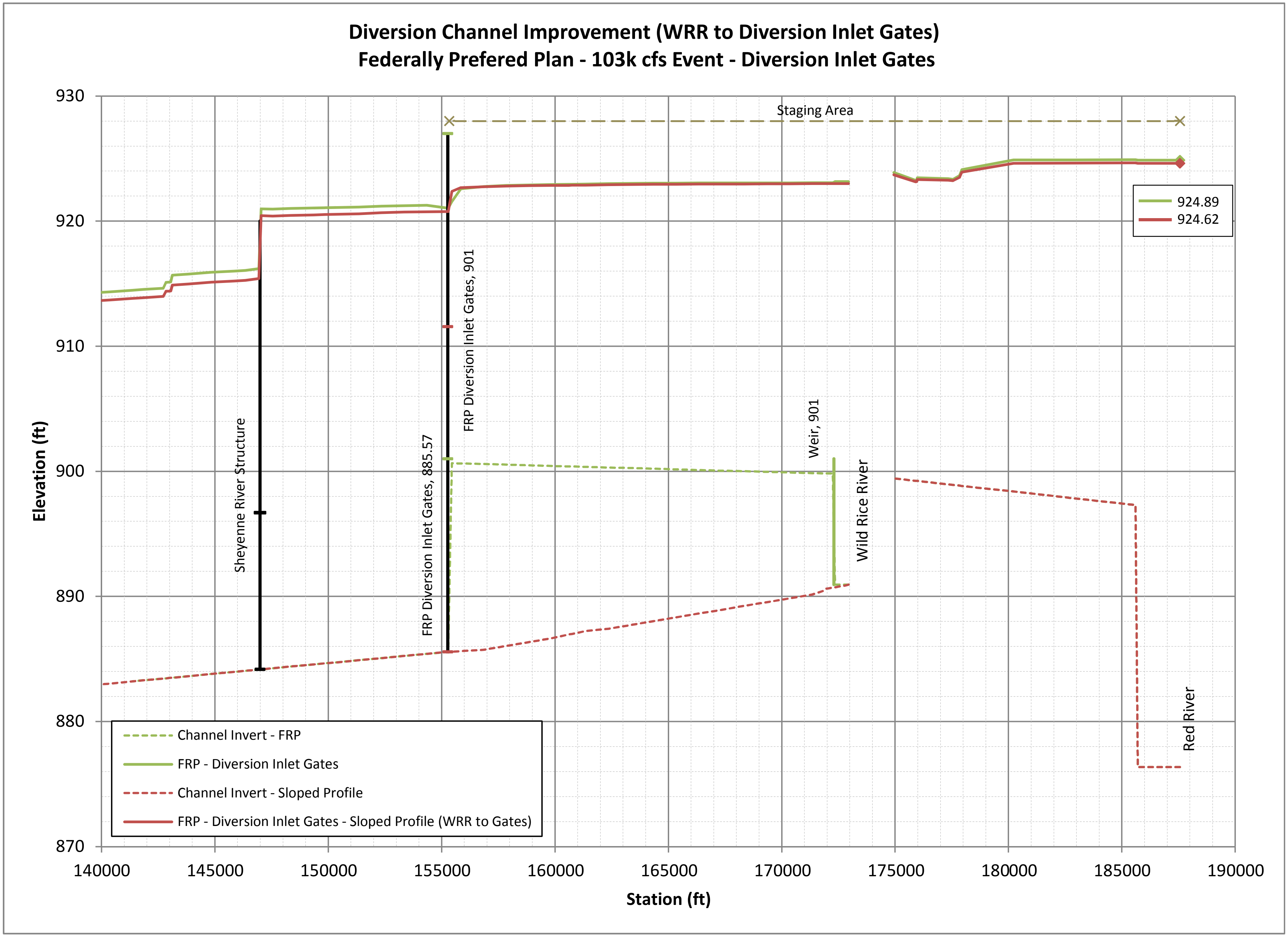
Red River Discharge Comparison, 1-Percent Chance Event
FRP Diversion Inlet Gate vs. Existing Conditions
Georgetown, MN
Georgetown Existing Conditions
Georgetown With Project
DIV Inlet
DIV Outlet
Shey/Maple Locals
Red River Control Structure
Fargo Gage
Red before DIV re-entry
Discharge (cfs)
70,000
65,000
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
3/13
3/18
3/23
3/28
4/2
4/7
4/12
4/17
4/22
4/27
5/2
Time

Figure 4



Diversion Inlet Weir vs. Diversion Inlet Gates
Federally Prefered Plan - 103k cfs Event
Elevation (ft)
Station (ft)
930
920
910
900
890
880
870
140000
145000
150000
155000
160000
165000
170000
175000
180000
185000
190000
Staging Area
921.74
921.13
925.40
924.89
Sheyenne River Structure
FRP Diversion Inlet Gates, 901
FRP Diversion Inlet Weir, 907
Weir, 901
Wild Rice River
Red River
Channel Invert - FRP
FRP - Diversion Inlet Gates
FRP - Diversion Inlet Weir

Figure 5



Diversion Channel Improvement (WRR to Diversion Inlet Gates)
Federally Prefered Plan - 103k cfs Event - Diversion Inlet Gates
Staging Area
924.89
924.62
Elevation (ft)
930
920
910
900
890
880
870
Station (ft)
140000
145000
150000
155000
160000
165000
170000
175000
180000
185000
190000
Sheyenne River Structure
FRP Diversion Inlet Gates, 885.57
FRP Diversion Inlet Gates, 901
Weir, 901
Wild Rice River
Red River
Channel Invert - FRP
FRP - Diversion Inlet Gates
Channel Invert - Sloped Profile
FRP - Diversion Inlet Gates - Sloped Profile (WRR to Gates)

Figure 6

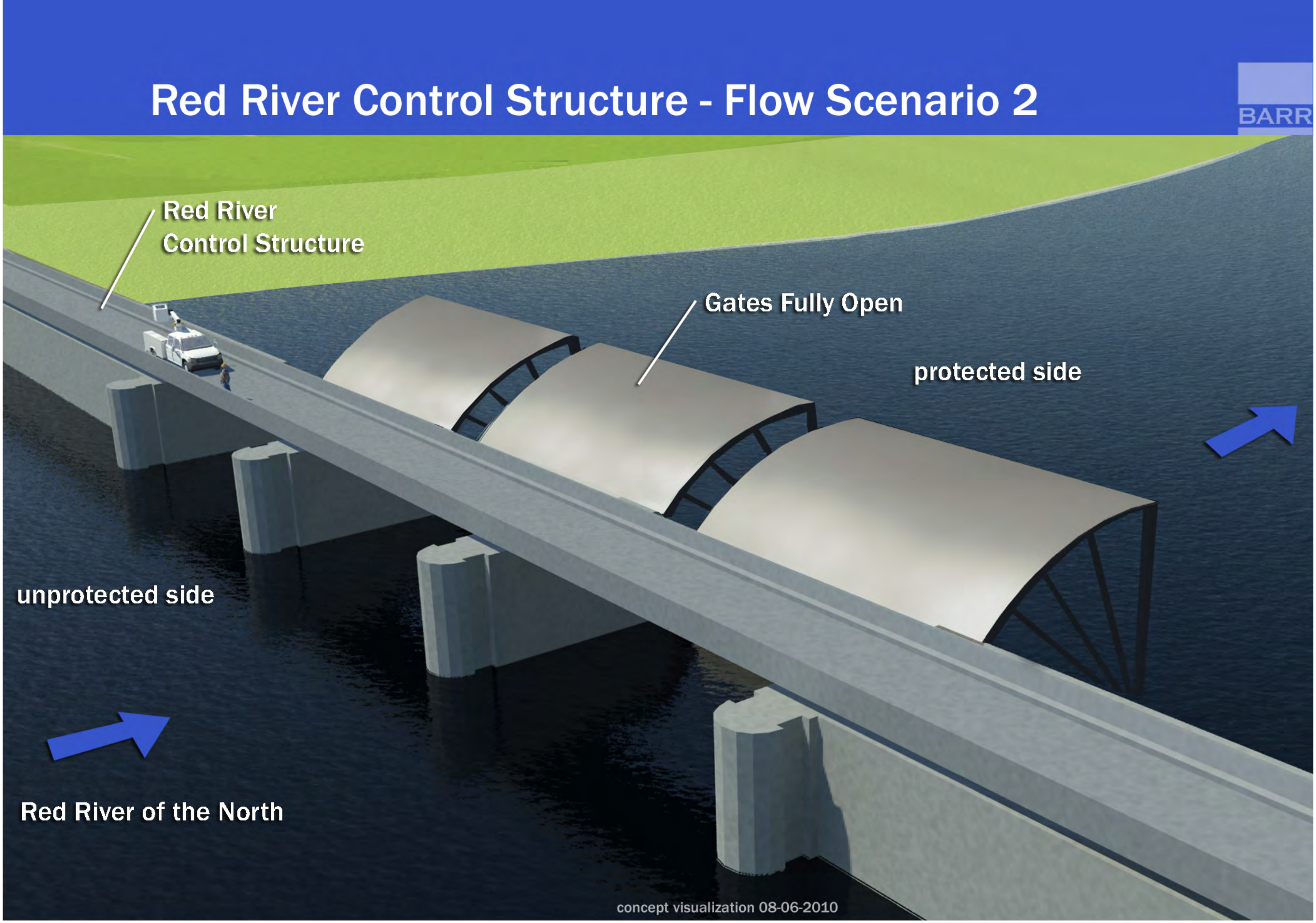
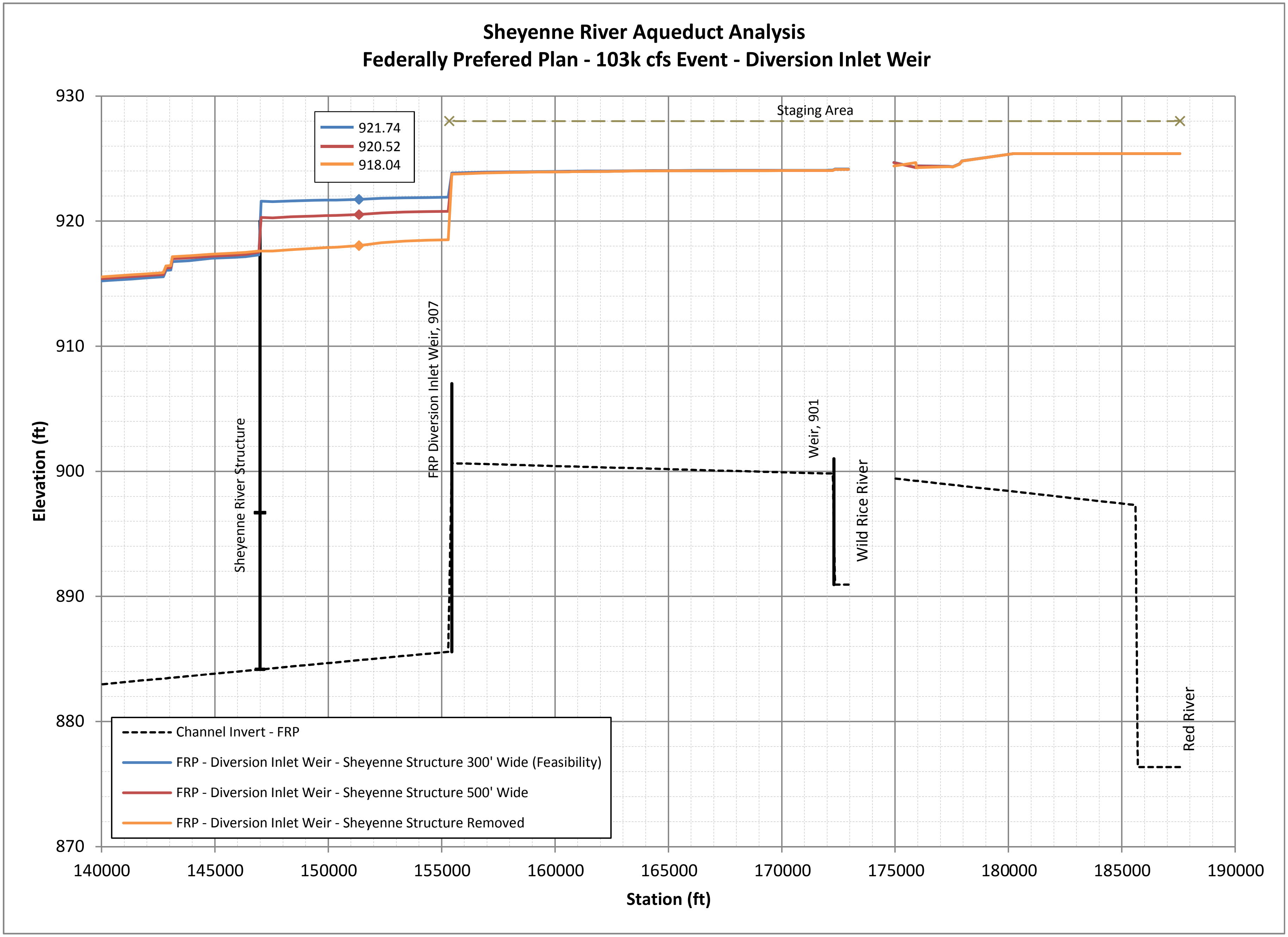


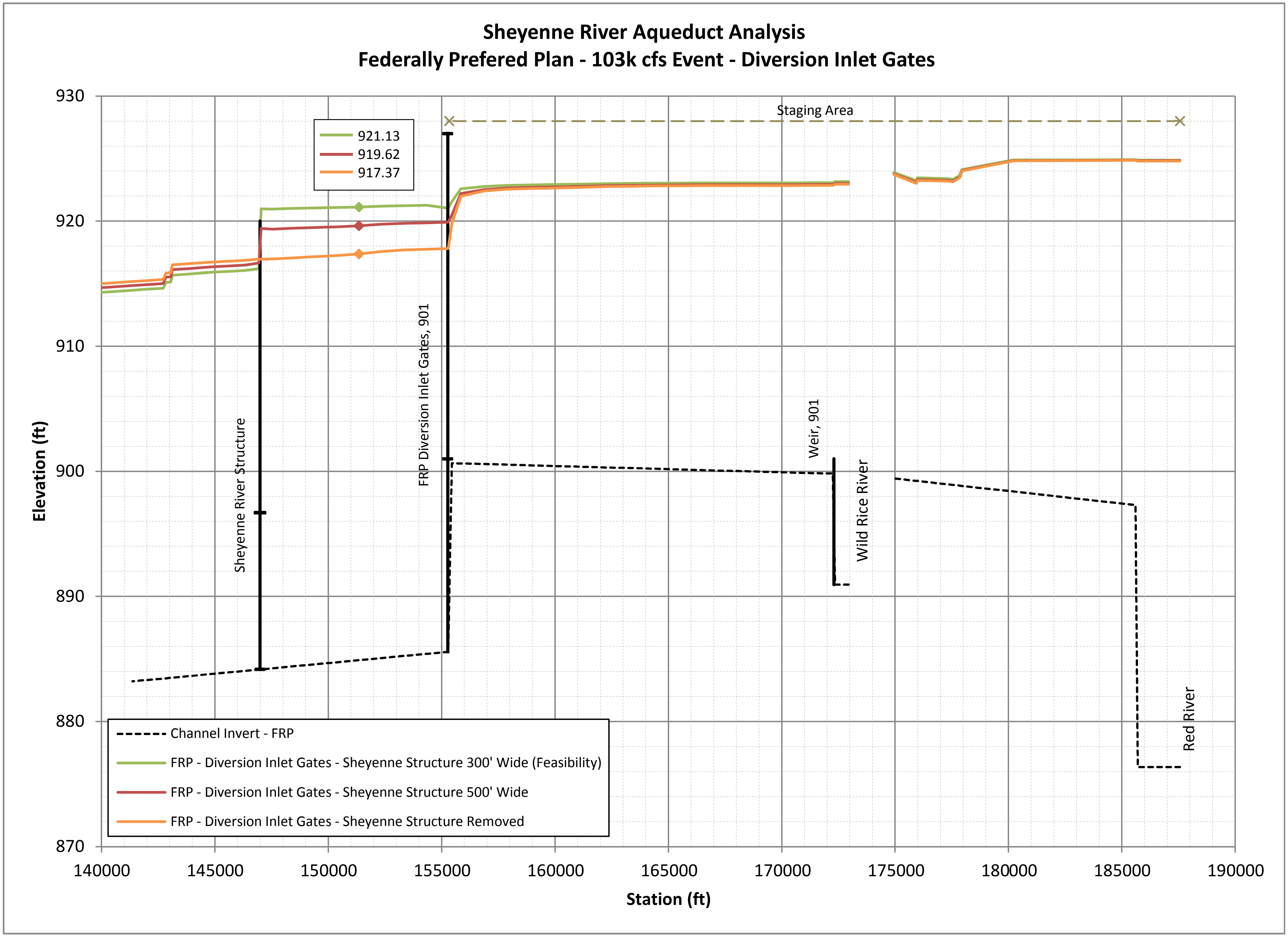
Figure obtained from FR/FEIS Report Appendix F, Hydraulic Structures - Figure F36

