Appendix B-3: Alternative 1 Dry Dam

HEC-ResSim Initial Alternative Assessment

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1. Alternative Description & Objective

This alternative prioritizes maintaining Rafferty Reservoir, Grant Devine Reservoir, and Lake Darling as dry dams and uses an operations set designed exclusively for flood control. In this modeled scenario, the guide curve for each reservoir was set constant to the invert elevation of its lowest outlet. Downstream maximum flow constraints were implemented to maximize the releases from reservoirs without incurring major flood damages. Results derived to reflect the suggested alternative were compared to the baseline model results, which reflect present day operations (Annex A & Annex B). This analysis was conducted using the full period of record available at the time of the simulation (1946-2017).

1.1 Alternative Development

This alternative was proposed as a bookend case by the Public Advisory Group during the 2019 March workshops held in Minot, ND and is meant to identify the maximum amount of flood control Rafferty, Grant Devine, and Lake Darling reservoirs could provide. The alternative details were discussed at the workshop and provided to the ResSim alternatives modeling team in April 2019. This case is considered to be the opposite of Alternative 2, which models the reservoirs at Full Supply Level with no drawdowns.

1.2 Alternative Fine Tuning

This alternative was not carried forward into Phase 3, as it is a representative extreme bookend case and will not be considered as a realistic alternative for this study.

1.3 HEC-ResSim Nomenclature

Within HEC-ResSim, a new network, alternative and simulation run was generated to reflect each proposed alternative. To generate the alternative network, a copy of the base network was made and modified to reflect the proposed alternative. A table indicating the nomenclature associated with the ResSim network, alternative and simulation used to model the alternative is listed in Table 1.

Table 1. Model nomenclature

Scenario	Time Window	ResSim Model Name	Network Name	Alternative Name	Simulation Name
Baseline	1946-2017	SourisRiverPos	cal2Fsl	Base	00_BL_AnxA_46_17
Dry Dam	1946-2017	SourisRiverPos	01_Dry_BL	01_Dry_BL	01_Dry_1946_2017

2. Operational Rules

Table 2 presents the operational rule changes that were made to the baseline HEC-ResSim model to simulate Alternative 1.

Table 2. Operation rules added specific to alternative

Name of Dam	Name of Rule, Outlet or IF Statement or State Variable Element	Rule Description
Rafferty Reservoir	ds_sherwood_sv	Constant downstream maximum constraint at Sherwood
Boundary Reservoir		
Grant Devine Reservoir	ds_sherwood_sv	Constant downstream maximum constraint at Sherwood
Lake Darling Reservoir	DS_Minot_sv	Constant downstream maximum constraint at Minot, ND

Two types of changes were made to specifically model this scenario. Both types of changes included changing aspects of rules that were already in the baseline model. The first type of change was changing downstream constraints within the graphical user interface (GUI). The second type of change was redefining aspects of the guide curves for the reservoirs within the state variables.

First, the downstream maximum flow constraint for Sherwood crossing was changed from a function of the "a_fld_MASTER_gc_gd" state variable to a function of date. The maximum flow constraint was then set to a constant maximum value of 3,200 cfs, which is the bank full capacity taken from Annex A, page A-22. Figure 4 displays the source for downstream constraints used in this alternative.

Second, the downstream flow constraint for Minot, ND was changed from a function of the "a_fld_MASTER_gc_gd" state variable to a function of date. The maximum flow constraint was then set to a constant maximum value of 5,000 cfs, which is the bank full capacity taken from Annex A, page A-22. Figure 4 displays the source for downstream constraints used in this alternative.

The guide curve for each reservoir was set in the "a_fld_MASTER_gc_gd" state variable by removing the GC calculation based on variable conditions and adding a hard coded guide curve elevation set to the invert elevation of each respective structure for Rafferty, Grant Devine, and Lake Darling.

The guide curve was further re-defined within the "a_fld_MASTER_gc_gd" state variable by removing all regular and conditional drawdowns.

It was an assumption by the modeling team to proceed with constant downstream constraints as opposed to seasonal constraints as the understood intent of this alternative is to model the reservoirs as dry dams and provide maximum available storage capacity at all times while maintaining bank full or less than bank full capacities downstream.

Figure 1 displays the operations rule tree for Rafferty Reservoir with the new operating rule implemented, with red boxes indicating the new rule at Sherwood. Figure 2 displays the operations rule tree for Grant Devine Reservoir with the new operating rule implemented, with red boxes indicating the new rule at Sherwood. Figure 3 displays the operations rule tree for Lake Darling Reservoir with the new operating rule implemented, with red boxes indicating the new rule at Minot, ND. Figures 4 and 5 display the state variable changes.

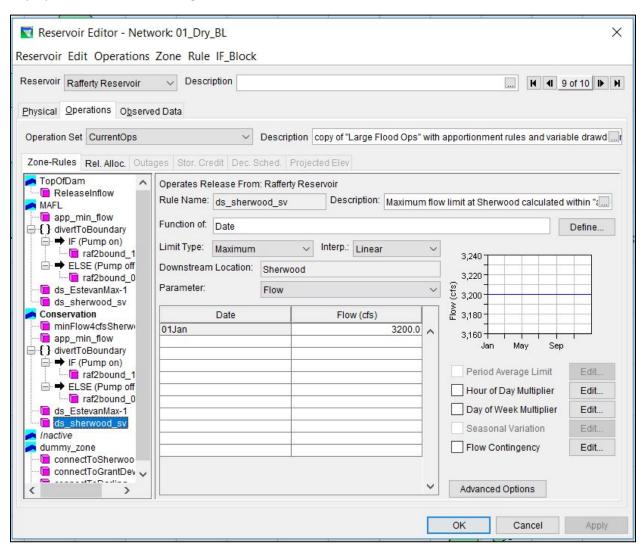


Figure 1. Rafferty Operations Tree

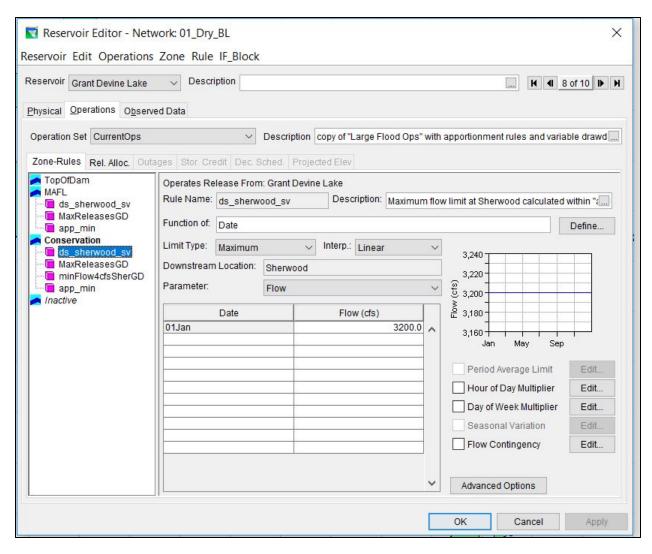


Figure 2. Grant Devine Operations Tree

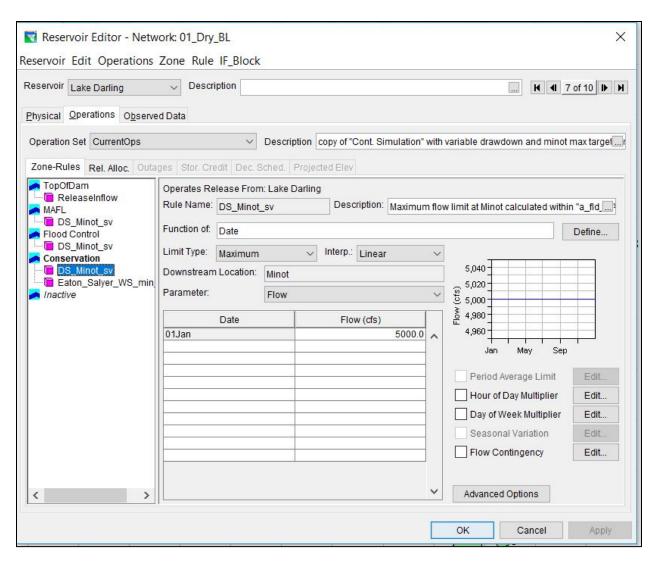


Figure 3. Lake Darling Operations Tree

```
State Variable Editor - Network: 01_DD_FC--0:01_DD_FC_Only
StateVariable Edit
Name: a_fld_MASTER_gc_gd
                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              ... H 4 1 of 14 D H
Parameter Name: ELEV-ZONE
                                                                                                                                                                                                                                      Parameter Type: Elev
  Initialization Main CleanUp
                                                                      gdElevStartDD = gdElevStartDD_TS.getPreviousValue(currentRuntimestep)
darElevStartDD = darElevStartDD_TS.getPreviousValue(currentRuntimestep)
             Model Variab
State Variabl
                                                       130)
131 rafElevStartDD_TS.setCurrentValue(currentRuntimestep, rafElevStartDD)
132 gdElevStartDD_TS.setCurrentValue(currentRuntimestep, gdElevStartDD)
133 darElevStartDD_TS.setCurrentValue(currentRuntimestep, darElevStartDD)
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- Gran Quideturve(doy, rafelev, raffulSupply, rafikormorandown, floodDrawdownEndDay, rafficalDD, raflevstartDD, stndDrawdownStartDay, feb1, feb1, fld_status)

(0.2966 = guflecurve(doy, gdflev, gdrulEsupply, gdflevsDrawdown, floodDrawdownEndDay, gdflnulDD, gdflevstortDD, stndDrawdownStartDay, feb1, feb1, feb1, feb1, feb1, fld_status)

14. SandOC = guldecurve(doy, boundElex, boundFulSupply), boundFulSupply, ly, floodDrawdownEndDay, boundFulSupply, houndFulSupply, houndFulSupply, floodDrawdownEndDay, boundFulSupply, houndFulSupply, floodDrawdownEndDay, darFlevStartDD, stndDrawdownStartDay, feb1, fld_status)

14. ddc 10.50, 801864

15. ddc 10.50, 801864
                                                            gdGC = 1765.091864
#print year, doy, rafGC, gdGC, boundGC, darGC
                                                           5
6## urite out guide curves
7 currentVariable.setValue(currentRuntimestep, gdGC)
8 network.getStateVariable("a_fld_gc_bound").setValue(currentRuntimestep, bound
9 network.getStateVariable("a_fld_gc_raf").setValue(currentRuntimestep, rafGC)
0 network.getStateVariable("a_fld_gc_dar").setValue(currentRuntimestep, darGC)
1
                                                              # ## calc estevan target
```

Figure 4. Alternative Guide Curve edits

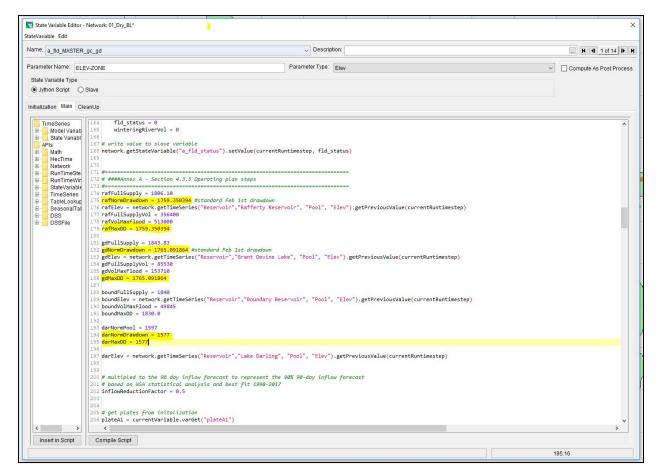


Figure 5. Alternative State Variable drawdown edits

3. Alternative vs Baseline Scenario Results

Plates 01-18 show hydrographs detailing the results of Alternative 1 relative to the baseline scenario at Rafferty, Boundary, Grant Devine, and Lake Darling reservoirs, as well as seven critical mainstem flow locations, for select "index" years. Index years were selected to be representative of high, medium, and low flow years in the basin. High flow years include 2011, 1976, 1975, and 1969, medium flow years include 1987, 1952, and 1946, and low flow years include 1937, 1988, and two extended drought sequences: 1931-1937 and 1988-1991. For Alternative 1, all index years within the simulation time window are plotted.

Plate 19 displays performance indicator results for all study reaches over the entire simulation (1946-2017). More information regarding performance indicator (PI) results and PI development can be found in the Data Collection for the Analysis of Alternatives Report (DW4) and Appendix A-5.

4. Summary of Results

In the Dry Dam scenario, pools at Rafferty, Grant Devine, and Lake Darling reservoirs remain lower than baseline conditions under most circumstances, often reach similar peak elevations and discharges in extreme events compared to baseline conditions, and provide no water supply for normal or drought conditions. Outflows from the reservoirs are at elevated levels for shorter periods of time during large events compared to baseline conditions. In the 2011 index event, the flow peak at Estevan, SK is slightly elevated in the alternative by approximately 1,000 cfs, while the flow peak at Minot, ND is approximately 14,000 cfs less than the baseline condition. Westhope experiences flows approximately 6,000 cfs less than the baseline condition.

Pool Elevations at all the main reservoirs reach the same elevations as baseline conditions in the alternative 2011 index event. They take longer to reach maximum allowable flood level (MAFL) however, and recede more quickly.

4.1 Performance Indicators

4.1.1 Reservoirs

This scenario severely restricts water supply and fish habitat in Boundary, Rafferty, Grant Devine, and Lake Darling reservoirs. At the Saskatchewan reservoirs, recreation is also heavily negatively impacted. At Lake Darling, performance indicators that are sensitive to high water conditions, such as the flood control indicators, cultural site preservation, and boating and fishing access, show improvement from the baseline condition. These results are to be expected, since there is very little water in Lake Darling in the Dry Dam scenario to cause flooding near the reservoir. It should be noted, however, that recreation would not be expected to improve in the Dry Dam scenario, because many boating access points would not be available due to very low lake levels.

4.1.2 Riverine Reaches

Since there is less water in the reservoirs during this simulation, there is typically more water flowing through the river. As shown in Figure 6, flows above 500 cfs (14 cms) are more common in Saskatchewan in the Dry Dam scenario. This increase in moderately high flows, coupled with no significant decrease in the magnitude of very large flood peaks, leads to more agricultural damages

throughout the system. In Estevan, since more moderate flood peaks are reduced, the coal haul roads spend less time inundated overall.

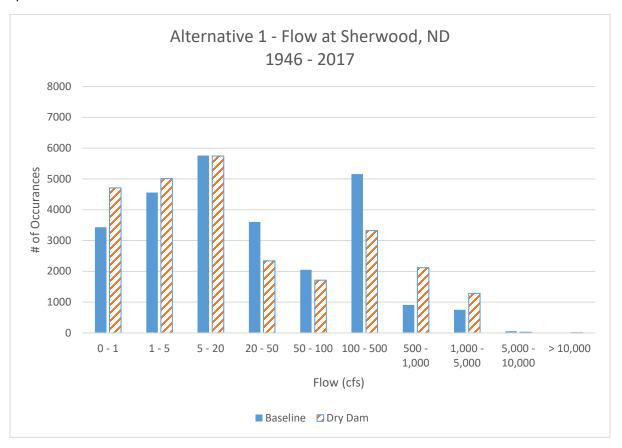


Figure 6. Flow distribution at Sherwood, ND

Downstream of Lake Darling, flows spend more time above 5 cfs (0.14 cms) and much less time below 1 cfs (0.03 cms), as shown in Figure 7. This change in the flow regime generally increases water supply, reduces fish kills, and makes the river easier to use for recreation. Structural damages generally show improvement from the baseline as well, but this is largely due to Lake Darling's ability to reduce peak flows during very large flood events. Since Westhope, ND is far downstream of the reservoirs, there is less change from the baseline scenario than other upstream reaches.

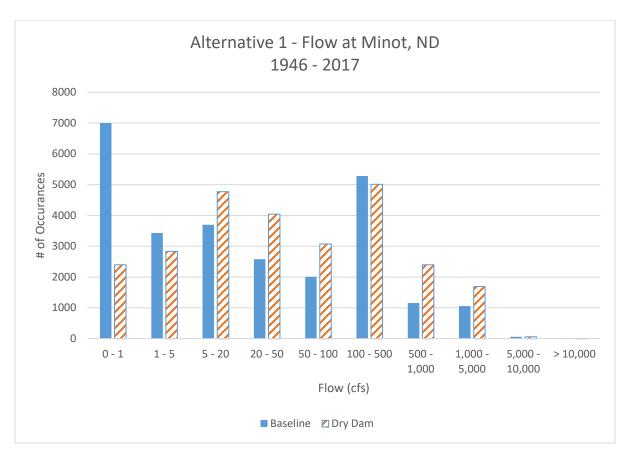


Figure 7. Flow distribution at Minot, ND

5. References

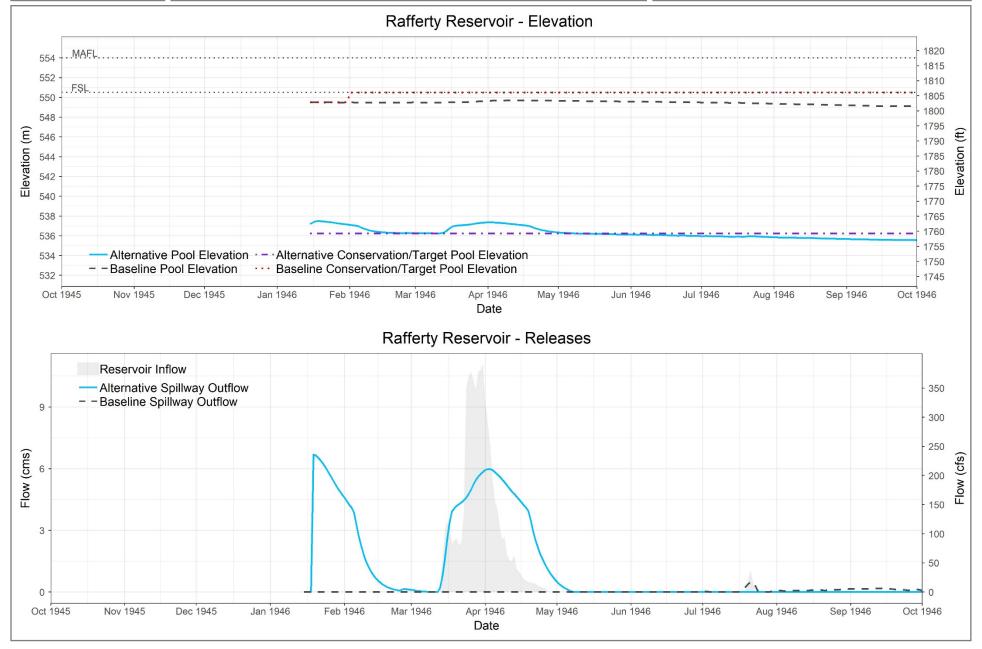
- 1. "HEC-DSSVue," U.S Army Corps of Engineers, Hyraulic Engineering Center, Febuary 2010.
- 2. "HEC-ResSim, Reservoir System Simulation, Version 3.3", U.S Army Corps of Engineers, Hydraulic Engineering Center, December 2018.
- 3. Canada and USA, 1989. Agreement between the Government of Canada and the United States for Water Supply and Flood Control in the Souris River Basin.
- 4. Canada and USA, 2000. Interim Measures As Modified For Apportionment of the Souris River.
- 5. Alternative assumptions were discussed with Elizabeth Nelsen (U.S. Army Corps of Engineers St. Paul District Water Management & Hydrology Section Chief), Curtis Hallborg (WSA), and Chanel Mueller (U.S. Army Corps of Engineers Hydrology Section)

Plate 01

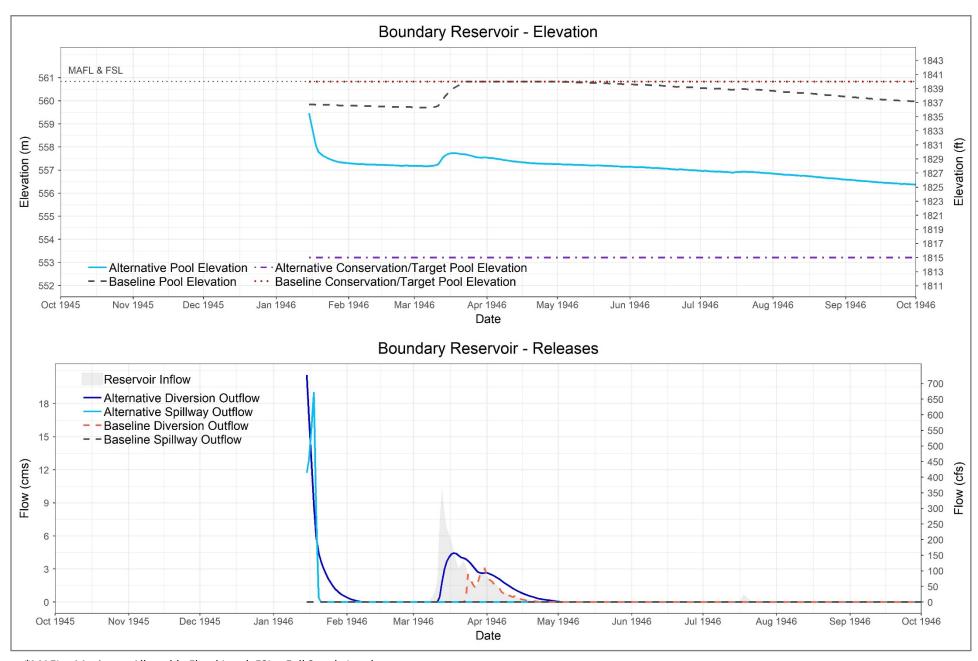
Reservoirs – 1946

Alternative 1 (Phase 2)

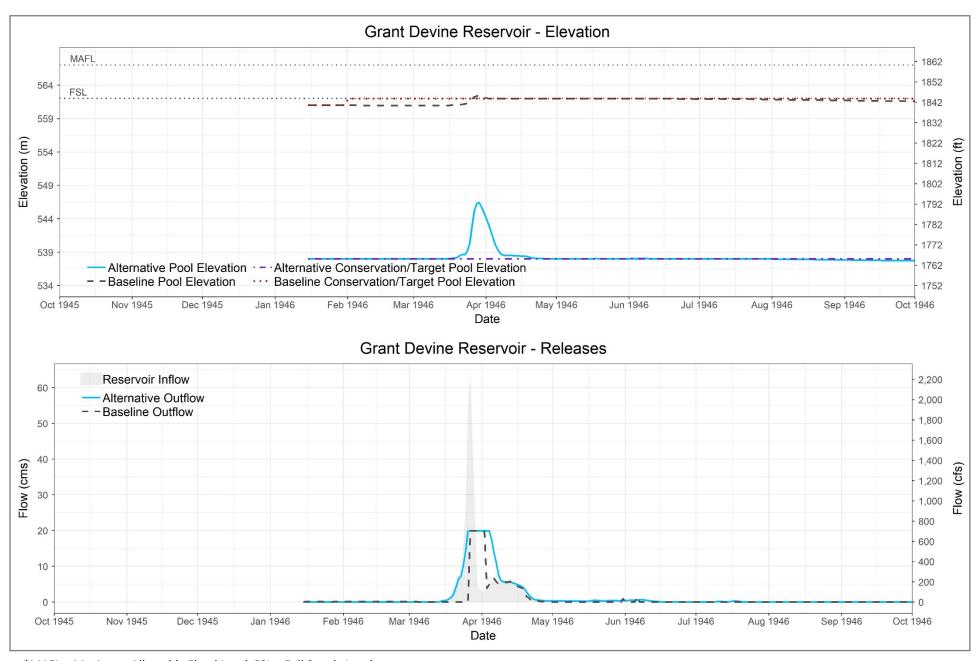
Souris River Plan of Study



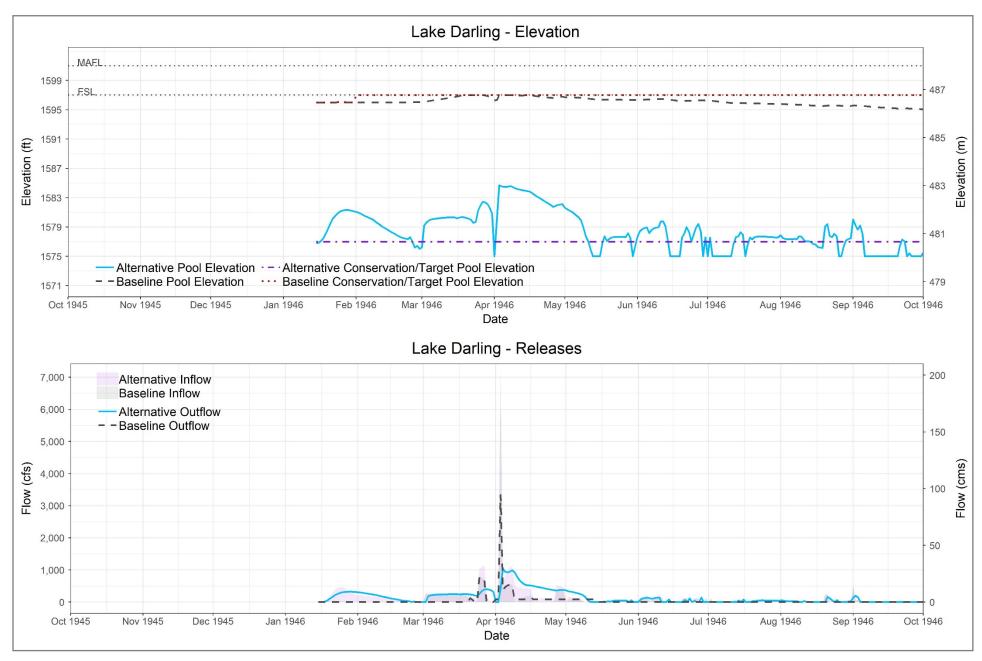
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