Figure 7



Sheyenne River Aqueduct Analysis
Federally Prefered Plan - 103k cfs Event - Diversion Inlet Weir
921.74
920.52
918.04
Staging Area
Sheyenne River Structure
FRP Diversion Inlet Weir, 907
Weir, 901
Wild Rice River
Red River
Channel Invert - FRP
FRP - Diversion Inlet Weir - Sheyenne Structure 300' Wide (Feasibility)
FRP - Diversion Inlet Weir - Sheyenne Structure 500' Wide
FRP - Diversion Inlet Weir - Sheyenne Structure Removed
Elevation (ft)
930
920
910
900
890
880
870
140000
145000
150000
155000
160000
165000
170000
175000
180000
185000
190000
Station (ft)

Figure 8



Sheyenne River Aqueduct Analysis
Federally Prefered Plan - 103k cfs Event - Diversion Inlet Gates
Staging Area
921.13
919.62
917.37
Sheyenne River Structure
FRP Diversion Inlet Gates, 901
Weir, 901
Wild Rice River
Red River
Channel Invert - FRP
FRP - Diversion Inlet Gates - Sheyenne Structure 300' Wide (Feasibility)
FRP - Diversion Inlet Gates - Sheyenne Structure 500' Wide
FRP - Diversion Inlet Gates - Sheyenne Structure Removed
Elevation (ft)
Station (ft)
930
920
910
900
890
880
870
140000
145000
150000
155000
160000
165000
170000
175000
180000
185000
190000

Figure 9

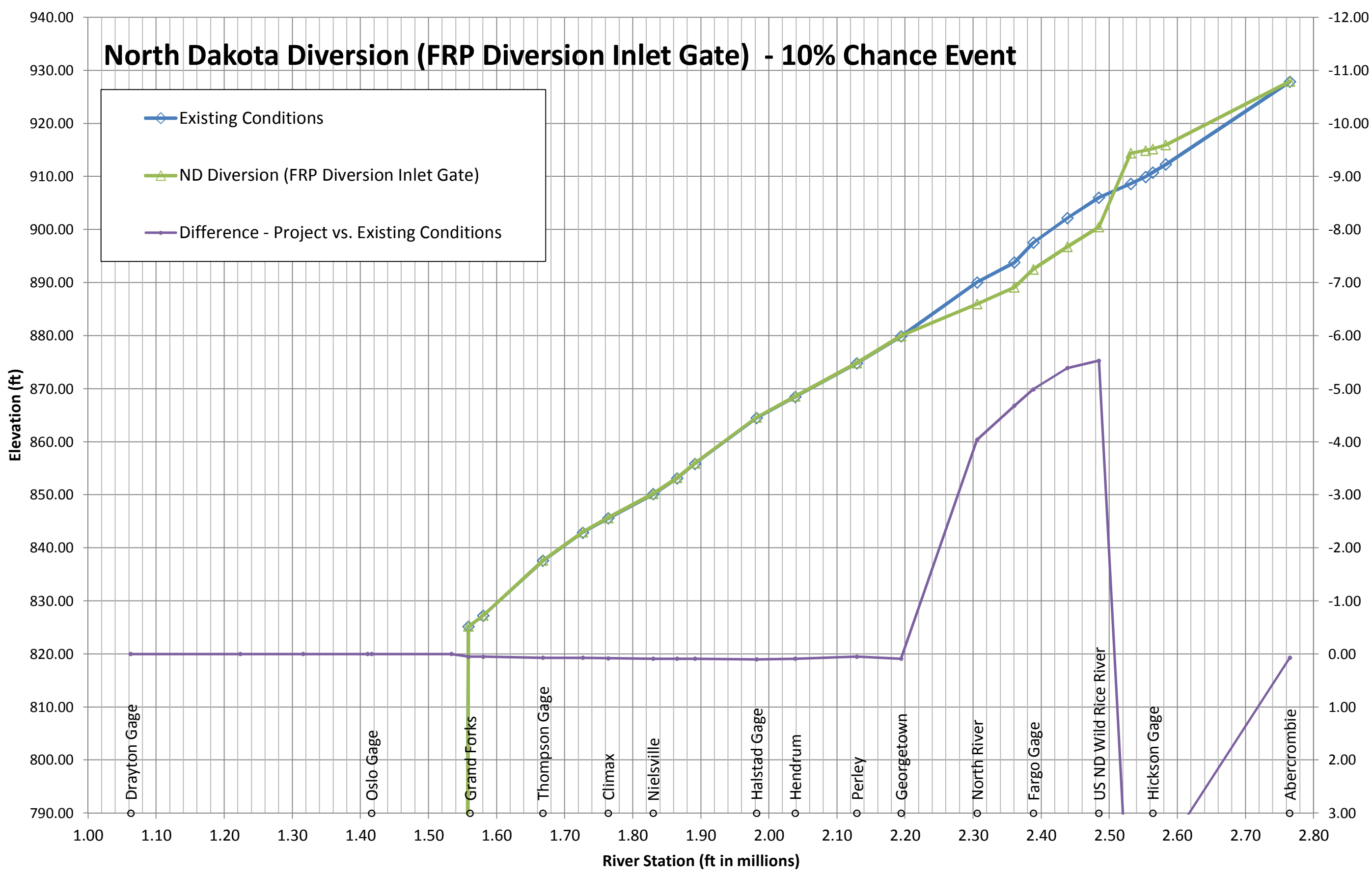
APPENDIX A – FRP – INLET GATE PROFILE TABLES

Appendix A.1 Diversion Inlet Gate Analysis - 10% Chance Event

North Dakota Diversion (FRP Diversion Inlet Gate) - 10% Chance Event

Location	Station	Existing Conditions	FRP Inlet Weir	Difference Inlet Weir vs. Existing Conditions	FRP Inlet Gate	Difference Inlet Gate vs. Existing Conditions	Change in Impacts Relative to Inlet Weir
		Elevation (ft)	Elevation (ft)	(ft)	Elevation (ft)	(ft)	(ft)
Grand Forks Gage	1558518	825.15	825.19	0.04	825.20	0.05	0.01
32nd Ave, Grand Forks	1580152	827.25	827.31	0.06	827.30	0.05	-0.01
Thompson Gage	1667877	837.58	837.63	0.05	837.65	0.07	0.02
Co. Hwy 25/ Co. Rd 221	1726274	842.90	842.95	0.05	842.97	0.07	0.02
DS Sandhill River/ Climax	1763746	845.59	845.64	0.05	845.67	0.08	0.03
Nielsville	1829877	850.14	850.20	0.06	850.23	0.09	0.03
DS Marsh River	1864960	853.13	853.19	0.06	853.22	0.09	0.03
US Goose River/ Shelly	1891054	855.86	855.91	0.05	855.95	0.09	0.04
Halstad Gage	1981580	864.50	864.48	-0.02	864.60	0.10	0.12
Hendrum	2038409	868.48	868.41	-0.07	868.57	0.09	0.16
Perley	2129181	874.83	874.59	-0.24	874.88	0.05	0.29
Georgetown	2194021	879.88	879.65	-0.23	879.97	0.09	0.32
North River/ Clay Co. Hwy 93	2305647	890.04	885.86	-4.18	886.00	-4.04	0.14
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	893.81	889.06	-4.75	889.13	-4.68	0.07
Fargo Gage (13th Ave S, 12th Ave S)	2388223	897.54 (34.8*)	892.51 (29.77*)	-5.03	892.55 (29.81*)	-4.99	0.04
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	902.15	896.74	-5.41	896.76	-5.39	0.02
US ND Wild Rice River	2484618	906.05	900.51	-5.54	900.52	-5.53	0.01
US FRP Diversion	2531315	908.66	914.40	5.74	914.44	5.78	0.04
Oxbow	2552977	909.96	914.86	4.90	914.92	4.96	0.06
Hickson Gage	2563754	910.78	915.15	4.37	915.22	4.44	0.07
Cass/Richland County Line	2582760	912.29	915.89	3.60	915.97	3.68	0.08
Abercrombie	2764908	927.87	927.93	0.06	927.94	0.07	0.01

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

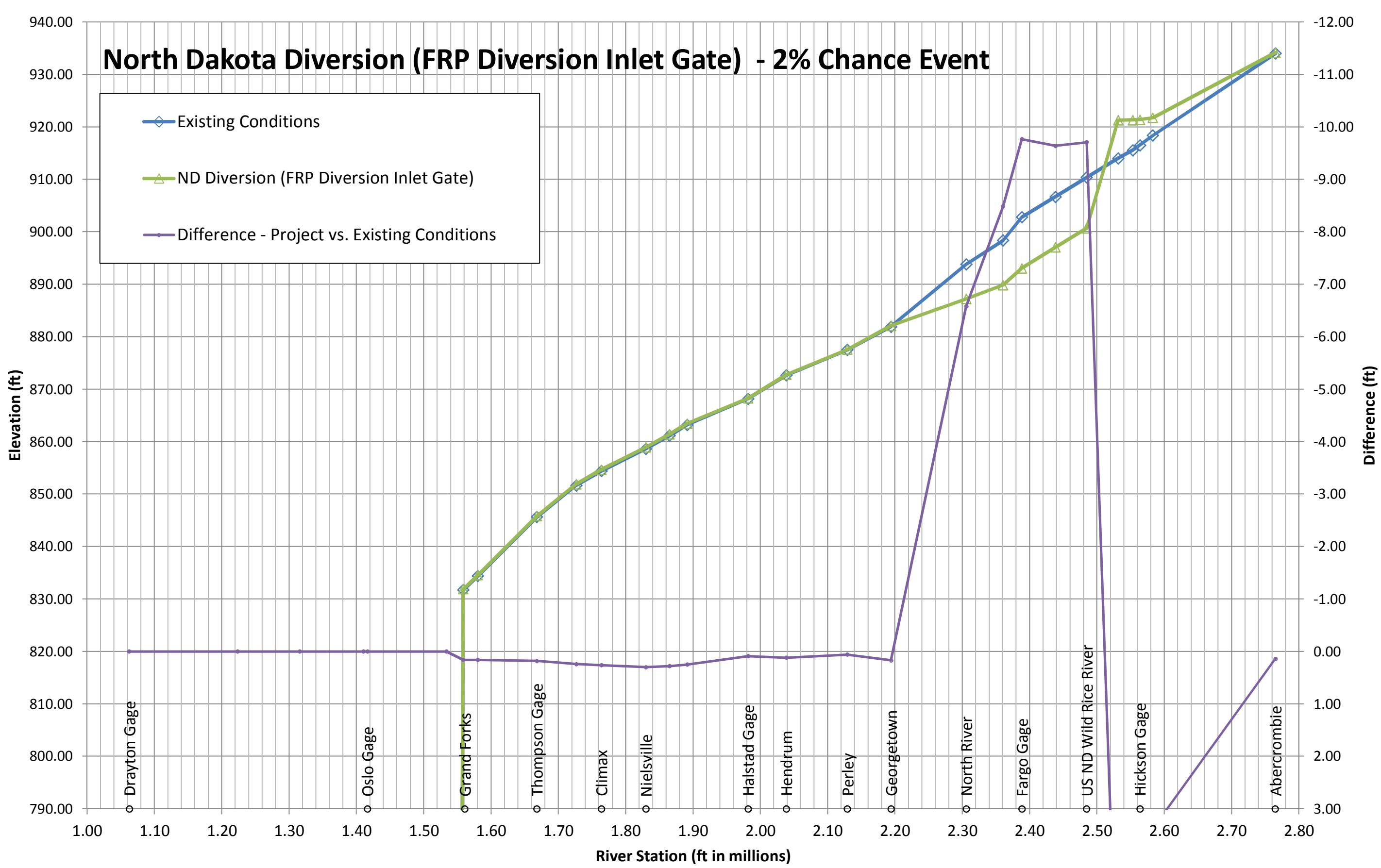


Appendix A.2 Diversion Inlet Gate Analysis - 2% Chance Event

North Dakota Diversion (FRP Diversion Inlet Gate) - 2% Chance Event

Location	Station	Existing Conditions	FRP Inlet Weir	Difference Inlet Weir vs. Existing Conditions	FRP Inlet Gate	Difference Inlet Gate vs. Existing Conditions	Change in Impacts Relative to Inlet Weir
		Elevation (ft)	Elevation (ft)	(ft)	Elevation (ft)	(ft)	(ft)
Grand Forks Gage	1558518	831.74	832.01	0.27	831.90	0.16	-0.11
32nd Ave, Grand Forks	1580152	834.40	834.66	0.26	834.56	0.16	-0.10
Thompson Gage	1667877	845.64	845.84	0.20	845.82	0.18	-0.02
Co. Hwy 25/ Co. Rd 221	1726274	851.65	851.93	0.28	851.89	0.24	-0.04
DS Sandhill River/ Climax	1763746	854.41	854.71	0.30	854.67	0.26	-0.04
Nielsville	1829877	858.65	858.88	0.23	858.95	0.30	0.07
DS Marsh River	1864960	861.16	861.35	0.19	861.44	0.28	0.09
US Goose River/ Shelly	1891054	863.20	863.37	0.17	863.45	0.25	0.08
Halstad Gage	1981580	868.18	868.22	0.04	868.27	0.09	0.05
Hendrum	2038409	872.67	872.70	0.03	872.79	0.12	0.09
Perley	2129181	877.51	877.44	-0.07	877.57	0.06	0.13
Georgetown	2194021	881.93	881.96	0.03	882.10	0.17	0.14
North River/ Clay Co. Hwy 93	2305647	893.82	886.37	-7.45	887.24	-6.58	0.87
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	898.37	889.28	-9.09	889.88	-8.49	0.60
Fargo Gage (13th Ave S, 12th Ave S)	2388223	902.83 (40.09*)	892.62 (29.88*)	-10.21	893.06 (30.32*)	-9.77	0.44
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	906.71	896.80	-9.91	897.07	-9.64	0.27
US ND Wild Rice River	2484618	910.41	900.54	-9.87	900.70	-9.71	0.16
US FRP Diversion	2531315	914.05	921.22	7.17	921.29	7.24	0.07
Oxbow	2552977	915.57	921.25	5.68	921.34	5.77	0.09
Hickson Gage	2563754	916.52	921.29	4.77	921.38	4.86	0.09
Cass/Richland County Line	2582760	918.40	921.70	3.30	921.78	3.38	0.08
Abercrombie	2764908	934.04	934.29	0.25	934.18	0.14	-0.11

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

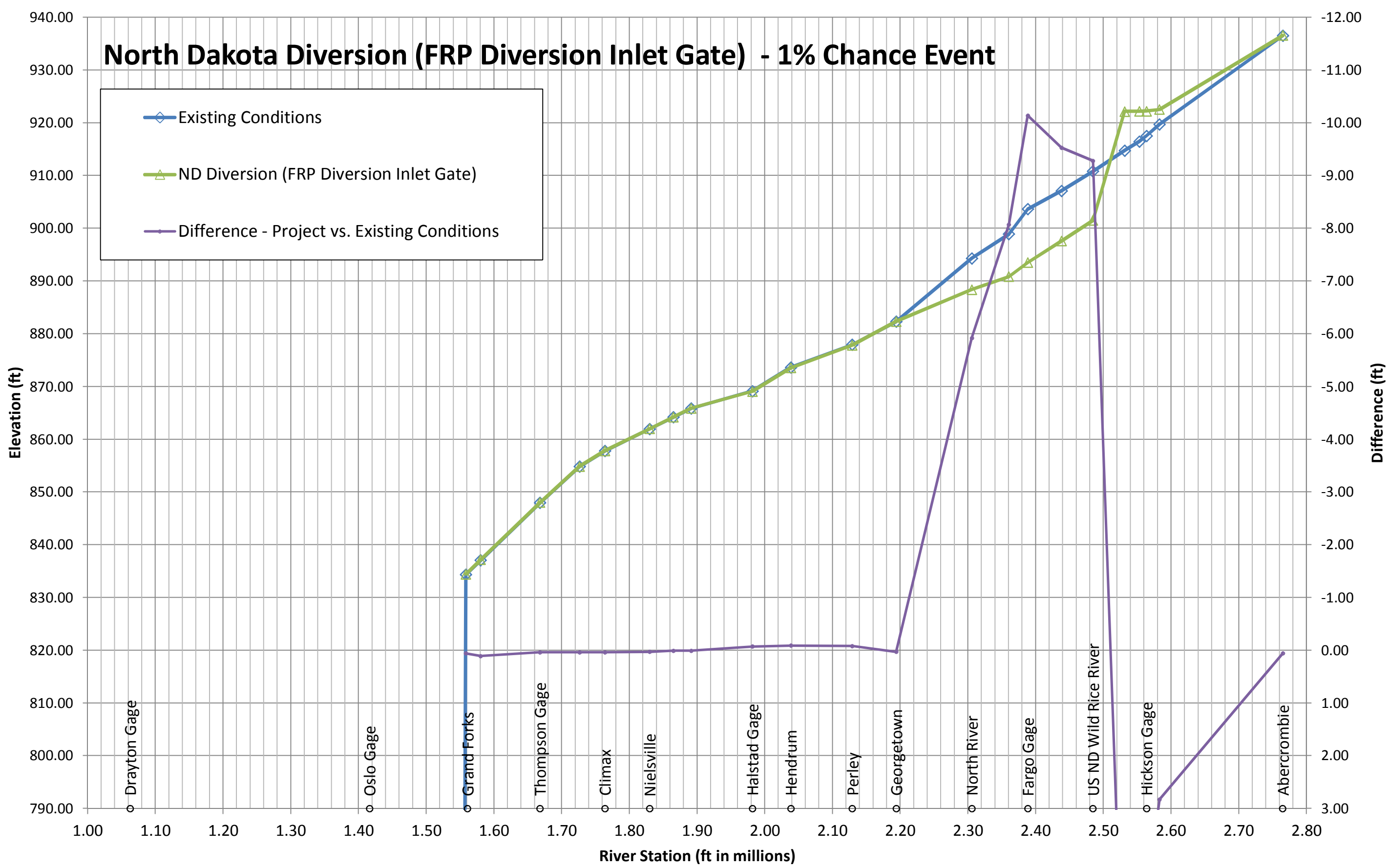


Appendix A.3 Diversion Inlet Gate Analysis - 1% Chance Event

North Dakota Diversion (FRP Diversion Inlet Gate) - 1% Chance Event

Location	Station	Existing Conditions	FRP Inlet Weir	Difference Inlet Weir vs. Existing Conditions	FRP Inlet Gate	Difference Inlet Gate vs. Existing Conditions	Change in Impacts Relative to Inlet Weir
		Elevation (ft)	Elevation (ft)	(ft)	Elevation (ft)	(ft)	(ft)
Grand Forks Gage	1558518	834.36	834.49	0.13	834.42	0.06	-0.07
32nd Ave, Grand Forks	1580152	837.06	837.27	0.21	837.17	0.11	-0.10
Thompson Gage	1667877	847.97	848.01	0.04	848.01	0.04	0.00
Co. Hwy 25/ Co. Rd 221	1726274	854.83	854.80	-0.03	854.87	0.04	0.07
DS Sandhill River/ Climax	1763746	857.78	857.74	-0.04	857.82	0.04	0.08
Nielsville	1829877	861.96	861.87	-0.09	861.99	0.03	0.12
DS Marsh River	1864960	864.20	864.11	-0.09	864.21	0.01	0.10
US Goose River/ Shelly	1891054	865.86	865.76	-0.10	865.87	0.01	0.11
Halstad Gage	1981580	869.15	868.91	-0.24	869.08	-0.07	0.17
Hendrum	2038409	873.64	873.32	-0.32	873.55	-0.09	0.23
Perley	2129181	877.93	877.69	-0.24	877.85	-0.08	0.16
Georgetown	2194021	882.31	882.13	-0.18	882.34	0.03	0.21
North River/ Clay Co. Hwy 93	2305647	894.32	886.12	-8.20	888.40	-5.92	2.28
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	898.91	889.94	-8.97	890.84	-8.07	0.90
Fargo Gage (13th Ave S, 12th Ave S)	2388223	903.65 (40.91*)	893.76 (31.02*)	-9.89	893.51 (30.77*)	-10.14	-0.25
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	907.12	898.34	-8.78	897.59	-9.53	-0.75
US ND Wild Rice River	2484618	910.80	902.32	-8.48	901.52	-9.28	-0.80
US FRP Diversion	2531315	914.74	922.98	8.24	922.16	7.42	-0.82
Oxbow	2552977	916.47	923.00	6.53	922.20	5.73	-0.80
Hickson Gage	2563754	917.55	923.01	5.46	922.23	4.68	-0.78
Cass/Richland County Line	2582760	919.72	923.14	3.42	922.55	2.83	-0.59
Abercrombie	2764908	936.52	936.63	0.11	936.58	0.06	-0.05

* Flood stage at USGS Gaging Station 05054000, Fargo, ND

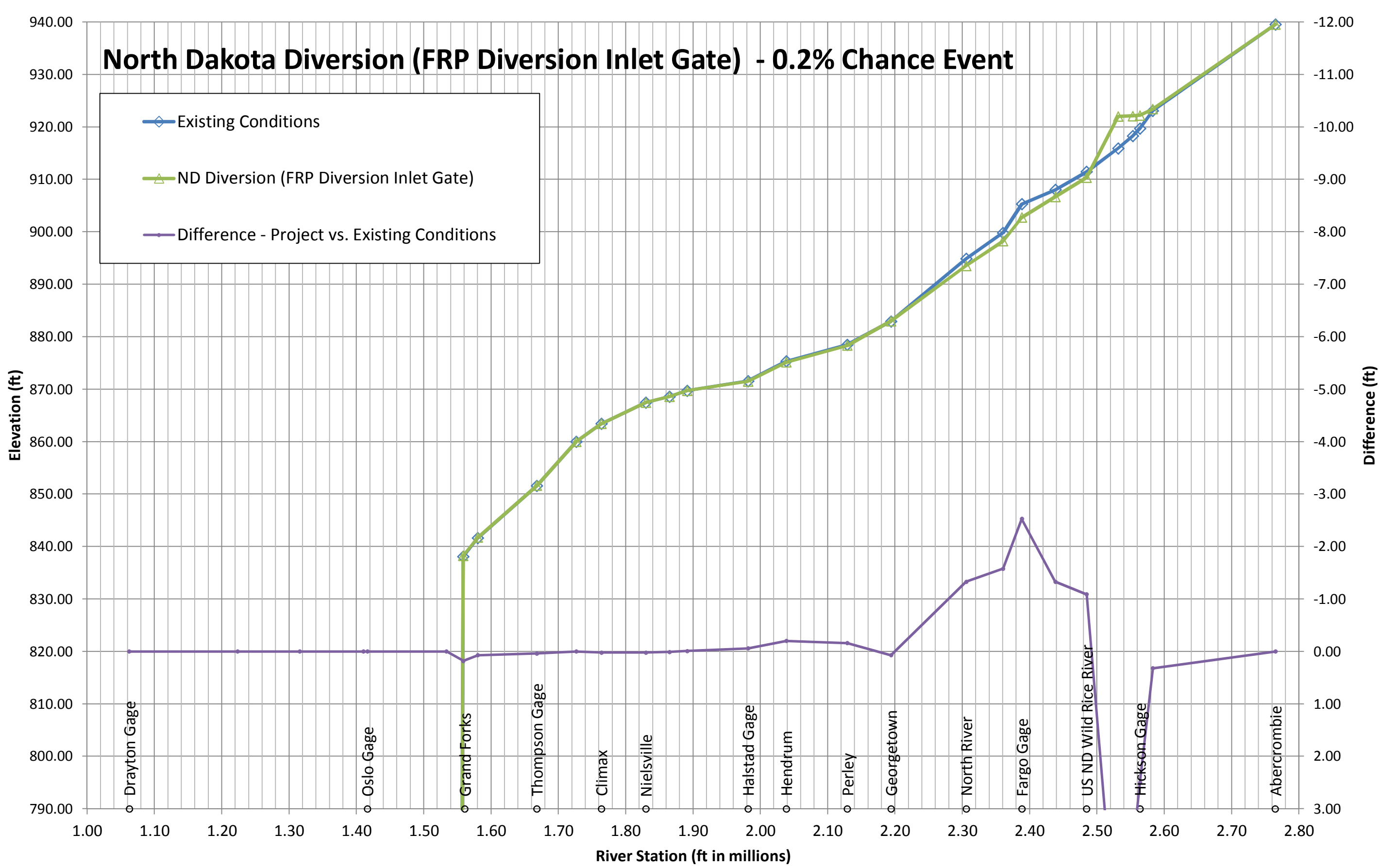


Appendix A.4 Diversion Inlet Gate Analysis - 0.2% Chance Event

North Dakota Diversion (FRP Diversion Inlet Gate) - 0.2% Chance Event

Location	Station	Existing Conditions	FRP Inlet Weir	Difference Inlet Weir vs. Existing Conditions	FRP Inlet Gate	Difference Inlet Gate vs. Existing Conditions	Change in Impacts Relative to Inlet Weir
		Elevation (ft)	Elevation (ft)	(ft)	Elevation (ft)	(ft)	(ft)
Grand Forks Gage	1558518	838.09	838.31	0.22	838.27	0.18	-0.04
32nd Ave, Grand Forks	1580152	841.66	841.74	0.08	841.73	0.07	-0.01
Thompson Gage	1667877	851.59	851.54	-0.05	851.63	0.04	0.09
Co. Hwy 25/ Co. Rd 221	1726274	859.99	859.87	-0.12	859.99	0.00	0.12
DS Sandhill River/ Climax	1763746	863.41	863.25	-0.16	863.43	0.02	0.18
Nielsville	1829877	867.47	867.28	-0.19	867.49	0.02	0.21
DS Marsh River	1864960	868.60	868.43	-0.17	868.61	0.01	0.18
US Goose River/ Shelly	1891054	869.74	869.58	-0.16	869.73	-0.01	0.15
Halstad Gage	1981580	871.57	871.36	-0.21	871.51	-0.06	0.15
Hendrum	2038409	875.34	875.10	-0.24	875.14	-0.20	0.04
Perley	2129181	878.51	878.32	-0.19	878.35	-0.16	0.03
Georgetown	2194021	882.94	882.96	0.02	883.01	0.07	0.05
North River/ Clay Co. Hwy 93	2305647	894.89	893.24	-1.65	893.56	-1.33	0.32
19th Ave N Fargo/ 28th Ave N Moorhead	2360321	899.83	897.96	-1.87	898.25	-1.58	0.29
Fargo Gage (13th Ave S, 12th Ave S)	2388223	905.29 (42.55*)	902.41 (39.67*)	-2.88	902.76 (40.02*)	-2.53	0.35
52nd Ave S Fargo/ 60th Ave S Moorhead	2438085	908.03	906.52	-1.51	906.70	-1.33	0.18
US ND Wild Rice River	2484618	911.46	910.22	-1.24	910.37	-1.09	0.15
US FRP Diversion	2531315	915.95	922.99	7.04	922.00	6.05	-0.99
Oxbow	2552977	918.27	923.07	4.80	922.11	3.84	-0.96
Hickson Gage	2563754	919.72	923.12	3.40	922.22	2.50	-0.90
Cass/Richland County Line	2582760	923.12	923.68	0.56	923.44	0.32	-0.24
Abercrombie	2764908	939.55	939.55	0.00	939.55	0.00	0.00

* Flood stage at USGS Gaging Station 05054000, Fargo, ND



APPENDIX B – DISCHARGE HYDROGRAPHS

Appendix B.1 – 10-percent Chance Event

Appendix B.2 – 2-percent Chance Event

Appendix B.3 – 1-percent Chance Event

Appendix B.4 – 0.2-percent Chance Event

APPENDIX B.1 – 10-PERCENT CHANCE EVENT DISCHARGE HYDROGRAPHS

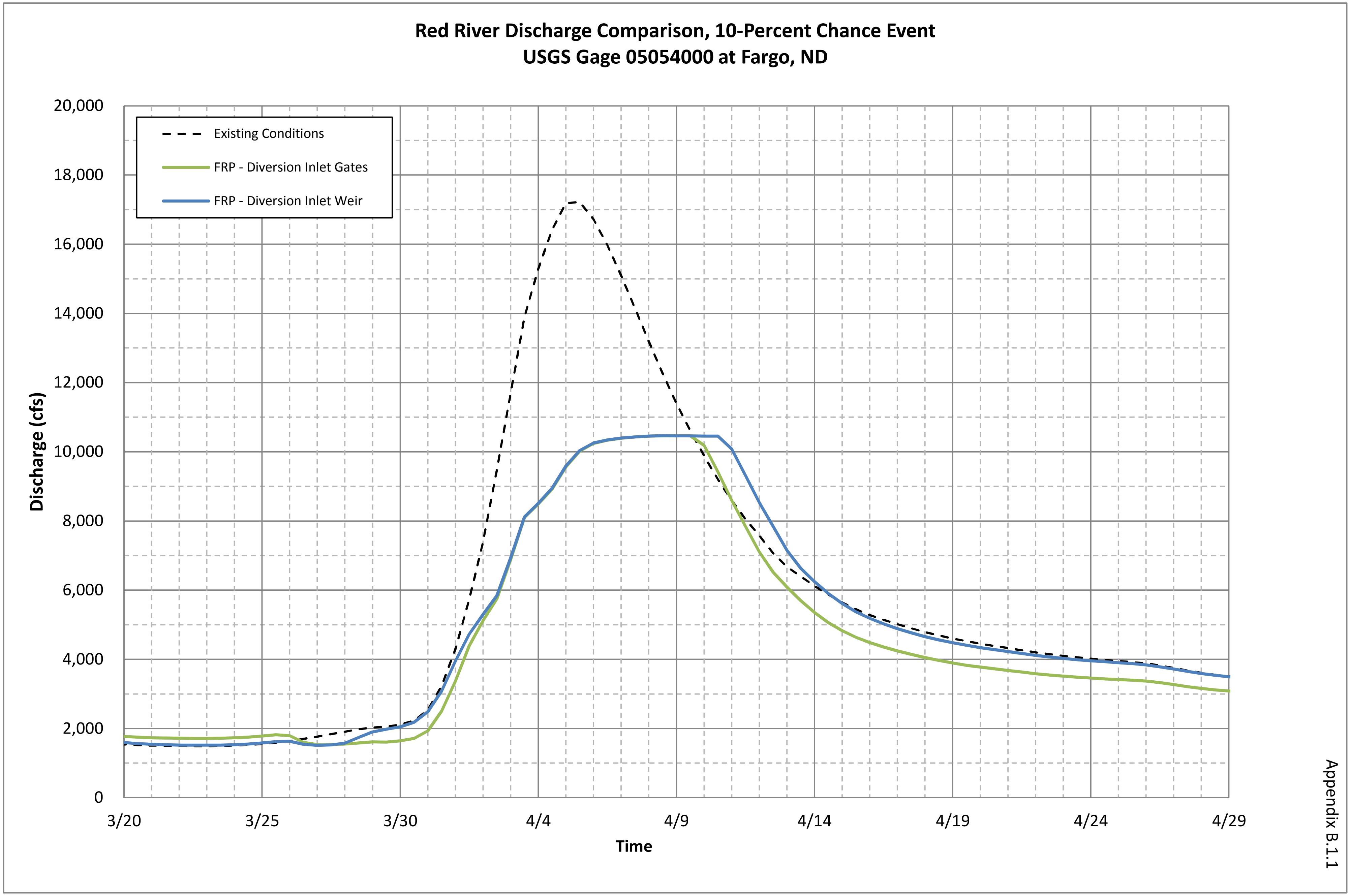
Appendix B.1.1 – USGS Gage 05054000 at Fargo, ND