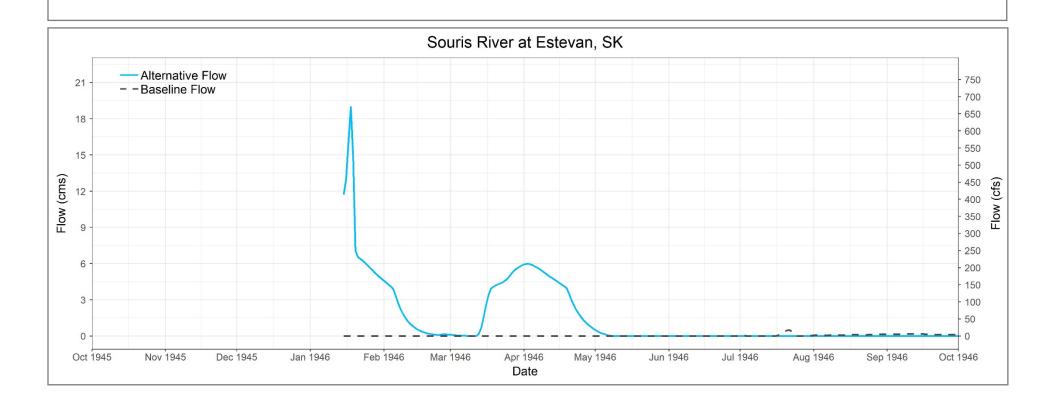


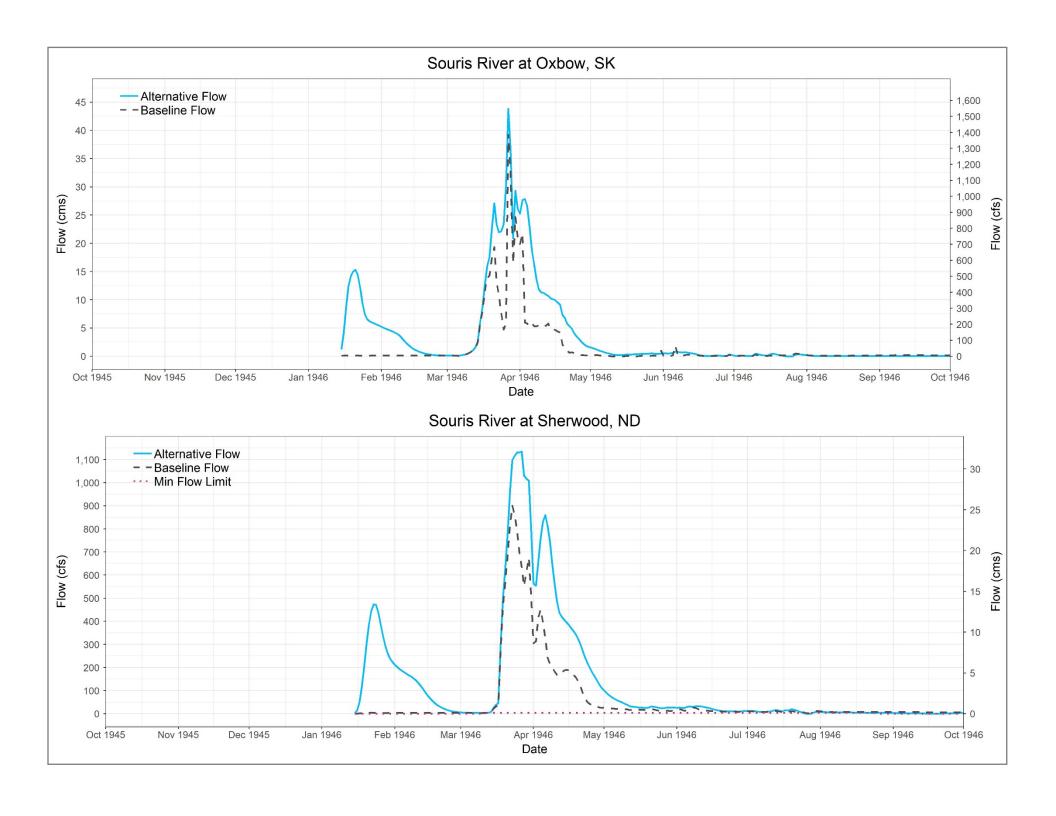
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

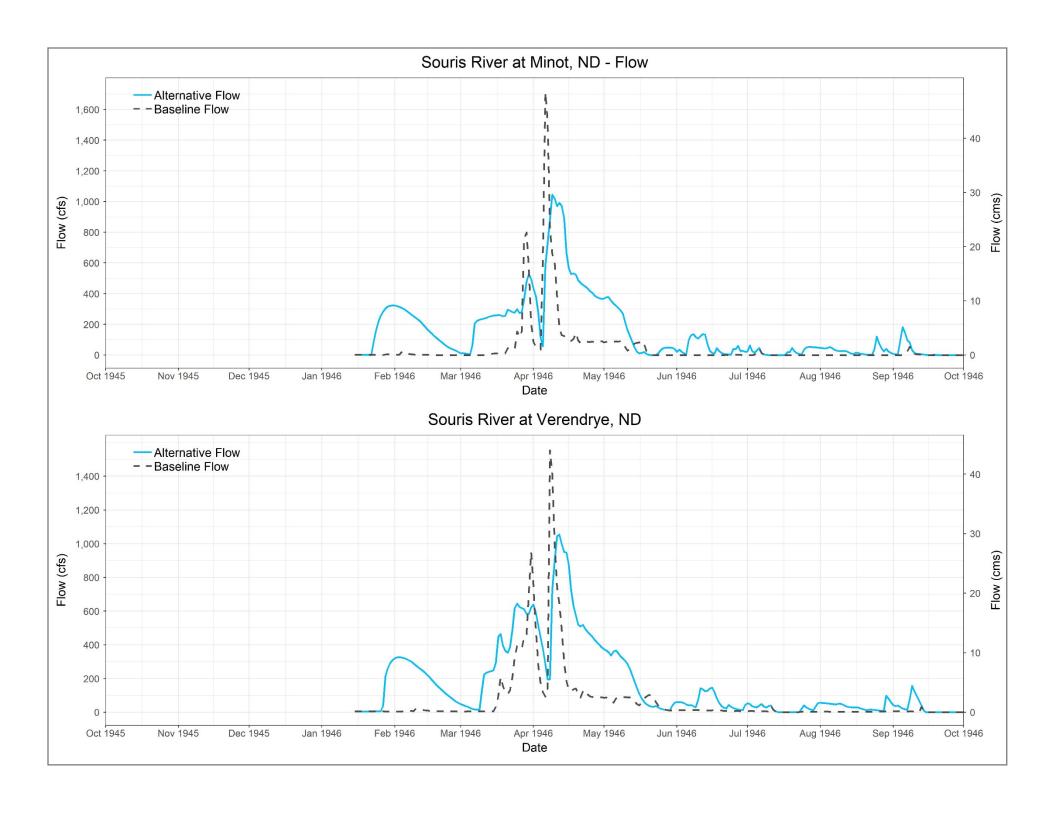


*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 02 Critical Flow Locations — 1946 Alternative 1 (Phase 2) Souris River Plan of Study







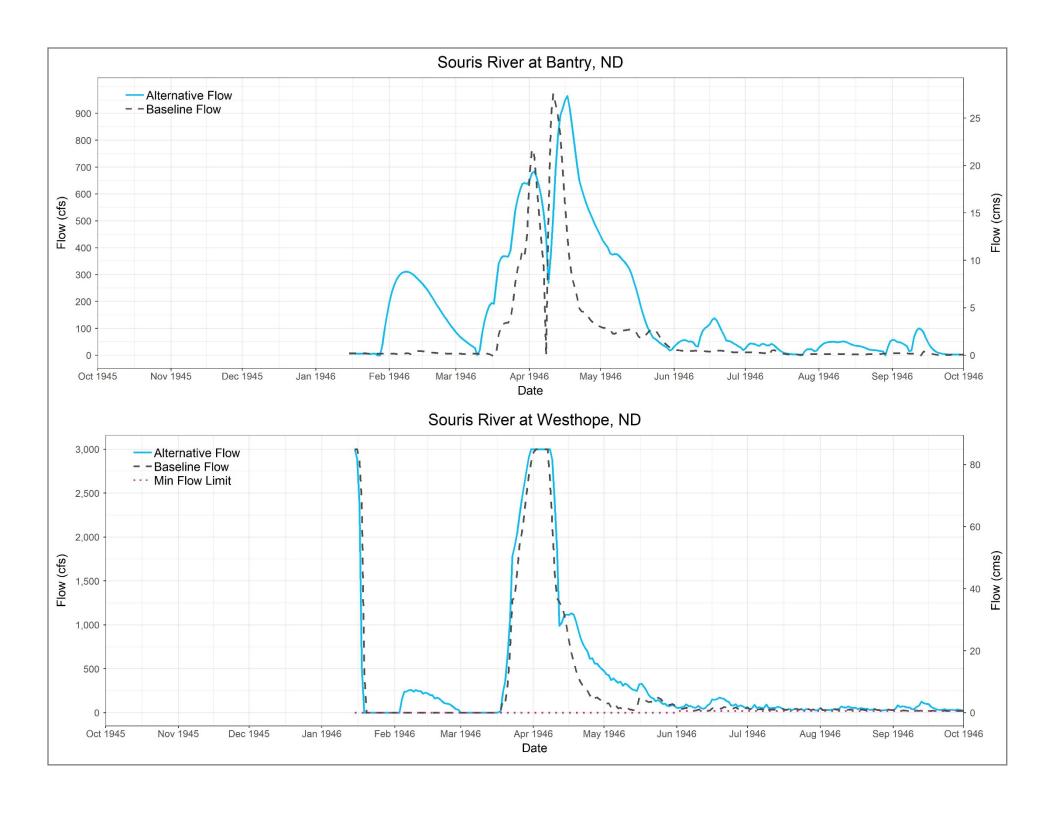
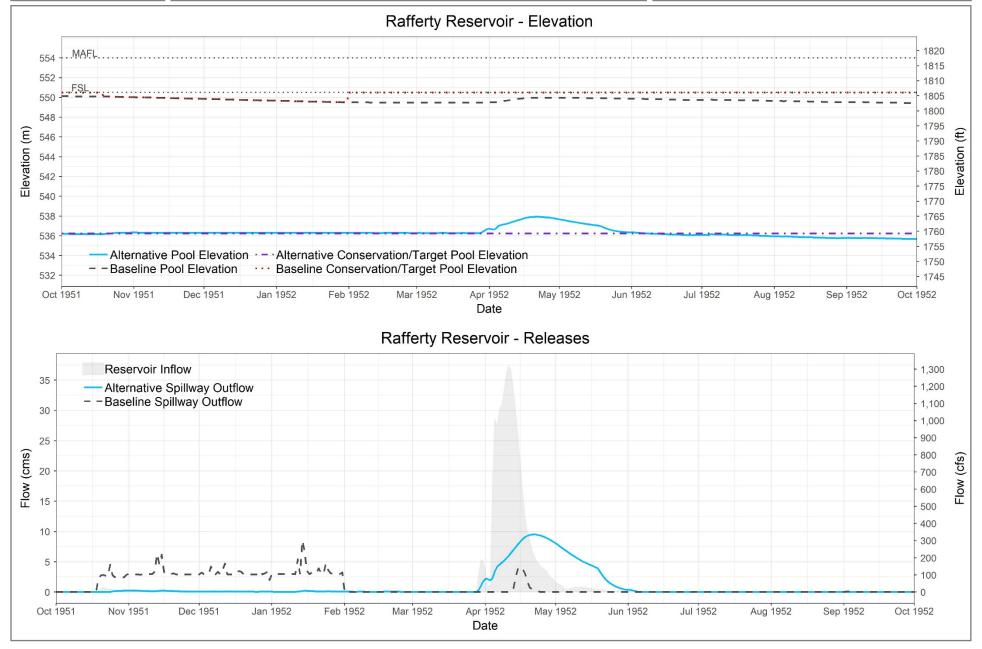


Plate 03

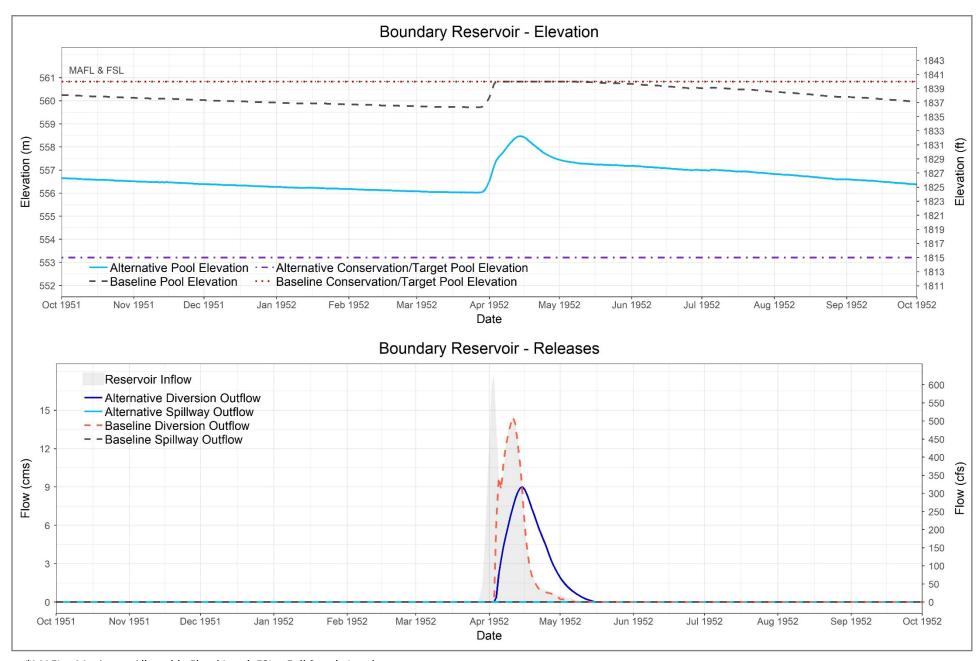
Reservoirs – 1952

Alternative 1 (Phase 2)

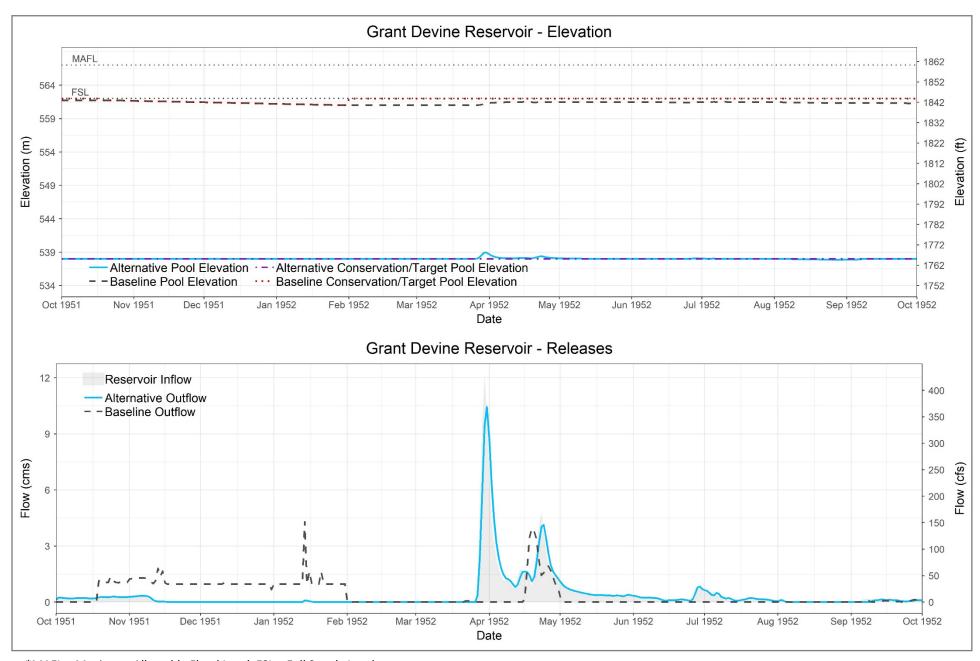
Souris River Plan of Study



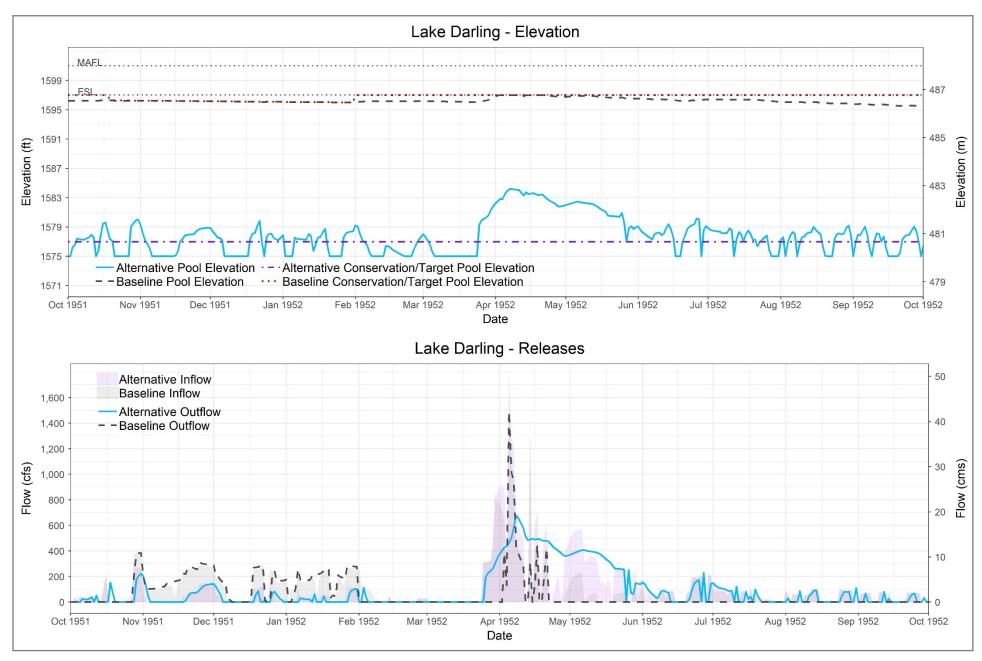
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

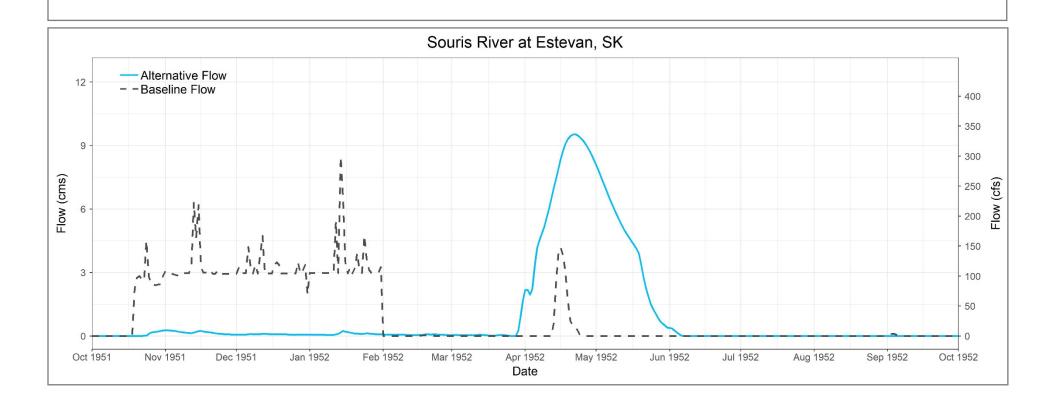


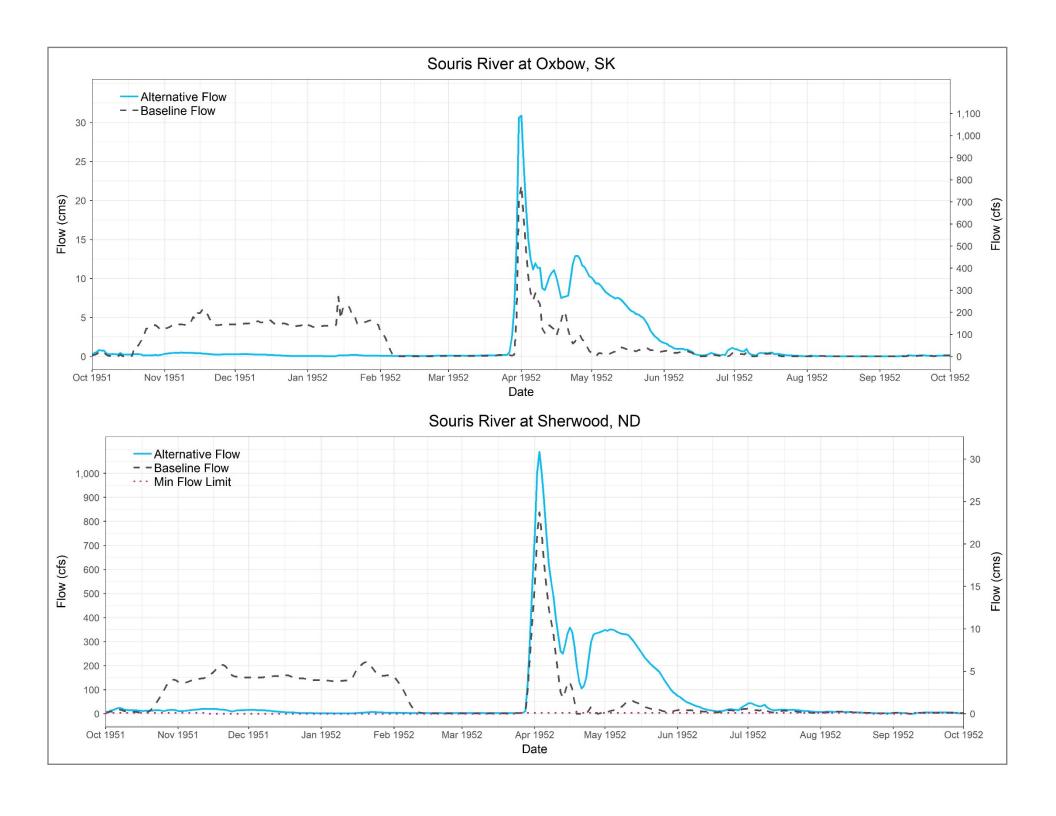
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

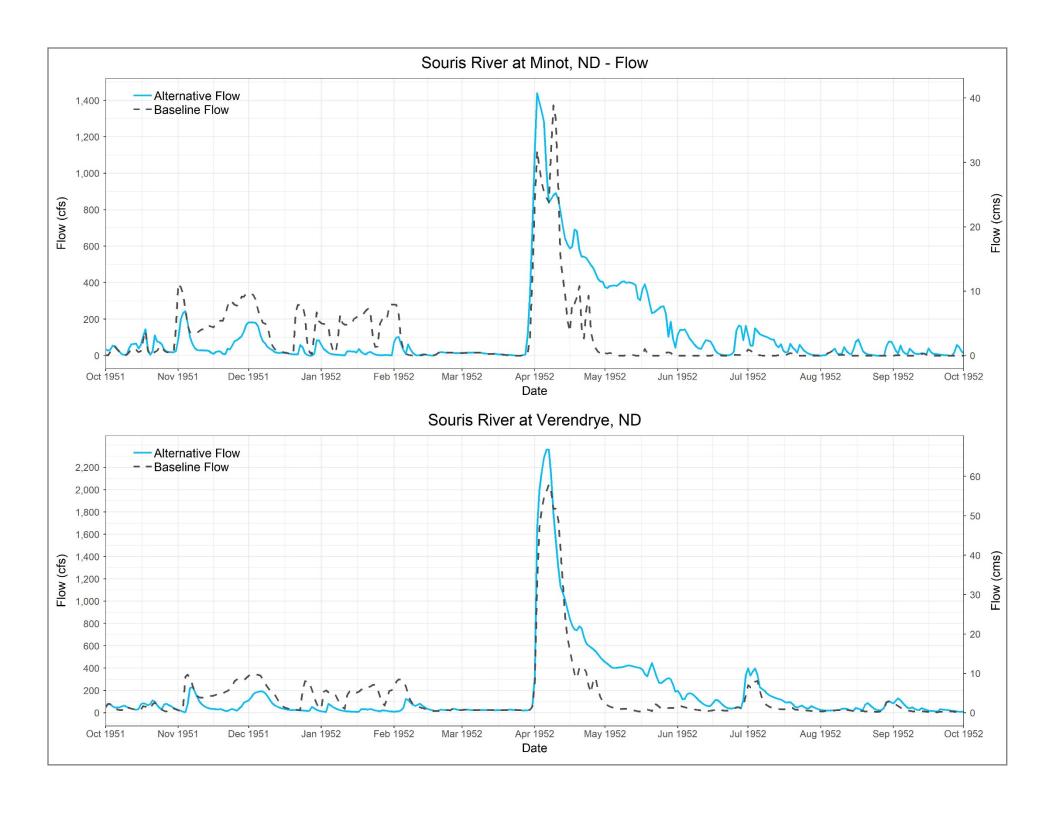


*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 04 Critical Flow Locations — 1952 Alternative 1 (Phase 2) Souris River Plan of Study