Appendix B.1.2 – Georgetown, MN

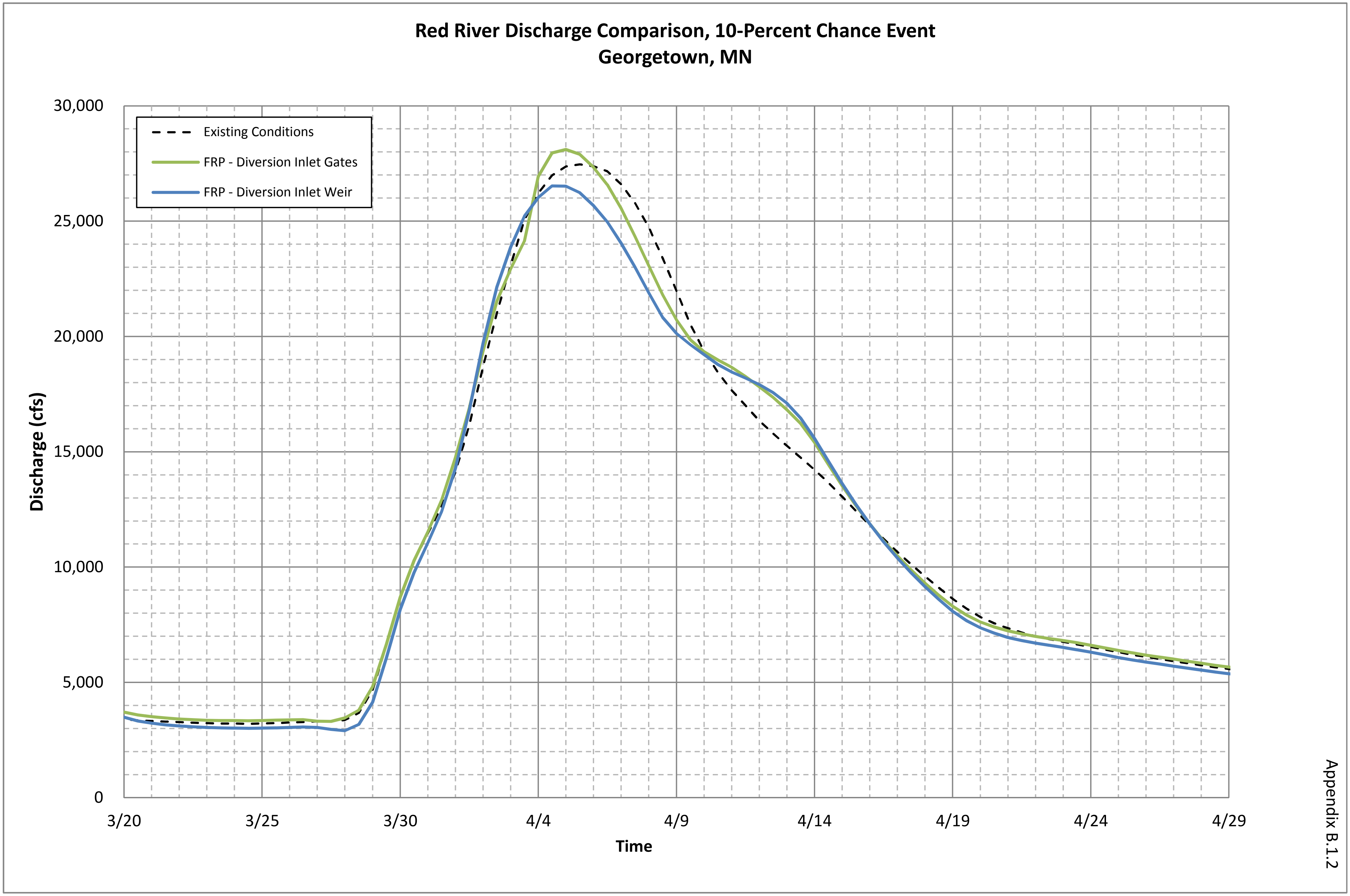
Appendix B.1.3 – USGS Gage 05064500 at Halstad, MN

Appendix B.1.4 – USGS Gage 05070000 near Thompson, ND

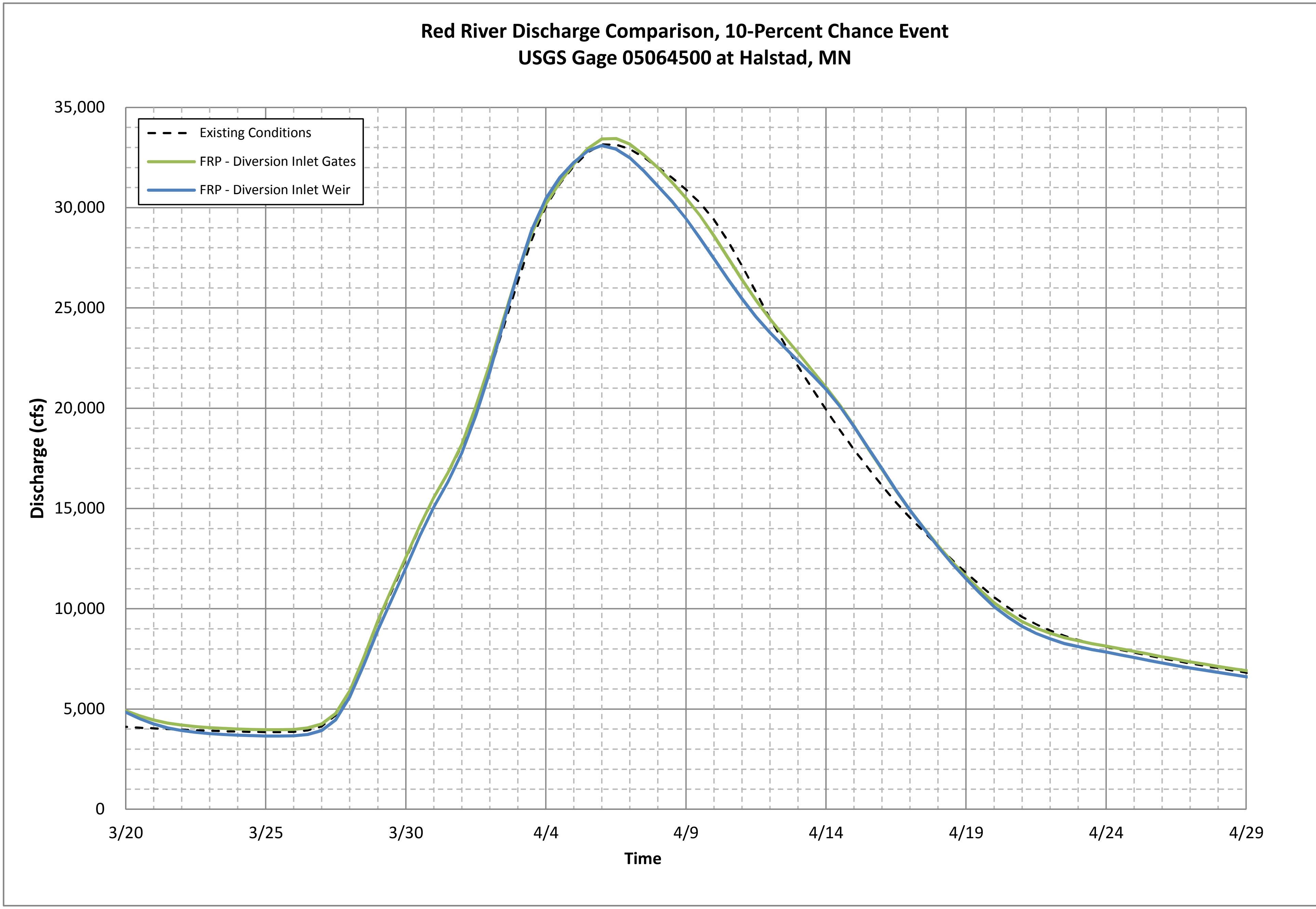
Appendix B.1.5 – USGS Gage 05082500 at Grand Forks, ND