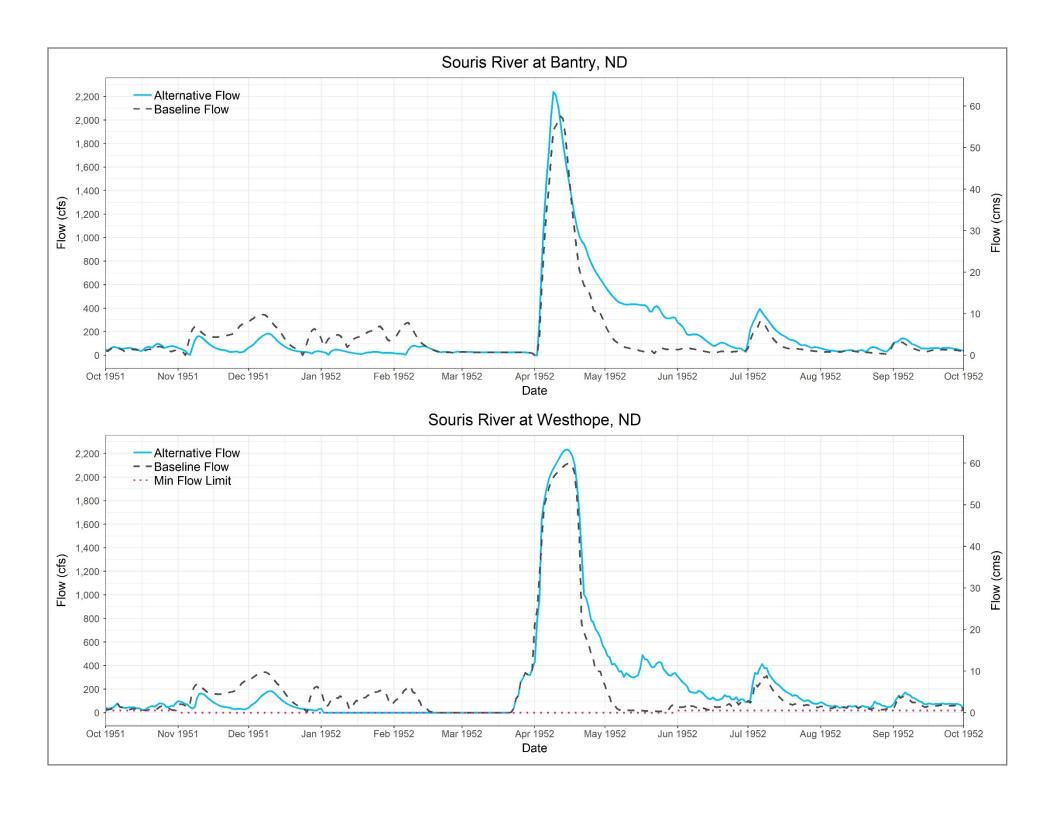
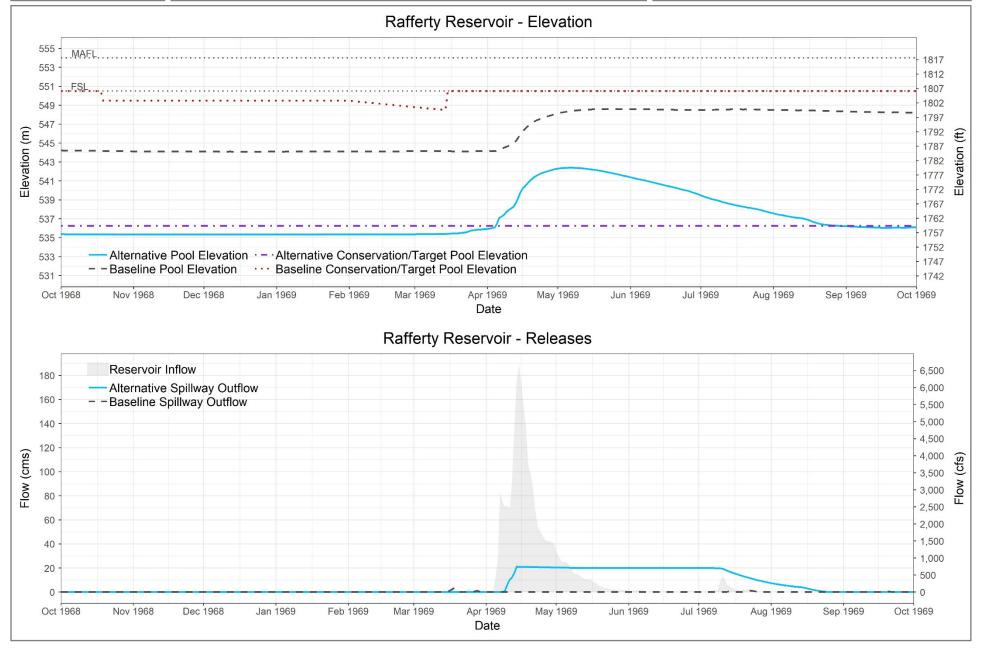


Plate 05

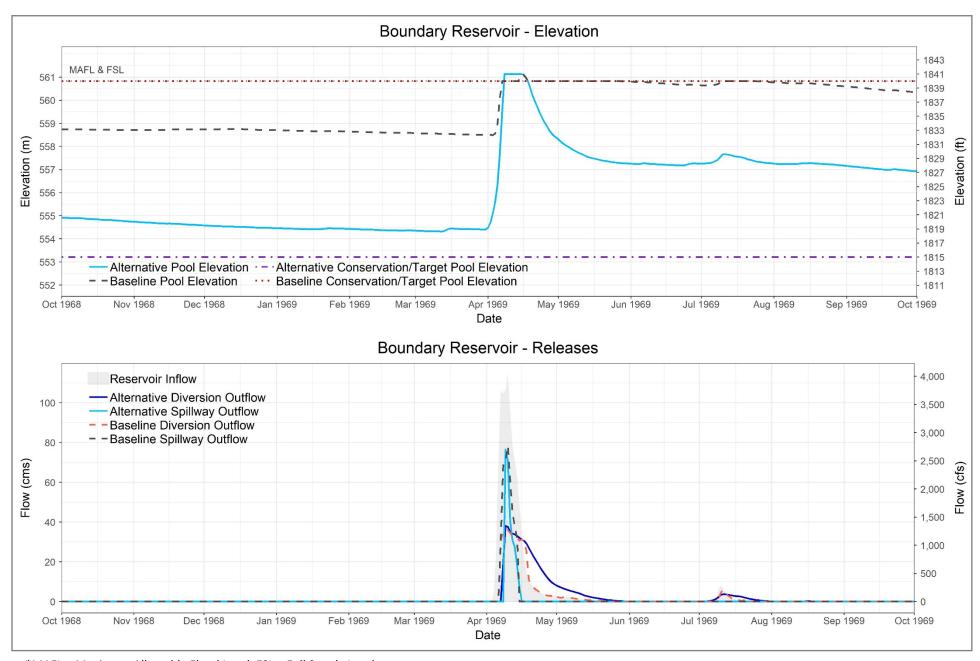
Reservoirs – 1969

Alternative 1 (Phase 2)

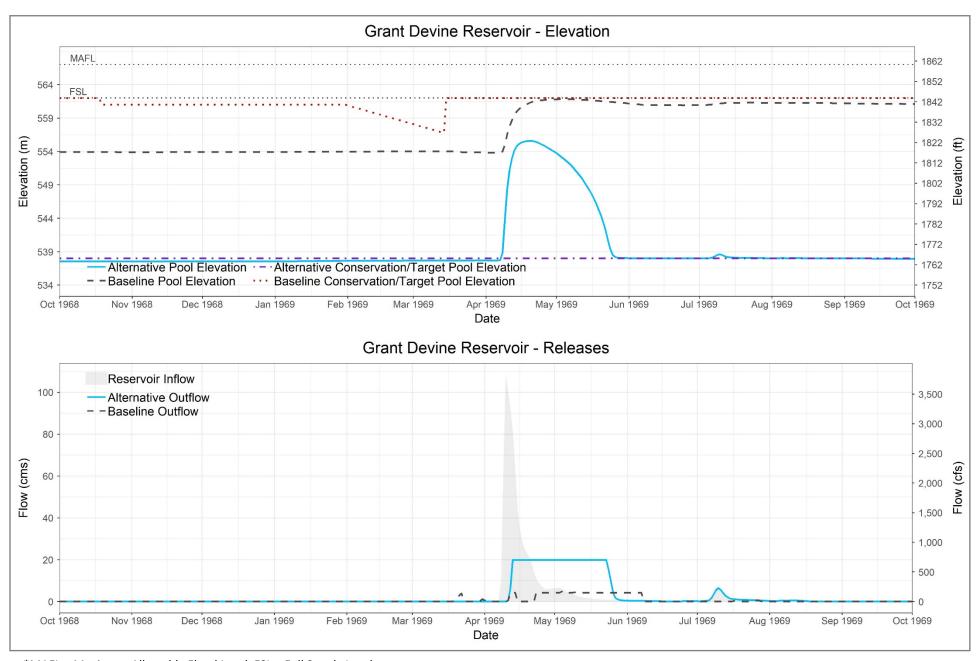
Souris River Plan of Study



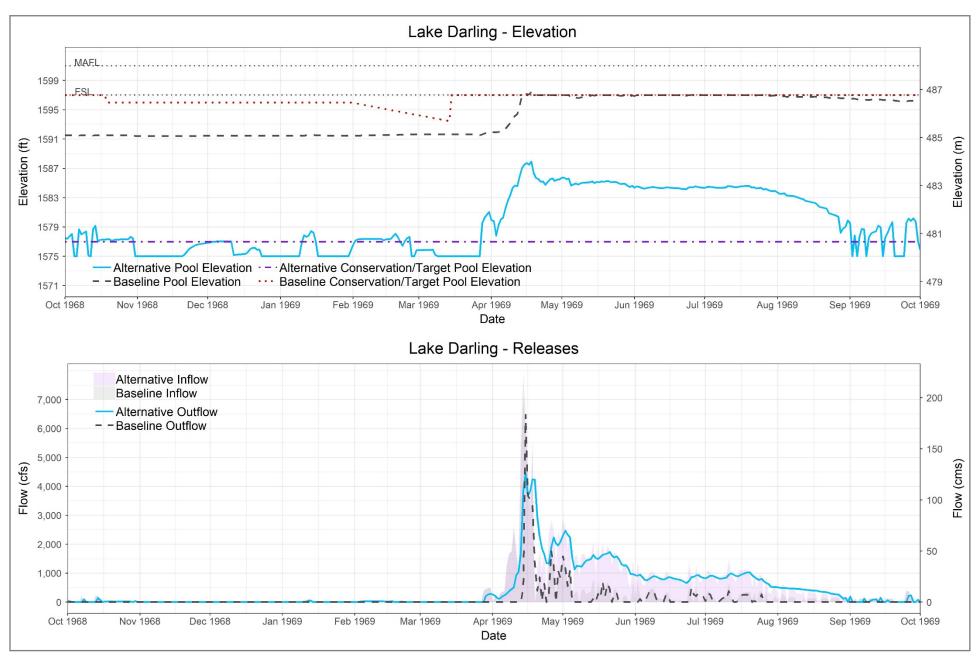
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

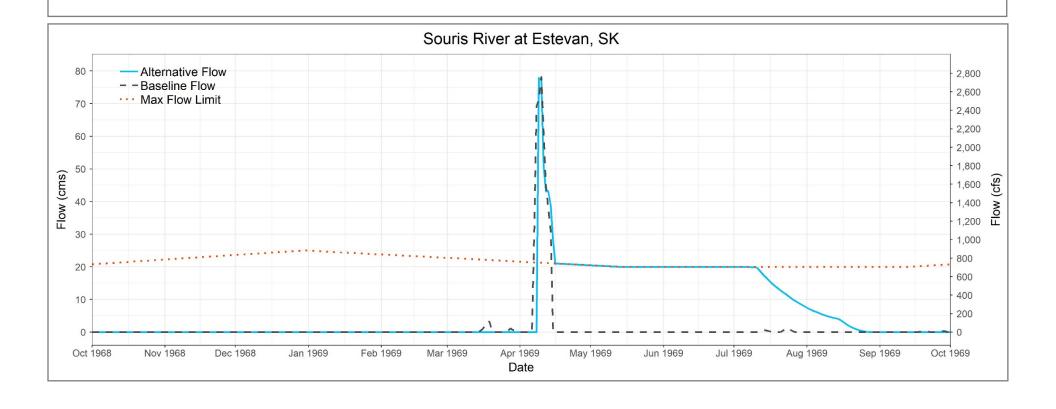


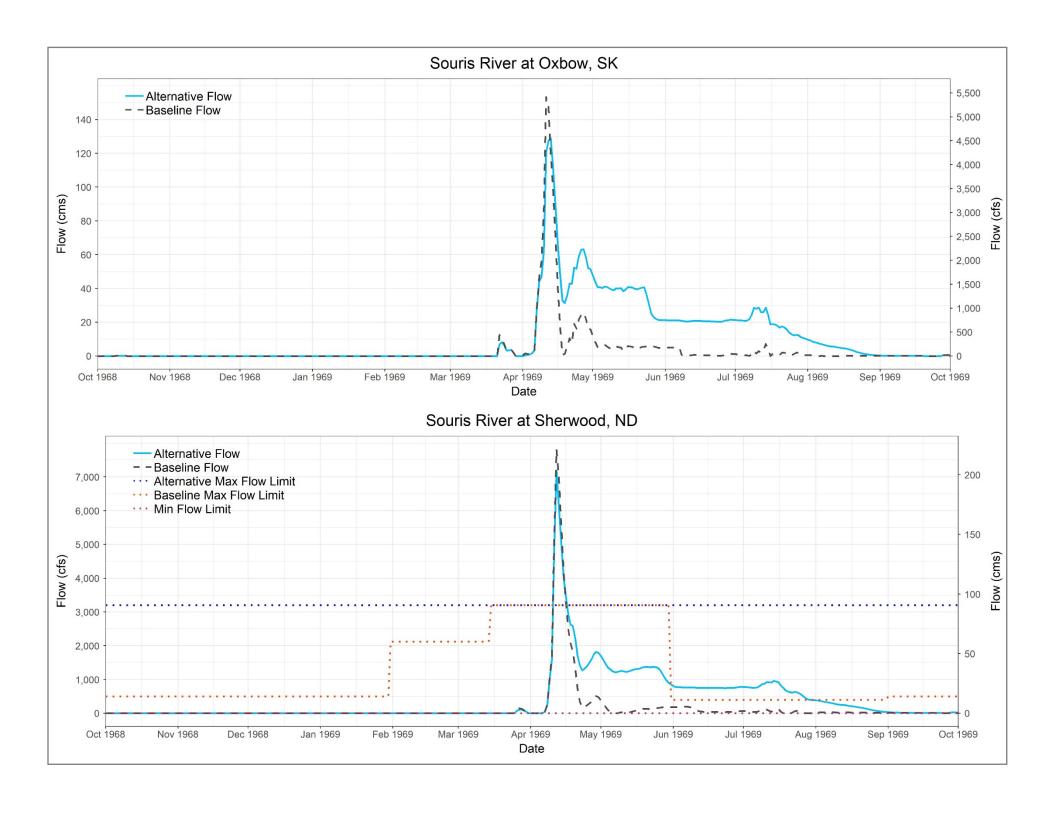
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

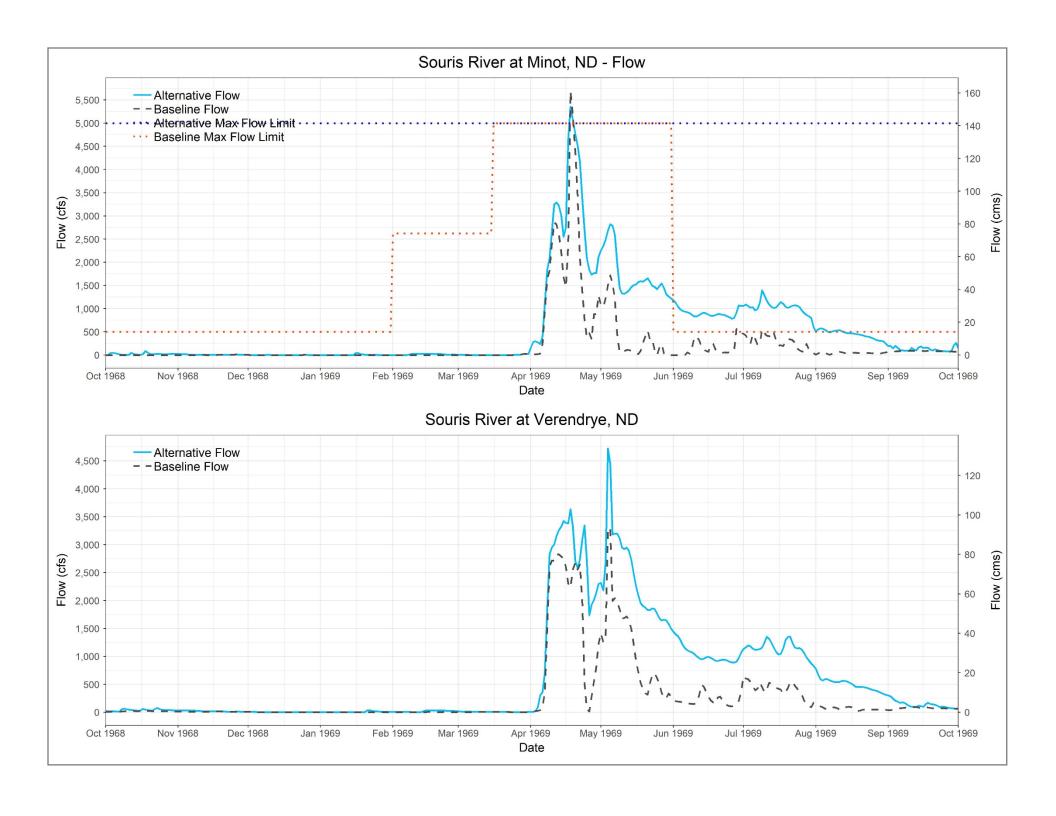


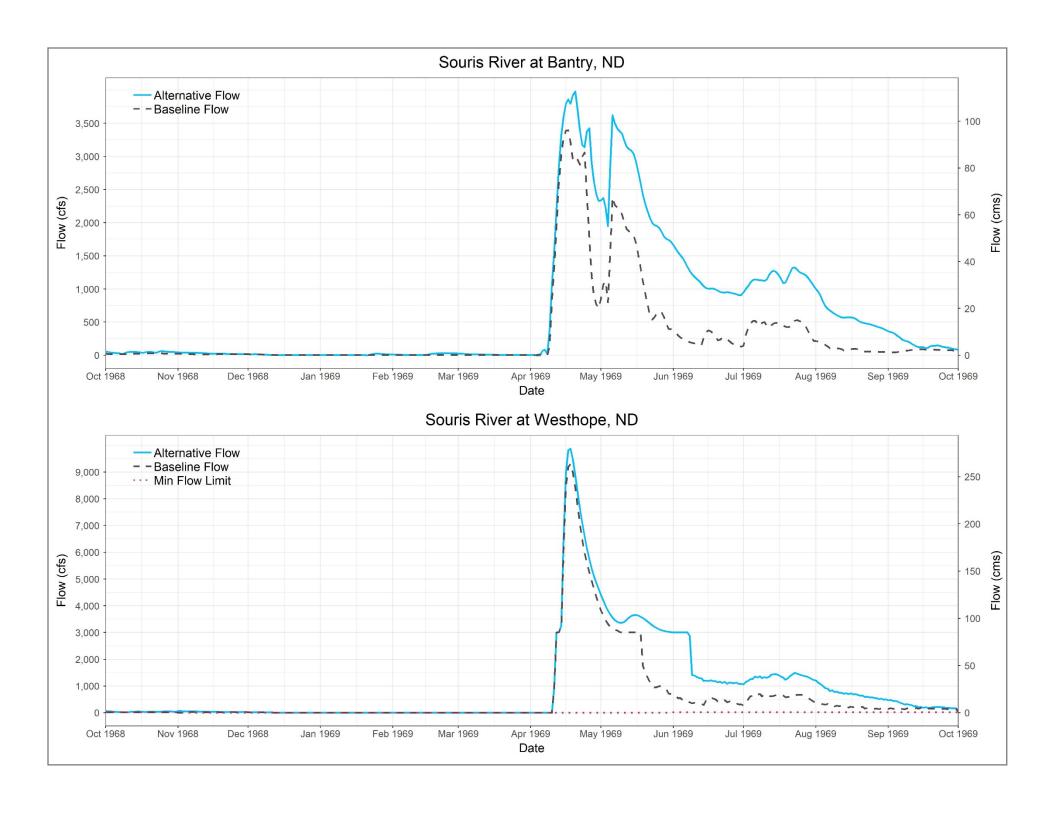
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 06 Critical Flow Locations — 1969 Alternative 1 (Phase 2) Souris River Plan of Study



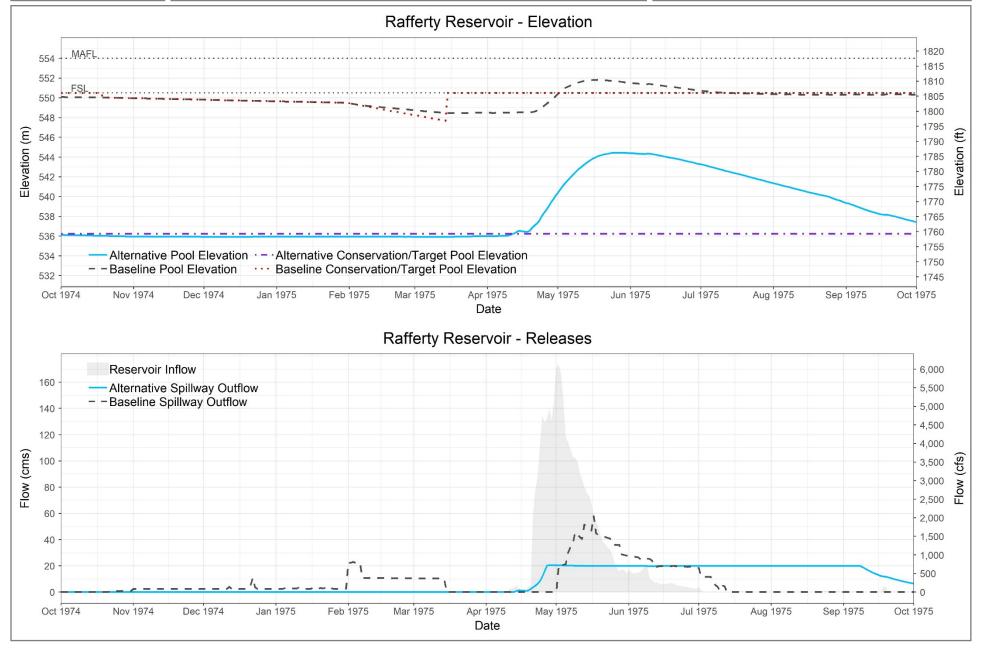




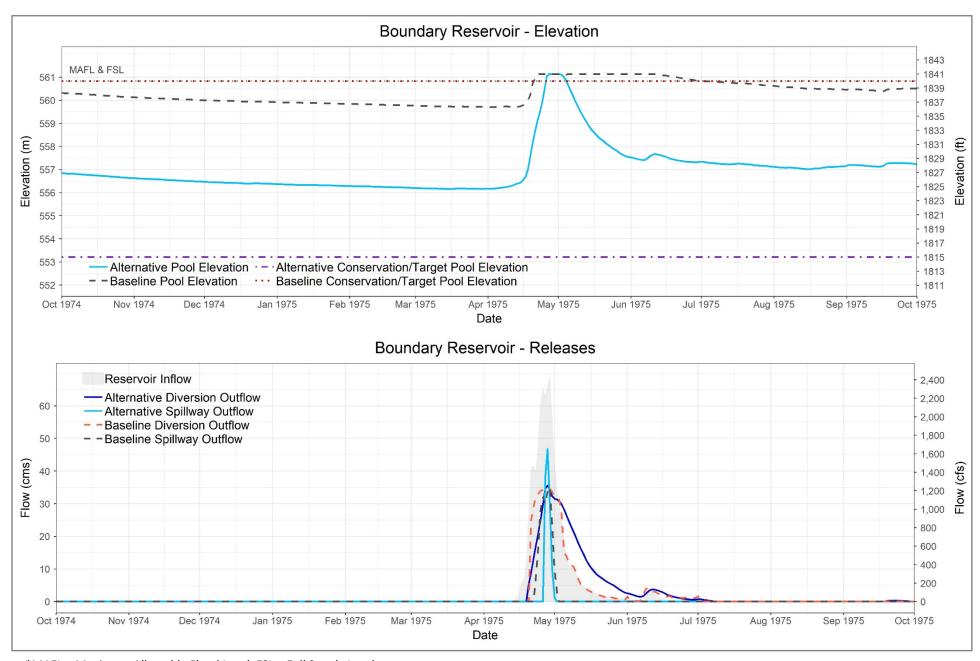


Reservoirs – 1975

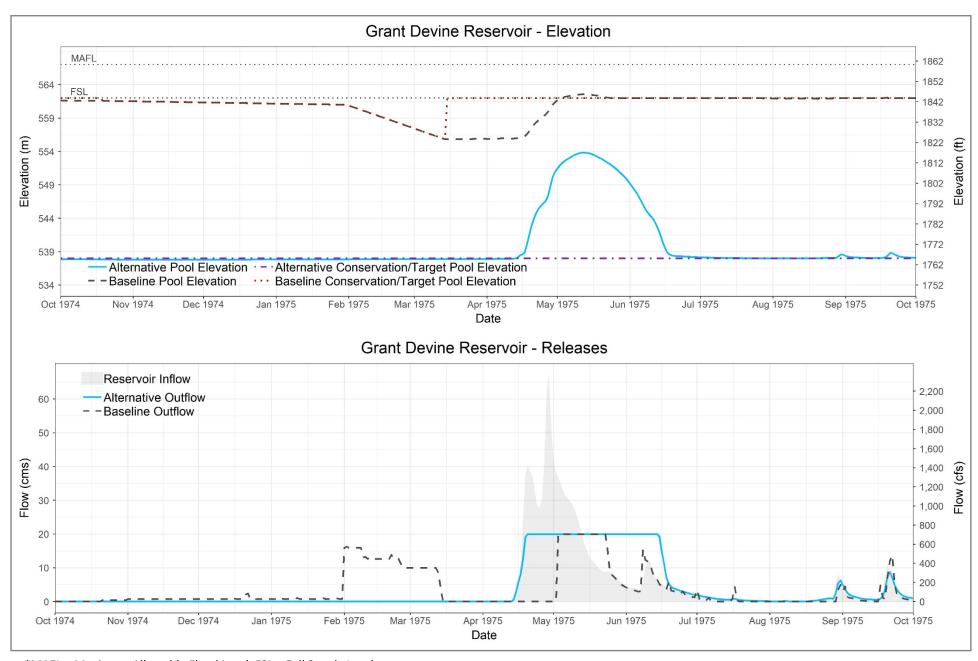
Alternative 1 (Phase 2)



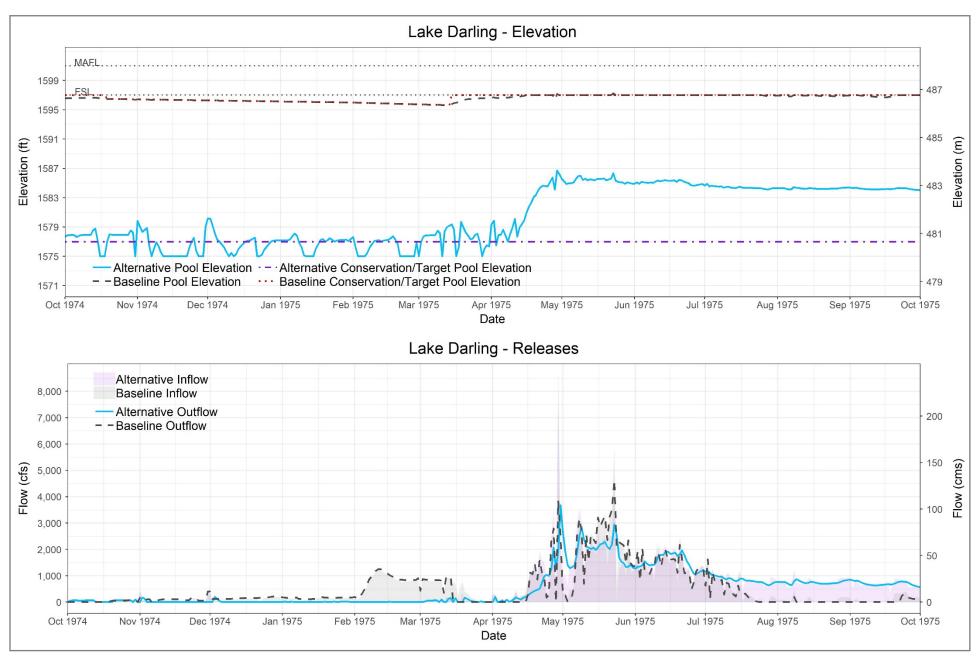
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



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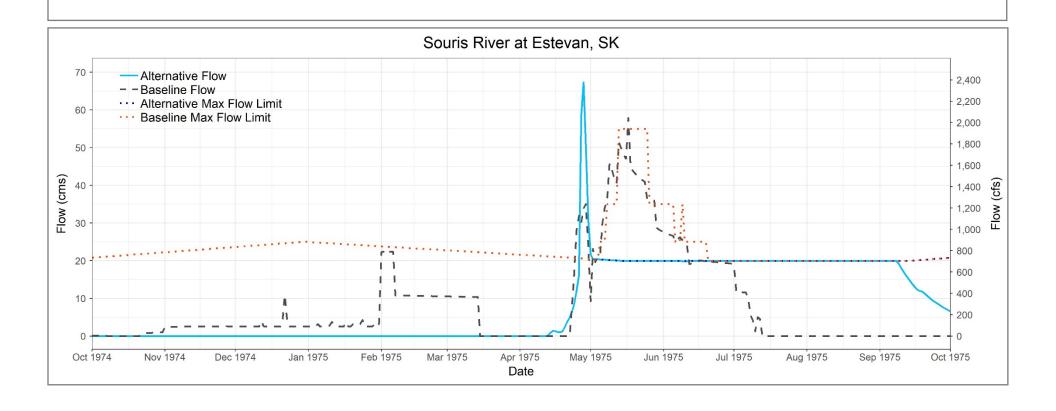


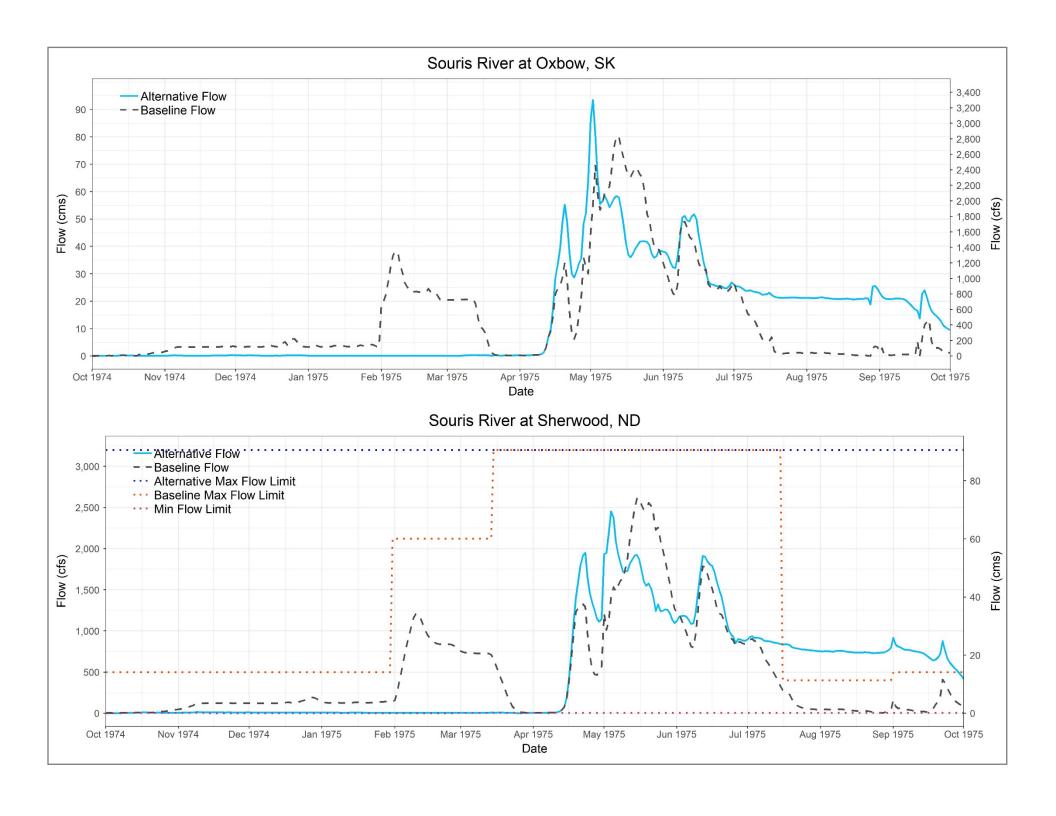
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

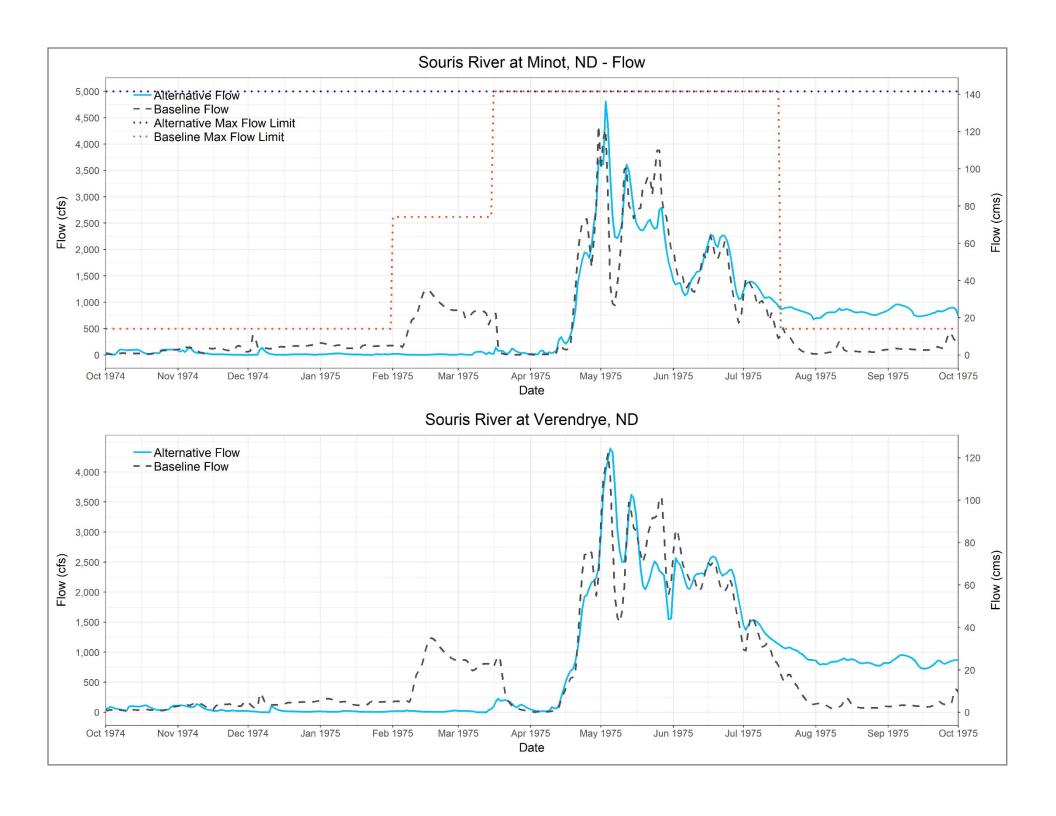


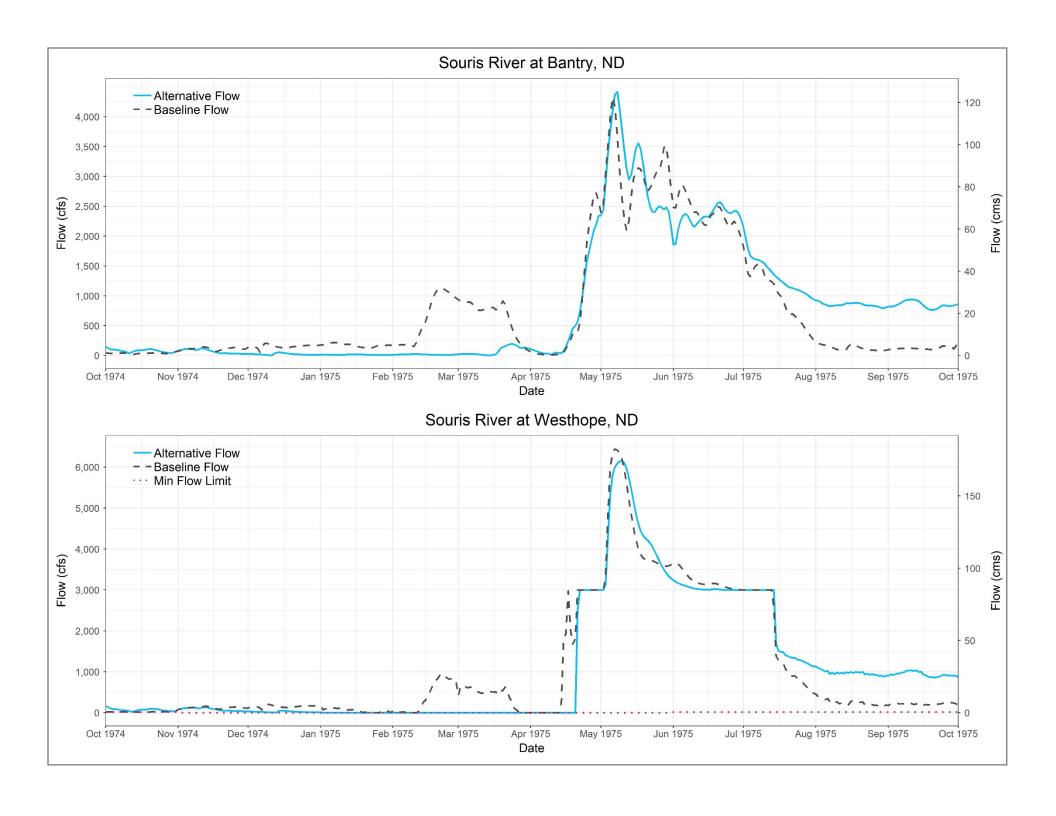
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 08 Critical Flow Locations — 1975 Alternative 1 (Phase 2) Souris River Plan of Study



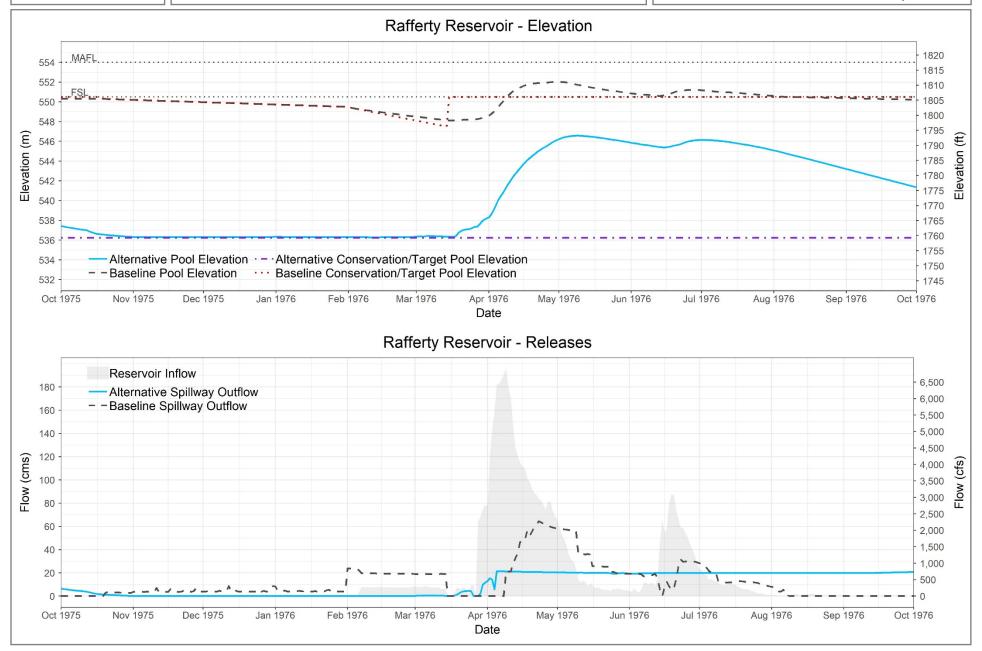




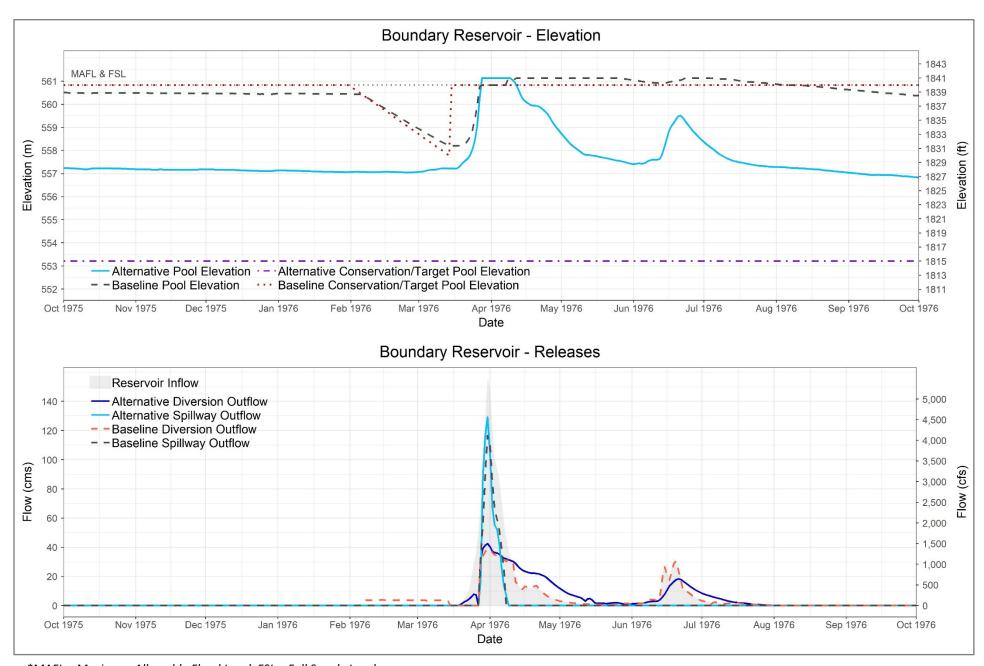


Reservoirs – 1976

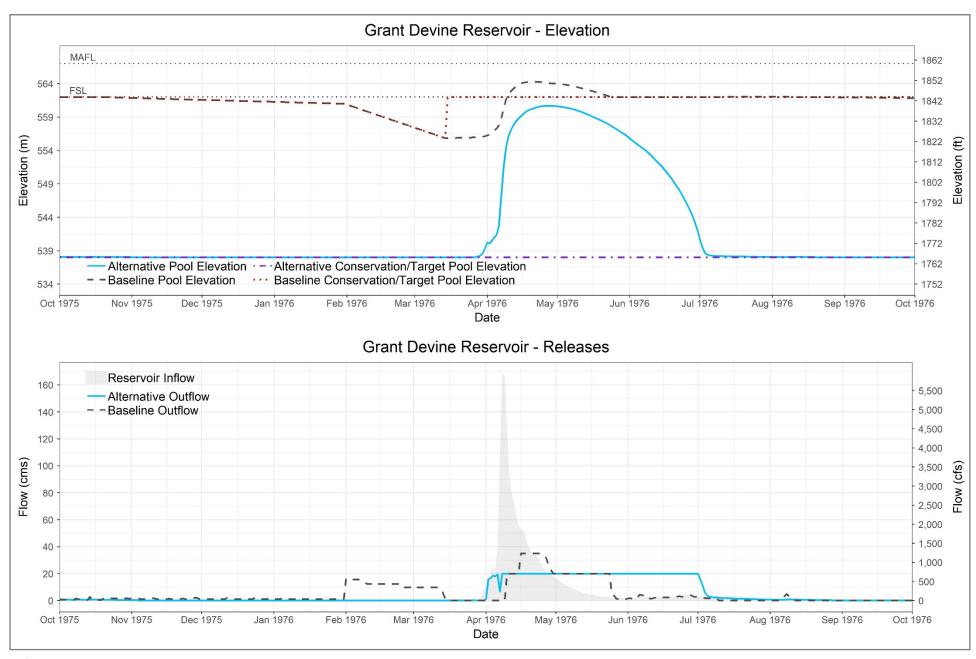
Alternative 1 (Phase 2)



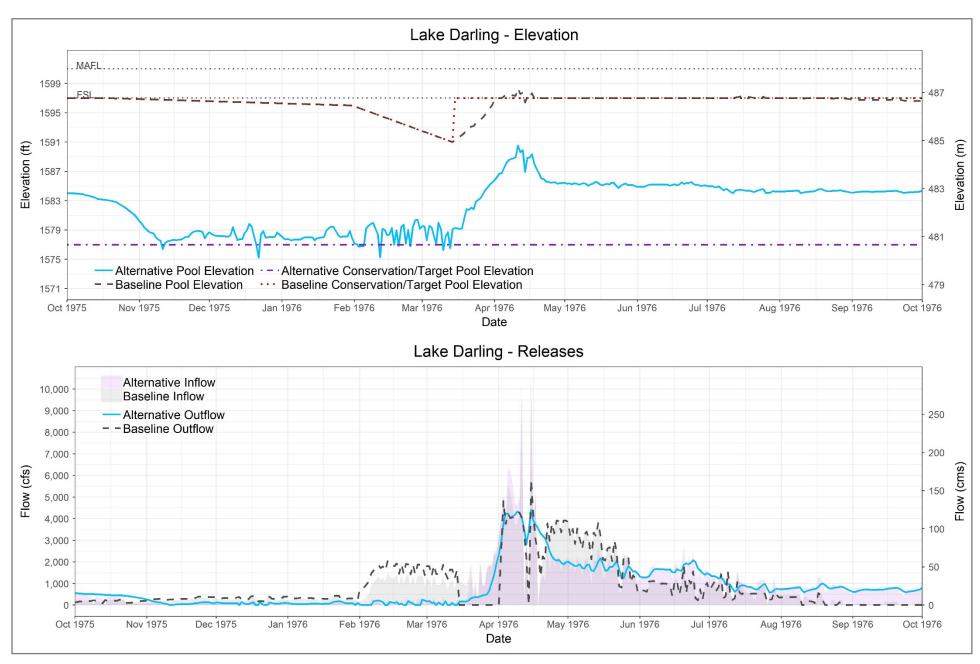
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

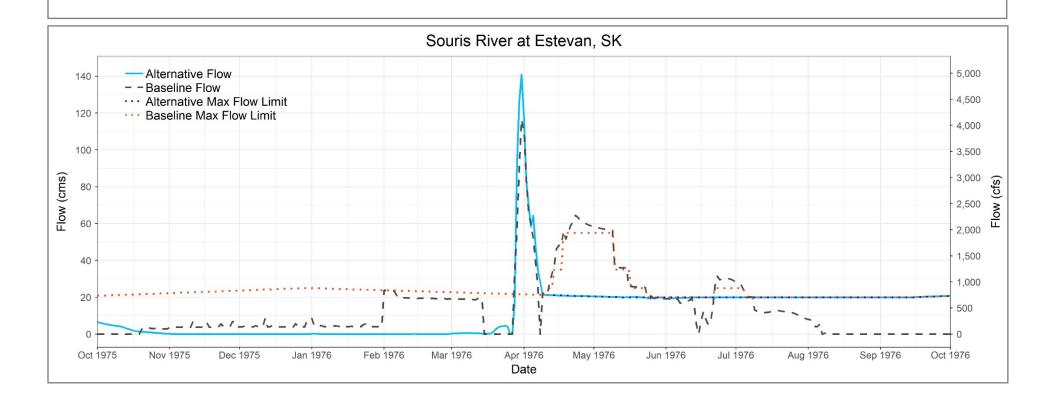


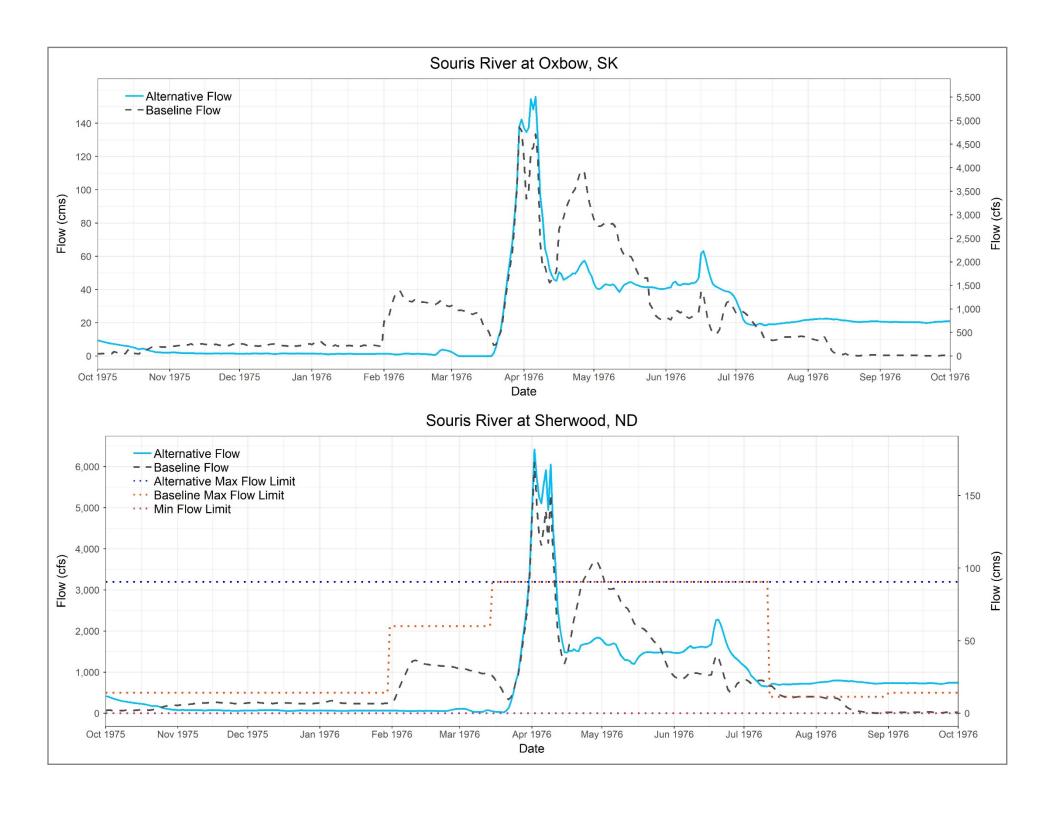
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