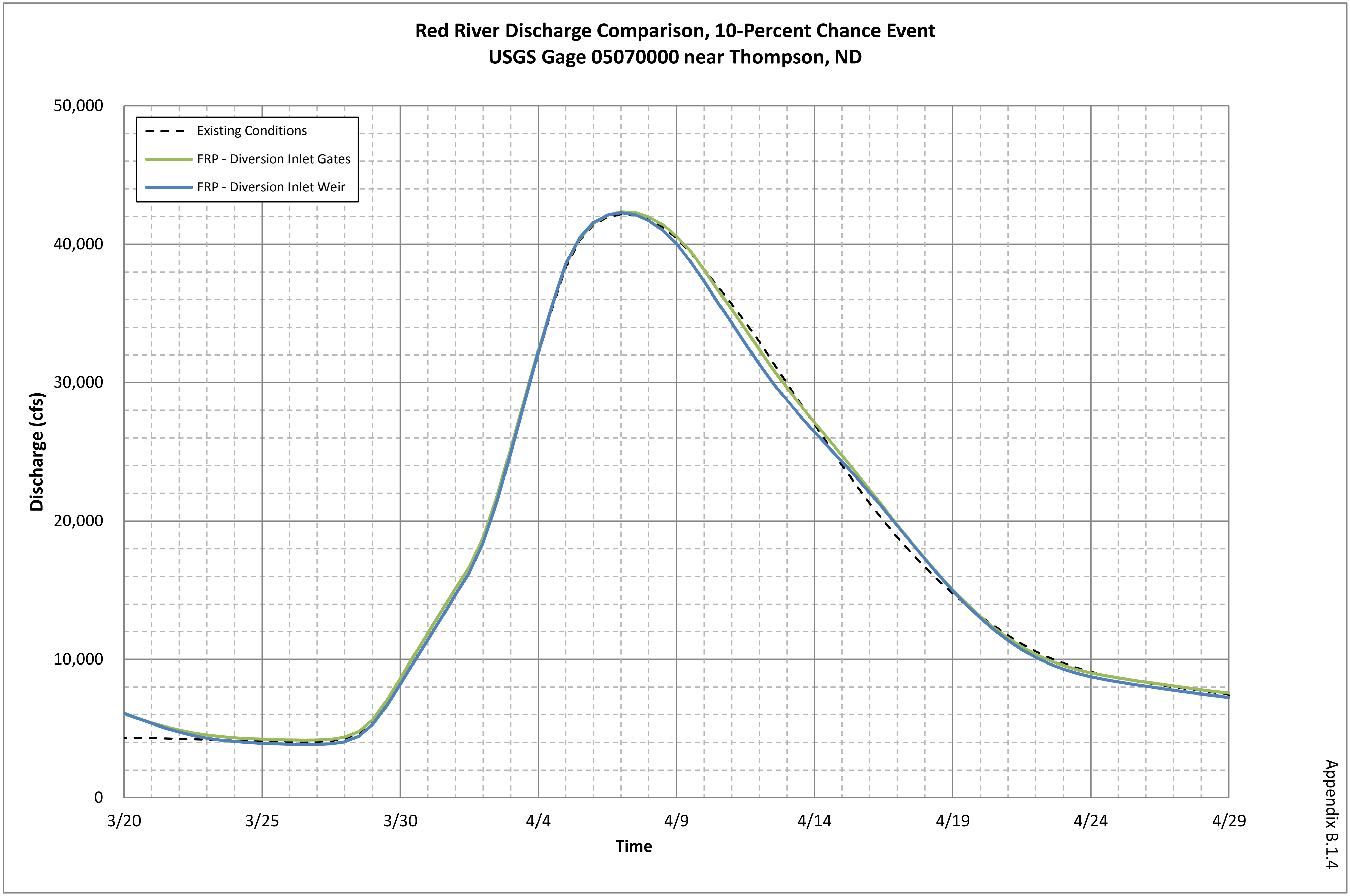
Appendix B.1.1



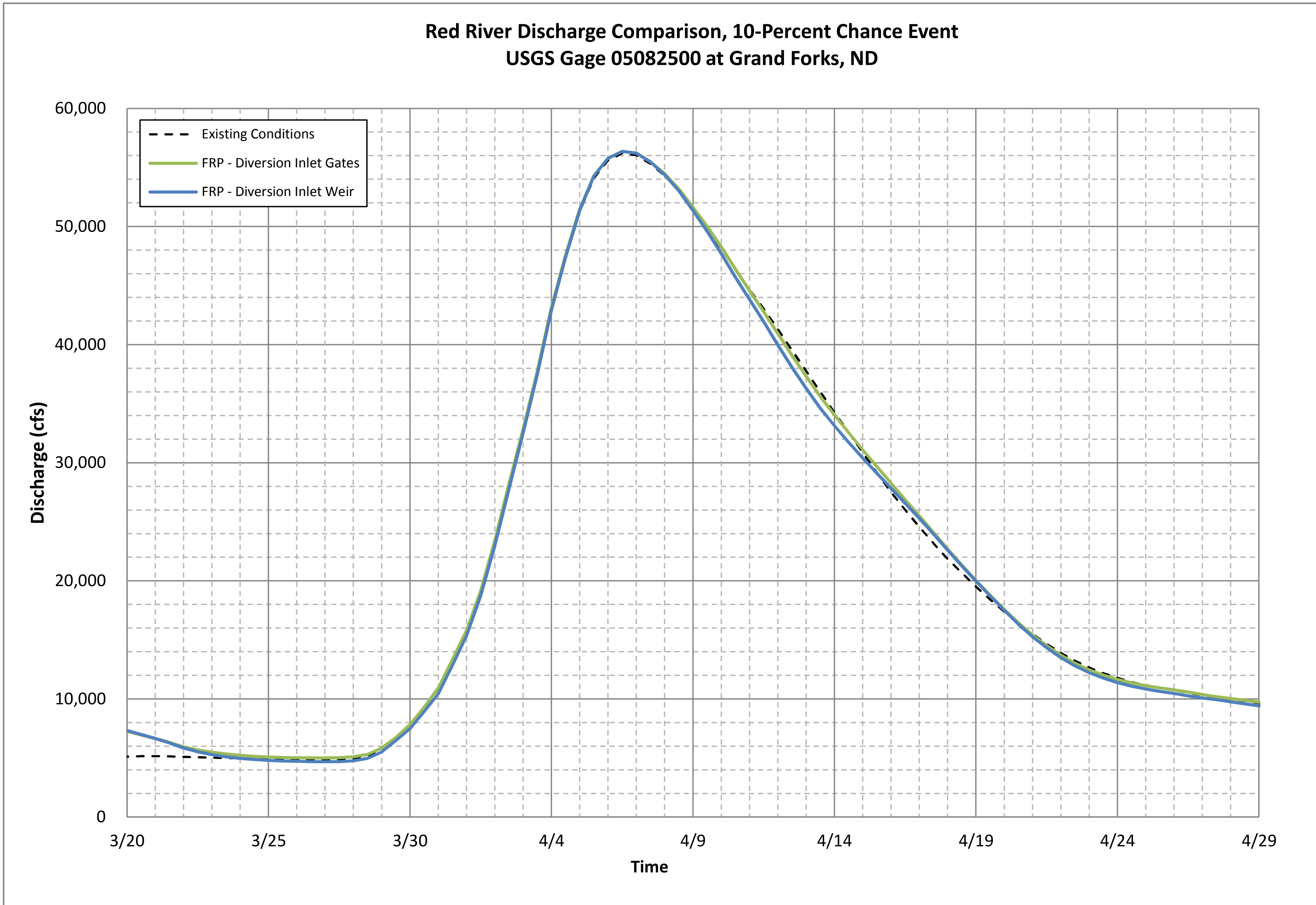
Appendix B.1.2



Appendix B.1.3

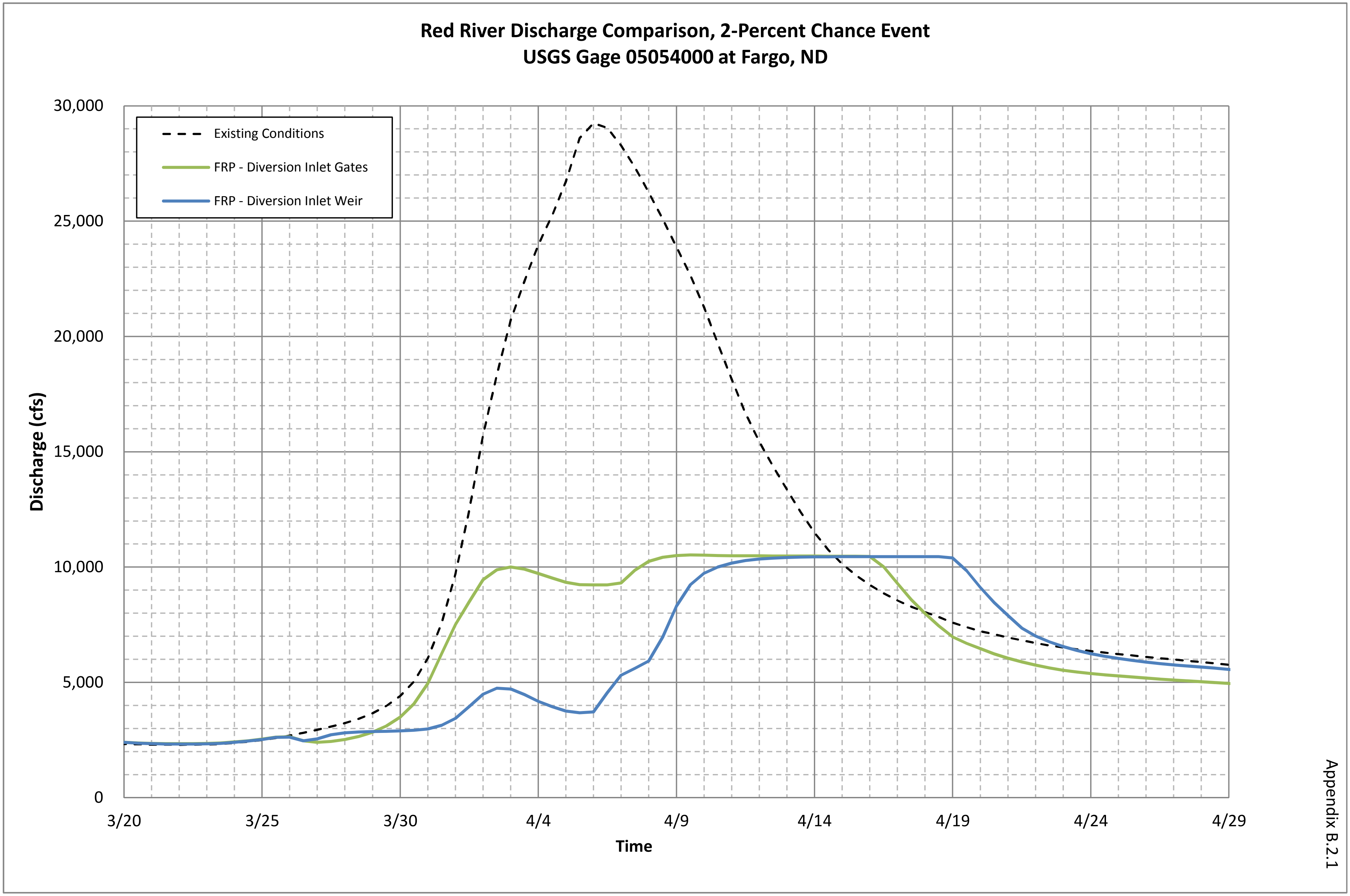


Appendix B.1.4

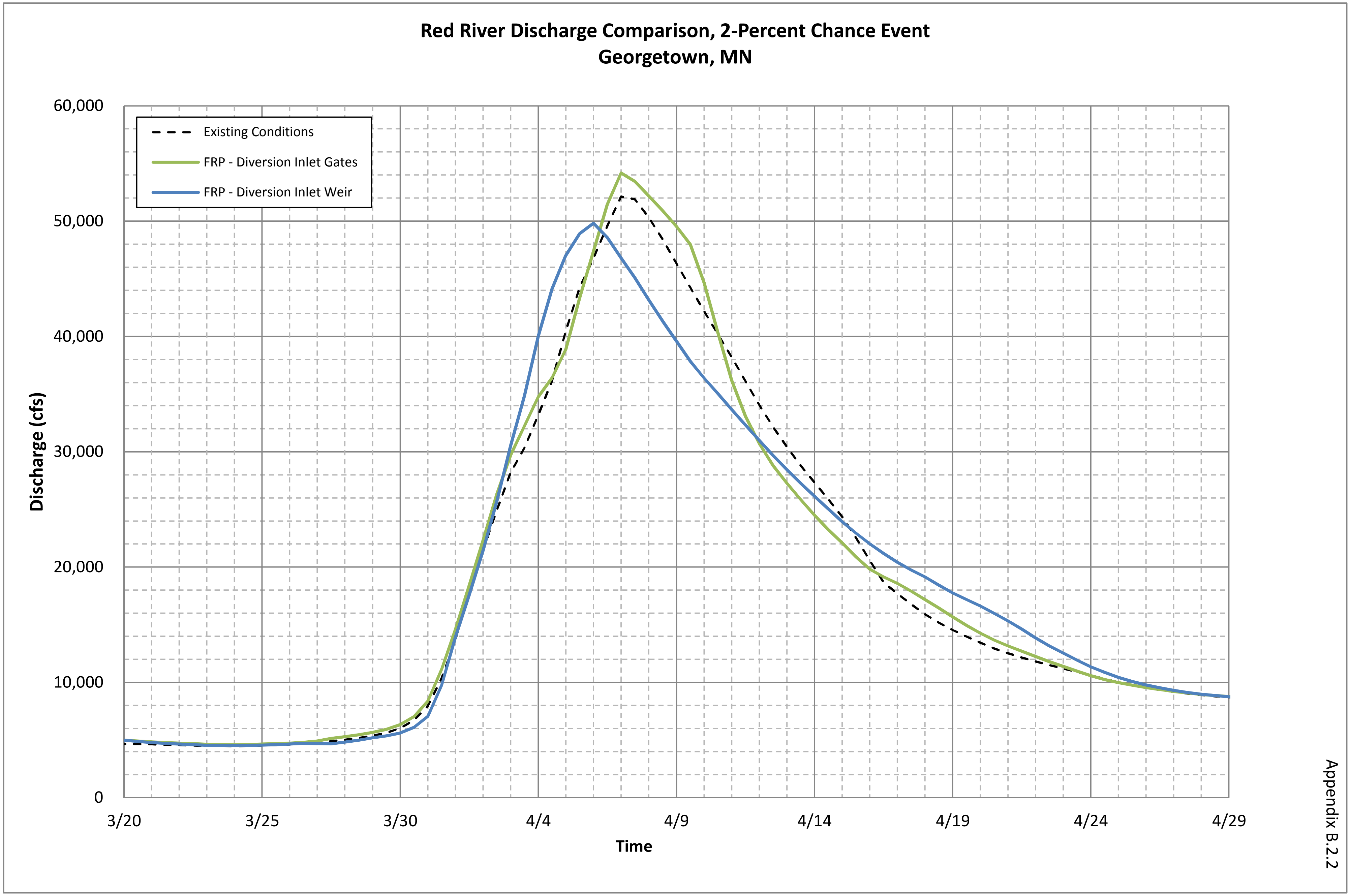


Appendix B.1.5

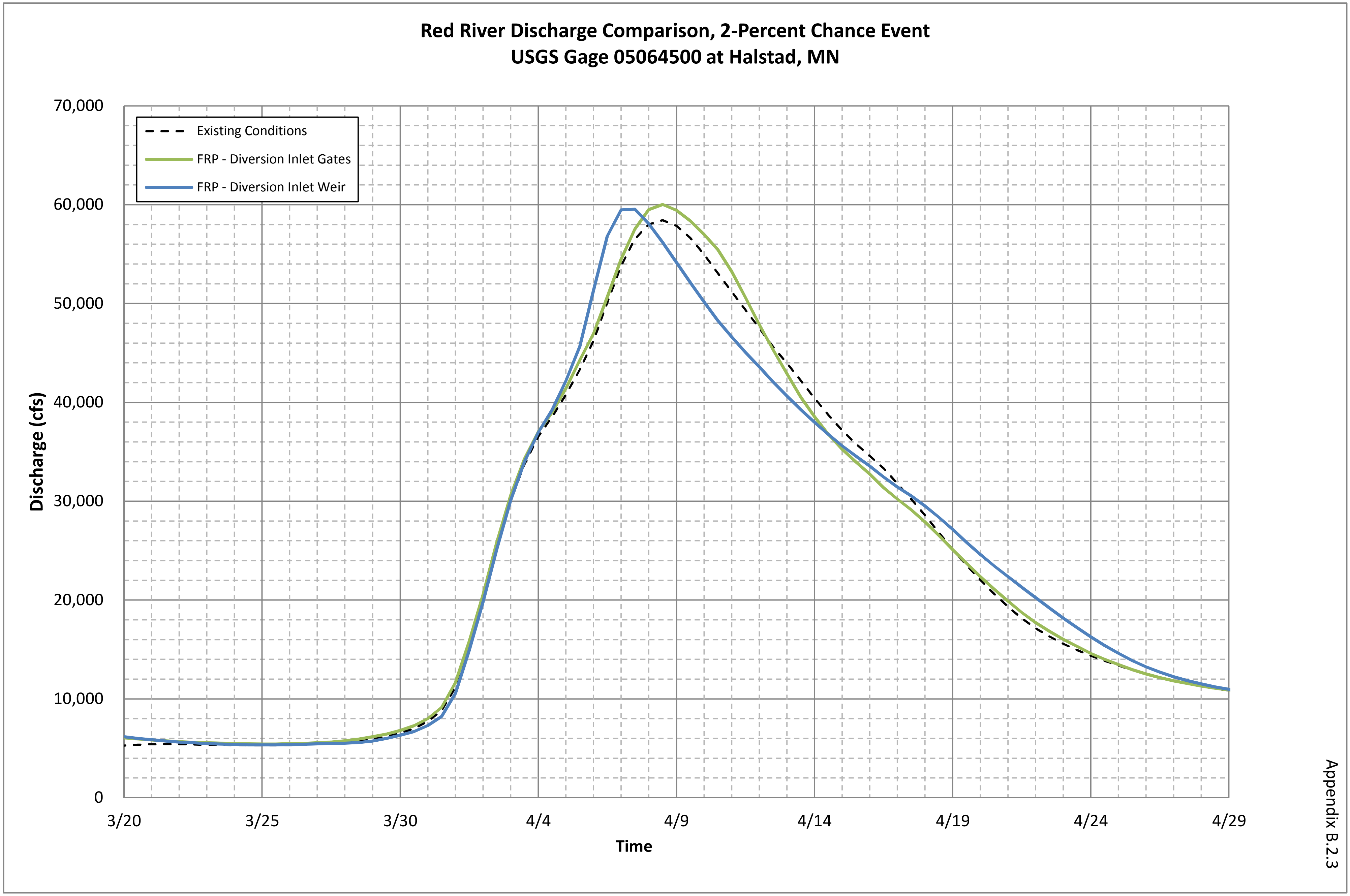
APPENDIX B.2 – 2-PERCENT CHANCE EVENT DISCHARGE HYDROGRAPHS