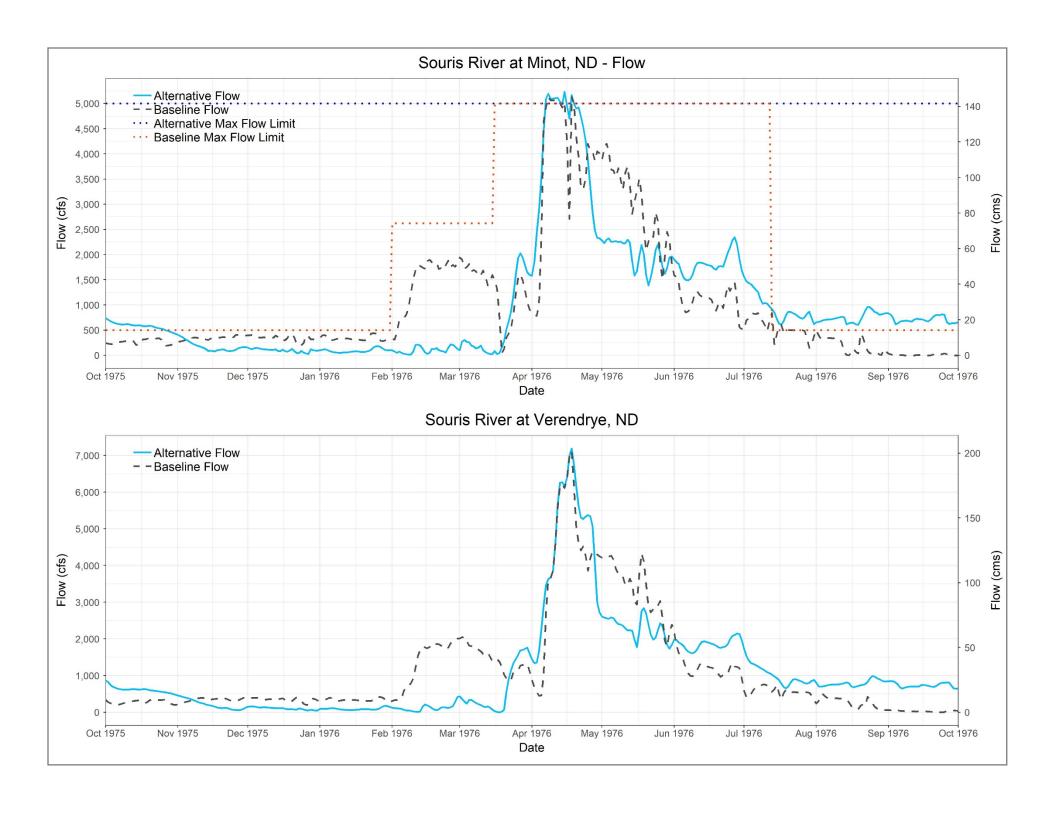


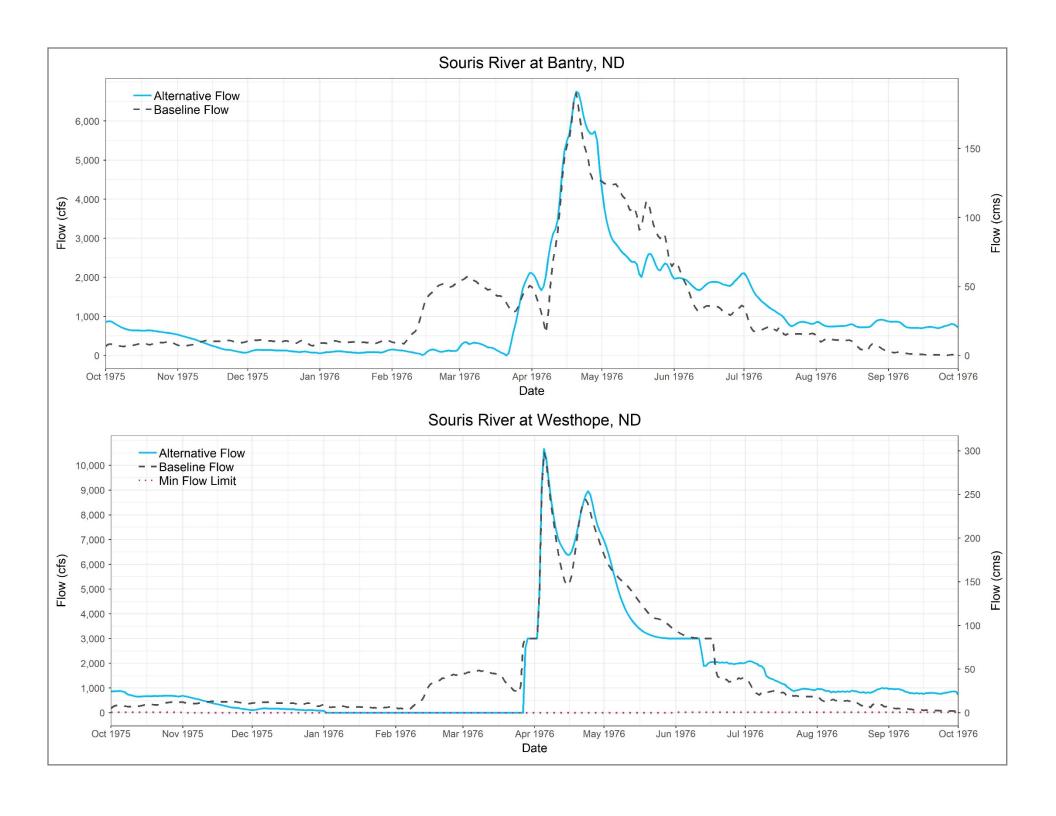
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 010 Critical Flow Locations — 1976 Alternative 1 (Phase 2) Souris River Plan of Study



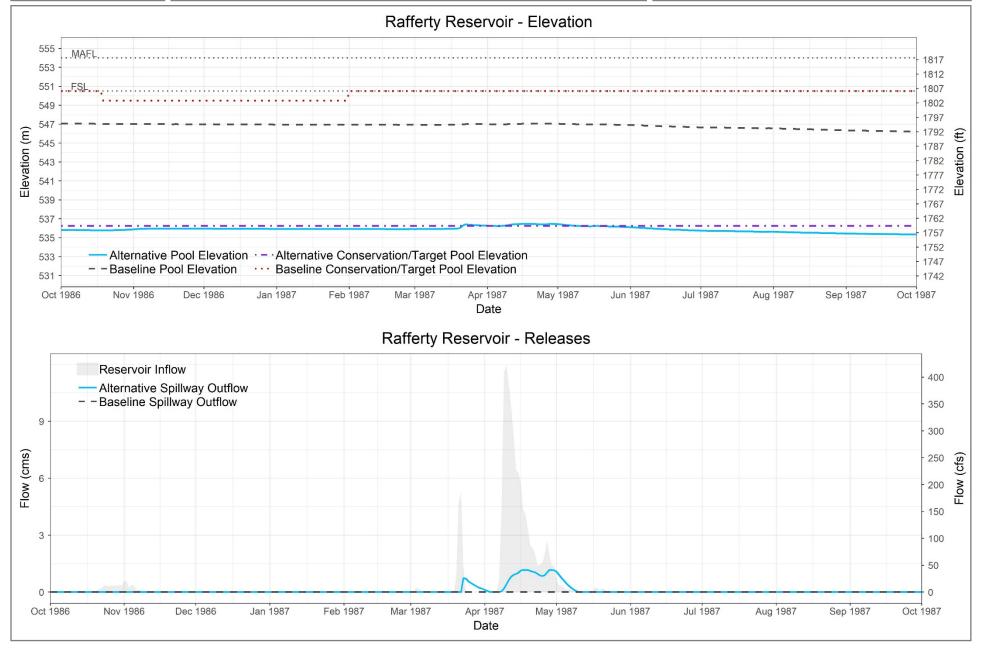




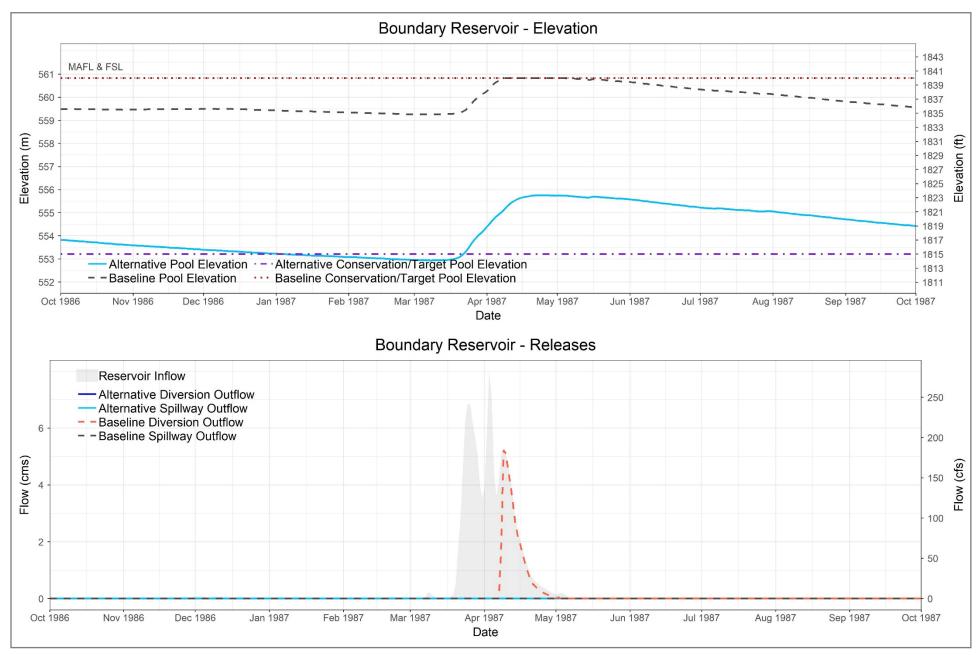


Reservoirs – 1987

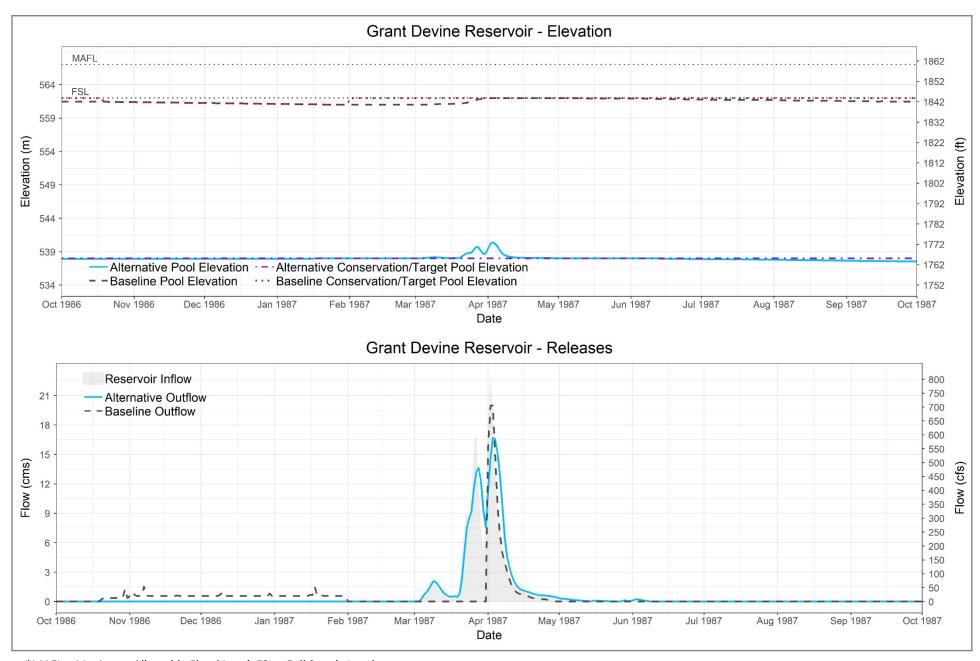
Alternative 1 (Phase 2)



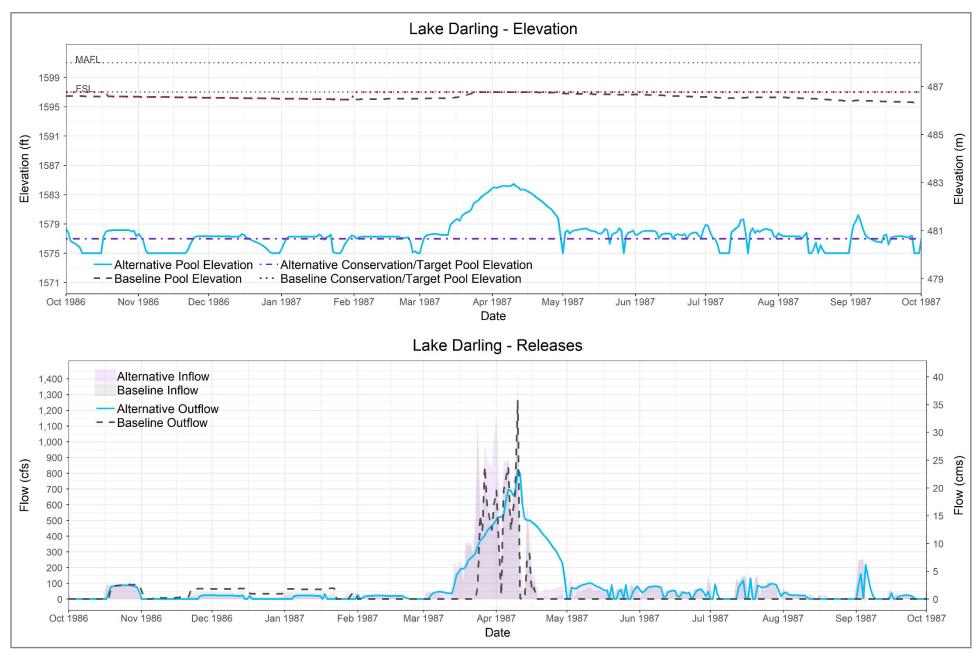
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



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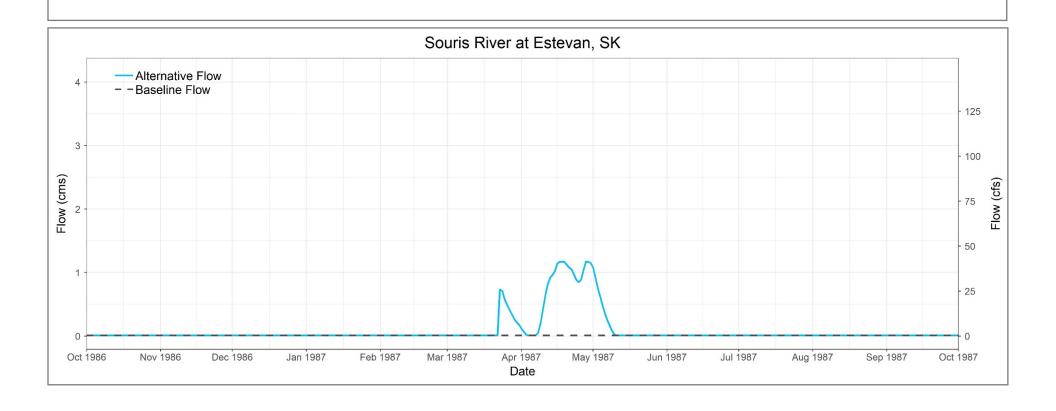


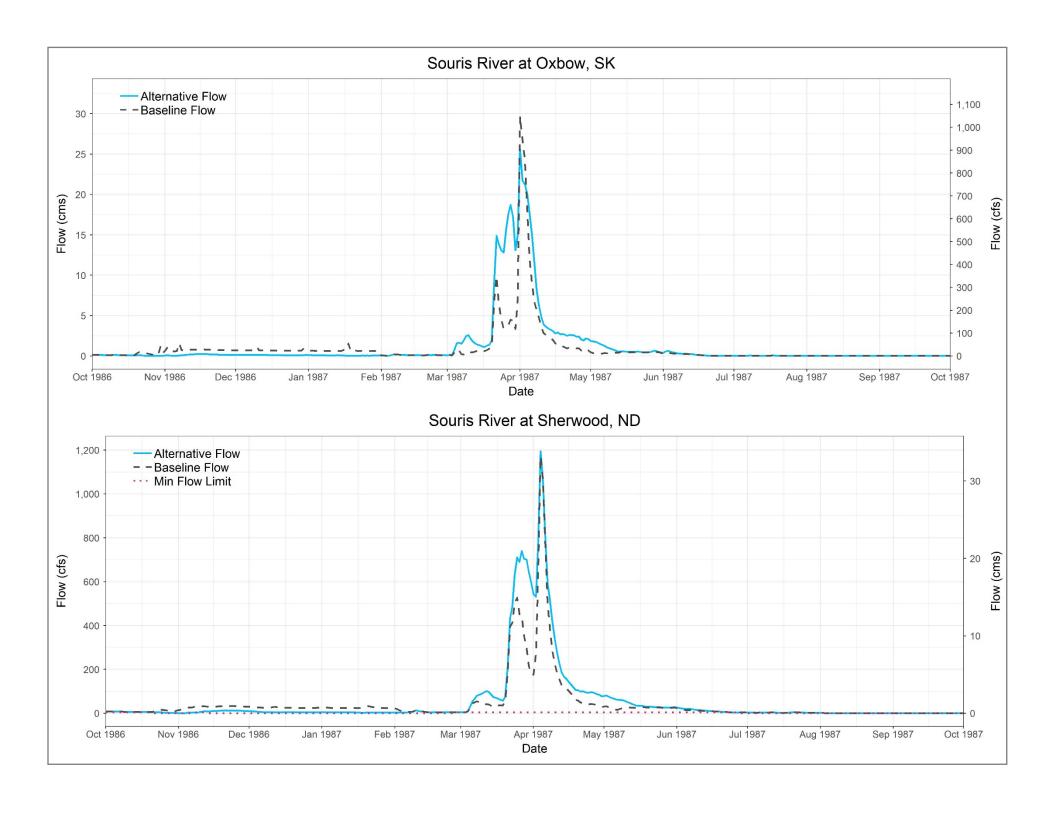
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

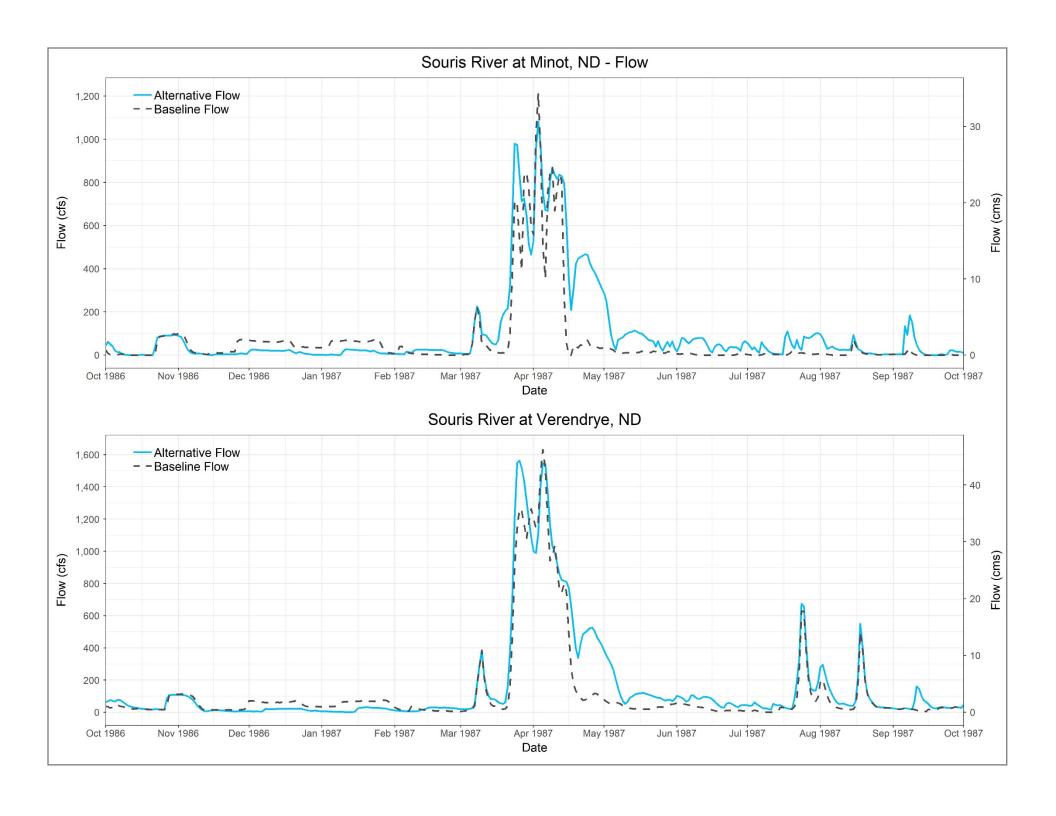


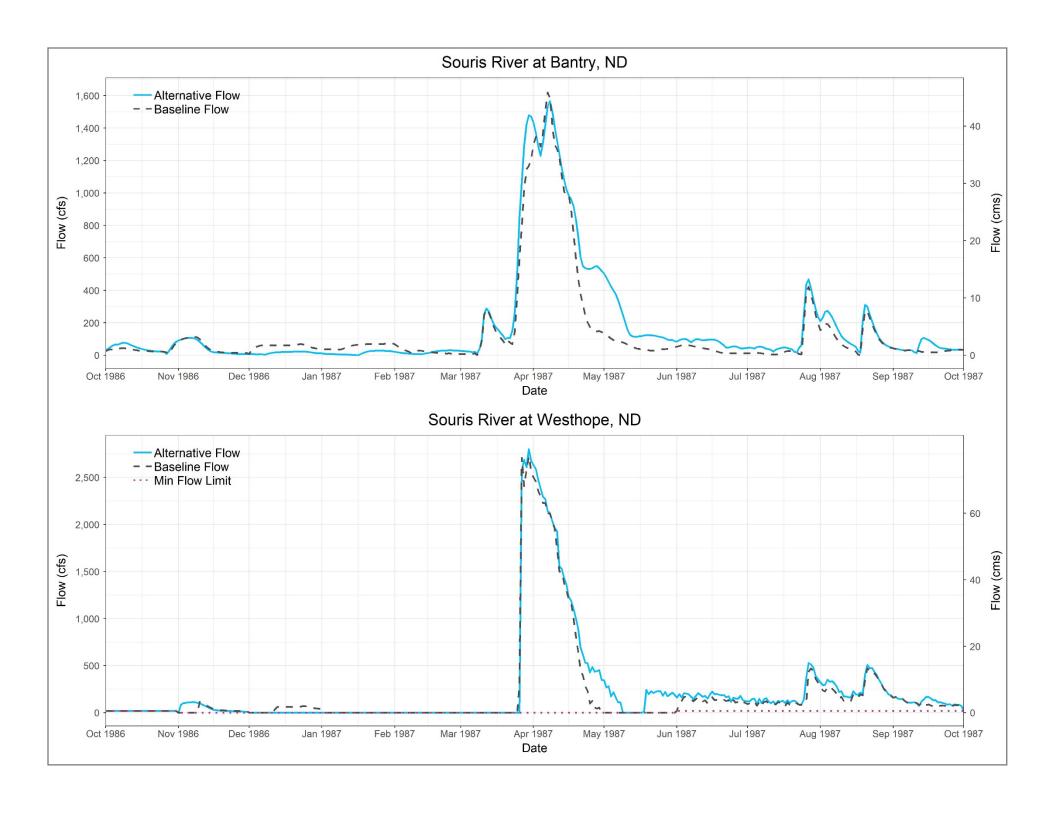
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 12 Critical Flow Locations — 1987 Alternative 1 (Phase 2) Souris River Plan of Study



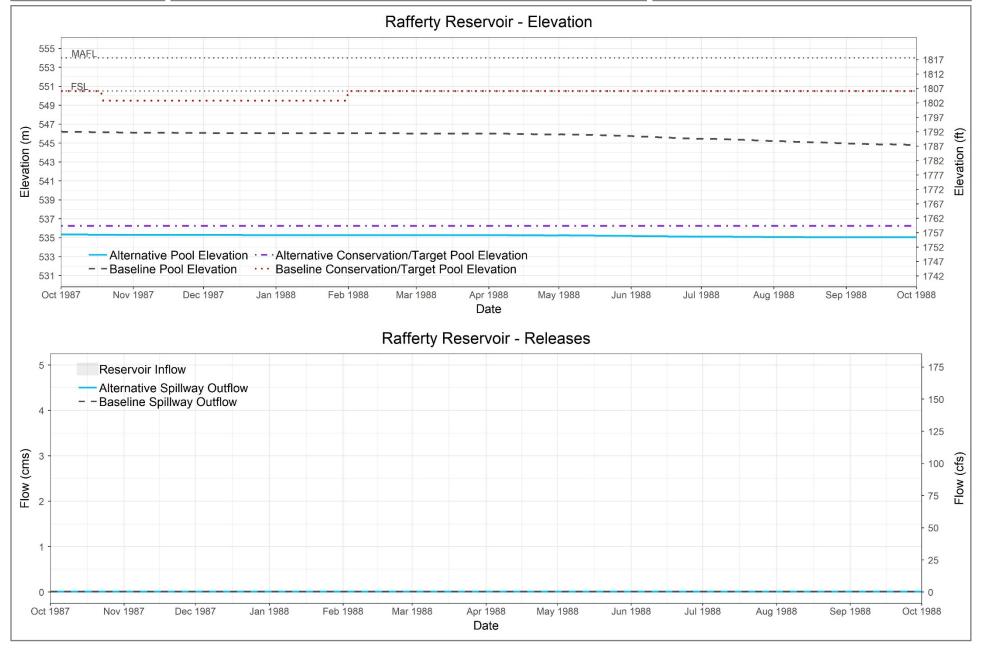




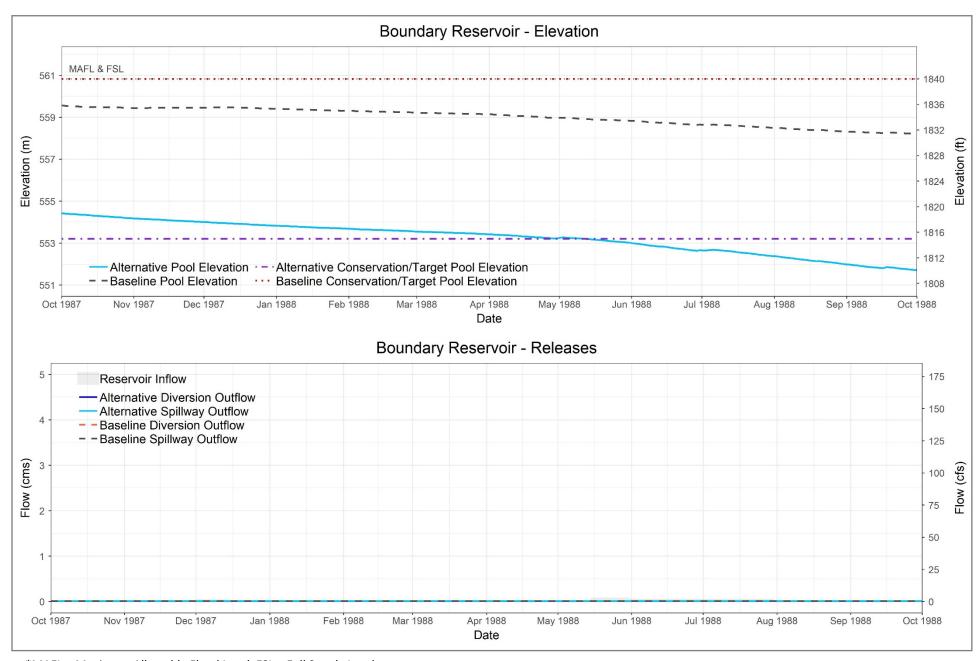


Reservoirs – 1988

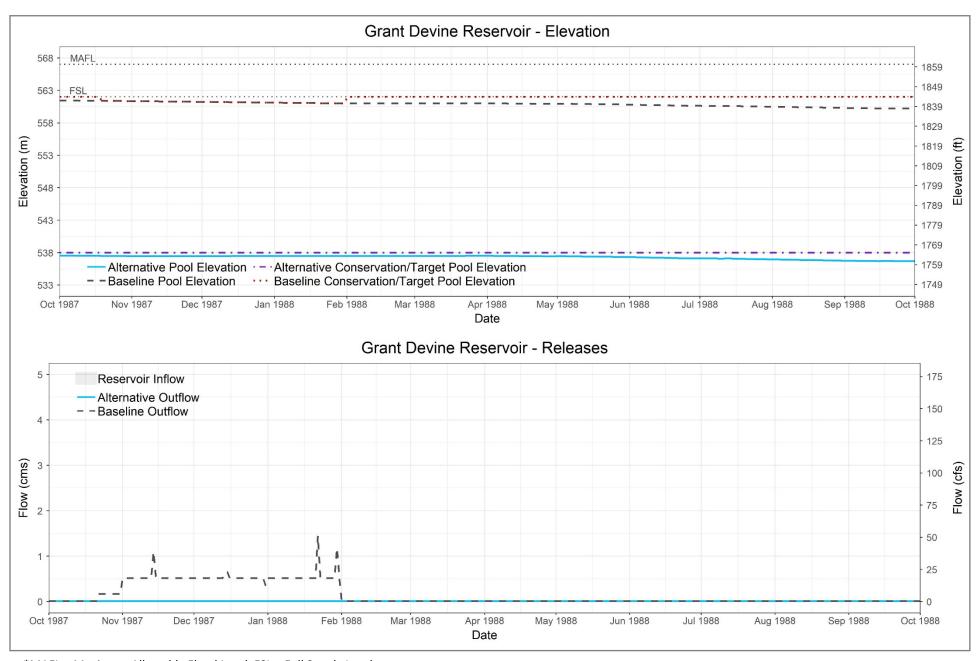
Alternative 1 (Phase 2)