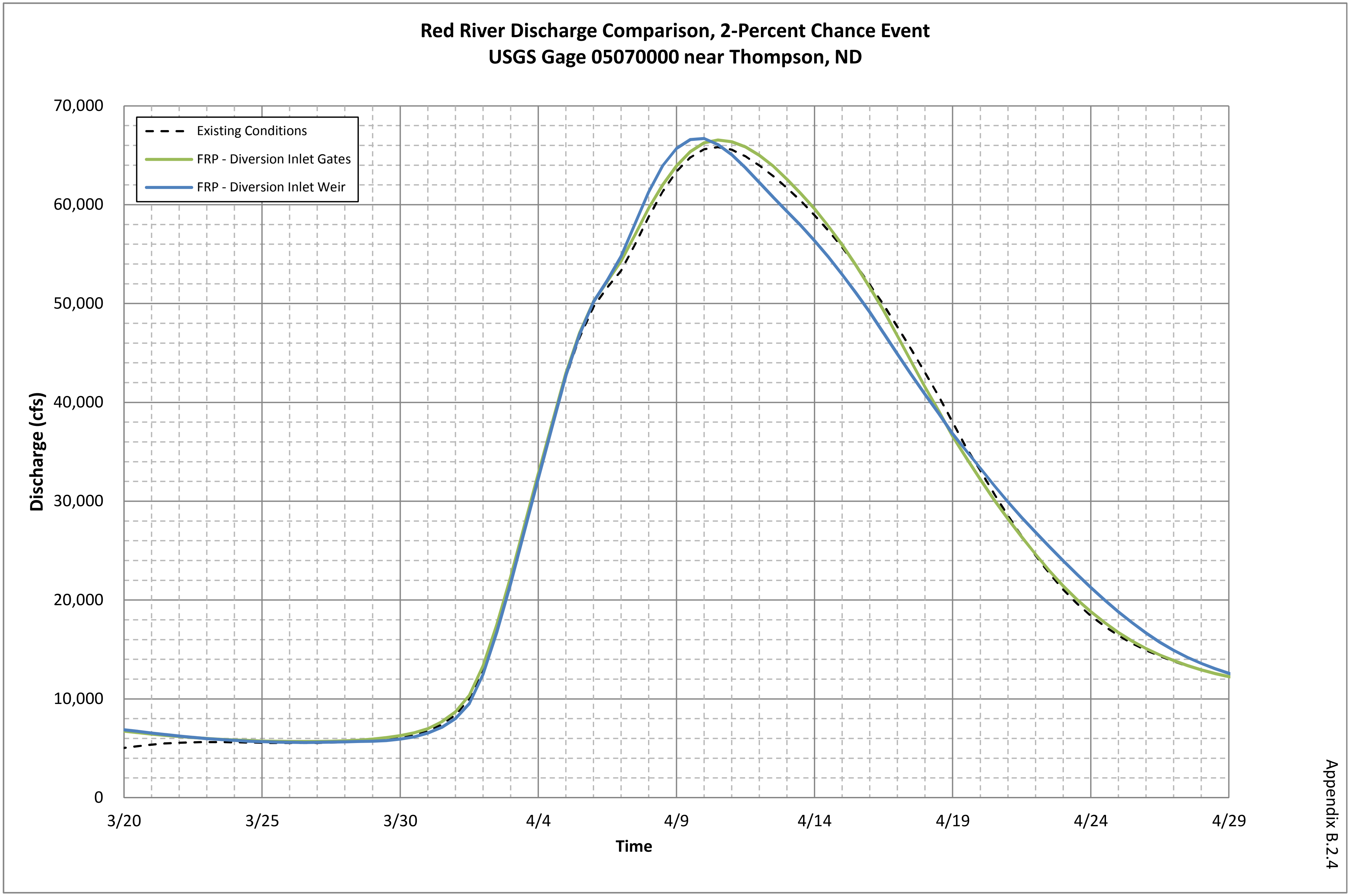
Appendix B.2.1



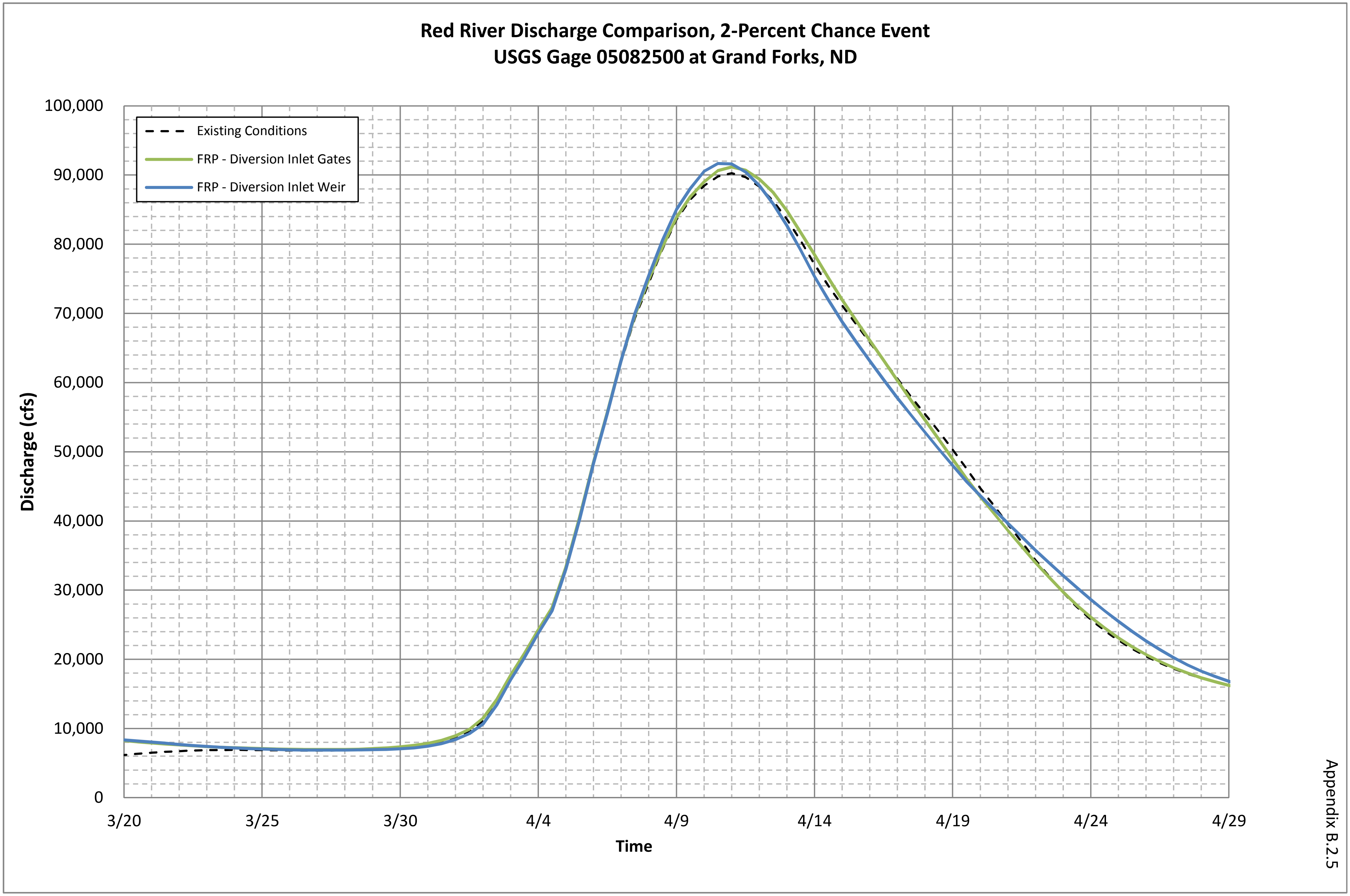
Appendix B.2.2



Appendix B.2.3

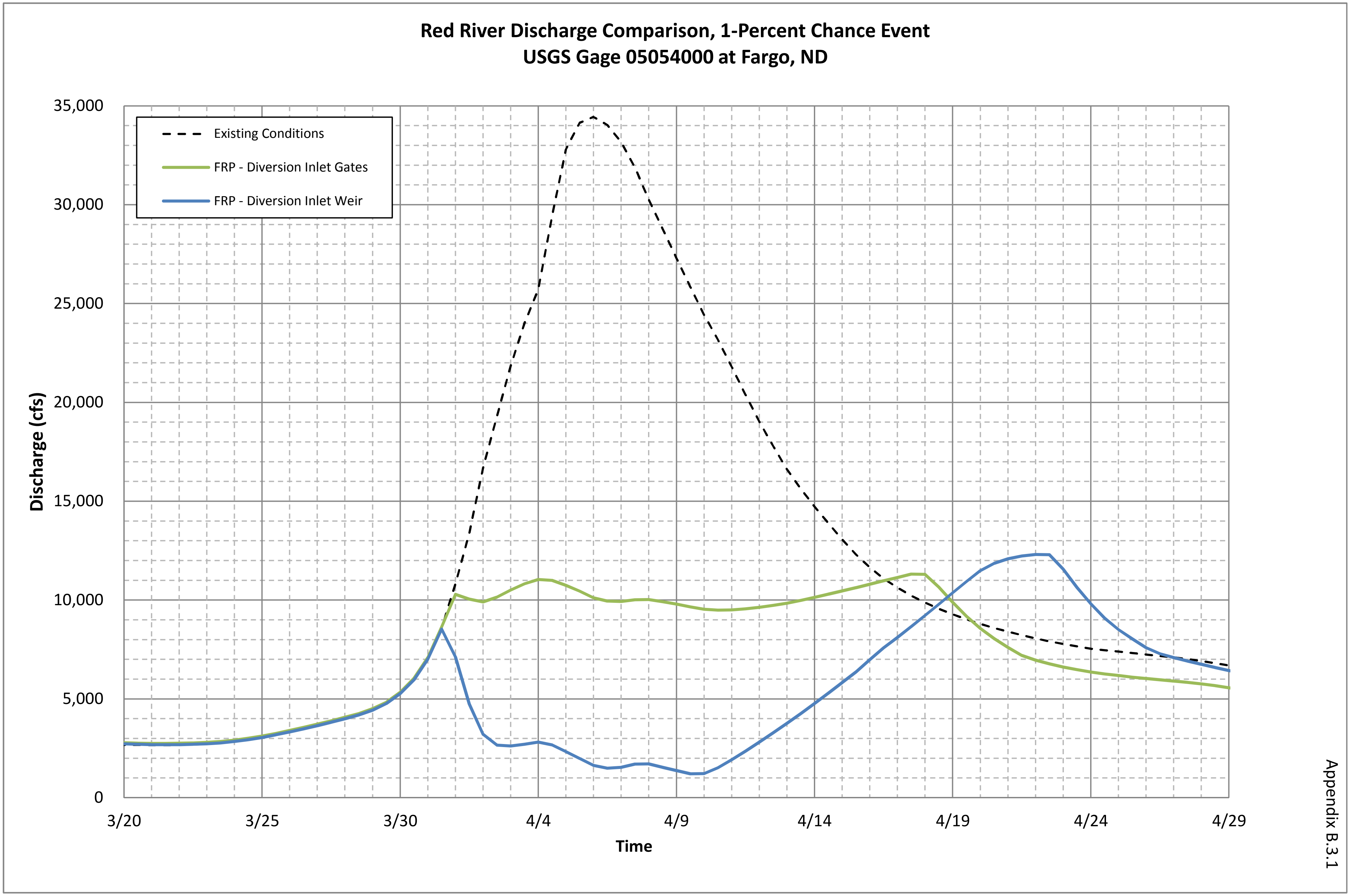


Appendix B.2.4

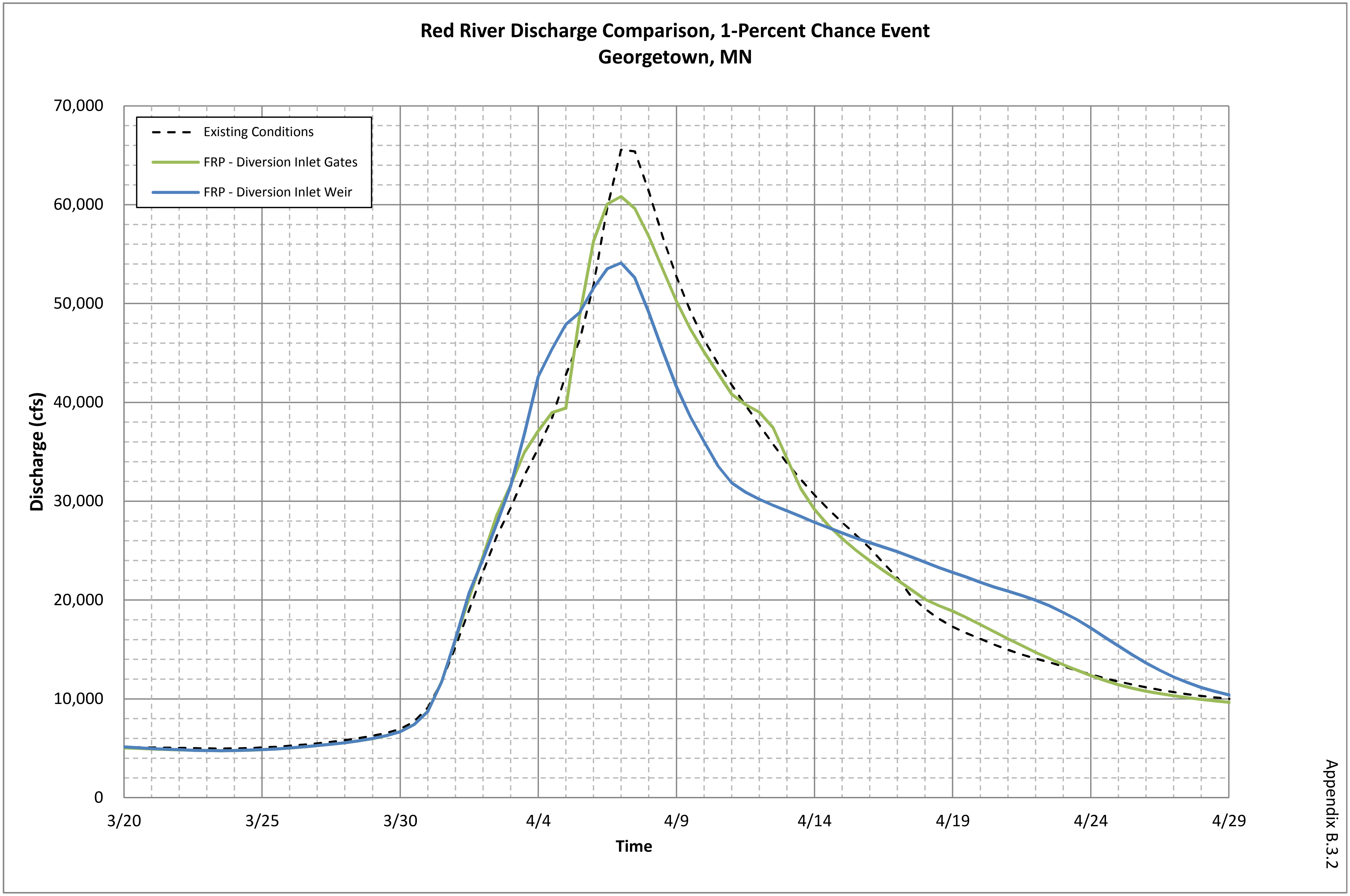


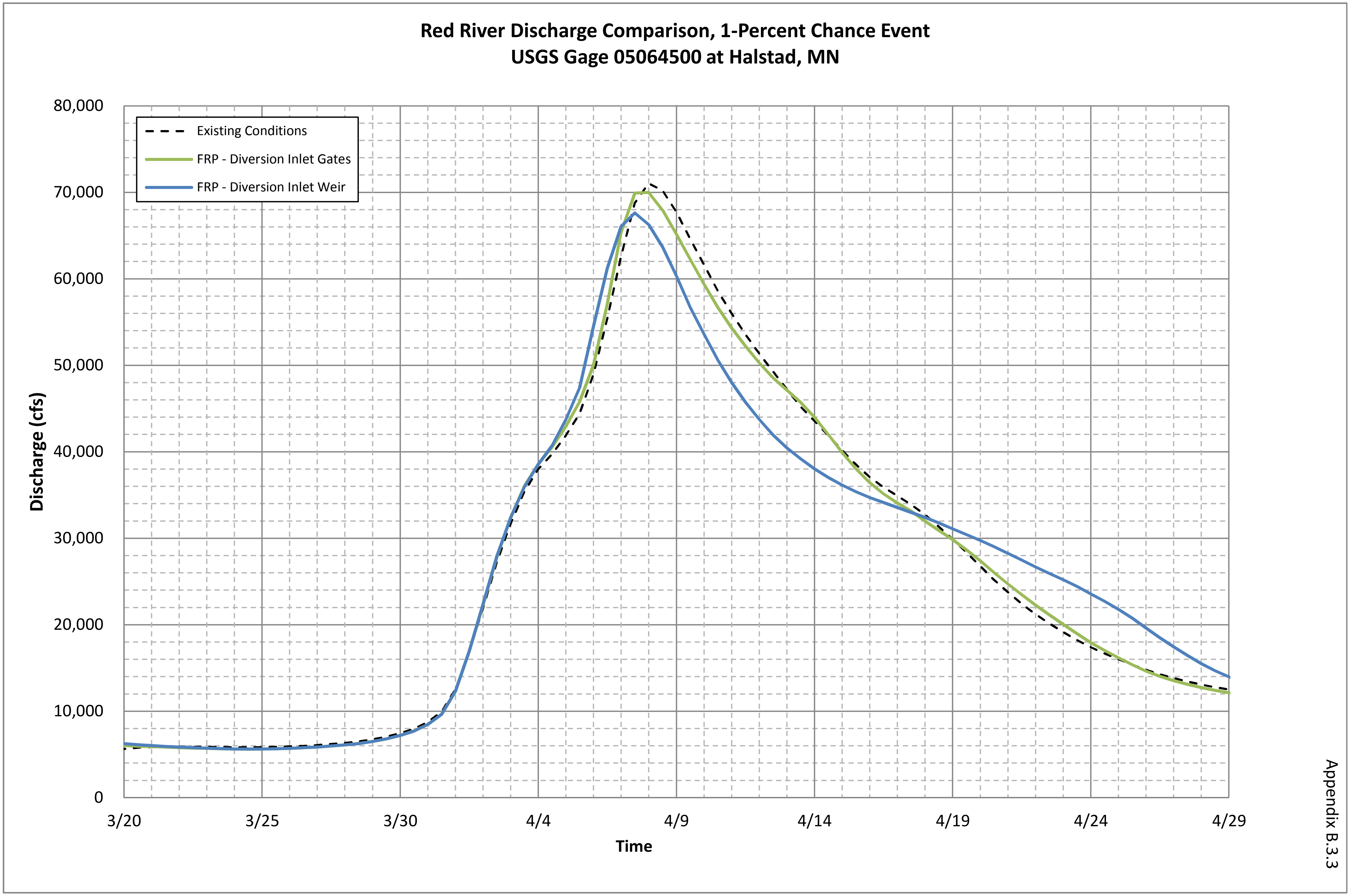
Appendix B.2.5

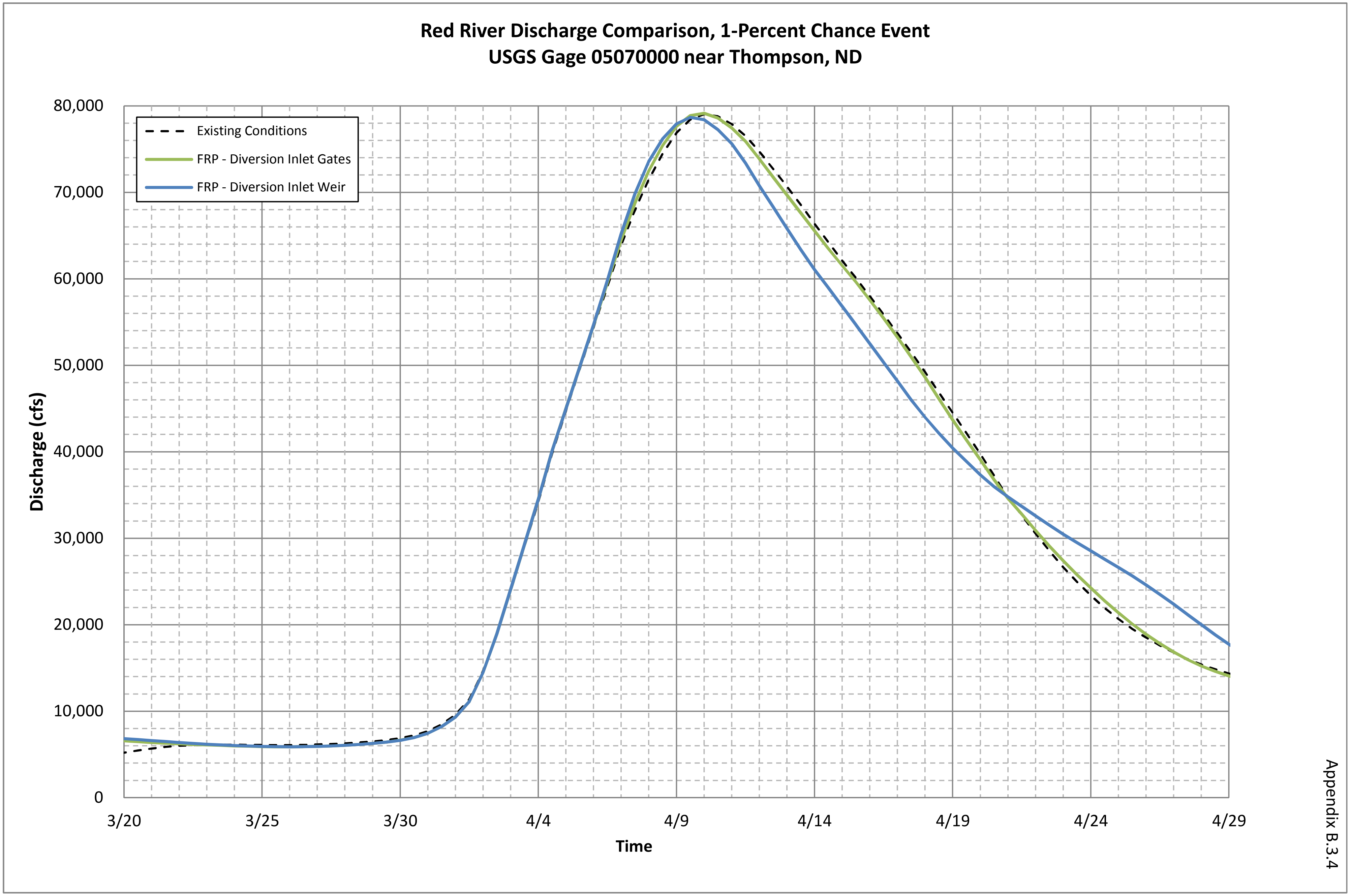
APPENDIX B.3 – 1-PERCENT CHANCE EVENT DISCHARGE HYDROGRAPHS



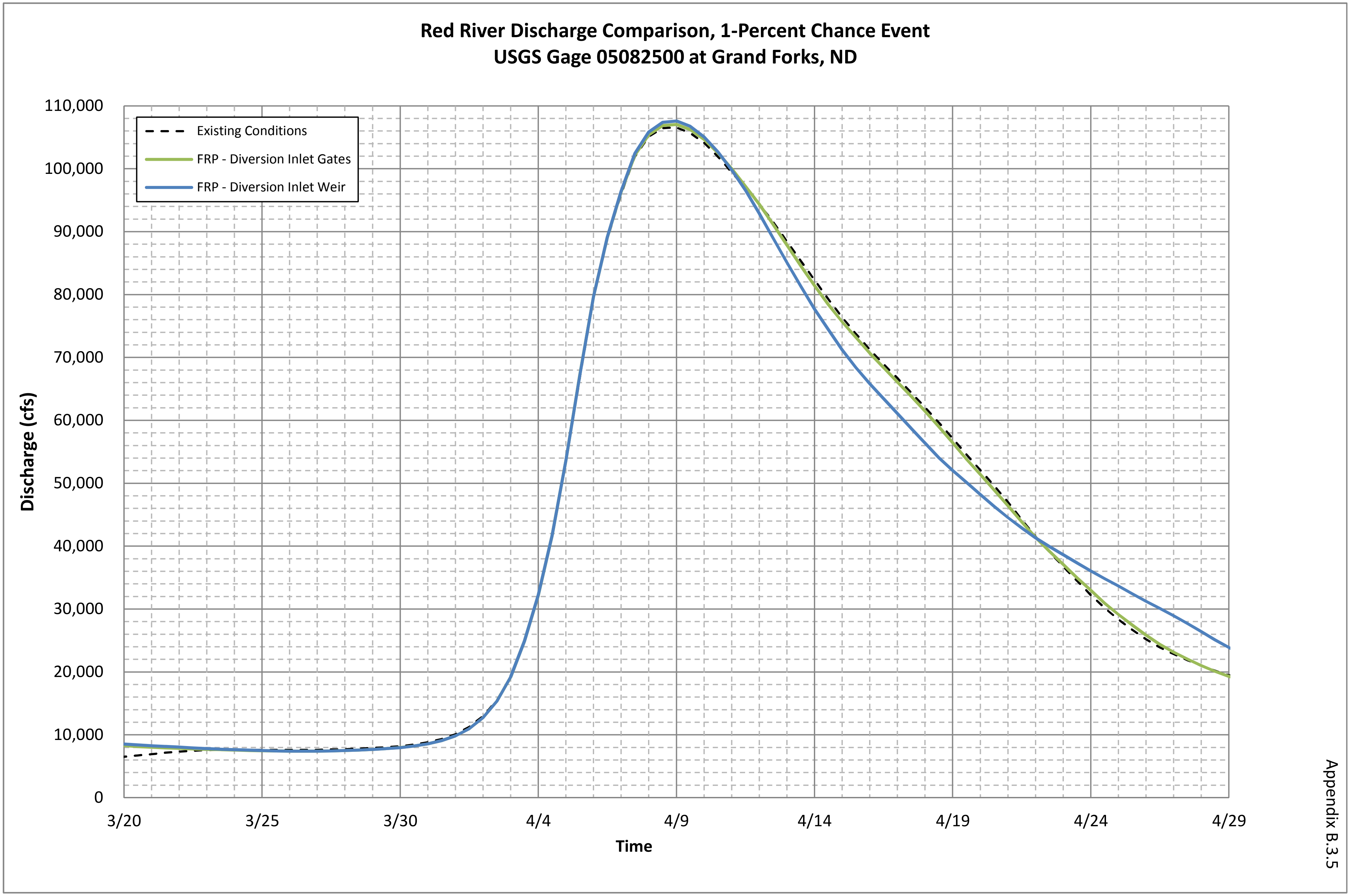
Appendix B.3.1


Red River Discharge Comparison, 1-Percent Chance Event
Georgetown, MN
Existing Conditions
FRP - Diversion Inlet Gates
FRP - Diversion Inlet Weir
Discharge (cfs)
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time


Red River Discharge Comparison, 1-Percent Chance Event
USGS Gage 05064500 at Halstad, MN
Existing Conditions
FRP - Diversion Inlet Gates
FRP - Diversion Inlet Weir
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Discharge (cfs)
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

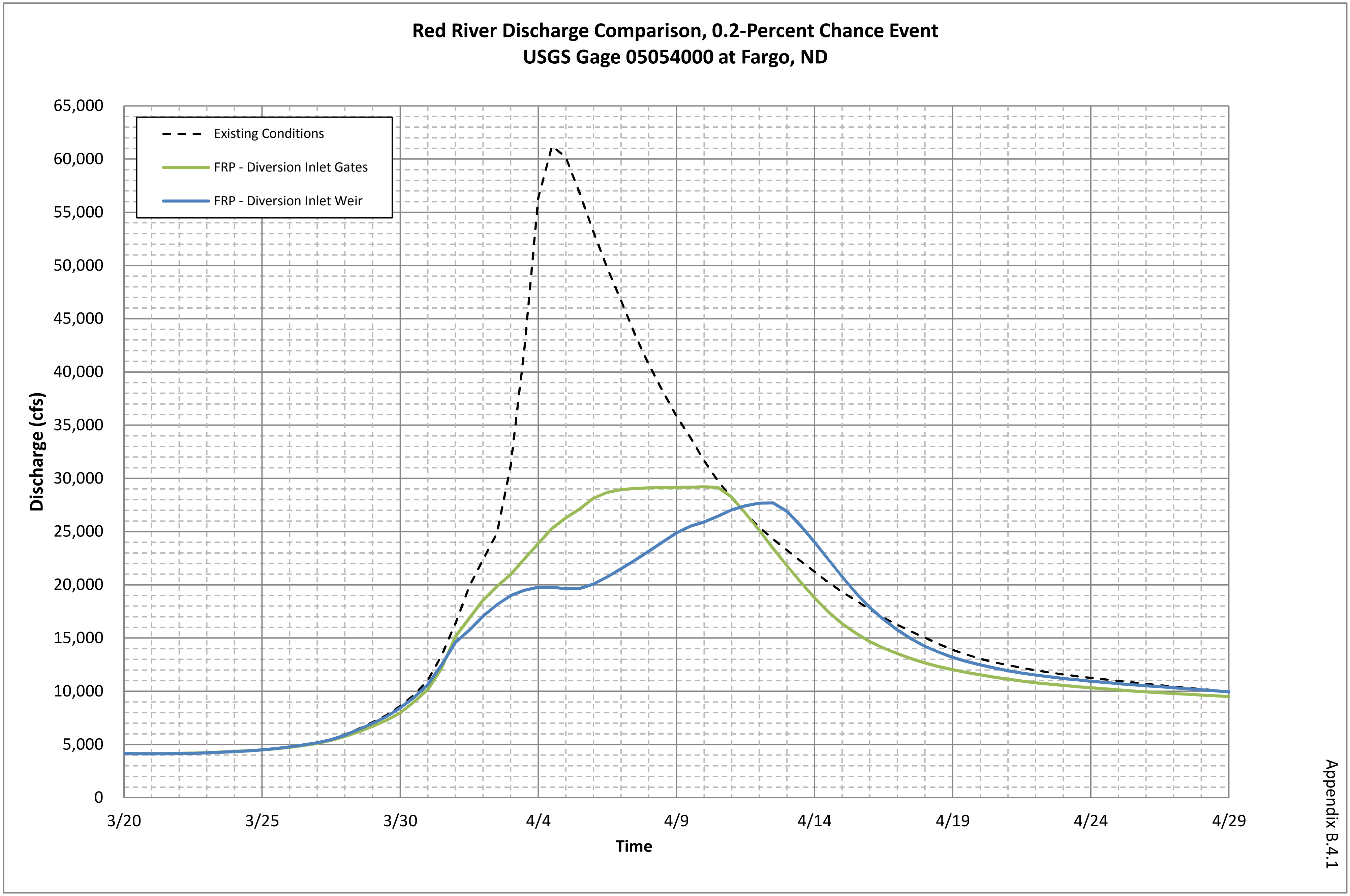


Appendix B.3.4

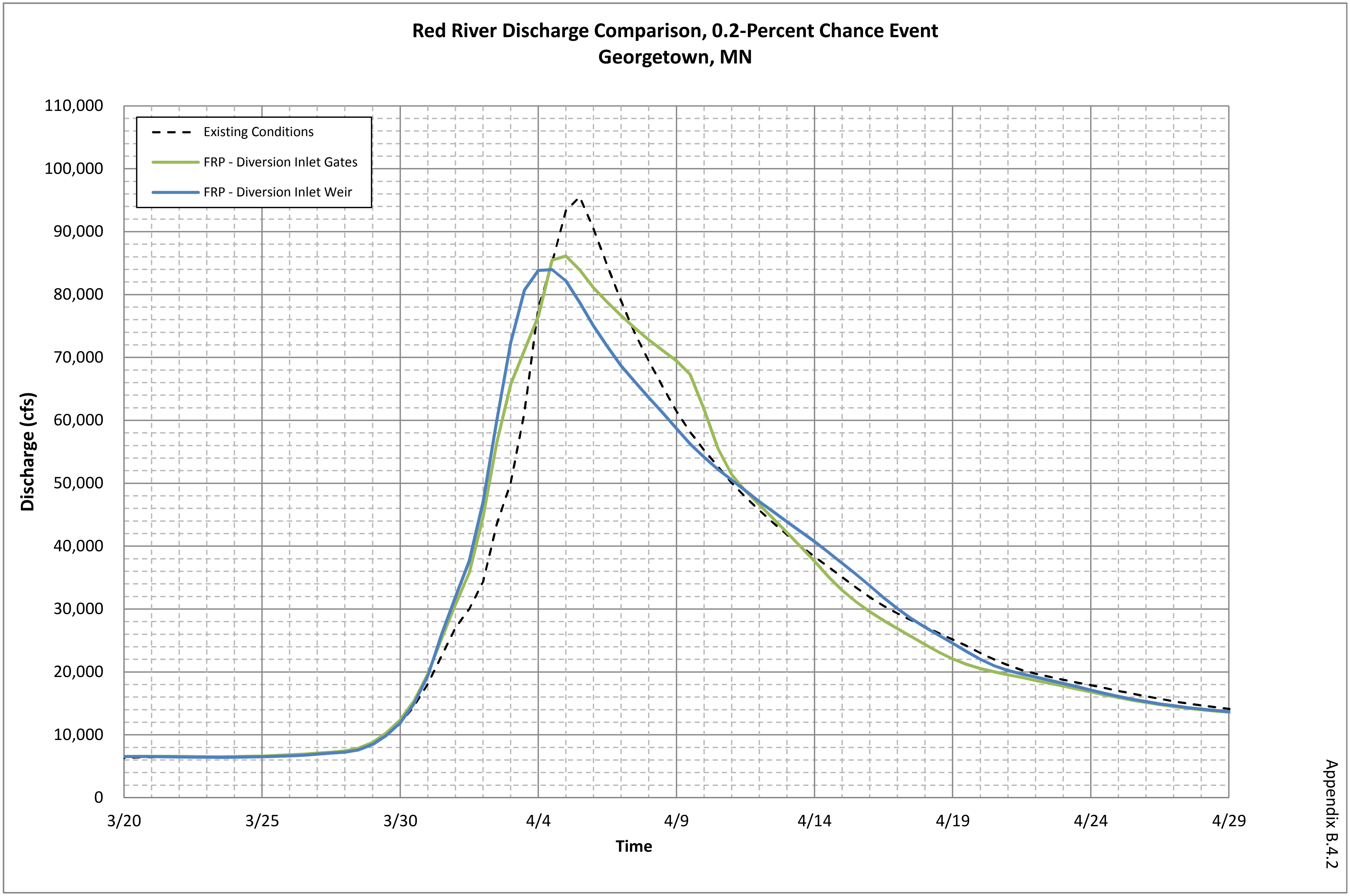


Appendix B.3.5

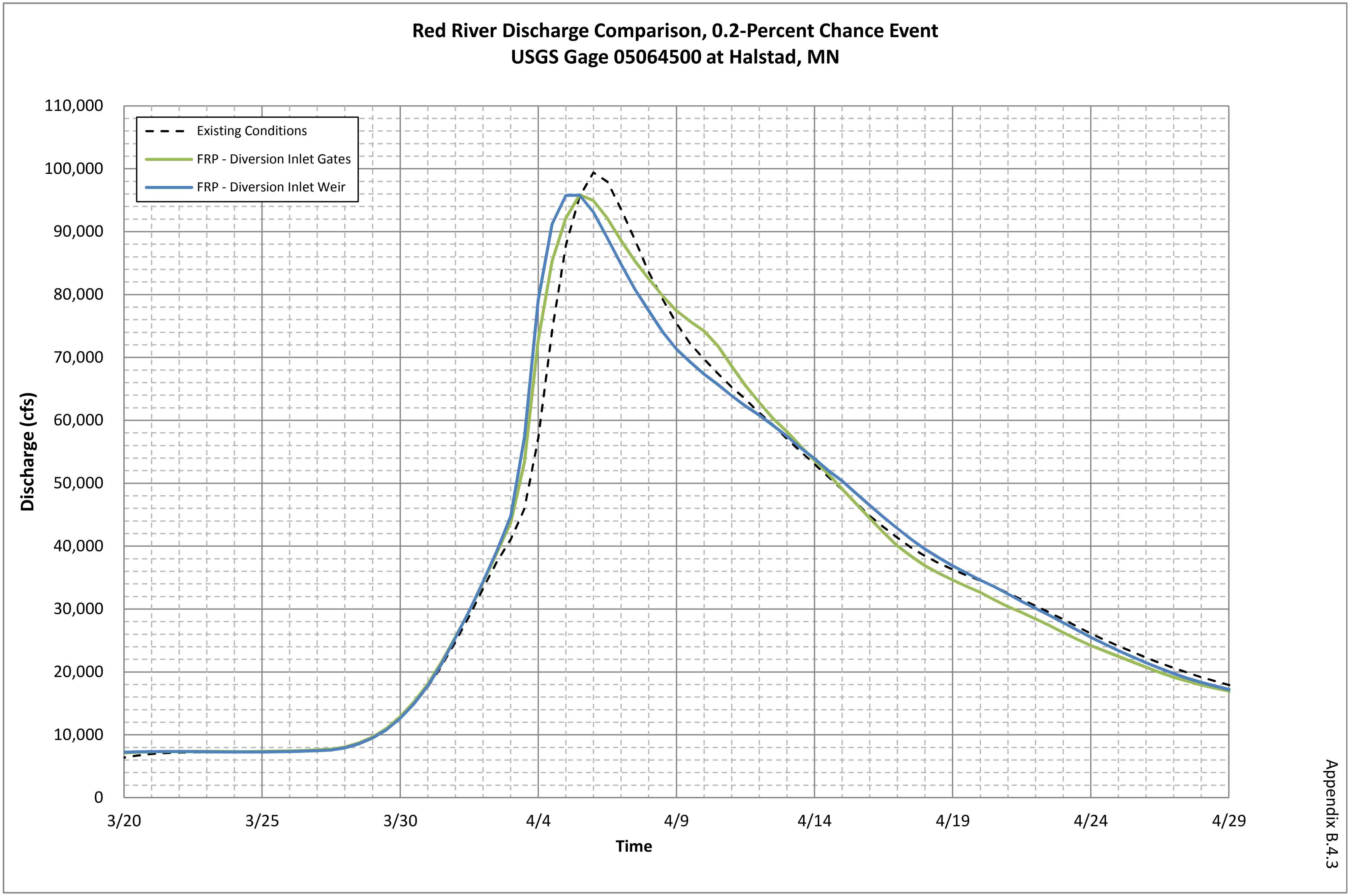
APPENDIX B.4 – 0.2-PERCENT CHANCE EVENT DISCHARGE HYDROGRAPHS

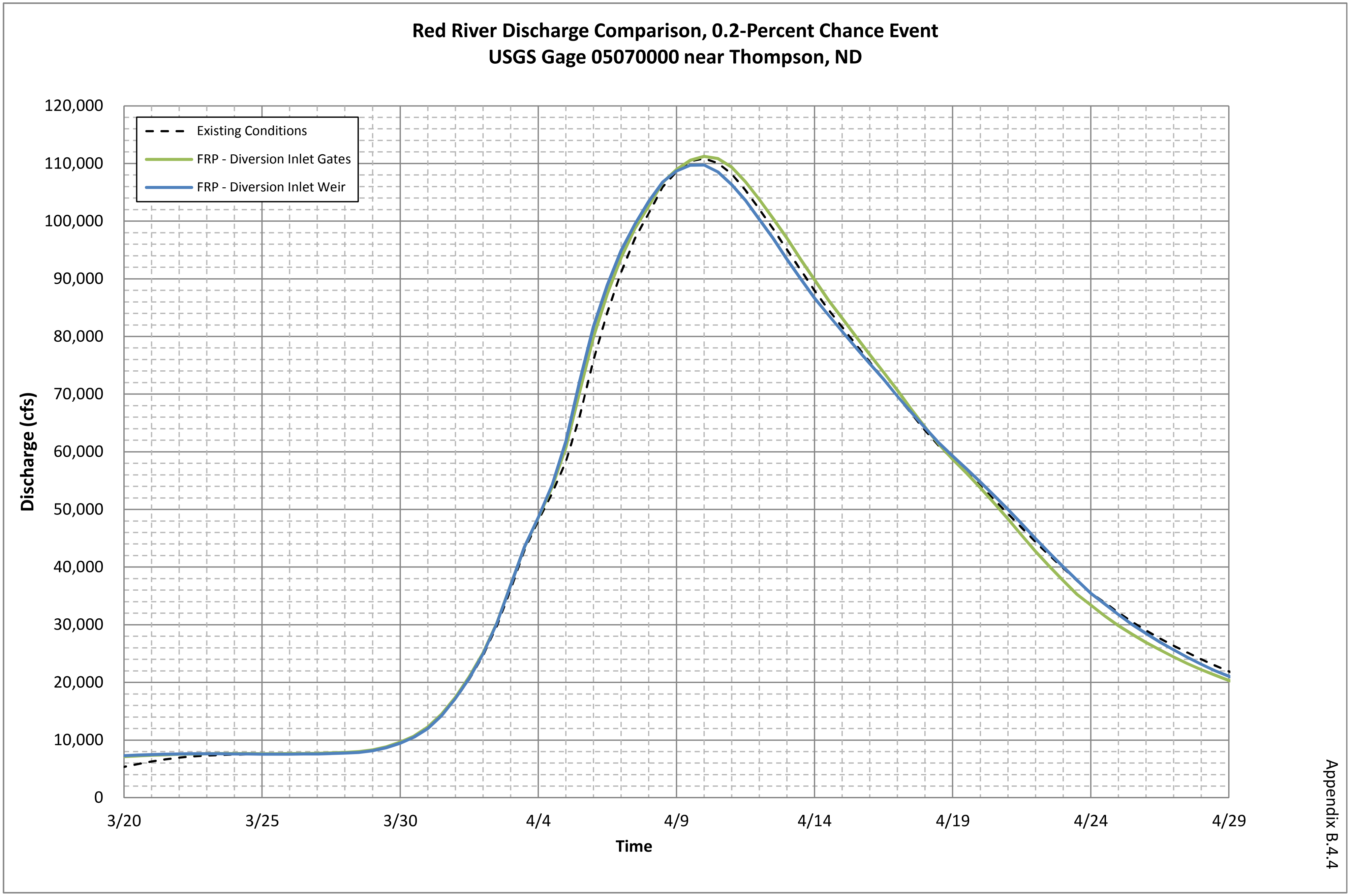


Appendix B.4.1

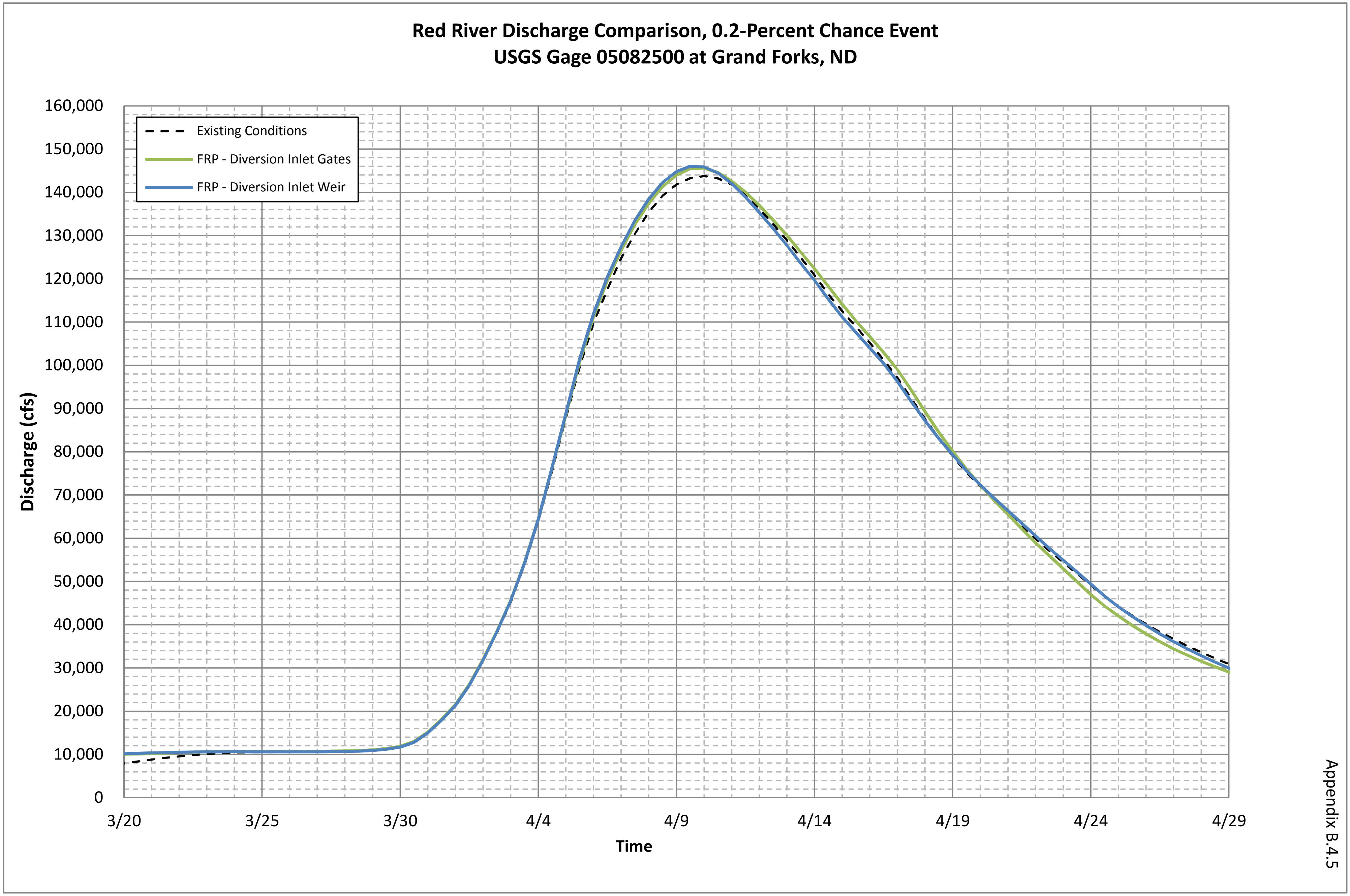


Appendix B.4.2


Red River Discharge Comparison, 0.2-Percent Chance Event
USGS Gage 05064500 at Halstad, MN
Existing Conditions
FRP - Diversion Inlet Gates
FRP - Diversion Inlet Weir
Discharge (cfs)
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time



Appendix B.4.4


Red River Discharge Comparison, 0.2-Percent Chance Event
USGS Gage 05082500 at Grand Forks, ND
Existing Conditions
FRP - Diversion Inlet Gates
FRP - Diversion Inlet Weir
Discharge (cfs)
160,000
150,000
140,000
130,000
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
3/20
3/25
3/30
4/4
4/9
4/14
4/19
4/24
4/29
Time

APPENDIX C – COST ESTIMATE

Appendix C.1 - Cost Estimate

FR/FEIS - April 2011
90' Inlet Weir at Elevation 903.25 ft.

ITEM	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	AMOUNT	CONTINGENCIES %	CONTINGENCIES AMOUNT	TOTAL AMOUNT	NOTES
09 06	**INLET WEIR TO DIVERSION STRUCTURE**								
09 06 01	**SITE WORK**	1.0	LS	$2,006,900.00	$2,006,900	30%	$602,100	$2,609,000	*1,2,3,4*
09 06 02	**INLET WEIR STRUCTURE**								
	Concrete Rollway Structure	1.0	LS	$1,904,800.00	$1,904,800	30%	$571,400	$2,476,200	*1,2,3,4,5*
	Structure Walls	1.0	LS	$3,536,500.00	$3,536,500	30%	$1,061,000	$4,597,500	*1,2,3,4,5*
	Riprap Erosion Protection	1.0	LS	$171,300.00	$171,300	30%	$51,400	$222,700	*1,2,3,4*
	Mech, Electrical, SCADA & Misc. Features	1.0	LS	$2,322,700.00	$2,322,700	30%	$696,800	$3,019,500	*1,2,3,4*
		DIVERSION INLET WEIR STRUCTURE TOTAL			**$9,942,200**		**$2,982,700**	**$13,000,000**	

Phase 6, July 2012
130' Inlet Weir at Elevation 907 ft.

ITEM	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	AMOUNT	CONTINGENCIES %	CONTINGENCIES AMOUNT	TOTAL AMOUNT	NOTES		
09 06	**INLET WEIR TO DIVERSION STRUCTURE**										
09 06 01	**SITE WORK**	1.0	LS	$2,764,220.75	$2,764,200	30%	$829,300	$3,593,500	*1,2,3,4*		multiplier from FR/FEIS Weir
09 06 02	**INLET WEIR STRUCTURE**									Multiplier	
	Concrete Rollway Structure	1.0	LS	$2,623,592.45	$2,623,600	30%	$787,100	$3,410,700	*1,2,3,4,5*	1.38	multiplier from FR/FEIS Weir
	Structure Walls	1.0	LS	$4,871,028.30	$4,871,000	30%	$1,461,300	$6,332,300	*1,2,3,4,5*	Inlet Weir 130 ft	multiplier from FR/FEIS Weir
	Riprap Erosion Protection	1.0	LS	$235,941.51	$235,900	30%	$70,800	$306,700	*1,2,3,4*	Ratio 106' to 146'	multiplier from FR/FEIS Weir
	Mech, Electrical, SCADA & Misc. Features	1.0	LS	$3,199,190.57	$3,199,200	30%	$959,800	$4,159,000	*1,2,3,4*	(90' weir to 130' weir)	multiplier from FR/FEIS Weir
		DIVERSION INLET WEIR STRUCTURE TOTAL			**$13,693,900**		**$4,108,300**	**$18,000,000**			

FRP Inlet Gate, July 2012
167' Inlet Foundation, Gates from RRCS (FE/FEIS)

ITEM	ITEM DESCRIPTION	QUANTITY	UNITS	UNIT PRICE	AMOUNT	CONTINGENCIES %	CONTINGENCIES AMOUNT	TOTAL AMOUNT	NOTES		
09 06	**INLET WEIR TO DIVERSION STRUCTURE**										
09 06 01	**SITE WORK**	1.0	LS	$3,477,995.57	$3,478,000	30%	$1,043,400	$4,521,400	*1,2,3,4*		multiplier from FR/FEIS Weir
09 06 02	**INLET WEIR STRUCTURE**									Multiplier + 10%	
	Concrete Rollway Structure	1.0	LS	$3,301,054.34	$3,301,100	30%	$990,300	$4,291,400	*1,2,3,4,5*	1.73	multiplier from FR/FEIS Weir
	Structure Walls	1.0	LS	$6,128,821.23	$6,128,800	30%	$1,838,600	$7,967,400	*1,2,3,4,5*	Inlet Structure 167 ft	multiplier from FR/FEIS Weir
	Riprap Erosion Protection	1.0	LS	$296,866.13	$296,900	30%	$89,100	$386,000	*1,2,3,4*	Ratio 106' to 167'	multiplier from FR/FEIS Weir
	Mech, Electrical, SCADA & Misc. Features	1.0	LS	$4,025,282.92	$4,025,300	30%	$1,207,600	$5,232,900	*1,2,3,4*	(3-45' gates with 8' wide piers/walls)	multiplier from FR/FEIS Weir
09 02 02 02	Gated Structure	1.0	LS	$6,029,918.40	$6,029,900	30%	$1,809,000	$7,838,900			ratio from FR/FEIS RRCS
										Multiplier + 10%	
										0.53	
		DIVERSION INLET GATE STRUCTURE TOTAL			**$23,260,000**		**$6,978,000**	**$30,000,000**		RRCS Gates 3-50'x47' FRP Inlet Gates 3-45'x25' (25/47) x (45/50)	

NOTES FOR CONTINGENCIES:

1. UNKNOWN QUANTITIES
2. LIMITED DESIGN WORK COMPLETED
3. UNKNOWN UNIT PRICES
4. ALIGNMENT NOT FINAL
5. LIMITED BORING INFORMATION AVAILABLE