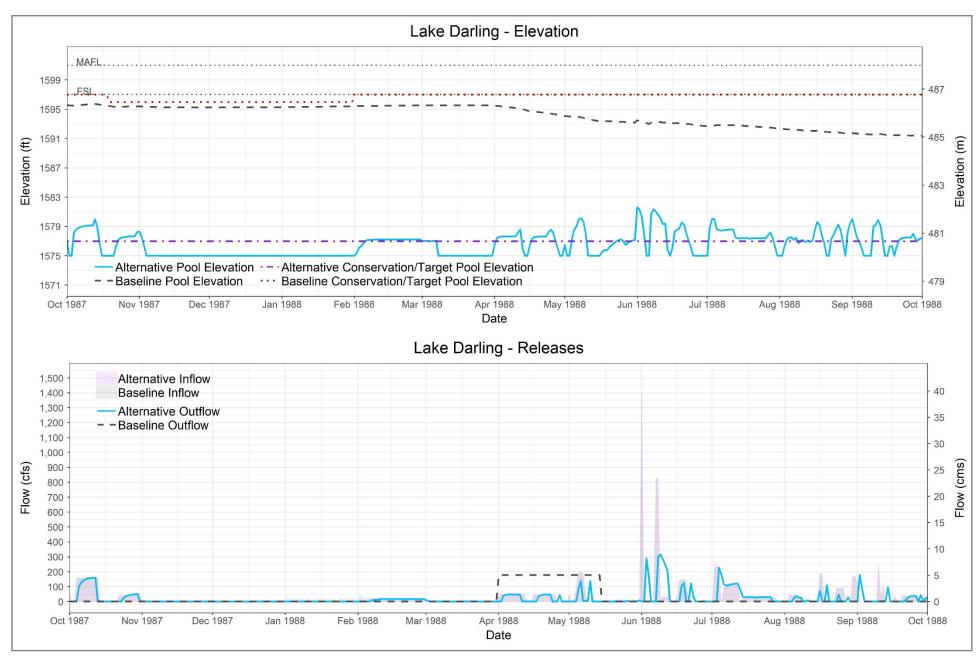
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

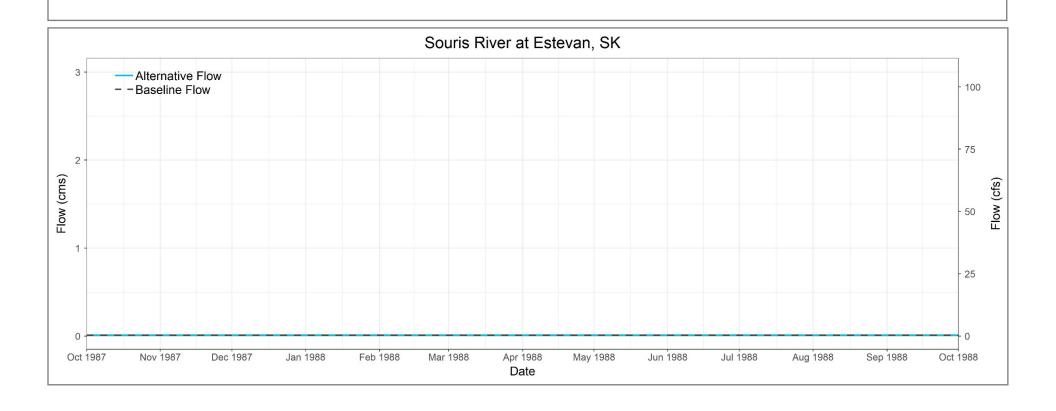


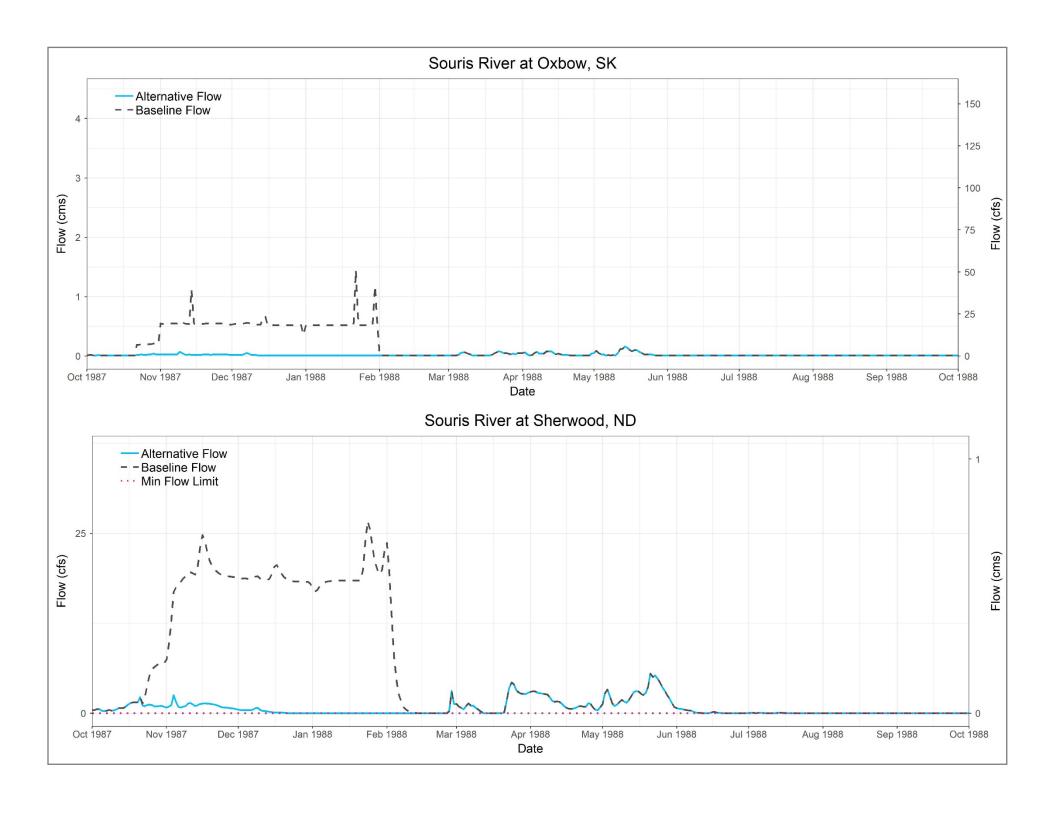
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

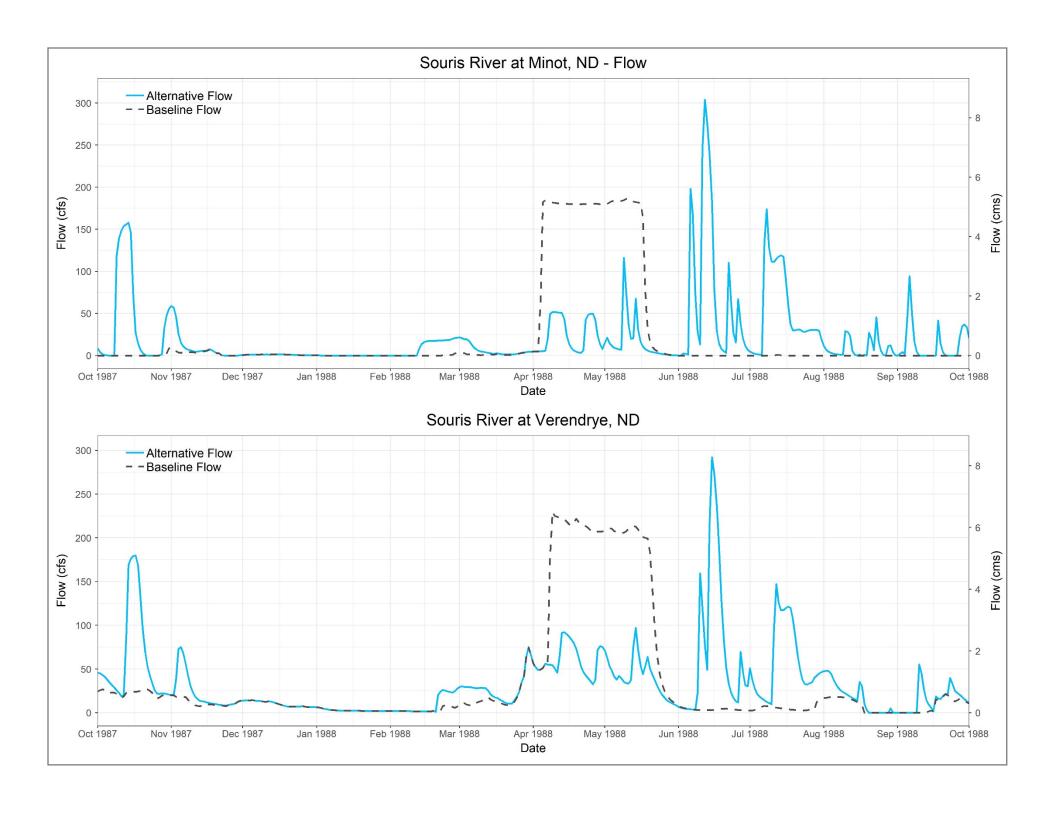


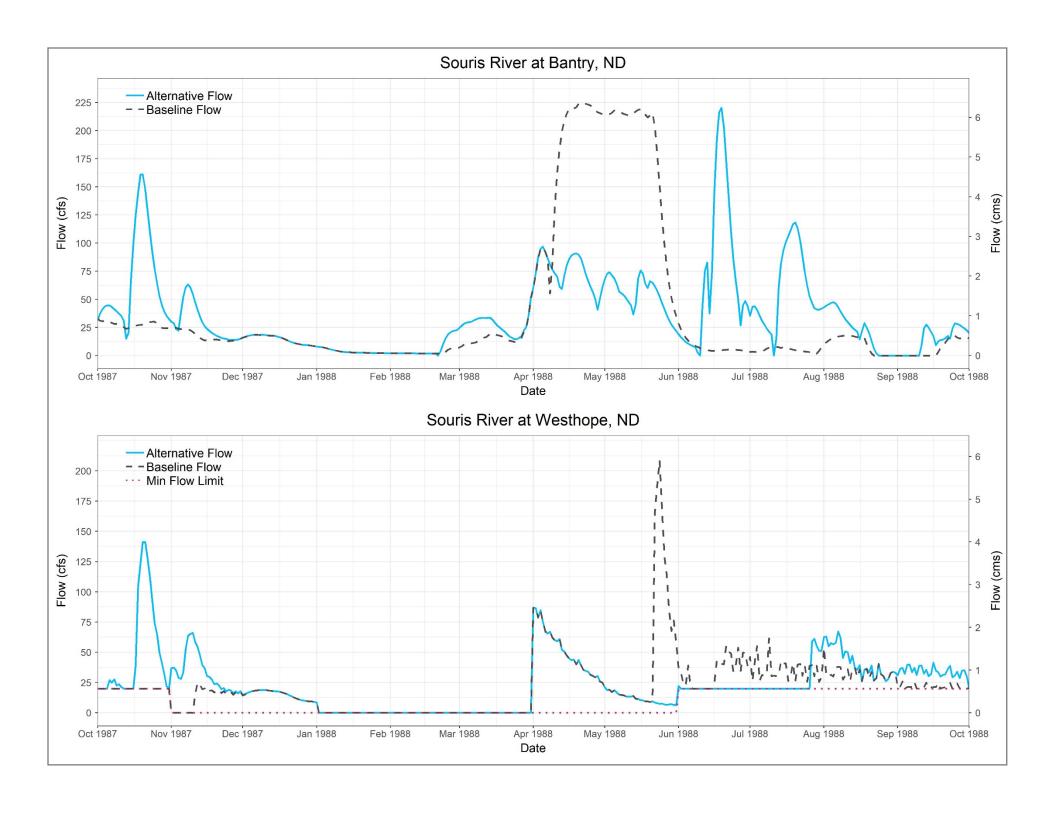
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 14 Critical Flow Locations — 1988 Alternative 1 (Phase 2) Souris River Plan of Study



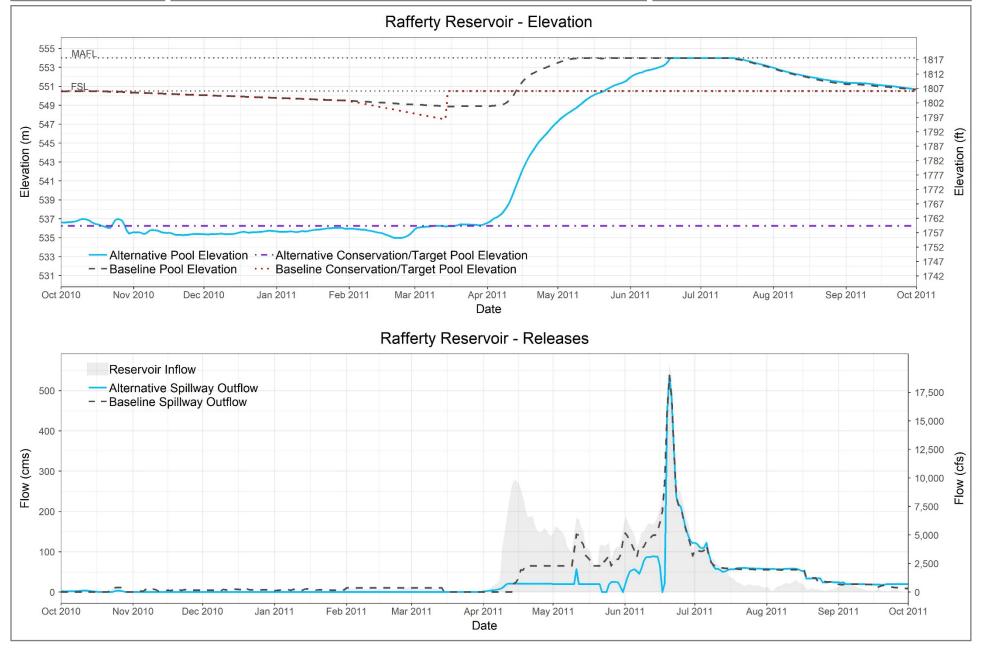




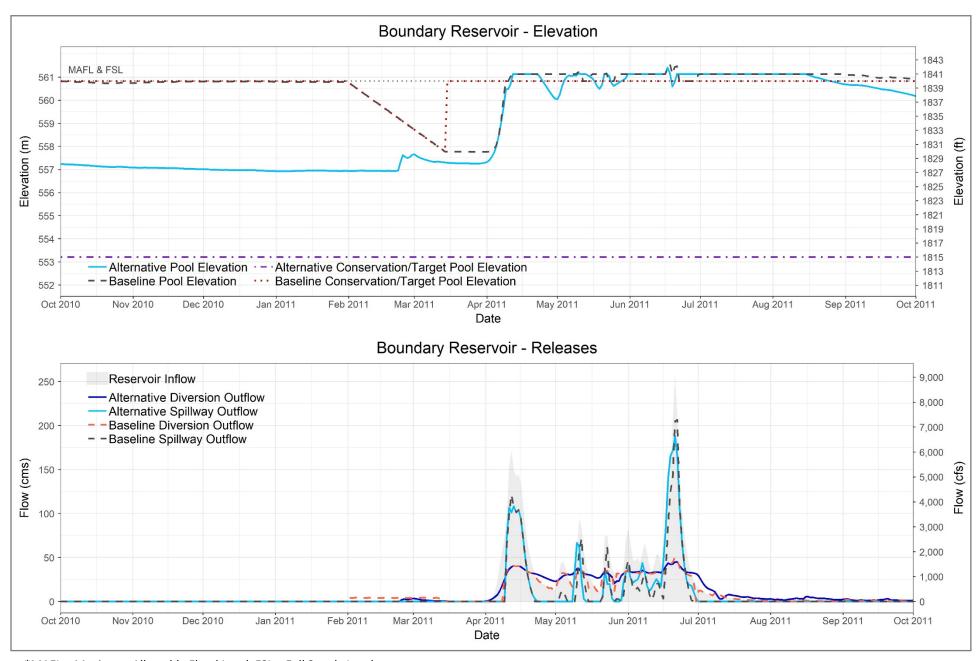


Reservoirs – 2011

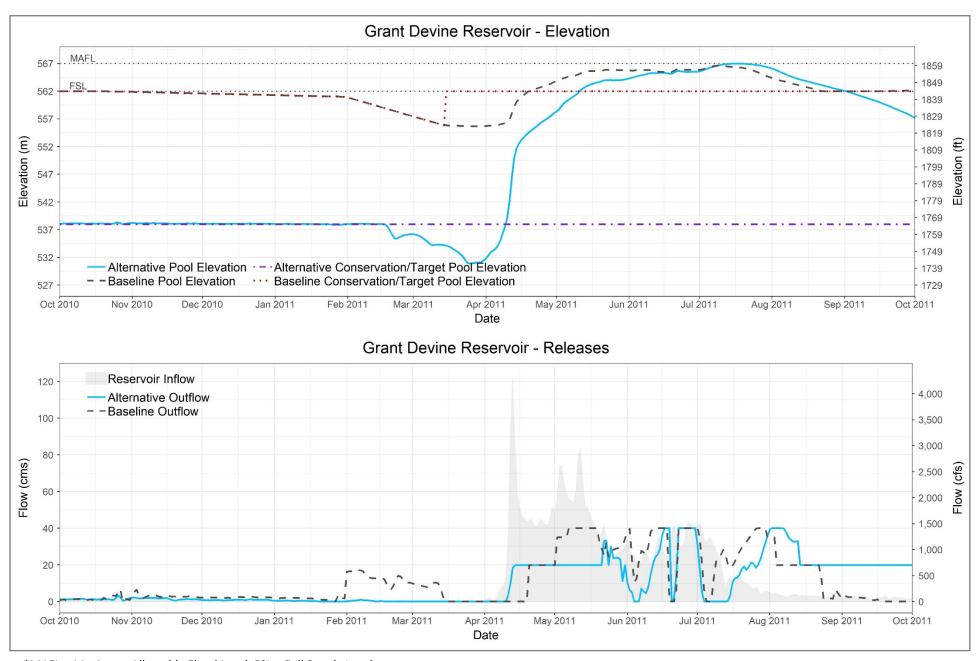
Alternative 1 (Phase 2)



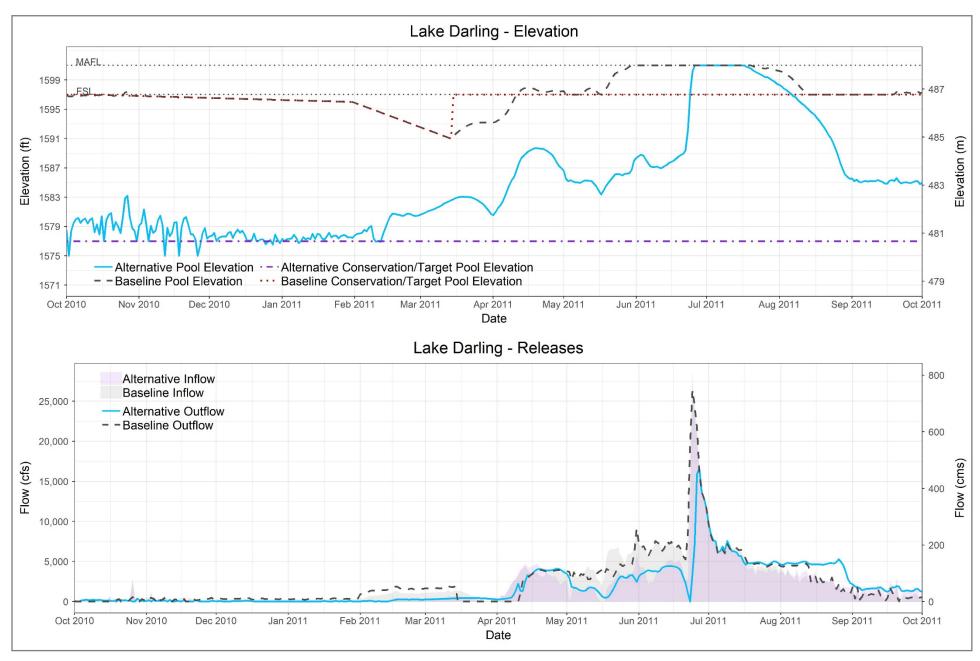
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

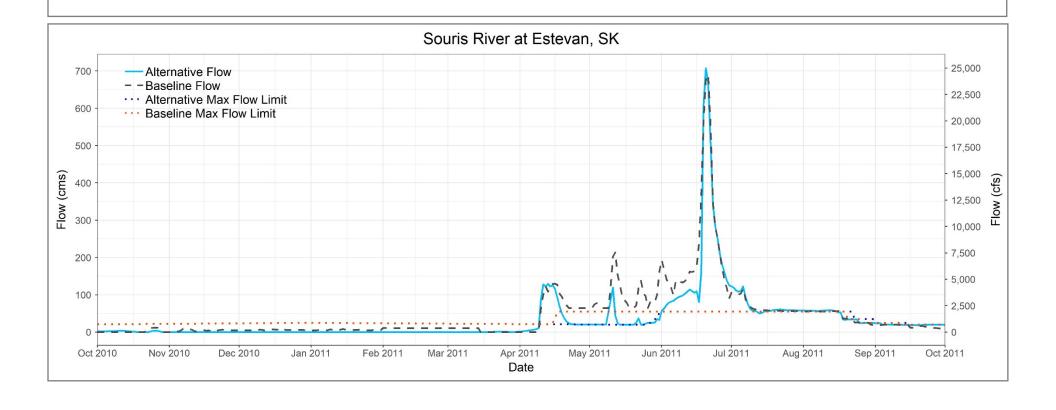


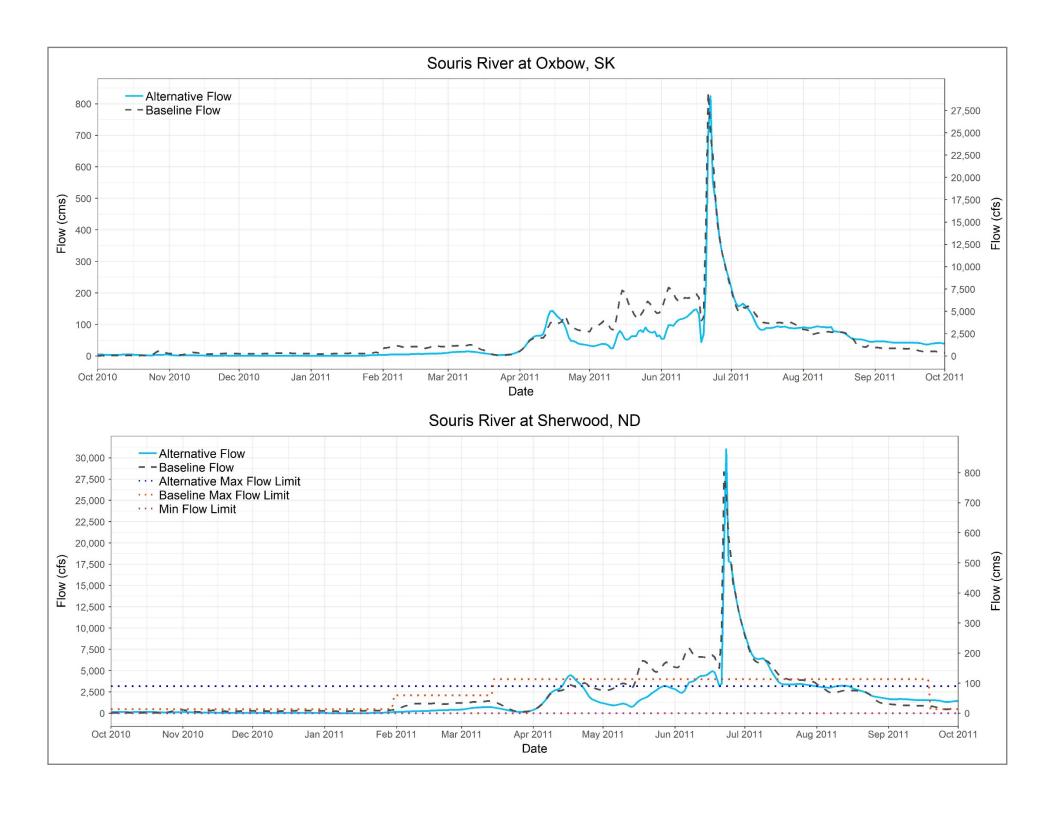
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

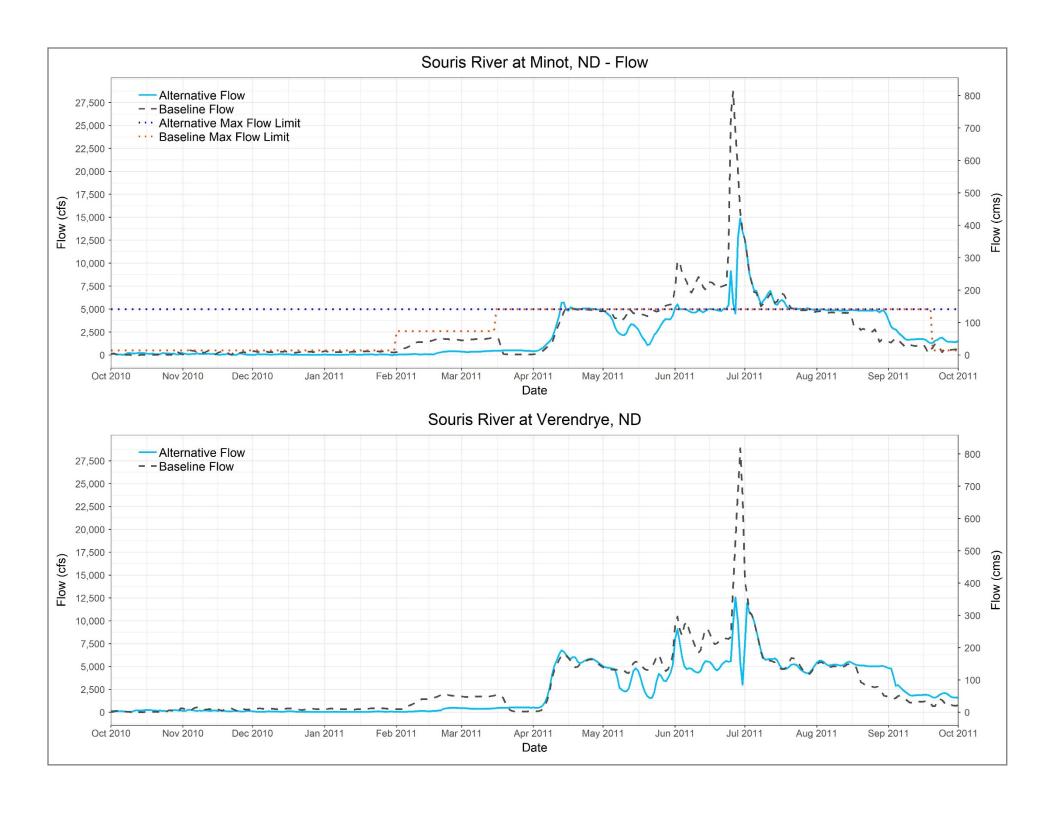


*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 16 Critical Flow Locations — 2011 Alternative 1 (Phase 2) Souris River Plan of Study







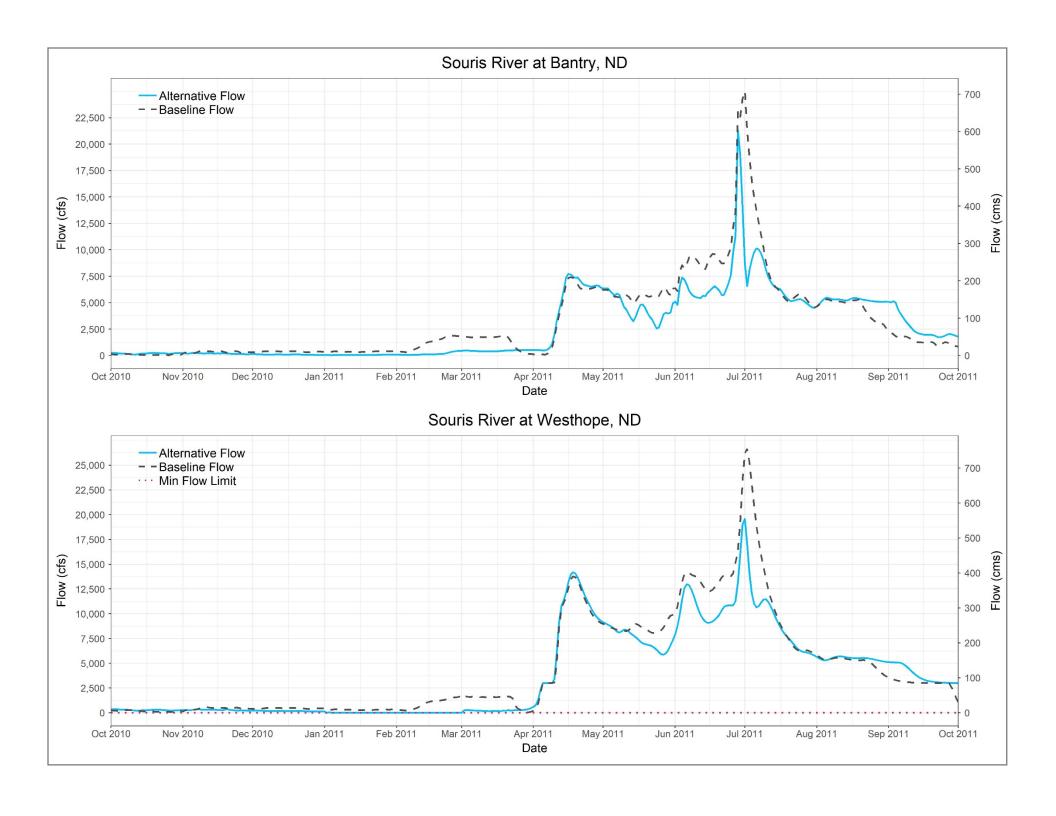
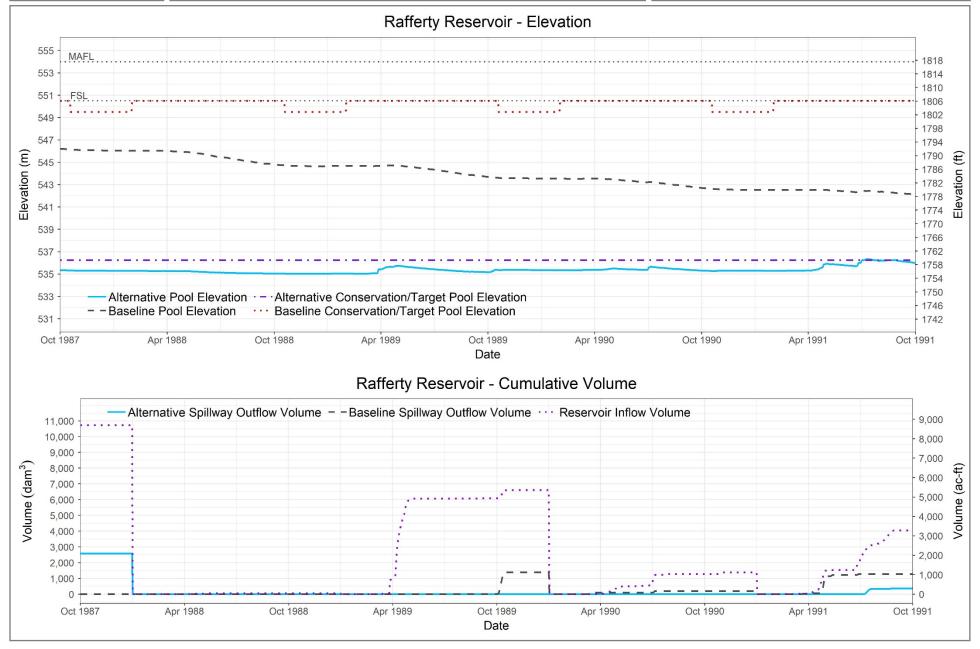


Plate 17

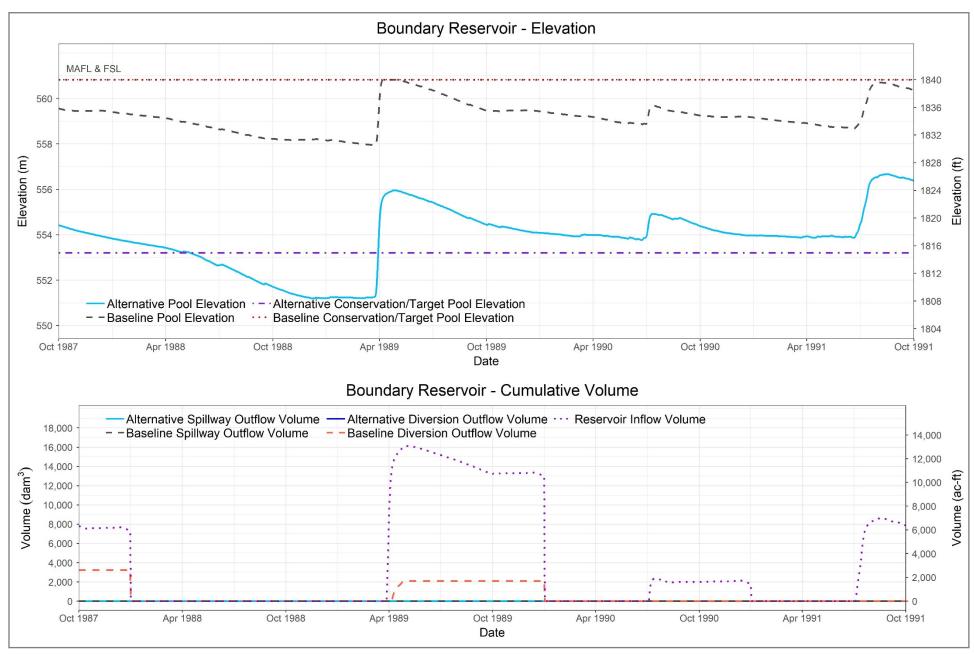
Reservoirs – 1988-1991

Alternative 1 (Phase 2)

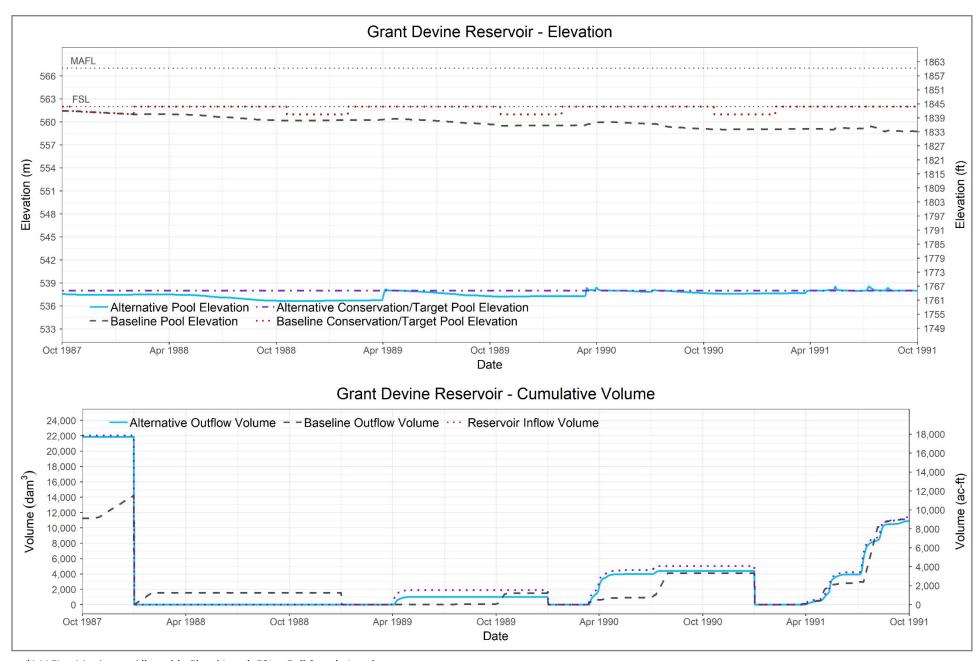
Souris River Plan of Study



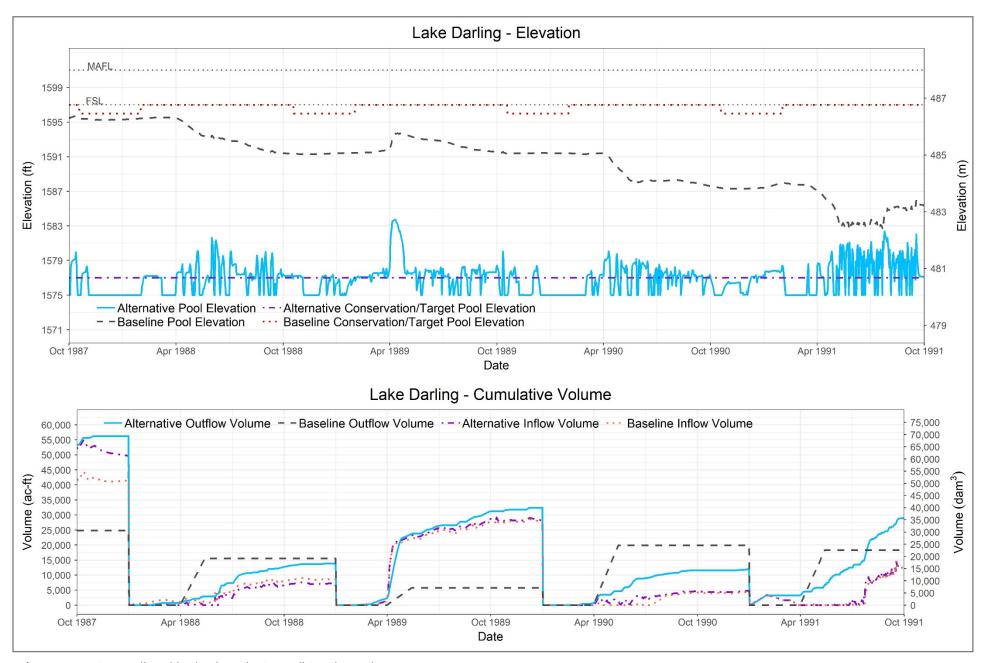
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level



*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

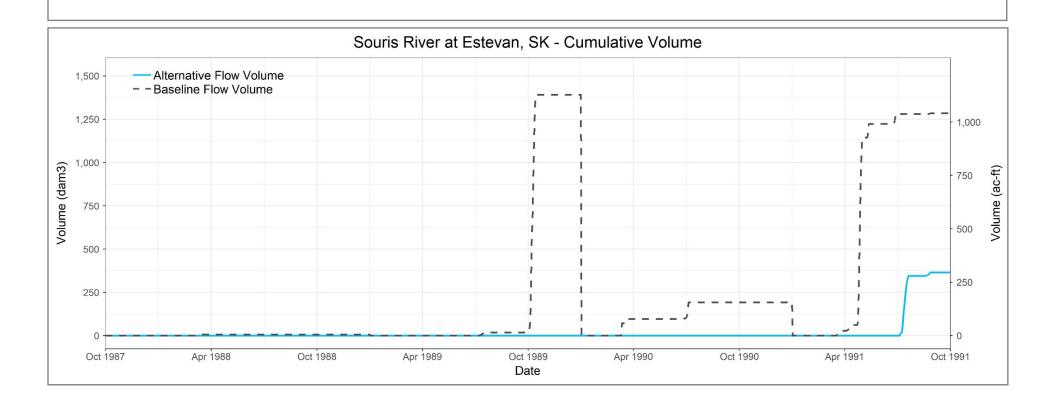


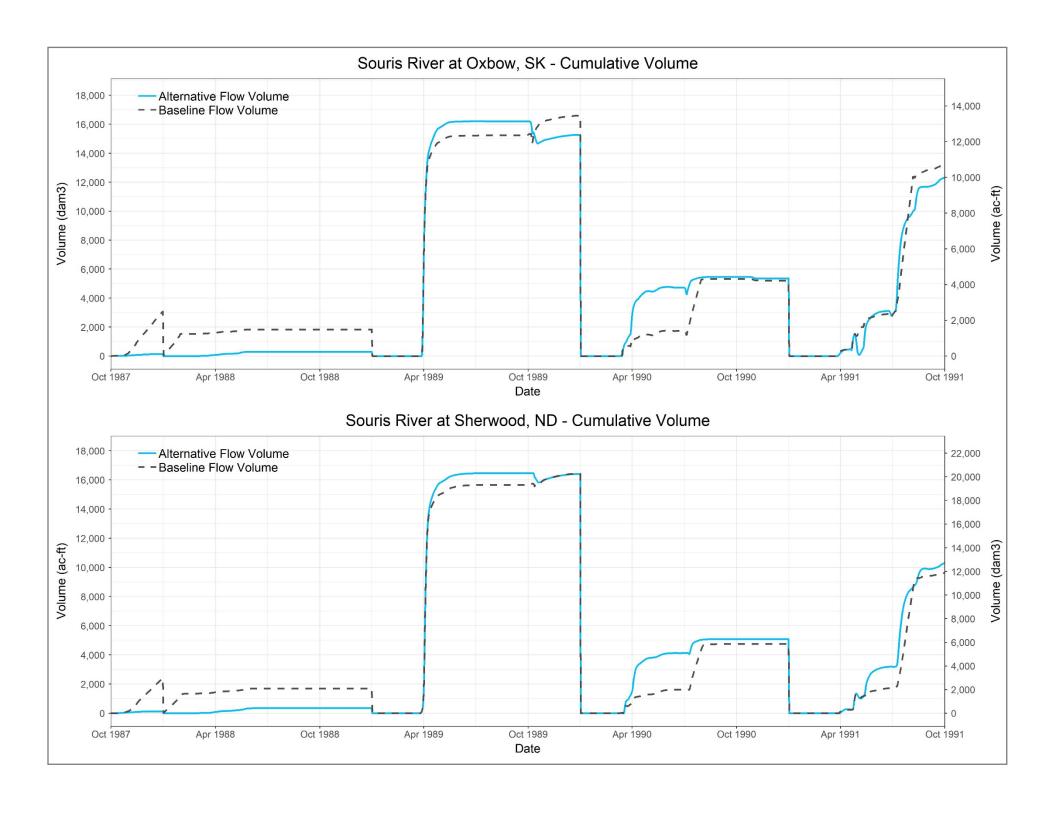
*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

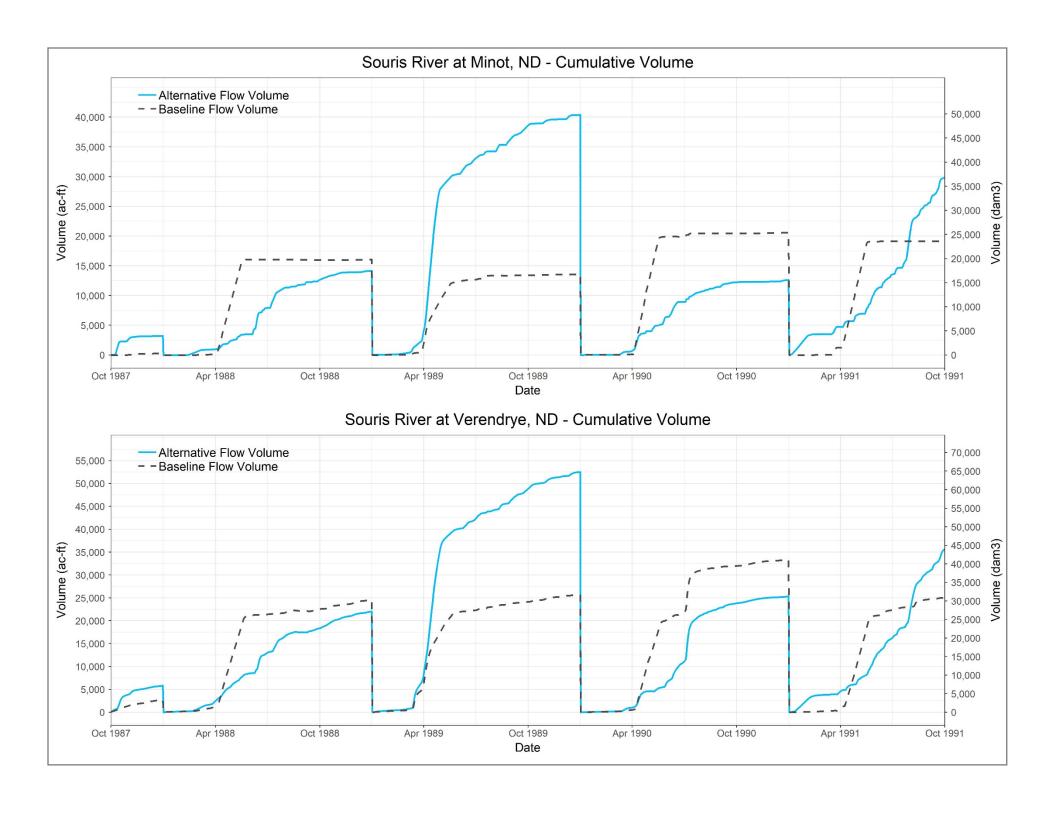


*MAFL = Maximum Allowable Flood Level, FSL = Full Supply Level

Plate 18 Critical Flow Locations — 1988-1991 Alternative 1 (Phase 2) Souris River Plan of Study







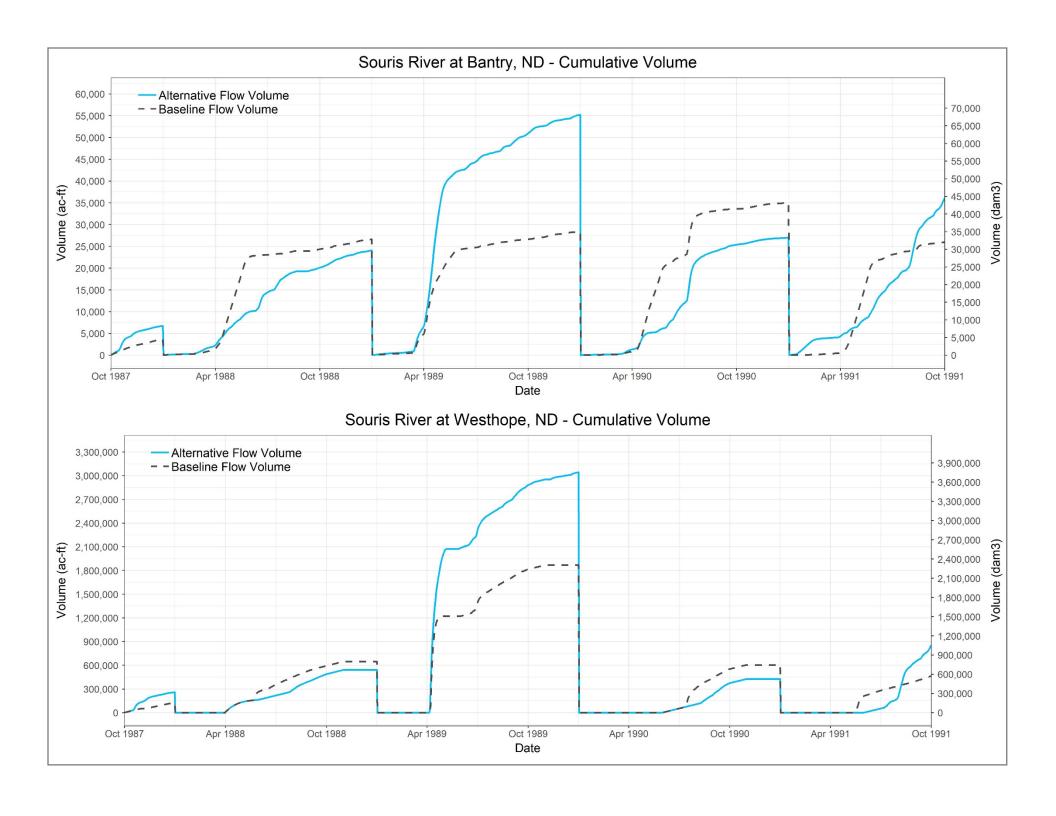
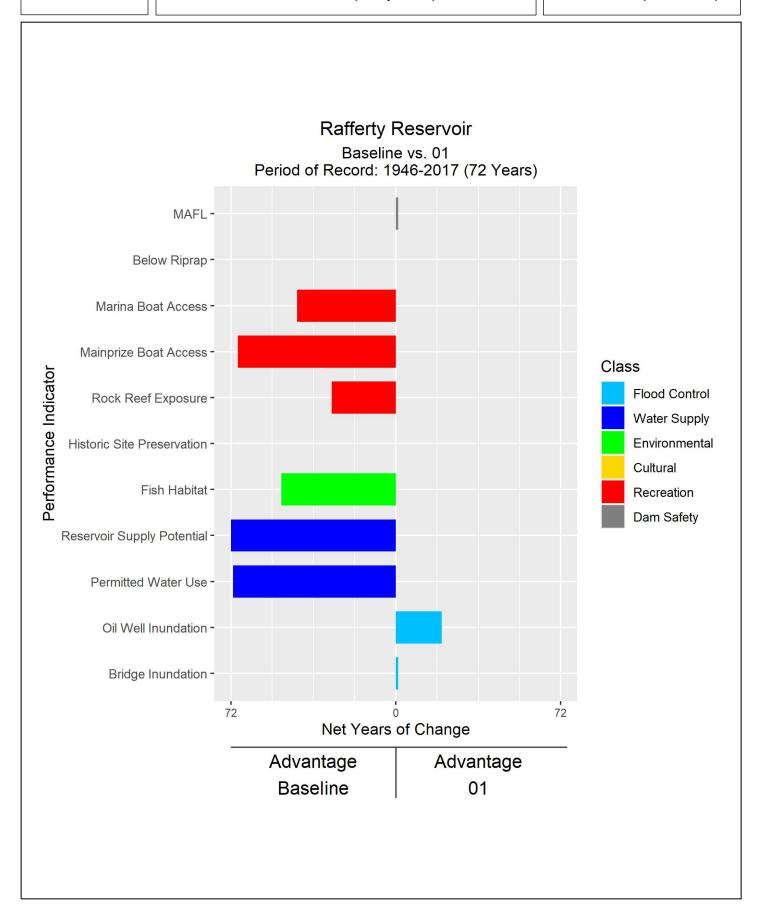


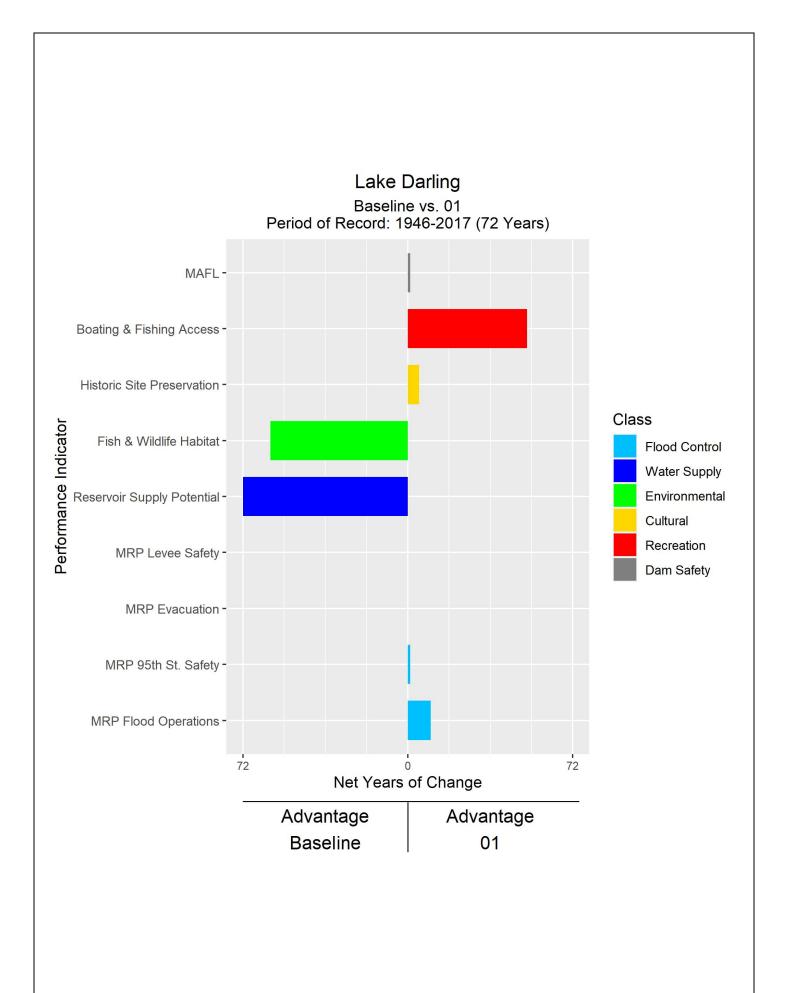
Plate 19

Performance Indicators 1946-2017 (72 years) Alternative 01 vs. Baseline (Phase 2)

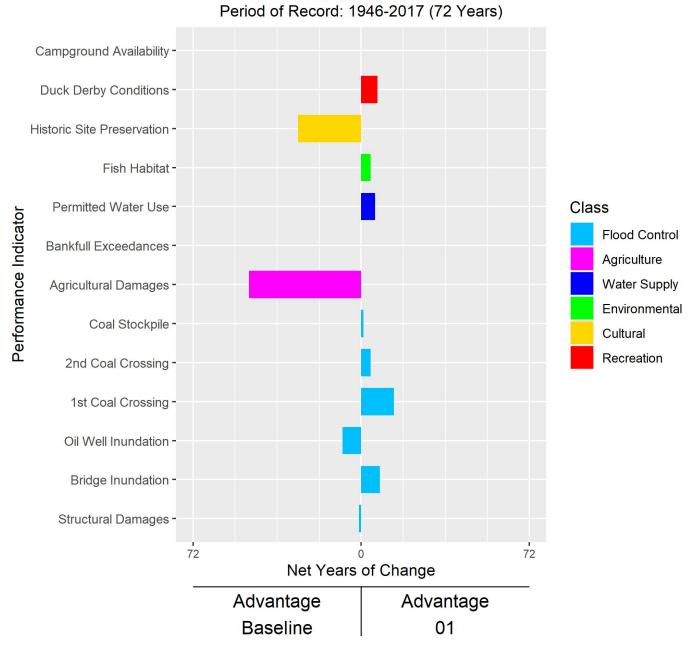


Boundary Reservoir Baseline vs. 01 Period of Record: 1946-2017 (72 Years) MAFL-Boat Launch Access -Performance Indicator Class Water Supply SaskPower Pumping -Recreation Dam Safety Reservoir Supply Potential -Permitted Water Use -72 72 Net Years of Change Advantage Advantage Baseline 01

Grant Devine Reservoir Baseline vs. 01 Period of Record: 1946-2017 (72 Years) MAFL-MMPP Boat Access -Fish Habitat (MMC) Fish Habitat (Reservoir) Reservoir Supply Potential -Class Flood Control Water Supply Environmental Recreation Dam Safety Permitted Water Use -Oil Well Inundation -72 72 Net Years of Change Advantage Advantage Baseline 01

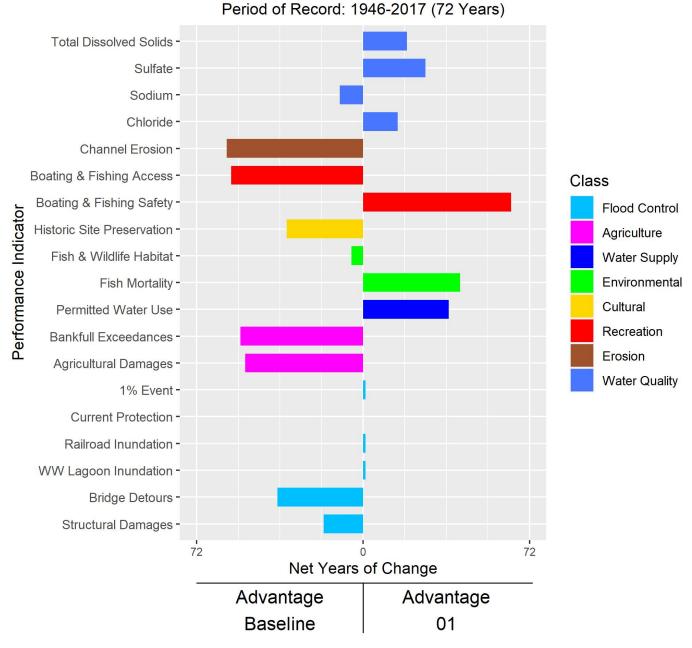


Saskatchewan - All Riverine Reaches



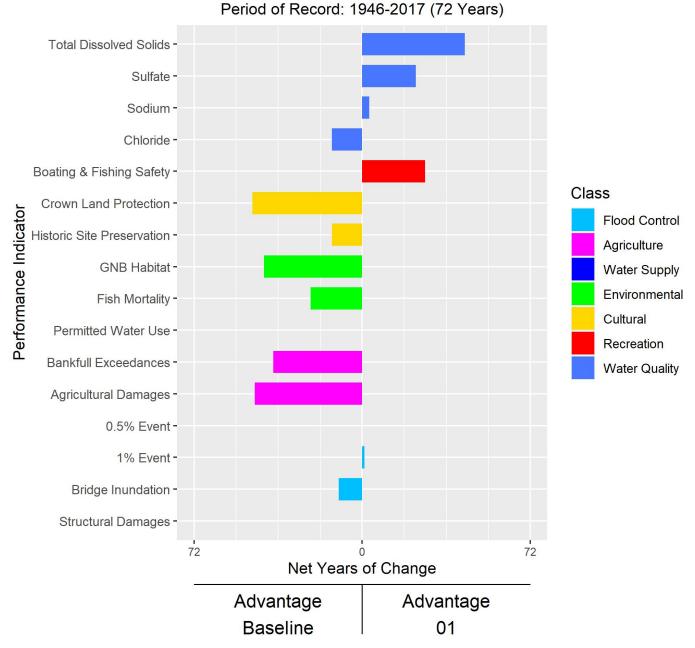
North Dakota - All Riverine Reaches

Baseline vs. 01 Period of Record: 1946-2017 (72 Years)



Westhope to Wawanesa

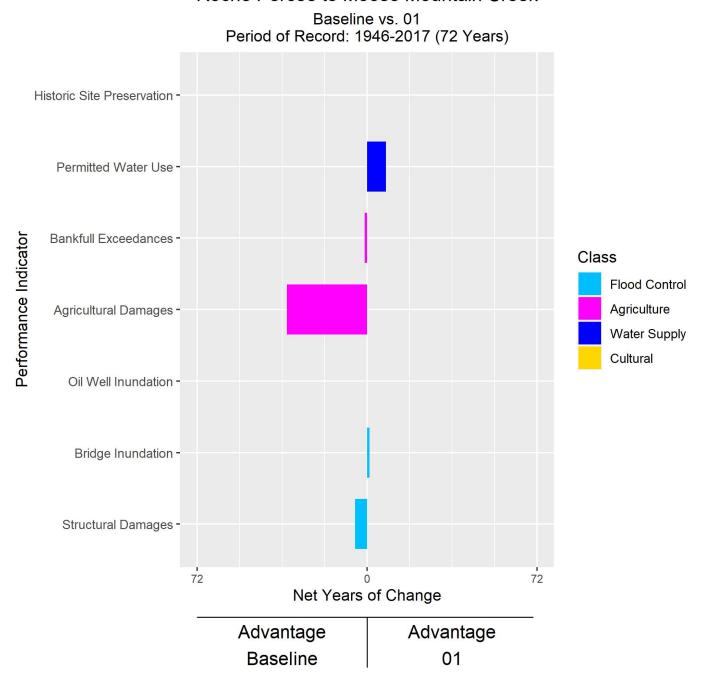
Baseline vs. 01 Period of Record: 1946-2017 (72 Years)



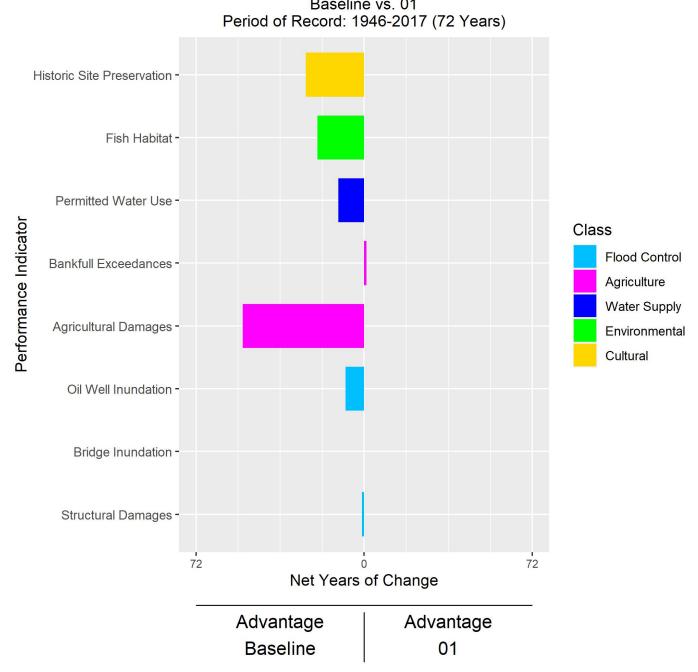
City of Estevan Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Campground Availability -Duck Derby Conditions -Historic Site Preservation -Fish Habitat -Performance Indicator Class Bankfull Exceedances -Flood Control Agriculture Agricultural Damages -Environmental Cultural Coal Stockpile -Recreation 2nd Coal Crossing -1st Coal Crossing -Bridge Inundation -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01

City of Roche Percee Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Bankfull Exceedances -Agricultural Damages -Performance Indicator Class Oil Well Inundation -Flood Control Agriculture Bridge Inundation -Structural Damages -72 72 Net Years of Change Advantage Advantage Baseline 01

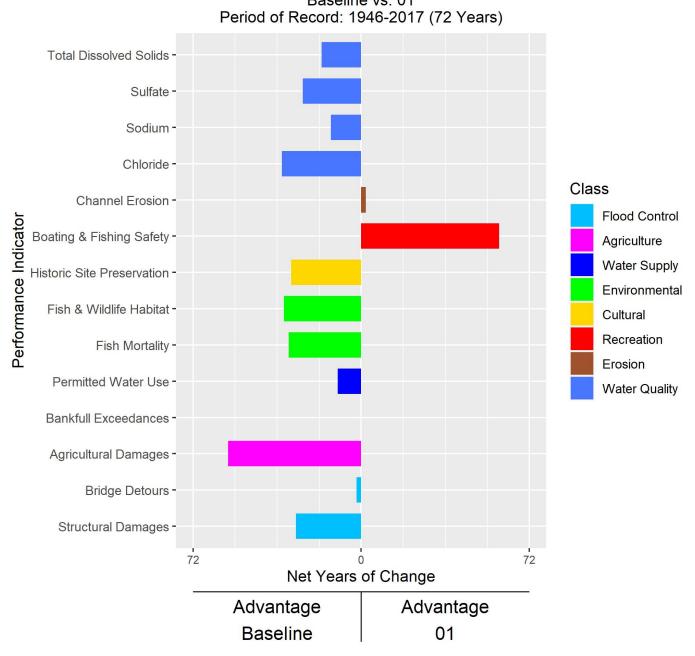
Roche Percee to Moose Mountain Creek



Moose Mountain Creek to Sherwood



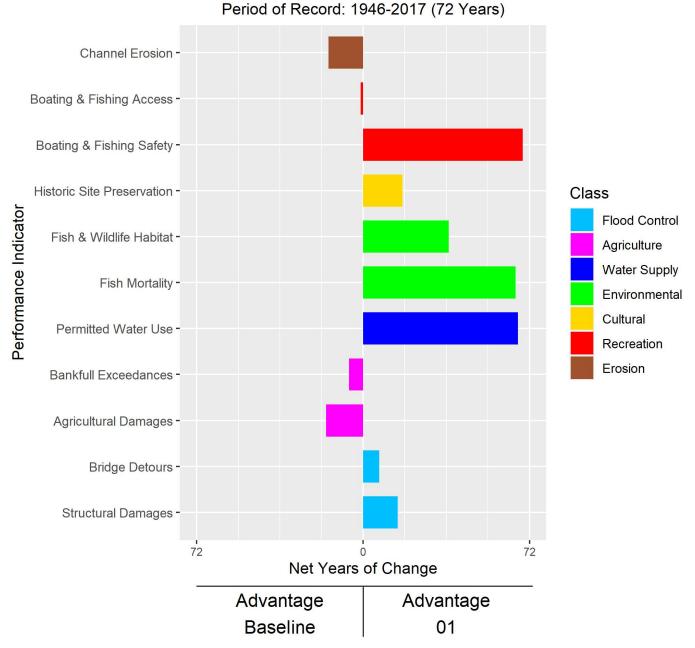
Sherwood to Mouse River Park



Mouse River Park Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Boating & Fishing Access -Boating & Fishing Safety -Historic Site Preservation -Class Fish & Wildlife Habitat -Performance Indicator Flood Control Fish Mortality -Agriculture Water Supply Permitted Water Use -Environmental Cultural Recreation Bankfull Exceedances -Agricultural Damages -Bridge Detours -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01

Lake Darling to Burlington

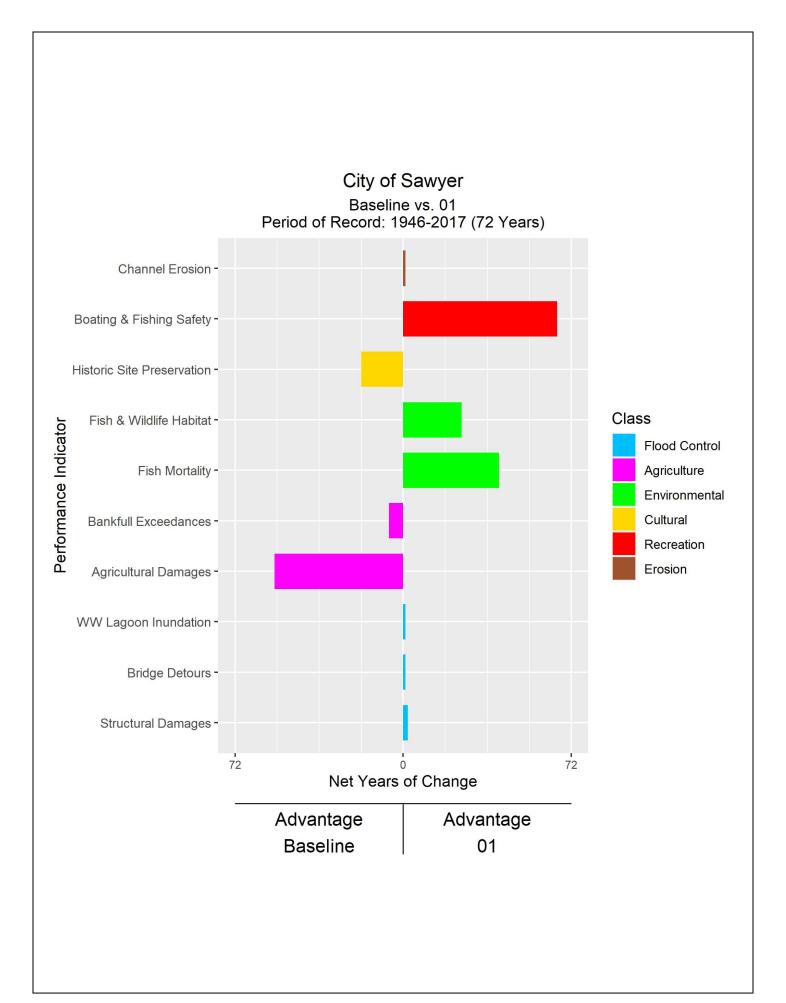
Baseline vs. 01 Period of Record: 1946-2017 (72 Years)



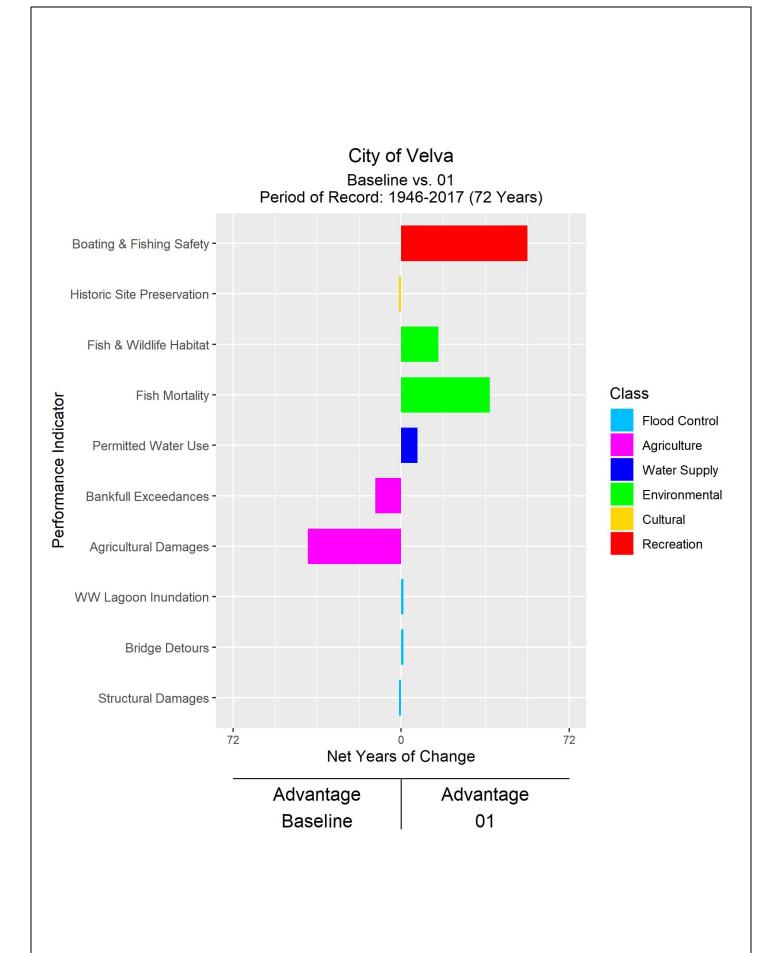
City of Burlington Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Channel Erosion -Boating & Fishing Safety -Fish & Wildlife Habitat -Class Fish Mortality -Performance Indicator Flood Control Permitted Water Use -Agriculture Water Supply Bankfull Exceedances -Environmental Recreation **Erosion** Agricultural Damages -WW Lagoon Inundation -Bridge Detours -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01

City of Minot Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Total Dissolved Solids -Sulfate -Sodium -Chloride -Channel Erosion -Class Boating & Fishing Access -Flood Control Performance Indicator Boating & Fishing Safety -Agriculture Historic Site Preservation -Water Supply Fish & Wildlife Habitat -Environmental Fish Mortality -Cultural Permitted Water Use -Recreation Agricultural Damages -**Erosion** 1% Event -Water Quality Current Protection -Railroad Inundation -WW Lagoon Inundation -Bridge Detours -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01

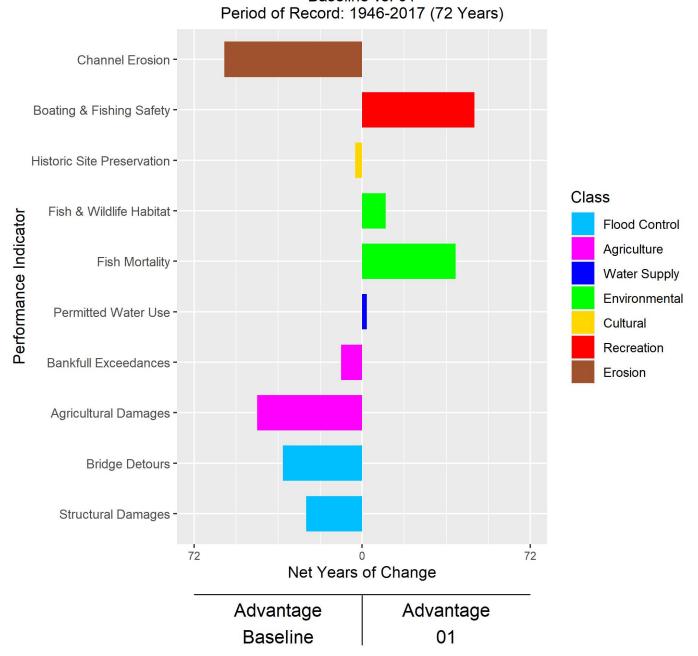
Minot to Sawyer Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Boating & Fishing Safety -Historic Site Preservation -Fish & Wildlife Habitat -Performance Indicator Class Fish Mortality -Flood Control Agriculture Bankfull Exceedances -Environmental Cultural Agricultural Damages -Recreation Railroad Inundation -Bridge Detours -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01



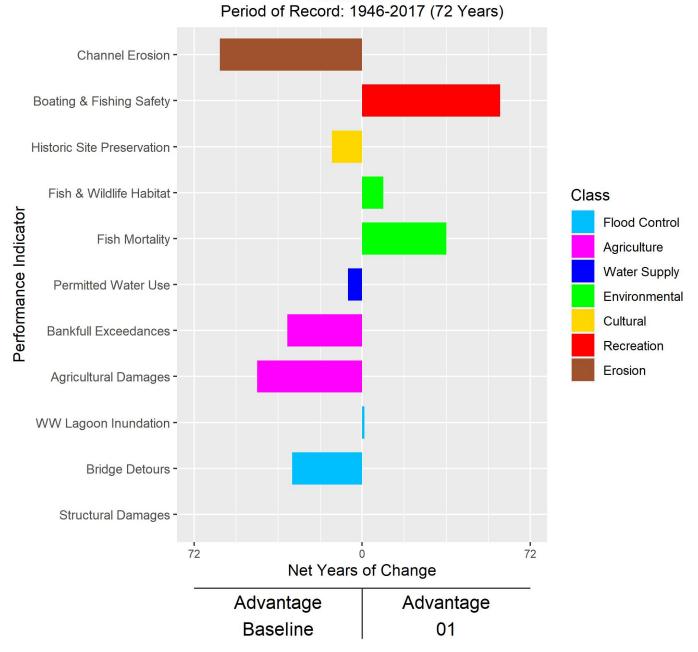
Sawyer to Velva Baseline vs. 01 Period of Record: 1946-2017 (72 Years) Boating & Fishing Safety -Fish & Wildlife Habitat -Performance Indicator Fish Mortality -Class Flood Control Agriculture Bankfull Exceedances -Environmental Recreation Agricultural Damages -Bridge Detours -Structural Damages -72 Net Years of Change Advantage Advantage Baseline 01



Velva to Eaton Irrigation

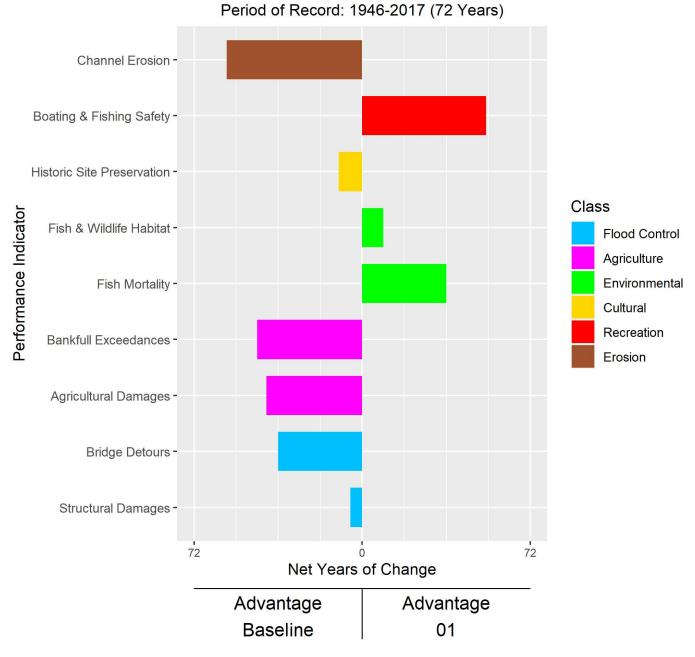


Eaton Irrigation District



Downstream of Towner

Baseline vs. 01 Period of Record: 1946-2017 (72 Years)



J. Clark Salyer National Wildlife Refuge

